Zinc Loading vs Performance Requirements for Zinc Rich Primers

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Abstract

Zinc rich primers; both inorganic and organic have been used by the coating industry for many years. Commonly used specifications for composition and/or performance include SSPC Paint 20 (1), SSPC Paint 29 (2), ASTM D5894 (3), ISO 12944(4), ISO 20340 (5). Compositional standards typically define performance based on the % by weight of zinc dust in the dry film, while performance standards may require testing of only the zinc rich primer itself or of the complete coating system. Certain standards have a combination compositional/performance approach. This paper compares the performance of different zinc level primers under different test conditions and highlights the problems that may be experienced when relying only on a compositional requirement or on an inappropriate testing requirement when selecting zinc rich primers.

Introduction

Zinc rich primers, either inorganic or organic, are the most commonly used primers for paint systems applied to atmospheric exposed structures in corrosive environments. While the original applications of inorganic zinc rich coatings were as single coat systems, these days the majority of zinc coatings are applied as the first coat in a two or three coat paint systems. Of these, the most common systems is to apply a zinc rich primer, followed by an epoxy intermediate and topcoated with a polyurethane (or other durable) finish.

A review of different standards shows a wide range in what is considered as being a "zinc rich" coating. The most commonly used standards are ISO12944 and SSPC Paint 20. ISO12944 defines zinc rich as being >80% by weight of zinc dust in the dry film while SSPC Paint 20 has three different levels:

Level 1 – equal or greater than 85 %
Level 2 – equal or greater than 77 % and less than 85 %
Level 3 – equal and greater than 65 % and less than 77 %

Both of these standards also have a performance testing element to them. For ISO12944, to qualify a coating system for use in a C5M environment, the system must pass 4,200 hours of ISO20340 cyclic testing with less than 3 mm of scribe creep. SSPC Paint 20 does not

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differentiate performance based on zinc level, but requires each level to pass 3,000 hours of ASTM B117 (6) salt fog test with no face rust. One key difference between the two tests is that the SSPC Paint 20 test is conducted on the primer alone without topcoating.

In addition to these two standards, there are multiple additional standards related to zinc rich coatings, many of which either refer to a different level of zinc dust in the dry film than either ISO12944 or SSPC Paint 20, or they refer to a % of metallic zinc in the dry film (rather than zinc dust, which typically contains from 94-98% metallic zinc) or they use a different testing protocol, such as ASTM D5894.

So the question is, with all these different standards for composition of zinc rich coatings and different testing protocols, how do you decide what coating is appropriate for a particular environment?

Laboratory Test Results

The authors have conducted a number of different studies on zinc rich coatings comparing their performance under different laboratory testing scenarios.

A comprehensive study was conducted on a wide range of commercially available and laboratory formulated zinc silicate coatings, with varying amounts of zinc dust content, using the ISO20340 cyclic accelerated corrosion test to compare performance of both single coat and three coat (zinc/epoxy/polyurethane) coating systems.

The test protocol of the ISO 20340 involve employment of 25 cycles of UV/Condensation, Salt Spray and low temperature (- 20 ^{0}C) exposure steps. Each cycle is composed of 3 + 3 + 1 day of consecutive exposure of the samples to the conditions described. The panels have a single 2 mm wide scribe down to bare steel and the results are recorded as the average rust creep from this scribe, as measured on 3 test panels for each system. The results from this study are shown below in **Figure 1** in the form of a scatter diagram plotting rust creep in mm against % zinc dust in dry film for the single coat systems and in **Figure 2** for the same primers when used as the first coat in a three coat system. Pictures of some of the test panels are included as **Figure 3**.

The results of this study revealed the following:

1/ There was no correlation between zinc dust level and scribe creep in single coat zinc silicate systems.

2/ There was no overall correlation between zinc dust level and scribe creep in three coat zinc primer systems, although a series of similarly formulated paints (same raw materials, only varying zinc content) did show a trend in performance vs zinc dust level.

3/ Topcoated zinc silicate coatings always, without exception, give <u>more</u> scribe creep than the same zinc silicate primer applied as a single coat.

