Control and Treatment of Hot-Dip Galvanize Surfaces

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Abstract.

Hot-dip galvanize can vary in appearance, and therefore usability, as a function of spangle size, zinc composition, mechanical treatment, and chemical or oiling treatments. Marketplace problems can develop because the customer finds the appearance is different than expected, or changes due to darkening, water staining, or field handling marks. These and other issues are reviewed, along with actions that can be taken to control them and minimize problems with end users.

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Introduction

The surface of metallic-coated steel sheet can be treated using one or more of several different processes and for many different reasons:

- Improved surface uniformity
- Resistance to storage stain
- Improved paint adhesion and/or corrosion resistance for prepainted sheets
- Improved surface lubrication for stamping and roll forming operations
- Improved resistance to handling and "fingerprinting" marks
- Preparing for field painting, etc.

Many of the above process or treatments are performed directly on the hot-dip line after the metallic-coating has been applied. Some are performed on separate process lines/facilities, or in the field.

Improved Surface Uniformity

Whether it is galvanize, galvanneal, aluminum-zinc, or aluminum coatings, many end uses require a surface that is more topographically uniform than is obtainable directly off hot-dip coating lines. This is so that the underlying surface does not show through the paint for such applications as exterior automotive body panels, appliance parts, and prepainted steel. The method used to make the surface more uniform is known as "temper passing" or "skin passing" and is done with a temper mill. In the case of galvanize, this process also reduces the coating's metallic lustre.

Figure 1 is a schematic of a 4-high temper mill located in a continuous coating line. Temper mills typically consist of two back-up rolls and two work rolls. The work rolls contact the two sheet surfaces with up to several hundred tons of force. This load, combined with the sheet being under high tension between the entry and exit bridle rolls, partially imprints the work roll blasted matte surface finish onto the sheet surface. Depending on the load employed, the sheet can be extended in length (and reduced in thickness) by as much as 2%.

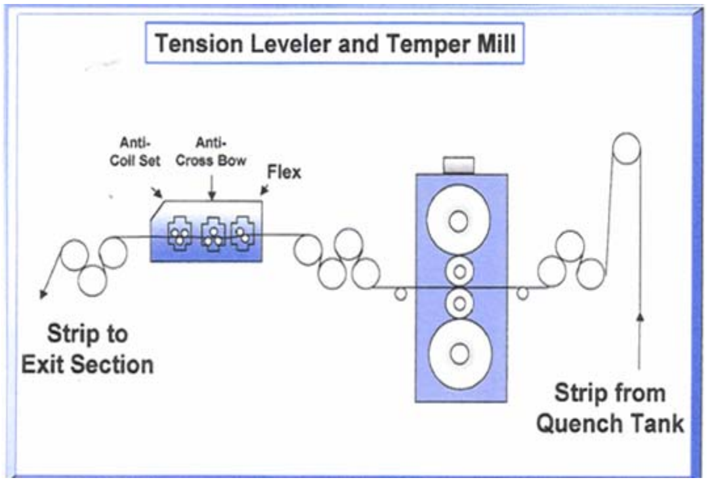

Figure 1 – Coating line temper rolling and leveling schematic

The surface roughness of the rolls is transferred to the sheet surface at an approximate ratio of 50%, e.g., to achieve a surface roughness of 40 micro-inches, a roll roughness of about 80 micro-inches is required. Figure 2 shows a typical automotive requirement for surface roughness in terms of average peak height versus peaks per inch.

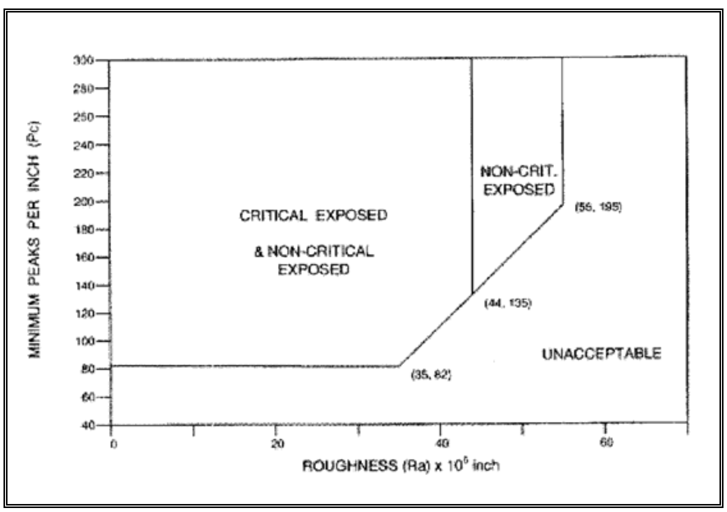

Figure 2 – Surface roughness requirements – DaimlerChrysler MS6000

Spangle – Figure 3 shows a classic, well-defined, large spangle pattern on a galvanized coating at a magnification of about 10X. This is defined in ASTM A 563/A 653M as a "Regular spangle" coating. Here the rate of dendrite growth dominated the solidification process leading to a small number of large spangles. One characteristic of such spangles is that they are thickest at their centers and thinnest at their edges, or grain boundaries. The grain boundaries can be said to be "depressed" and are difficult to smooth by subsequent temper passing. The most common method of obtaining a well-defined dendritic growth pattern on galvanize is to add lead to the coating. A typical lead level in coating baths on lines producing a visible spangle pattern is in the range of 0.05 to 0.10%. The higher the level of lead, the larger is the spangle.

