Performance of Zinc-Rich Paint vs. Hot-Dip Galvanizing

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All zinc coatings are not equal relative to their corrosion performance. There are many characteristics that distinguish the two corrosion protection systems.

The performance of hot-dip galvanizing and the performance of zinc-rich paint are often viewed as equivalent due to the false perception that all zinc coatings are 'galvanizing' (e.g., zinc-rich paints are commonly referred to as 'cold galvanizing'[1]). The interchangeable use of the word 'galvanizing,' to represent a family of coatings that uses zinc as a means of corrosion protection, has falsely portrayed all zinc coatings as being equal with regard to their corrosion performance.

This article examines the basis of the comparison of zinc-rich paints to hot-dip galvanizing, specifically the tests applied to support the comparison. It also presents ten characteristics that distinguish the two corrosion protection systems.

History of Zinc as Corrosion Protection for Steel

Zinc was first demonstrated to protect steel from corrosion in 1742 during a demonstration by a French chemist named **P.J. Malouin**. The first patents for using zinc as steel corrosion protection were filed in France and Britain in the early 1800s, citing a process that cleaned steel in large tanks followed by dipping the steel in a bath containing pure liquid zinc.[2] This is commonly known today as batch hot-dip galvanizing. Over 200 years later, the inherently simple hot-dip galvanizing process has changed little and is one of the most widely used forms of protecting steel from corrosion.

The use of zinc in hot-dip galvanizing has spawned numerous other processes that utilize elemental zinc as a means of corrosion protection, such as zinc-rich paints.

Zinc-rich paints were first developed in Australia during the 1930s. Over the years, the formulations of the paint have changed and currently there are various grades of zinc-rich paint available on the market. Each of these paints differs in concentration of zinc dust, binder material (organic or inorganic) and application method.[3] It is important to note the performance of zinc-rich paints are not all equivalent. Specific formulations and application methods can significantly alter the performance from one type of zinc-rich paint to the next.

All zinc coatings are portrayed as providing two types of corrosion protection for steel: barrier and cathodic. Barrier protection protects steel by means of a semi-impermeable barrier to the elements that cause corrosion. This is the main mechanism by which paint operates. However, by including metallic zinc in coatings, cathodic protection is also theoretically provided to the steel. Zinc is more electro-negative than steel, thus when the two are in contact in the presence of an electrolyte, it interrupts the normal corrosion process of steel by donating its electrons to prevent steel from losing its electrons. Thus, zinc sacrifices itself in order to protect steel from corroding.

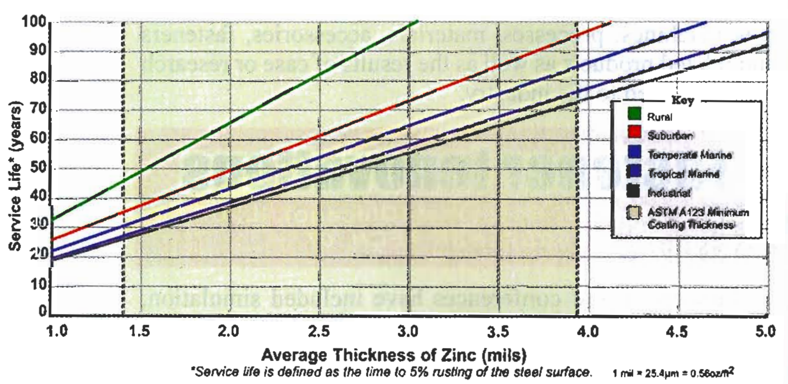
Batch Hot-Dip Galvanizing

Batch, or after-fabrication hot-dip galvanizing, is used in a variety of industries to protect a myriad of steel products. As a factory-controlled process, hot-dip galvanizing produces a coating resulting from a metallurgical reaction between liquid zinc and iron in steel. The coating consists of four layers, three of which are zinc-iron alloy and the fourth is a top layer of pure zinc. As a result of this reaction, a tightly adherent, abrasion-resistant coating is formed. Typical coatings on structural steel will be in excess of 4 mils (103 mm), but can vary based on the thickness and type of steel. Unlike most coatings where a thickness is specified, the galvanizer must provide a minimum coating thicknesses depending on which coating specification is used (e.g., *ASTM A123, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*, is the most common).

Bridge, highway, electrical utility, industrial and marine construction projects have all realized the benefits of hot-dip galvanizing. Hot-dip galvanizing is relatively maintenance-free and commonly prevents any corrosion of the substrate steel for 50 to 80 years in most atmospheric environments (industrial, urban, marine and rural), with millions of data points established over the past 85 years to support that position. The accompanying **Service Life Chart shows** the estimated service life of hot-dip galvanized coatings in a variety of environments.