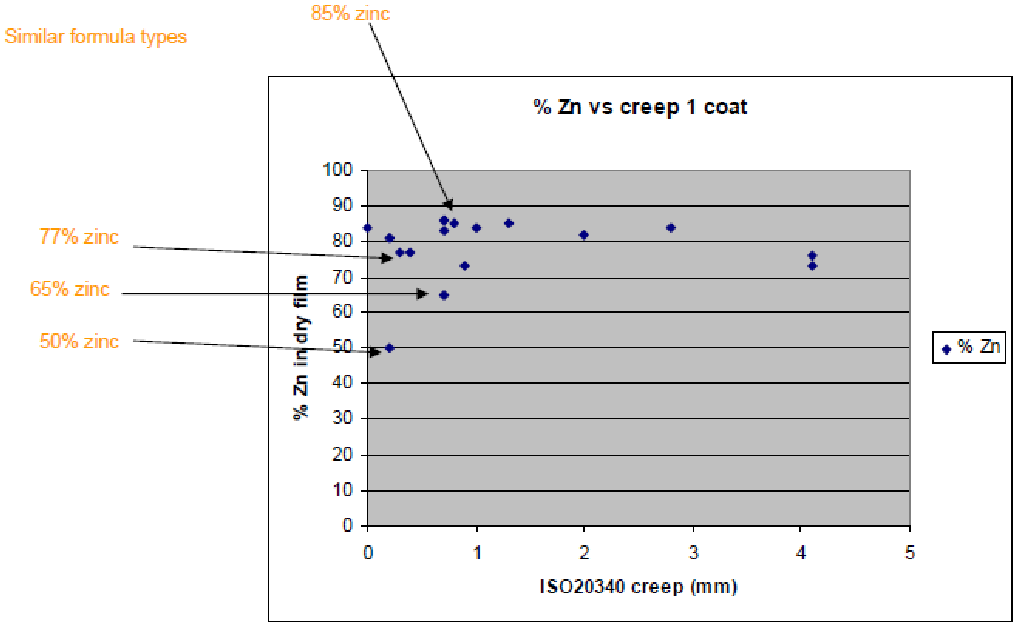


Figure 1 – scribe creep vs zinc dust level for various zinc silicate single coat systems

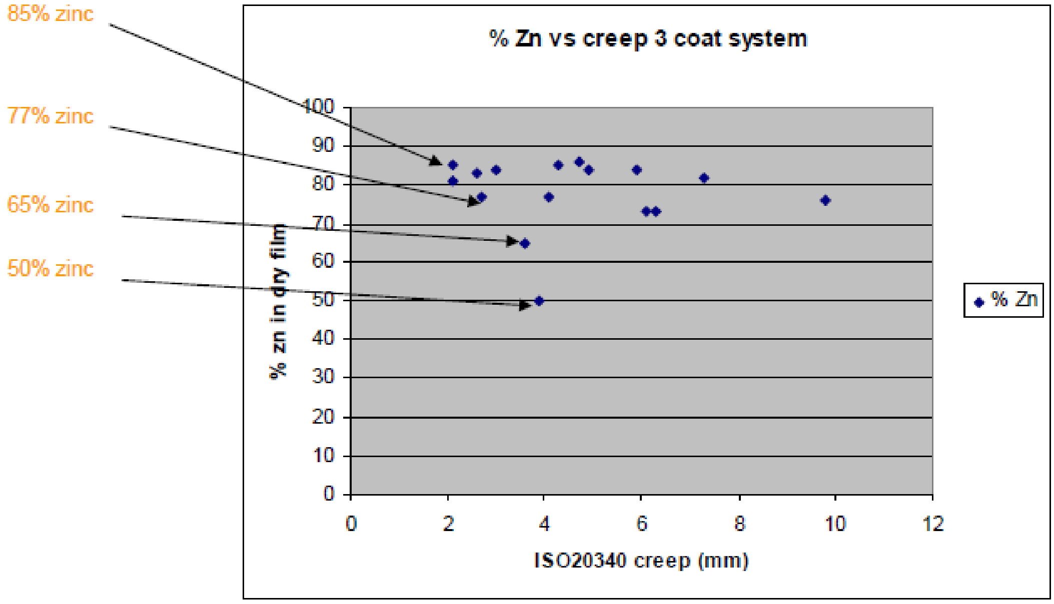


Figure 2 – scribe creep vs zinc dust level for various zinc silicate primers in a three coat system