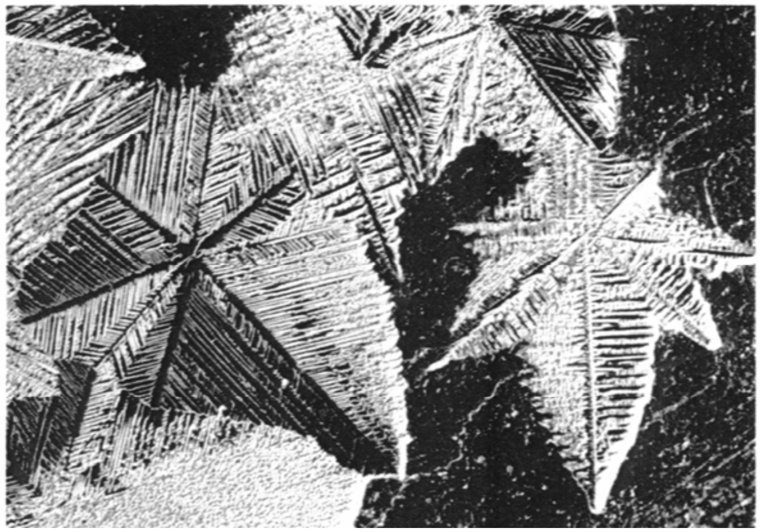

Figure 3 – Classic spangled structure of a hot-dip galvanized coating

While the spangle on hot-dip galvanized steel sheet has been its primary identifying feature for many years, the demand for a very smooth product has necessitated that spangle size be reduced until it is barely visible to the unaided eye. Prior to the use of lead-free zinc, spangle formation was suppressed by impinging steam or zinc powder onto the molten zinc coating above the zinc bath. These were known as “Minimized spangle” coatings. Without lead, the driving force for large spangles is removed, and the surface is quite flat with less depression at the grain boundaries. The use of minimizing technology is not required. Figure 4 shows the very flat spangle boundaries of a lead-free coating.

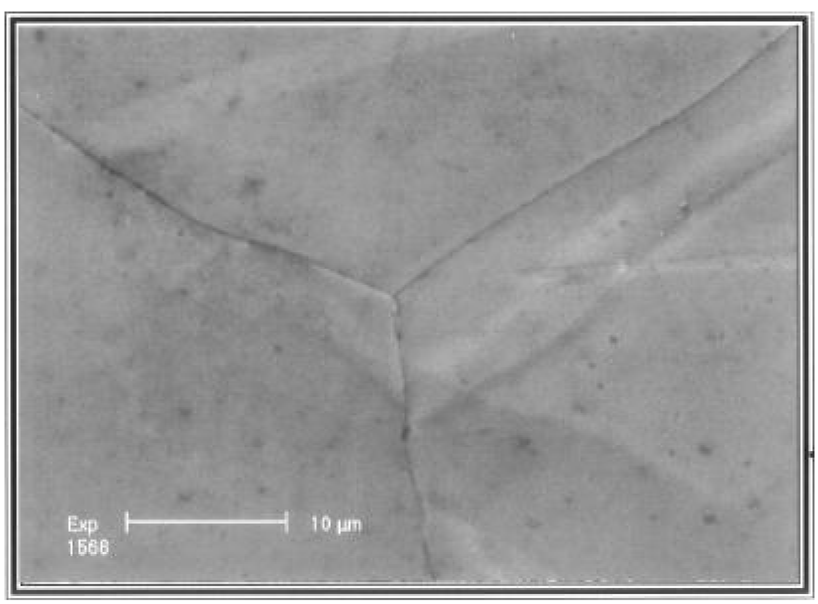

Figure 4 – Spangle boundaries of a lead-free galvanized coating

Even though referred to as "Spangle-free", lead-free coatings still have a grain pattern that is, at best, barely visible to the unaided eye. Typically, the spangles are about 0.5 mm in diameter and are clearly visible when seen at 5 to 10X magnification. However, the grains no longer grow by a dendritic mode but by a cellular mode of growth. Essentially, zinc grains nucleate on the steel surface, and grow outward toward the free surface. Temper rolling of spangle-free galvanize is able to produce a smooth, matte surface with controlled roughness and little, if any, evidence of the zinc grain boundaries or metallic lustre.

As there are now environmental concerns about the use of lead, some galvanized sheet manufacturers that still market a spangled product have developed practices whereby a small amount of antimony is added to the lead-free zinc coating bath. Antimony influences spangle formation in a similar fashion to lead while being environmentally acceptable. The final result is a relatively smooth, visibly spangled coating. Typically, the amount of antimony in the coating bath is about 0.03 to 0.10%. Keep in mind, however, that to achieve the highest quality, extra smooth coating, a spangle-free practice is recommended.

Galvanneal coatings are produced by using a reheating furnace above the zinc bath to convert the still molten galvanize coating to a zinc-iron alloy. By heating to 590°C for a few seconds, the zinc and iron diffuse into each other, creating a zinc-based coating with a bulk 10% iron content. It is matte grey in appearance and has a surface that encourages excellent paint adherence and very good spot weldability. Figure 5 illustrates the nature of a galvanneal coating at high magnification, showing the needle-like zinc-iron crystals into which the pre-treatment and/or paint can "lock".