Zinc-Rich Paints

Zinc-rich paints are usually applied by brushing or spraying onto steel cleaned by sand blasting. Organic or inorganic zinc-rich paints are usually applied to a dry film thickness of



Service-Life Chart for hot-dip galvanized coatings in various environments.

2.5 to 3.5 mils and can be applied in a shop or in the field. It is important to note the paint must be constantly agitated to ensure a homogenous mixture of zinc dust and the binder material, whether it is organic or inorganic.

Organic zinc paints consist of epoxies, chlorinated hydrocarbons and other polymers that act as the 'glue' to hold the zinc dust particles together and promote adhesion to the substrate steel. Inorganic zinc paints are based largely on alkyl silicates that perform the same function. With either binder, the zinc dust concentration must be high enough to promote electrical conductivity in the dry film. Otherwise, cathodic protection will not be provided to the substrate steel. Even so, there is some question as to whether cathodic protection is possible at all due to the encapsulation of the zinc dust particles in the binder.

Zinc-rich paints are commonly used to touch-up or repair hot-dip galvanized steel. It is easy as in-field application makes it a very suitable repair material approved for use according to *ASTM A780, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*. Other uses of zinc-rich paints include interior or exterior items that cannot be hot-dip galvanized due to size limitations or where on-site coating application is required.

Testing

Some manufacturers and distributors of zinc-rich paints or cold galvanizing compounds, make claims to Project Specifiers that their products are "equivalent to hot-dip galvanizing" or "as good as galvanizing." These claims are based on the performance of their products and hot-dip galvanized steel in accelerated salt spray or salt fog tests, as defined by *ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus*.

Although appropriate to test paints and other organic/non-organic coatings, *ASTM B117* tests do not allow the pure zinc coating applied via the hot-dip galvanizing process to experience the typical, real-world, wet and dry cycles that occur in exterior use. The wet-dry cycles allow the pure zinc to develop its patina of zinc corrosion products—zinc oxide, zinc hydroxide and zinc carbonate—which form sequentially over time. The final zinc carbonate patina is what gives hot-dip galvanized steel its long-term corrosion protection. Depending on the level of corrosive elements in the atmosphere, the patina and underlying zinc may protect the substrate steel for 50 to 80 years or more without the need for maintenance.

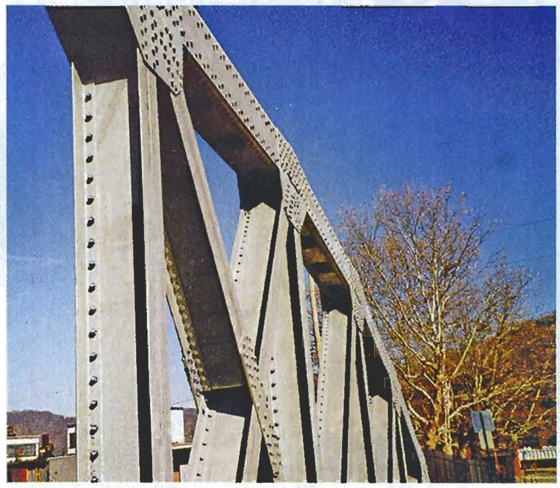
Criteria for Comparison

The primary criterion of comparison of zinc-rich paints to hot-dip galvanizing is durability in use. This durability results primarily because:

- The metallurgical reaction between the iron in steel and the liquid zinc used in the galvanizing process results in zinc-iron metallic alloy layers that are a metallic barrier, impervious to corrosive elements.
- Zinc is anodic to steel and thus, zinc preferentially corrodes very slowly over decades to protect the substrate steel.
- The galvanizing process coats all exterior and interior surfaces, difficult-to-reach corners and recesses and edges and corners with cathodic and barrier protecting zinc.

Specifically, there are at least ten characteristics to compare hot-dip galvanizing to zinc-rich paints. Eight of the

Product being removed from zinc bath.