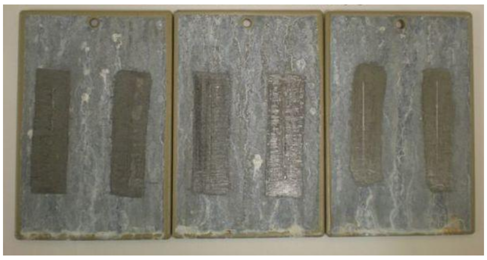
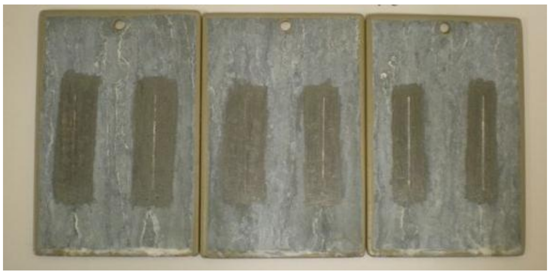
  

85% zinc dust 80% zinc dust 77% zinc dust

Figure 3 – ISO20340 panels of similar formula types

A different study was conducted using a series of similar laboratory formulations at different zinc dust levels according to the SSPC Paint 20 protocol of 3,000 hours of ASTM B117 salt fog testing. Panels from this study are shown in **Figure 4**.

This study indicates that although SSPC Paint 20 has three different zinc level requirements, the performance test in this specification is unable to distinguish between them.

85% zinc dust 80% zinc dust

77% zinc dust 65% zinc dust

Figure 4 – 3,000 hours ASTM B117 salt spray exposure according to SSPC Paint 20 requirements on different zinc level primers.

A separate study conducted compared two different zinc epoxy primers, both formulated at 80% by weight zinc dust in the dry film, in both ASTM B117 salt spray exposure and

ASTM D5894 cyclic prohesion/QUV exposure. A key difference between ASTM B117 and ASTM D5894 is that while B117 uses a neutral (sodium chloride) salt spray, D5894 uses a slightly acidic (sodium chloride/ammonium sulfate) salt spray that is designed to mimic acidic fall out that is typically seen in industrial environments. This study was also conducted using both single coat and topcoated (zinc/epoxy/polyurethane) systems. **Figure 5** shows the panels that were in a single coat exposure, while **Figure 6** shows panels from the topcoated exposure.

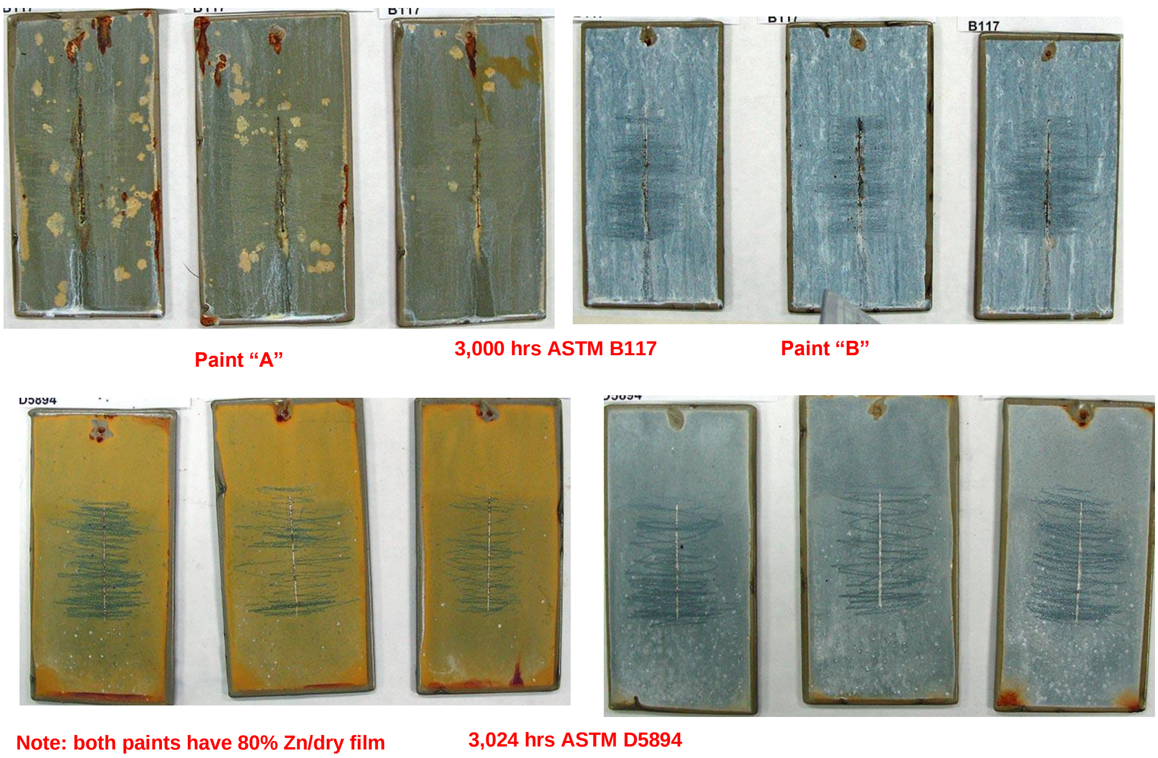


Figure 5 – single coat zinc rich epoxy systems exposed to ASTM B117 and ASTM D5894 accelerated corrosion tests.