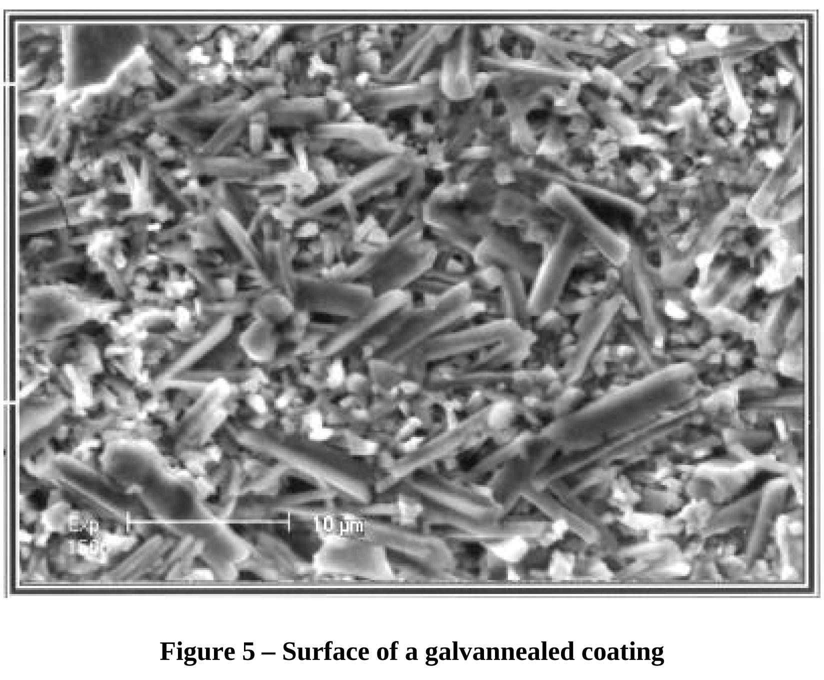

Figure 5 – Surface of a galvannealed coating

Galvanneal intended for automotive exposed parts is also temper passed in order to control the surface roughness profile in preparation for the final paint coating process, where the object is to achieve a high DOI (distinctness of image). Because of the cold work imparted to the sheet by temper rolling, the steel has slightly higher strength and slightly lower ductility. In fact, temper rolling of coated sheet is sometimes done primarily to increase its yield strength.

Most temper rolling of coated sheet is done on mill stands that are located in the coating line, although it can be done on stand-alone mills. It is important that the flatness of the sheet not be adversely affected by temper rolling, so this is an aspect that must be monitored during this operation. Given that the sheet can be extended up to 2%, its thickness can therefore be reduced by that amount. Allowance for temper rolling should be made when setting the sheet cold rolled thickness prior to galvanizing.

Improving Resistance to Storage Stain

Chemical Treatments – Chromium Based

To reduce the susceptibility of metallic coated steel sheet to storage stain, the practice for many years has been to treat it with an aqueous solution of chromic acid, chromium salts and mineral acids to produce a thin-film coating on the surface. This inorganic chemical or "passivation" treatment is applied at the end of the coating line. The solution dissolves some of the metal and forms a protective film containing complex chromium and metal compounds[1]. The exact formation mechanism for chromate coatings is not fully understood but in general is a dissolution and precipitation process similar to what occurs during phosphating. The thickness and color of chromate coatings depend mainly on the chromate concentration, pH and dipping time. The coatings are usually applied so thin that they are essentially invisible. Thicker coatings may have a yellowish or greenish appearance and could be anywhere from 0.1 to 0.6 μm thick. The total chromium content of the coating is usually 1-2 mg/ft^2, with less than half as hexavalent chromium in a complex mixture of metal salts and oxides.

Galvanized sheet produced on hot-dip coating lines has an aluminum oxide (alumina) layer a few tens-of-nanometers-thick[2] on the surface, which comes from the aluminum used to inhibit the zinc-iron alloying reaction. This alumina layer forms very rapidly once the strip comes out of the zinc pot. For chromate passivation to be effective, this oxide layer must be removed during the passivation reactions. The passivating solution must therefore contain enough fluoride to attack and dissolve the surface alumina layer prior to deposition of the chromium compounds.

What is Storage Stain?

Storage stain is a corrosion stain that is typically white, but which can also take the form of a grey or black deposit on the surface. Since the most common form of discoloration is white in appearance, storage stain is often called **white rust**. It can occur when sheets of galvanized steel that are in close contact (in a coil or stacked in lifts/bundles) get wet, either by water intrusion, or by condensation from air trapped between the sheets. The discoloration is due to the corrosion products that form after zinc reacts with moisture in the absence of free air circulation.

Protection of the zinc is afforded through barrier and passivation effects. The complex chromium oxide acts a barrier while the hexavalent chromium contained in the film serves to re-passivate exposed metal. Water that comes in contact with the film dissolves the hexavalent chromium, forming a chromate solution, which then forms a fresh passivation film on the surface. This is the reason for the "self healing" ability of chromate passivation films. This self-healing attribute is limited under wet conditions, such that chromium based passivating films do not prevent the eventual formation of storage stain if the water is allowed to remain between contacting surfaces.

The effectiveness of chromating in preventing white rusting of zinc in four different tests is shown in Figure 6. The severity of the salt spray test is evident in this chart. Note also that staining is immediate if the surface chrome level is at or below 0.5 µg/cm^2.