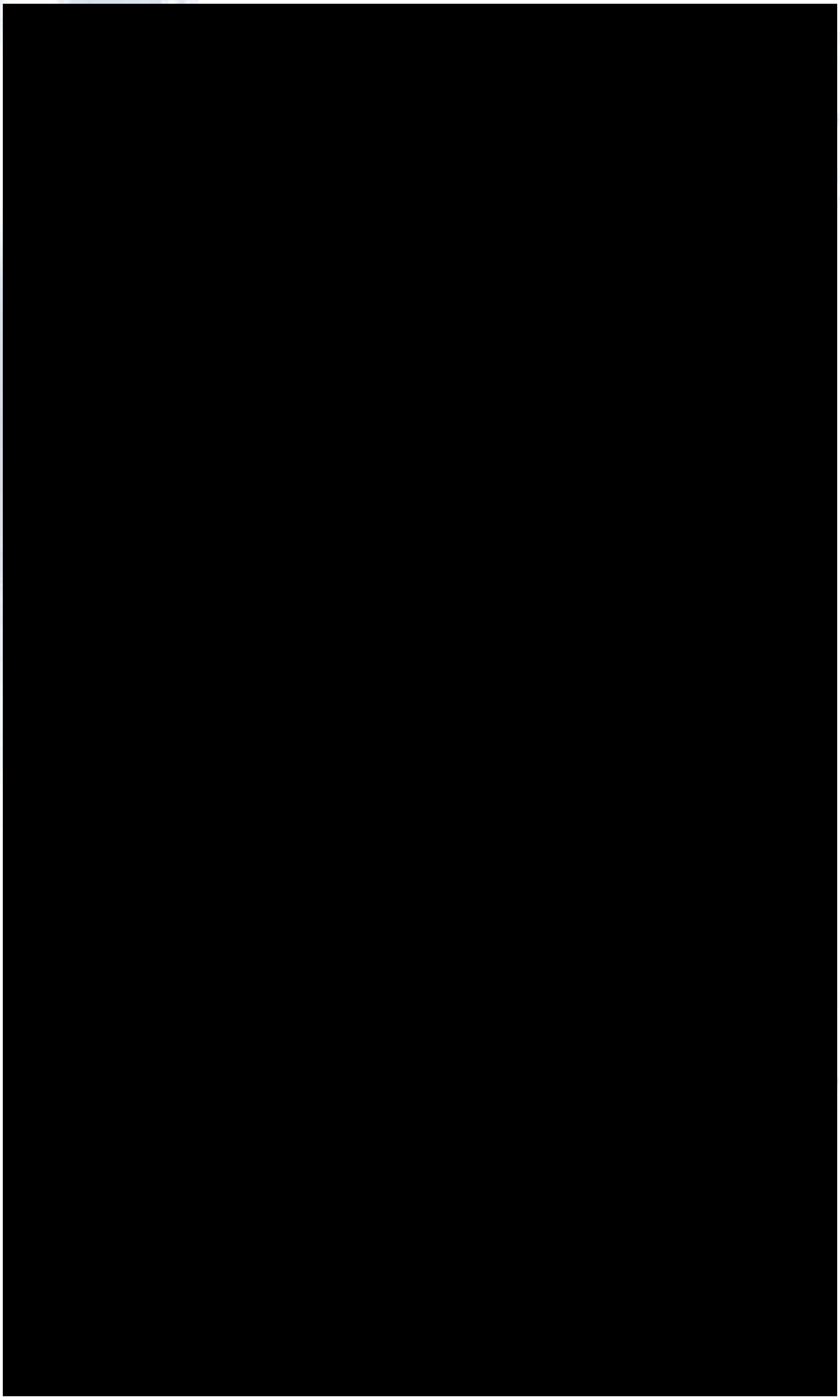


Hot-dip galvanized steel bridge frame.

Zinc-rich paint application.

characteristics were researched by the independent **South African Bureau of Standards**. To see the full report, visit **www.galvanizeit.org/zincpaint.pdf**.

The ten characteristics that can assist in the comparison of hot-dip glavanizing to zinc-rich paints include the following points. The first eight of the characteristics below were researched by the independent South African Bureau of Standards.



1. Coating Thickness: Hot-dip galvanizing is of uniform thickness, even at edges and corners. The zinc-rich paint is typically not of uniform thickness and thus protection is variable along the surface. The corners and edges are particularly susceptible to corrosion because there is usually less bonding of paint at those locations.

2. Salt Fog Test (simulating marine environment): Hot-dip galvanizing exhibited zero base steel corrosion after a period of 1500 hours, at which time the test was stopped. Significant base steel attack was observed on the zinc-rich painted coupons after 1000 hours.

3. Damp Sulphur Dioxide Test (simulating industrial environment): Hot-dip galvanized steel samples exhibited no signs of base steel corrosion after 40 cycles of the test. The zinc rich painted samples showed base steel corrosion and severe edge corrosion after nine cycles.