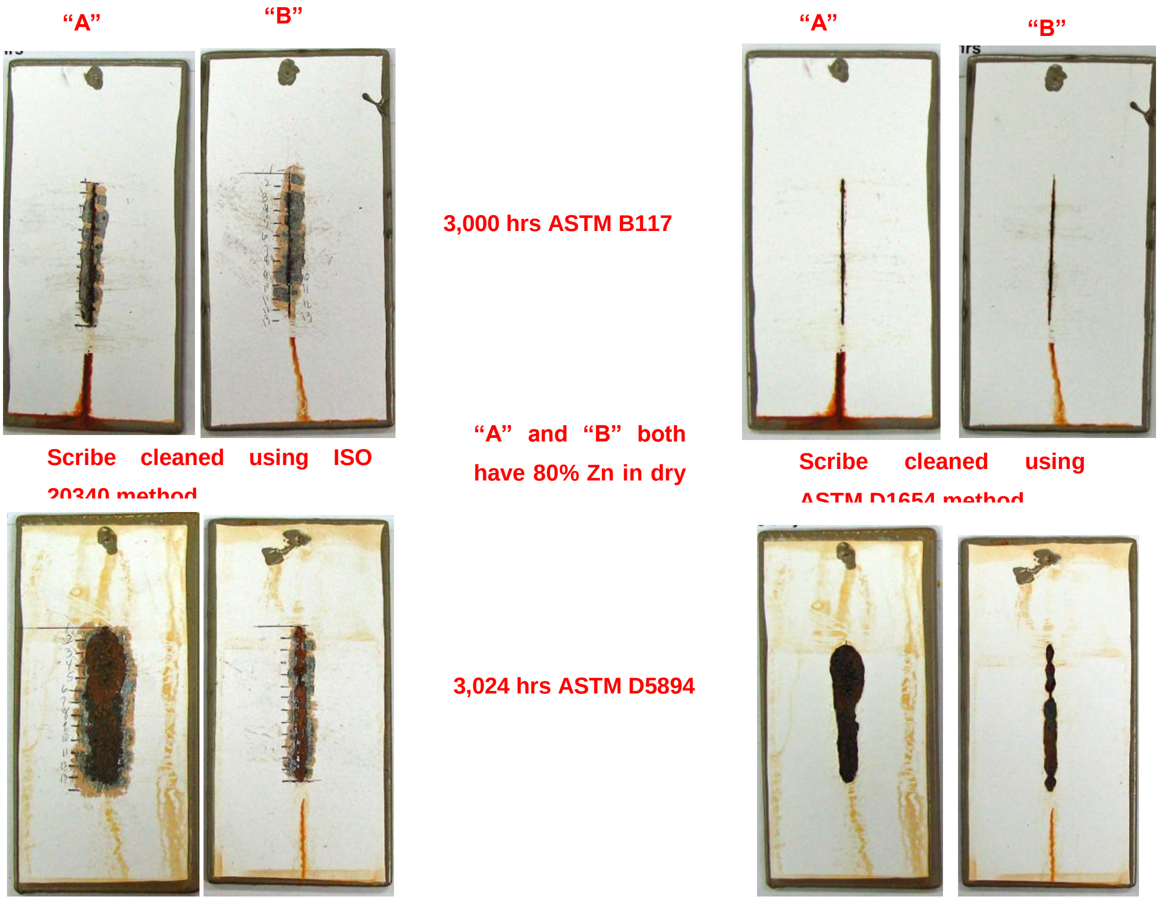


Figure 6 – Three coat zinc rich epoxy/epoxy/polyurethane systems exposed to ASTM B117 and ASTM D5894 accelerated corrosion tests, also showing different scribe evaluation techniques.

These tests showed the following trends:

1/ Two different zinc rich epoxy formulations with the same level of zinc dust in the dry film showed equivalent performance when tested as a single coat in both ASTM B117 and ASTM D5894 tests.

2/ The same two zinc rich epoxy formulations with the same level of zinc dust in the dry film showed different performance when tested as a three coat system in both ASTM B117 and ASTM D5894 tests.