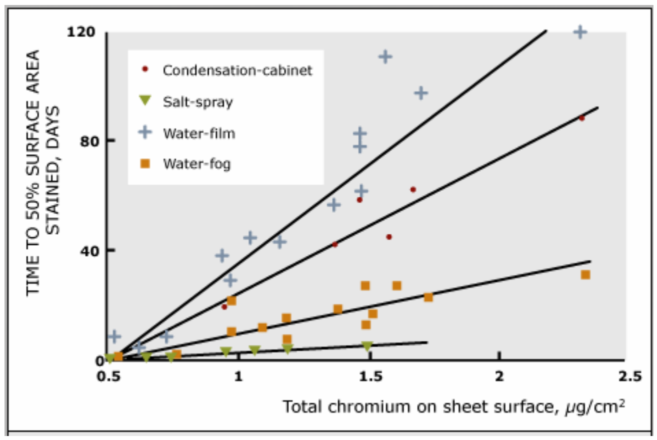

Figure 6 – Effect of chromating on the performance of galvanized sheet in various accelerated corrosion tests[3]

The white rust that forms on storage stain-damaged galvanize is mostly zinc hydroxide, although it will eventually turn black if left unchecked. When storage stain on galvanize turns black it usually means that iron has become part of the corrosion product and enough zinc has been consumed to expose the steel substrate and the remaining zinc is of little, if any, protective value.

Figure 7 – Extensive storage stain (white rust) on sheets used to erect a storage building

Figure 7 shows the post installation appearance of sheets that were stained by water while stacked. Even though such a building is aesthetically unappealing, the degree of storage stain exhibited in Figure 6 will rarely compromise the coating to any significant extent and the condition will gradually disappear with time. Nevertheless, rejection of the sheets is the usual result of such an occurrence.

The stain that forms on water damaged galvanneal is grey to black in color due to the iron in the coating. The corrosion products that form on water damaged zinc-aluminum coatings often have a black to grey appearance – the result of hydrated aluminum hydroxide formation. Figure 8 illustrates the nature of storage stain that forms on galvanneal.

Figure 8 – Storage stain on galvanneal

Galvanneal is generally more at risk from water damage than galvanize since much of it is produced for the automotive industry which uses only unpassivated material.

Premature Spangle Darkening

Premature darkening of the zinc coating can sometimes occur on galvanized sheet after a few days of exposure on new buildings[4]. Reported characteristics include: the darkening only occurs in rural environments; it occurs within one week of initial exposure to the atmosphere; only the outer surface is darkened; and some sheets adjacent to darkened sheets remain bright.

Darkening is much more prominent on galvanized sheets that have a large, plainly visible spangle. Some spangles are darkened more than others (refer to Figure 9). This is due to the varying surface chemistry of different spangles and/or the different levels of the spangle-forming element (lead or antimony) that concentrate on the surface of individual spangles. Premature darkening is not generally reported as being present on spangle-free galvanize. Coatings that are naturally spangle-free do not have lead or antimony added to the coating bath.

Figure 9 – Severe spangle darkening on galvanize

Is it passivated? - It is sometimes necessary to find out if surface has been passivated. Unless the sheet has been heavily treated it is not possible to visually determine this. There are a variety of testing methods available. Surface passivation can be quickly evaluated with 5% hydrochloric acid. A drop will "fizz" on unpassivated zinc surfaces but show little reaction on passivated zinc. The amount of chromium on the surface can always be tested by using chemical stripping and laboratory analysis. The industry standard is to use x-ray fluorescence devices. Field analysis for the qualitative presence of chromate can be performed by placing a drop of a diphenylcarbohydrazide solution on the surface of the sheet and observing if there is a color change or not. If the drop remains clear, no

The Down side of Passivating with Chromium-based Treatments

Two drawbacks of chromium-based chemical treatments are that they interfere with the paintability and weldability of zinc based metallic-coated sheet.

Paintability – Passivation films decrease the adhesion of most paints to zinc. They also severely interfere with the deposition of iron and zinc phosphate coatings. If galvanize is to be prepainted or post fabrication factory painted, it is sometimes produced as unpassivated, although passivated galvanize can be prepainted under limited conditions. Also, passivated Al-Zn coatings are considered paintable in North America. Passivation films cannot easily be removed, even by strong caustic solutions, and the chrome that is removed may contaminate the cleaning and pretreatment solutions on continuous paint lines.

Note – passivated galvanneal (zinc-iron) can be successfully field painted because of its microscopically rough surface but chrome contamination of any cleaning and phosphate baths remains an issue.

Weldability – Chromium passivation interferes with spot weldability by "poisoning" the copper alloy welding electrodes, resulting in shortened electrode life and therefore the likelihood of poor spot welds. To optimize spot weldability, do not use passivated metallic-coated steel sheet products.

chromate is present. This test is described in ASTM D 6492 – Detection of Hexavalent Chromium on Zinc and Zinc/Aluminum Alloy Coated Steel.

Another quick method of finding out if galvanized sheet has been passivated, with chrome or non chrome treatments, is to use a simple condensing humidity test. Place a 4”-6” square of the galvanized sheet as a lid on a beaker containing 140°F water and leave for 15 minutes. After drying, if the underside remains shiny, it is passivated. If it is stained to any degree, it is not passivated. This is illustrated in Figure 10. Note that there is less stain near the outer edge of the test area on the unpassivated sample. This may simply be due to less condensation forming here, or because the galvanized sheet did not reach as high a temperature as in the central area.

