



SSPC GUIDE 12 to ZINC - RICH COATING SYSTEMS

1. Scope

1.1 This guide provides general information on the description, selection, and application of zinc-rich coatings as well as the selection and application (including surface preparation) of topcoats.

1.2 Zinc-rich coatings as referenced in this Guide are broadly defined as coatings containing high levels of zinc such as SSPC-Paint 20 or SSPC-Paint 29.

1.3 Zinc-rich coatings are classified as follows:

- Type IA Inorganic - post-cured, water-borne, alkali silicates
- Type IB Inorganic - self-cured, water-borne, alkali silicates
- Type IC Inorganic - self-cured, solvent-borne, alkyl silicates
- Type IIA Organic - thermoplastic binders
- Type IIB Organic - thermoset binders

1.4 Zinc-rich coatings, both topcoated and untopcoated, have been used successfully in a wide variety of environmental zones. For a detailed breakdown of applicability of various types of zinc-rich coatings in different environmental zones, see Table 1.

2. Description

The guide describes two types of zinc-rich coatings; how to select zinc rich coating systems for either topcoated or untopcoated service; and requirements for surface preparation, application, and inspection and repair of zinc rich coatings.

3. Referenced Standards

3.1 SSPC STANDARDS AND JOINT STANDARDS:

Guide 9 Guide for Atmospheric Testing of Coatings in the Field

Guide 15	Field Methods for Retrieval and Analysis of Soluble Salts on Steel and other Nonporous Substrates
PA 1	Shop, Field, and Maintenance Painting of Steel
PA 2	Measurement of Dry Coating Thickness With Magnetic Gages
Paint 20	Zinc-Rich Coatings (Type I - Inorganic and Type II - Organic)
Paint 27¹	Basic Zinc Chromate-Vinyl Butyral Wash Primer
Paint 29	Zinc Dust Sacrificial Primer, Performance-Based
Paint 30	Weld-Through Inorganic Zinc Primer
PS 12.01	One-Coat Zinc-Rich Painting System
PS Guide 22.00	Guide for Selecting One-Coat Preconstruction or Prefabrication Painting Systems
SP 1	Solvent Cleaning
SP 5/NACE No. 1	White Metal Blast Cleaning
SP 6/NACE No. 3	Commercial Blast Cleaning
SP 10/NACE No. 2	Near-White Blast Cleaning
SP 12/NACE No. 5	Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating

3.2 ASTM INTERNATIONAL STANDARDS²:

D 520	Standard Specification for Zinc Dust Pigment
D 3359	Test Methods for Measuring Adhesion by Tape Test
D 3363	Standard Test Method for Film Hardness by Pencil Test
D 4541	Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
D 4752	Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub

¹ This paint contains chromate pigments. Users are urged to follow all health, safety, and environmental requirements in applying, handling, or disposing of these materials.

² ASTM International 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. Standards are available online at <http://www.astm.org>.

TABLE 1
Guidelines for Surface Preparation and Topcoating
of Zinc-Rich Primers in Various Environments

Note: This table provides general guidelines only. Its use should be limited to determination of generic suitability and minimum surface preparation requirements. There are substantial differences in performance between the various types of zinc-rich coatings in a given environment. These recommendations provide minimum acceptable surface preparation, primer, and topcoating requirements for the designated environmental zones. However, recommendations do not imply equivalent system performance. For specific conditions, the coating manufacturer should be consulted.

ZINC-RICH BINDER TYPES

Environmental Zones	IA		IB		IC		IIA		IIB	
	Untopcoated	Topcoated	Untopcoated	Topcoated	Untopcoated	Topcoated	Untopcoated	Topcoated	Untopcoated	Topcoated
1A Interior, Normally Dry	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 6	R-SP 6	R-SP 6	R-SP 6	R-SP 6	R-SP 6
1B Exterior, Normally Dry	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 6	R-SP 6	R-SP 6	R-SP 6	R-SP 6	R-SP 6
2A Frequently Wet, Fresh Water	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 10
2B Frequently Wet, Salt Water	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 10	NR	R-SP 10	NR	R-SP 10
2C Fresh Water Immersion	Q-SP 5	Q-SP 5	Q-SP 5	Q-SP 5	Q-SP 10	Q-SP 10	NR	Q-SP 10	Q-SP 10	Q-SP 10
2D Salt Water Immersion	Q-SP 10	Q-SP 10	Q-SP 10	Q-SP 10	Q-SP 10	Q-SP 10	NR	Q-SP 10	NR	Q-SP 10
3A Chemical Exposure, Acidic (pH 2 to 5)	NR	Q-SP 10	NR	Q-SP 10	NR	Q-SP 10	NR	Q-SP 6	NR	Q-SP 6
3B Chemical Exposure, Neutral (pH 5 to 10)	R-SP 10	R-SP 10	R-SP 10	R-SP 10	R-SP 6	R-SP 6	R-SP 6	R-SP 6	R-SP 6	R-SP 6
3C Chemical Exposure, Alkaline (pH 10 to 12)	NR	R-SP 10	NR	R-SP 10	NR	R-SP 6	NR	R-SP 6	NR	R-SP 6
3D Chemical Exposure, Solvent	R-SP 10	Q-SP 10	R-SP 10	Q-SP 10	R-SP 6	Q-SP 6	NR	NR	NR	Q-SP 6
3E Chemical Exposure, Severe	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

