

## Introduction

The surface of zinc and zinc alloy-coated steel sheet can be treated using one or more of many methods. **This GalvInfoNote deals with pretreatments used to prepare coated sheet for factory painting.** Other treatments are used for different reasons, namely:

- Improving uniformity of appearance (see GalvInfoNote 2.8)
- Treatments for enhancing formability (see GalvInfoNote 2.9)
- Imparting resistance to storage stain (see GalvInfoNote 2.10)
- Preparing galvanize for field painting (see GalvInfoNote 2.11)
- Treatments for resistance to handling and fingerprint marks (See GalvInfoNote 2.13)

All coil painting lines have the ability to apply pretreatments prior to application of the paint. Also, some hot-dip lines can apply zinc phosphate to the coated sheet.

## Phosphate Pre-treatments

A common class of pretreatment used to obtain good bonding between paint and galvanized or galvanized coatings is *phosphate pretreatment*. Two of the most widely used versions 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 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** – It can be applied to galvanized sheet by the steel manufacturer (for field painting) or the coil coater (manufacturer of prepainted sheet), or 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 – a very difficult task.

The usual zinc phosphating process involves several steps, whether application is on a coil line or to formed parts. If there are oils present on the surface of the galvanized or galvanized 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 galvanize/galvanized surface for the deposition of a superior zinc phosphate coating. Titanium phosphate aids in the development of a uniform coating having small zinc phosphate crystals. While several mechanisms have been suggested, the conditioner can be thought to create seed crystals, which promote the growth of zinc phosphate crystals on the surface of the sheet. Again, the surface **must be water break-free** (no beading when the surface is wet) 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 galvanized 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 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 zinc or zinc-iron 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. After this 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<sup>2</sup> 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) 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<sup>1</sup>, e.g., galvaneal, as the amount of adhesion-enhancing phosphate formed increases with increasing iron content in the coating. It may be that the nature of the galvaneal coating surface (see GalvInfoNote 1.3, Figure 3) simply results in less under-paint corrosion because of superior mechanical bonding that occurs. In any case, the galvaneal (zinc-iron) coated sheet used by many automotive companies for auto body panels has time-tested excellent corrosion resistance when coated with zinc phosphate and the various multilayer paints systems used by 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 1 in the unpainted state.



Figure 1 – Unpainted Bonderized steel roof (courtesy of Steelscape Inc.)

Figure 2 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.

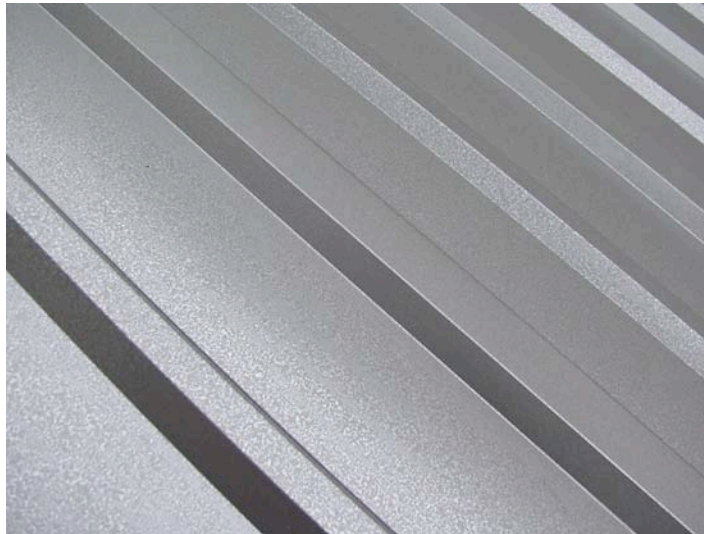


Figure 2 – Bonderized and lacquered galvanized sheet panel (courtesy of Steelscape Inc.)

**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 as it incorporates some 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 powdercoating operations use iron phosphate pretreatments. The heavier thickness of the paint applied by this method is a good barrier against the onset of corrosion.

Additional information on phosphate coatings can be obtained from ASM Handbook Volume 5 Surface Engineering, 1994, pp. 378-404, available at <http://asmcommunity.asminternational.org/portal/site/www/>

## Chromate Conversion Pre-treatments

Chromate conversion treatments change the zinc surface to a complex oxide layer about 0.5 -3 mm thick, and contain chromium hydroxide, zinc hydroxy-chromate, and zinc chromate<sup>2</sup>. When used as paint pre-treatments on prepainting lines these coatings are usually heavier than when used as passivation treatments, 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 fresh chrome pre-treatment is deposited 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 (see GalvInfoNote 2.10), has resulted in these treatments beginning to be phased out and replaced with the less environmentally sensitive, chrome-free, zinc phosphate pre-treatments. While a well-applied chromate conversion coating does afford substantial added corrosion resistance to many prepainted 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.

Additional information on chromate conversion coatings can be obtained from ASM Handbook Volume 5 Surface Engineering, 1994, pp. 405-411, available at <http://asmcommunity.asminternational.org/portal/site/www/>

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<sup>1</sup> Zhang, Xiaoge Gregory: *Corrosion and Electrochemistry of Zinc*, Plenum Press, New York, 1996, p. 262.

<sup>2</sup> Fudge, Duane W; Favilla, John R; *Coil Passivation*, Galvatech '04 Conference, Chicago, IL, April 4-7, 2004.