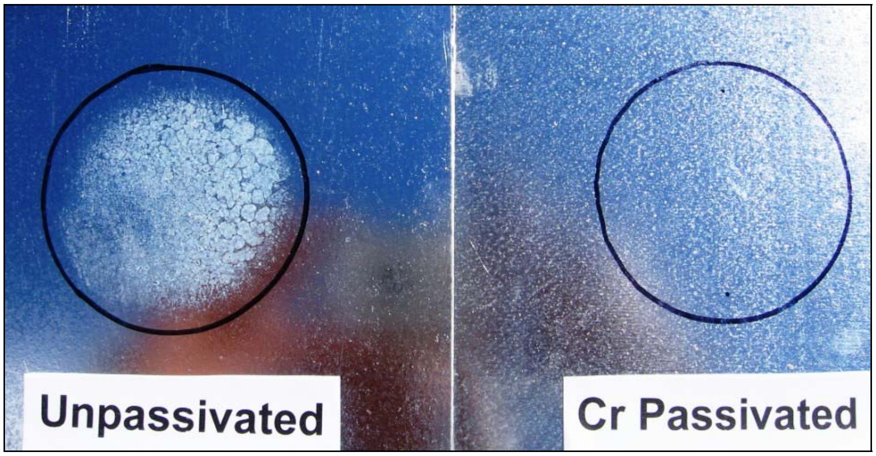

Figure 10 – Fifteen minute condensing humidity test on unpassivated versus passivated galvanize

Chemical Treatments – Non-Chrome

Because of environmental concerns, e.g., European Union RoHS initiative, alternatives to chrome treatments are being sought. There are other chemical passivation treatments available, both removable and permanent, that do not use chromium. **Removable** treatments from various suppliers in various stages of commercialization are designed to protect the coated sheet until it reaches a prepainting line, where the film can be removed prior to the painting operation.

What is RoHS?

Article 4(1) of Directive 2002/95/EC of the European Parliament on the restriction of the use of certain hazardous substances in electrical and electronic equipment provides that from July 1, 2006, new equipment put on the market does not contain lead, mercury, cadmium, hexavalent chromium, PBB or PBDE. This directly affects galvanized sheet as much of it is passivated with solutions containing hexavalent chromium. A request has been received from the industry to exempt Cr^{+6} passivation coatings but has not been not been ruled on at this time.

Permanent non-chrome treatments are under also under development by various treatment suppliers that are actively involved in commercializing these products.

Oils

An alternative to using passivation treatments is to apply oil to the sheet surface. Specially formulated oils are used that contain rust inhibitors, which are usually polar products designed to strongly adsorb onto metal surfaces. They are effective in providing protection from humidity rust due to their ability to prevent moisture from condensing between the laps of a coil or sheets of a bundle. They are not so effective, however, in preventing the penetration of bulk water, e.g., rain, between laps. If water does penetrate between the laps of a coil or sheets in a bundle, the oil will not prevent the onset of storage stain.

Oil also has the benefit of being easily cleaned off at a paint line, so some temporary protection can be given to metallic-coated sheet without the risk of contaminating the cleaning and pre-treatment chemicals with chrome. For added protection, and/or to assist lubrication during forming, passivated sheets can also be oiled.

Pre-treatments for Metallic-Coated Sheet

Phosphate Pre-treatments

A common class of pretreatments used to obtain good bonding qualities between paint and galvanized or galvannealed coatings are *phosphate pretreatments*. Two of the most widely used treatments are *zinc phosphate* and *iron phosphate*. Zinc phosphate is used as a pretreatment on coil prepainting lines and in post fabrication factory paint processes, including automotive body plants. It can also be applied directly on galvanizing lines to provide a product designed for field painting. Iron phosphate is used primarily in post-fabrication factory painting operations to ensure good paint adhesion. In addition to the excellent effect that phosphate coatings have on paint adhesion, they decrease, (more so in the case of zinc phosphate), the tendency for paint disbondment during atmospheric exposure in a corrosive environment.

Zinc Phosphate – As stated above, zinc phosphate coatings can be applied to the galvanized sheet by the steel manufacturer (for field painting) or the coil coater (manufacturer of prepainted sheet), or they can be factory applied to cut sheets or fabricated articles by the end-use manufacturer. It is very difficult, if not impossible, to successfully phosphate galvanize that has been chemically treated with chromate, unless the chromate has been removed – in itself a very difficult task.

The usual zinc phosphating process involves several steps, whether it is applied on a coil line or to formed parts. If there are oils present on the surface of the galvanized or galvannealed steel, the first step is to remove the oil by degreasing. This might involve cleaning with the use of a hot aqueous, alkaline cleaning solution or by other forms of degreasing using solvents. Hot alkali cleaning is preferred because is very difficult to get a clean enough surface (water break-free) using solvent cleaning. The next step is a conditioning stage; the application of a titanium phosphate conditioner to prepare the galvanized/galvannealed surface for the development of a superior zinc phosphate coating. Titanium phosphate aids in the development of a uniform phosphate coating having small zinc phosphate crystals. While several mechanisms have been suggested, the conditioner can be thought to act as seed crystals which promote the growth of zinc phosphate crystals on the surface of the galvanized sheet. Again, the surface **must be water break-free** for this conditioning stage to be effective.

After conditioning, the zinc phosphate coating is applied by immersion in a zinc phosphate solution or by spraying it onto the surface of the galvanized or galvannealed sheet or part. During the time that the surface is in contact with the acidic phosphate solution it actually dissolves a small amount of the galvanized (zinc) coating. At the surface of the zinc, the acid attack of the zinc phosphate produces a localized increase in the pH, resulting in the precipitation and deposition of insoluble zinc phosphate crystals on the surface of the galvanized coating. After allowing the reaction to take place for some time, this crystallizing action leaves behind a continuous, relatively thick solid film of zinc phosphate on the surface. After the zinc phosphate film is deposited, the steel is removed from contact with the solution and then thoroughly rinsed and dried.

Zinc phosphate coatings often receive a final sealing rinse treatment. Typically, the sealer contains chromates for enhanced corrosion protection, although chrome-free sealers are available.