3/ Topcoated zinc rich systems show a greater degree of scribe rust creep in ASTM D5894 testing than in ASTM B117 testing.

4/ A color change was seen in the system pigmented with yellow iron oxide in the single coat ASTM D5894 test which is due to the consumption of zinc pigment by the acidic salt spray.

5/ The method of evaluating the scribe affects the result.

Discussion

The test results show that the % of zinc dust in the dry film, whether in an inorganic zinc silicate or an organic zinc epoxy primer, is not the sole determining factor in product performance. There are many other formulation variables that can affect how a primer performs and these are not taken into account in the typical zinc rich compositional standard.

Indeed, field experience shows that the majority of real world problems are related to the application of zinc silicates – dry spray, poor curing at low humidity, overcoating before full curing of the primer and pinholing of topcoats – rather than any perceived performance differences due to zinc dust level.

The test data also shows how the performance of a single coat of zinc rich primer is unrelated to the performance of a two or three coat system. When considering the corrosion protection mechanism of zinc rich primers this should not come as a surprise.

Zinc rich primers are touted as offering "galvanic protection" to steel. However, studies have shown that a single coat of zinc silicate primer only protects galvanically for approximately 90 days. After this time period, the porous zinc silicate film becomes "plugged" with insoluble zinc corrosion products and acts much more as a barrier coating. The barrier coating that is formed is very dense, compact and well adhered and does provide very good protection. In this regards, a zinc silicate is superior to galvanizing, which will continue to protect galvanically until the zinc layer is consumed. However, the weakness of a single coat zinc rich system is the susceptibility of zinc to attack by acidic ($pH < 5.5$) or basic ($pH > 9$) conditions. This is demonstrated by the performance of the yellow iron oxide pigmented zinc epoxy in the ASTM D5894 test. The color change at the surface shows how the zinc pigment is being consumed – a longer time exposure will surely result in an overall rusting of the test panel as the zinc dust corrodes.

Topcoated zinc rich systems do not have the initial overall galvanic protection of a single coat system, nor do they end up with the zinc rich film becoming plugged with insoluble zinc corrosion products. Rather, the exposed zinc at the very edge of a damaged area will continuously sacrifice itself in the corrosive environment. The result is generally superior to a non zinc primed system, but does not match the single coat zinc rich performance. In addition, an acidic environment will result in an accelerated consumption of zinc at the damaged area and the more acidic the environment, then the greater the effect will be. Clearly, the protection mechanism of a topcoated zinc rich system is different than a single coat system and therefore comparing primer performance without topcoating is a highly questionable procedure.

The study where similar formulation types were included with different zinc levels did show a correlation in performance with zinc level when topcoated and tested by ISO20340 methodology. However, the same test series shows a much greater "non correlation" when considering only zinc dust level on a wide variety of formulations. This results questions the whole principle of compositional specifications and the generally perceived wisdom that "the more zinc the better".

Conclusions

The tests conducted give rise to the following conclusions:

1/ Zinc primer anticorrosive performance is a function of a number of formula variables, not just % of zinc in dry film, and therefore specifications based on zinc content do not result in the use of the best performing systems.

2/ Zinc primer performance should be considered based on the overall properties of the product, including ease of application, tolerance to application conditions and speed of drying/overcoating not just the anticorrosive performance of the product in a laboratory test.

3/ Testing conducted to qualify zinc rich primers should <u>always</u> be conducted as part of a coating system unless the primer is intended to be used as a single coat system. Testing of a single coat of zinc rich primer is meaningless if it will be topcoated in practice.

4/ The testing environment should be a reasonable representation of the real world exposure conditions. Systems that will be used in industrial environments should be tested according to the best industrial simulations and systems to be used in marine environments should be tested according to the best marine simulations. The results will vary depending upon the environment.

Bibliography References

(1) SSPC Paint Specification No.20 – Zinc-Rich Primers (Type I, Inorganic, and Type II, Organic

(2) SSPC Paint Specification No.29 – Zinc Dust Sacrificial Primer, Performance-Based

(3) ASTM D 5894 – Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)

(4) ISO 12944 – International Standard, Paint and varnishes – Corrosion protection of steel structures by protective paint systems – Part 6; Laboratory performance test methods

(5) ISO 20340 – International Standard - Paints and Varnishes - Performance requirements for protective paint systems for offshore and related structures

(6) ASTM B-117 – Standard Practice for Operating Salt Spray Apparatus

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