4. Cathodic Protection (Vee cuts: 10 x 115 mm/0.4" x 4.5"): Hot-dip galvanized steel showed no signs of corrosion after 1500 hours exposure in the salt fog test.[4] The zinc-rich painted steel samples exhibited red rust on the exposed area after only 24 hours, and after 550 hours red rust was evident over the entire exposed surface.

5. Immersion Tests (2000 hours in corrosive mine water): No base steel corrosion, as the hot-dip galvanized steel samples formed stable surface deposits (zinc salts). A substantial increase in nominal thickness of the zinc-rich paint coating showed swelling due to water absorption, resulting in forming of voluminous corrosion products (iron-oxide) in the coating.

6. UV Exposure: Hot-dip galvanized coatings are not affected by UV light. The UV attack on zinc-rich paint was not severe.

7. Abrasion Tests: Hot-dip galvanizing's zinc-iron alloy layers have a DPN hardness from 179 to 250, all harder than the base steel. Data indicated that zinc-rich paint has one-third the abrasion resistance of the hot-dip galvanized coating.

8. Temperature Test: In a 15-minute exposure in temperatures up to 350°C (662°F), hot-dip galvanized coatings did not change appearance or performance traits. The zinc-rich paint deteriorated at 250°C (482°F) and became powdery at 350°C (662°F), even when cooled to room temperature.

9. Bond Strength: Zinc to steel bond produced by hot-dip galvanizing is approximately 3600 psi (25 MPa), making it difficult to scratch or abrade. Conversely, the bond strength of zinc-rich paints is of a lower order at 600 psi (4 MPa).

10. Weather Conditions: Galvanizing is a factory-controlled process, and can be done 24 hours a day, seven days a week, 365 days each year. Zinc-rich paints have specific temperature and humidity limitations.

Summary

While it is true that *ASTM A780* allows for zinc-rich paints to be used, it is not equivalent to hot-dip galvanizing. Zinc-rich paint does not deliver the consistent coating thickness over all surfaces and is not 100% metallic and impervious to moisture and other electrolytes that initiate corrosion. Zinc-rich paint may or may not be a cathodic protection system, depending on the zinc percentage in the dry film. Hot-dip galvanizing provides cathodic protection by nature of zinc being anodic to steel. Zinc-rich paint is not bonded to the substrate steel like hot-dip galvanized coatings. Zinc-rich paints cannot be applied in any weather condition. Hot-dip galvanizing is a factory-controlled process and as such is independent of weather conditions. Additionally, Zinc-rich paints do not perform in the temperature extremes that hot-dip galvanized coatings can and do.

A claim made on the Canadian website for one zinc-rich paint manufacturer says, "For outdoor use ZINGA should be applied in two layers with a total thickness of approximately 80 microns. An application such as this has been shown to last 14 years even in polluted areas."

On the other hand, galvanized steel has hundreds of thousands of documented cases from around the world that categorically show it to last for up to 50 years without maintenance in a host of environments.

To receive additional information on the performance of zinc-rich paint versus hot-dip galvanizing, contact the author or **Circle 201.** FTI

Foot Notes/References...

[1] *Cold galvanizing is a misnomer, as the term galvanizing by definition means there is a metallurgical reaction between steel and zinc, which does not take place when zinc-rich paints are applied to steel.*

[2] ***American Galvanizers Association,*** *"An Anecdotal History of the Galvanizing Industry," 1992, http://www.galvanizeit.org/showcontent,53,85.cfm.*

[3] *"The A to Z of Materials, Zinc-Rich Paint versus Hot-Dip Galvanizing," http://www.azom.com/details.asp?ArticleID=1289.*

[4] *Hot-dip galvanized coatings provide both barrier and cathodic protection and are proven over millions of applications throughout the world. Zinc-rich paints provide barrier protection but because many zinc-rich paints use non-conductive binders and the zinc-oxide content is somewhere between 65% and 95%, there is reason to question whether zinc-rich paints provide any cathodic protection.*

[5] *DPN (diamond pyramid number) is a progressive scale to measure hardness, similar to Brinell and Rockwell scale testing.*

Association Profile...The American Galvanizers Association (AGA), *Centennial, CO, USA, is a nonprofit trade association that serves the needs of after-fabrication galvanizers, fabricators, architects, specifiers and engineers. The AGA offers technical support on today's applications and state-of-the-art technological developments in hot-dip galvanizing for corrosion control.*

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