The steps in a 6-stage zinc phosphating operation are:

- Alkaline cleaning
- Water rinse
- Titanium activator rinse
- Application of the zinc phosphate solution (spray or immersion)
- Hot water rinse
- Sealing rinse

The total cycle might take several minutes. For example, a spray phosphating time might be of the order of 3 minutes to develop a film weight of 150 to 300 mg/ft^2 of surface area. However, for coil-line phosphating, typical treatment times are in the range of 5 to 10 seconds, requiring solution parameters to be adjusted accordingly.

To accomplish the development of the preferred fine zinc phosphate crystalline surface, it is important to closely follow the specified temperatures, times, and chemical concentrations in each of the above stages.

For both zinc and iron phosphating, the first way the product is improved is that the somewhat rough and porous phosphate film allows for mechanical keying between the phosphate and the paint. The substantial quantity of oxygen in the phosphate film also promotes chemical bonding (hydrogen bonding) to occur between the paint and phosphate coating. In the case of zinc phosphating, the zinc in the coating significantly reduces the rate of *paint undercutting* at areas where the integrity of the paint is destroyed. Since prepainted steel is fabricated after painting, it can have uncoated shear cut edges exposed to the environment and can be subject to damage during installation. Prepainted steel that is pretreated with zinc phosphate therefore has excellent bond line durability, giving more resistance to paint undercutting that can start at sheared edges or damaged areas. This is also the case on factory painted articles that may be subject to paint damage during use.

To further describe this benefit (*reduced rate of paint undercutting corrosion*), consider a prepainted galvanized surface. If the paint is damaged, the natural tendency is for the corrosion reaction to undercut the paint and move laterally along the sheet surface by corroding and dissolving the galvanized coating near the bond line. This breaks the bond between the paint and the sheet, and the paint can then peel off. A well-developed zinc phosphate pretreatment slows down this lateral rate of undercutting corrosion, and a considerably longer product life results.

Some investigators claim that zinc phosphating is particularly effective on zinc coatings containing high levels of iron[4], e.g., galvanneal, as the amount of adhesion-enhancing phosphate formed increases with increasing iron content in the coating. It may be that the nature of the galvanneal coating surface (refer to Figure 4) simply results in less under-paint corrosion because of superior bonding that occurs. In any case, the galvanneal (zinc-iron) coated sheet used by many automotive companies for auto body panels has proven excellent corrosion resistance after being coated with zinc phosphate and the various multilayer paints systems used in auto body manufacturing plants.

As stated earlier, some steel sheet manufacturers produce phosphate-treated galvanize directly off galvanizing lines. This product has a matte grey appearance and provides a corrosion inhibiting, crystalline zinc phosphate, micro-porous surface that promotes exceptional adherence and corrosion resistance of field-applied paints. This product is commonly known as **"Bonderized Steel"**, and is illustrated in Figure 11 in the unpainted state.

Figure 11 – Unpainted Bonderized steel roof (courtesy of Steelscape Inc.)

Figure 12 is close-up of **Bonderized** sheet that has been coated with a clear acrylic lacquer. The popularity of this material for unpainted architectural uses is growing rapidly in some areas of the United States. The lacquer coating preserves the **Bonderized** look for a longer time.

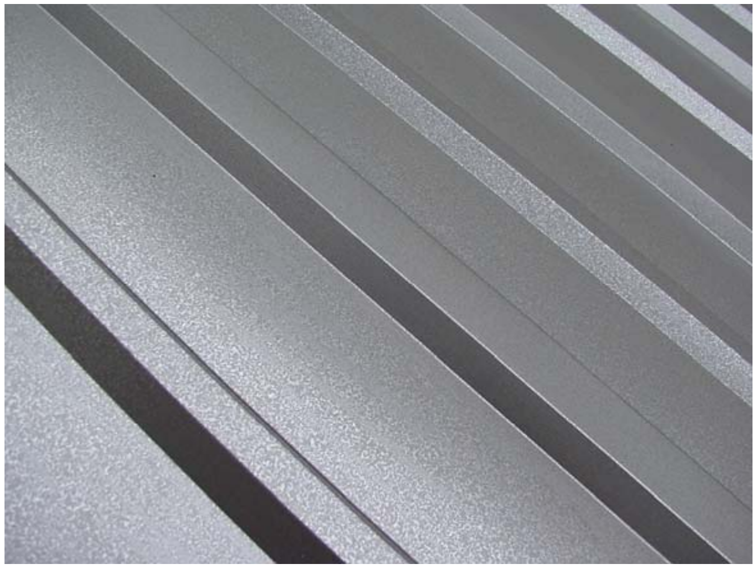

Figure 12 – Bonderized and lacquered galvanized sheet panel (courtesy of Steelscape Inc.)

Iron Phosphate – Many post-fabrication factory phosphating operations use iron phosphate. As it is easier to apply than zinc phosphate, iron phosphating is generally performed using a 3 stage process (clean, iron phosphate, rinse/sealer), although there are some 5 stage processes. Iron phosphating is less costly than zinc phosphating and does not offer the same corrosion resistance benefits as the zinc-bearing version. However, if an iron phosphate bath is run with the proper conditions, a zinc phosphate coating can be applied on zinc coated sheet due to the zinc from the galvanized layer. Iron phosphating does result in excellent paint adhesion by the same method described earlier for zinc phosphating. Since iron phosphating is used primarily for treating fabricated assemblies, the entire surface gets treated then painted, leaving few if any uncoated edges where corrosion can easily begin. Many powder coating operations use iron phosphate pretreatments. The heavier thickness of the paint applied by this method is a good barrier against the onset of corrosion.

Chromate Conversion Pre-treatments

Chromate conversion treatments change the zinc surface to a complex oxide layer about 0.5-3 μm thick, and contain chromium hydroxide, zinc hydroxy-chromate, and zinc chromate[5]. When used as paint pre-treatments on prepainting lines these coatings are usually heavier than when used as a humid stain resistant coating, and thus have a greenish/yellow-iridescent, brown or drab appearance. The color varies with bath formulation, process parameters, film thickness, and substrate. These treatments are used on both zinc and aluminum-zinc coated steel sheet to enhance the corrosion resistance of the final prepainted product.

On prepainting lines, these treatments can be applied with the traditional tank-spray process, or by a dry-in-place (DIP) method using roll coaters. Galvanize intended for prepainting is usually produced as unpassivated. On the other hand, passivated Al-Zn (GALVALUME®) is routinely pre-treated on prepaint lines to remove some of the passivation chrome, then deposit fresh chrome pre-treatment on top of the remaining chrome passivate to give excellent corrosion resistance and paint adhesion. Chemical treatment suppliers should be consulted for specific products to be used for this application.

Chromium based pre-treatments may contain both trivalent and hexavalent chromium. The environmental drive to cease using hexavalent chromium, e.g., EU RoHS initiative, has resulted in these treatments beginning to be phased out and replaced with the less environmentally sensitive zinc phosphate pre-treatment. While a well-applied chromate conversion coating does afford substantial added corrosion resistance to many prepaint systems used on zinc-coated steel sheet, zinc phosphate treatments have gained favor because of their superior resistance to under-film corrosion as described in the previous section.

Surface Lubrication

The main reason for applying oil to the surface of metallic-coated steel sheet is to provide lubricity to aid subsequent roll forming or stamping operations. Some end uses require heavy oiling, while others need only a very small amount. The oil prevents galling, scratching, and fracturing during fabrication. The steel supplier applies the oil on the coating line just before the sheet is recoiled. In many cases the oils used to aid lubricity are the same oils used for storage stain resistance. Typically, oil is applied electrostatically, using a device that first atomizes the oil, and then deposits it on both sheet surfaces in a controlled manner using electrostatic forces. This allows close control of the amount of oil on the surface.

Most of the oils used to aid forming are of the typical fluid variety (mineral “slushing” oils) with varying viscosity and levels of volatile components and rust inhibitors. Oils with a high volatile content are designed to evaporate when the sheet is exposed to the air and hence are called “vanishing” oils. Some oils become “dry lubricants” after they are applied and therefore do not “run” off the sheet. Other end users want some degree of protection and added lubricity without the presence of conventional oils. This has led to the development of thin, clear polymer coatings that are discussed in the next section.

Another product applied for surface lubrication is **dry film lubes**. Typically they are water-borne acrylic coatings applied in-line (on a coating line or prepaint line) that have similar characteristics to the acrylic coatings described in the next section except they are not designed for long term corrosion resistance. Their purpose is to provide superior lubrication during difficult forming operations.

Resistance to Fingerprinting and Handling Marks

Some metallic-coated sheet products are susceptible to surface marking during processing and handling. For instance, galvanized sheet can be permanently marked by the perspiration of workers who come in contact with it during the manufacture of heating/ventilating ductwork. While not harming performance, the marking affects the esthetics of the product when intended for an exposed end use, such as shown Figure 13. The white stains are most likely the result of the salt from the worker’s perspiration permanently marking the surface. Once stained in this manner, there is no known method of restoring the original metallic lustre.

Figure 13 – Fingerprinting and handling marks on exposed galvanized ducting

Aluminum-zinc coated sheet is subject to roll forming and handling marks that appear as permanent black smudging. Contact with the forming rolls in roofing sheet lines can leave permanent black abrasion lines on the sheet surface. Workers constructing roofs can leave hand prints and boot marks that turn dark and remain visible for years.

To provide a product that is resistant to marking, the industry has developed acrylic coatings for metallic-coated sheet. They are usually applied at the coating line using a roll-coating technique and infrared and other curing ovens. The coating is clear and typically consists of a water-soluble acrylic resin and inorganic corrosion inhibitor. Benefits may include: can be roll formed dry without need of vanishing oil; resists hand and/or foot marking during handling and installation; provides good resistance to storage stain/transit corrosion; and retains brightness over a longer time.

Keep in mind that these products are not all alike. Some are more paintable than others, and if not painted, tend to dissipate after 12 to 18 months. These types also tend to be less roll-formable. The coatings that are more roll-formable (and have a tendency to be less paintable) are good at staying on the surface for many years and thus enhance the long term corrosion resistance, and brightness, of the sheet product. Again, chemical treatment suppliers should be consulted for the appropriate product to use in a specific circumstance.

Most producers of acrylic-coated metallic-coated sheet market the product with the term "Plus" added to their normal coated sheet trade names, e.g., "GALVALUME® Plus" or "ZINCALUME® Plus".

Other Treatments

Preparing for Field Painting of Galvanize

It is very difficult to obtain good paint adherence on **new zinc-coated surfaces** passivated with chromate solutions. Where possible, the sheet should be allowed to “weather” for at least 12 months to allow the surface to oxidize. In some environments it may take up to 18 months for sufficient oxidation to occur to provide good paint adhesion. Passivated galvanize remains brighter longer than unpassivated, but even the latter must weather for a period of time before it is ready for painting. This is to allow erosion of the alumina layer (see page 6) that is on the surface.

Weathered galvanize has oxidized to the point where chromate and alumina films have been largely washed away and the zinc at the surface has been converted to zinc oxy-carbonate. Good paint adhesion is more readily achieved on such a surface. **To determine if the galvanize is ready to be painted, check if it is water break-free.** If it is not then it must weather for a longer time or be treated with phosphoric acid before painting.

Light sanding is another method of preparing galvanized surfaces for painting, but there is always the risk that the zinc thickness will be reduced to the point where corrosion resistance is compromised.

Another source of information on painting galvanize is ASTM specification D 2092 Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting.

On any galvanized surface that is being painted, it is extremely important that the surface be clean and dry. Any surface dirt or rust must be removed with a stiff wire brush. Grease and oil must be removed with mineral spirits or detergent and water. All traces of soap should be removed by thorough rinsing. Paint only when the surface is completely dry. Again, having a water break-free surface is preferred to obtain good adhesion.

Numerous proprietary pretreatment solutions, including zinc phosphate, are available from many suppliers. The use of these solutions should be seriously considered to maximize the adherence, and thus protective life, of the paint.

Many different primers are available that are designed for galvanize. The paint supplier should be consulted as to whether a primer is necessary and is compatible with the topcoat being used. Similarly, the topcoat should be designed for metal surfaces, whether or not a primer is used. Some topcoats designed for painting metal work best without a primer. Many paints designed for wood do not perform well on galvanized steel. Products of decomposition in the oils of these paints react with the zinc surface and cause the paint to peel. Most paints designed for galvanize are based on acrylic resins.

To summarize, when field painting galvanized steel:

- Allow adequate time for weathering or pretreat the surface
- If weathering or pretreatment is not possible, light sanding of the surface may be an option

- Paint on a clean, dry surface
- Use paint designed for galvanized steel, including any primer that is used
- Follow the paint suppliers recommendations

Dulling the Metallic Lustre

The GalvInfo Center has received a number of calls from users of galvanized sheet who wish to dull the bright metallic lustre or sheen exhibited by galvanized sheet on building roofs and walls. While most owners of galvanized buildings prize the bright metallic look, some are attempting to achieve a particular esthetic effect and/or desire a duller look. The reflection of the sun off of shiny galvanized buildings may cause problems with neighbors and/or passing traffic. In some cases, city or county building authorities prohibit the use of shiny metallic siding and impose a maximum reflectivity, e.g., maximum reflectivity index of 0.35. Of course it is always possible to obtain a very dull appearance by using pre-phosphated galvanize as described previously, but the matte grey appearance of this product may not be what is desired. If the need for a dull surface is known during the design stage, another option is to order galvanize as “skin passed”. The surface of this product has a matte metallic appearance, but without lustre or sheen.

While the GalvInfo Center does not advocate or promote the practice, it is possible to dull the normal bright appearance of passivated new galvanize in the field. One method is to apply a product such as ZEP Toilet Bowl Cleaner to the surface for approximately 10 minutes, then thoroughly rinse off and dry the sheet. This, and similar products, contain small amounts of phosphoric and/or hydrochloric acid and will, over 10 minutes, noticeably etch the surface as shown on the right in the photograph below. In Figure 14, the areas to the left illustrate the normal bright, reflective metallic finish of spangle-free galvanize. The metallic sheen has been removed from the “dulled” area on the right and the very small zinc grains made visible. The dulled area is water break-free.

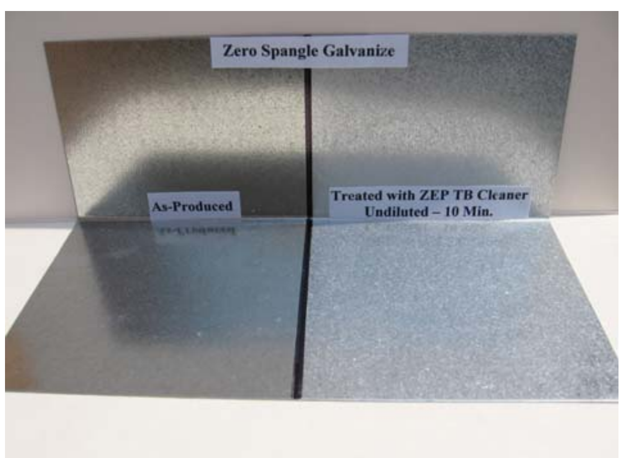

Figure 7 – Galvanized sheet can be dulled using acid-containing household cleaners

CAUTION: The results shown above were obtained by using a corrosive agent on a small surface area. Using this procedure on a large area has not been tried and may not uniformly etch the surface. Extreme precautions must be taken if this is attempted, both from the standpoint of personal safety and the effect on the galvanize surface. Protective personal safety equipment guarding against splashing of the solution must be used, and thorough rinsing of the surface must be achieved. The effect on the service life of the sheet after performing this dulling procedure has not been determined.

Summary

There are many surface treatments that can be applied to metallic-coated sheet products for many different reasons. Most of these treatments involve the application of carefully formulated chemicals to achieve the desired outcome, whether it is protection from water damage, improved corrosion resistance, or as an assist to metal forming. It is not possible to list the scores of products available to surface-treat zinc and zinc-based coated steel sheet. To find a product suitable for your application, the GalvInfo Center encourages readers to consult with our Sponsors (see list at www.galvinfo.com), whether it is to learn about the chemical treatment best suited for a given purpose, or to determine the characteristics of the final surface-treated coated sheet product.

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