BINDER TYPES:

IA = Inorganic; post-cured, waterborne alkali silicates

IB = Inorganic; self-cured, waterborne alkali silicates

IC = Inorganic; self-cured, solvent-borne alkyl silicates

IIA = Organic; thermoplastic binders (e.g., phenoxy)

IIB = Organic; thermoset binders (e.g., epoxy polyamide, moisture-cured polyurethane)

RECOMMENDED USAGE:

R = Recommend

NR = Not Recommended

Q = Some products recommended, others not recommended. (See Sections 5.2, 5.3, 5.4, and 5.5.)

RECOMMENDED SURFACE PREPARATION:

The number refers to the minimum SSPC blast cleaning surface preparations as follows:

SP 5 = SSPC-SP 5, White Metal Blast Cleaning

SP 6 = SSPC-SP 6, Commercial Blast Cleaning

SP 10 = SSPC-SP 10, Near-White Blast Cleaning

NOTE: For pitted old steel, the blast cleaning requirement should be the next higher degree of cleanliness.

i.e., the SP 10 shown above should be SP 5, the SP 6 shown above should be SP 10.

4. Types of Zinc-Rich Coatings

4.1.1 A zinc-rich coating is an anticorrosive coating for iron and steel incorporating zinc dust in a concentration sufficient to enable the zinc metal in the dried film to corrode preferentially to the ferrous substrate, i.e., to give galvanic protection. Note that SSPC-Paint 20 and SSPC-Paint 29 require 65% minimum zinc loading in the dry film. Galvanic action is not universally accepted as the primary method by which these coatings protect the substrate.

4.1.2 Some zinc-rich coatings are used as prefabrication primers or shop primers, where they are applied to freshly blast cleaned steel plates and sections. The prefabrication primers, often at a lesser thickness, are intended to protect the steel throughout the fabrication period until the final painting system can be applied to the finished structure. At that juncture, the pre-fabrication primer may be incorporated into the final system or removed. SSPC-PS Guide 22.00 and SSPC-Paint 30 discuss the use of zinc-rich coatings as prefabrication primers.

4.1.3 Zinc-rich coatings may be used as a one-coat system or may be overcoated with one or more other coatings. The use of untopcoated zinc-rich systems is discussed in Section 5.3 and the use of topcoated systems is discussed in Section 5.4.

4.2 VEHICLES FOR ZINC-RICH COATINGS: Zinc-rich coatings are available in a number of different commercial types. These coatings may be categorized as having inorganic (Type I) or organic (Type II) vehicles.

4.2.1 Inorganic Vehicles: Type I inorganic vehicles include post-cured water-borne alkali silicates (IA); self-cured, water-borne alkali silicates (IB); and self-cured, solvent-borne alkyl silicates (IC). The vehicles of Types IA and IB may include the alkali metals (commonly sodium, lithium, and potassium), while IC vehicles are alkyl silicates (most commonly ethyl silicates). Type IA vehicles are post-cured with a separate wash solution, usually mildly acidic in nature, applied as an aftercoat. Type IB vehicles are chemically similar to Type IA vehicles, except they are formulated to self-cure upon exposure to moisture and carbon dioxide in the air. Type IC vehicles self-cure upon exposure to atmospheric moisture.

4.2.2 Organic Vehicles: Type II vehicles include those with thermoplastic binders (IIA) and thermoset binders (IIB). Type II thermoplastic vehicles include polymers of chlorinated rubber, styrene, vinyl, and other organic materials that soften upon exposure to heat. Type IIB thermoset vehicles do not soften upon heating, and include polymers of epoxy, polyurethane, polyester, silicone, and other chemically cross-linked materials.

4.3 PIGMENTATION FOR ZINC-RICH COATINGS: The major pigment component in these coatings is zinc dust of

the type described in ASTM D 520. Zinc-rich coatings are successfully formulated with zinc dust levels ranging from 65 to 95 percent by weight in the dried film.

4.4 NUMBER OF COMPONENTS: Inorganic and organic zinc-rich coatings are supplied as a single- or multi-component package. Many multi-component packages separate the zinc pigment and vehicle and provide directions for mixture immediately prior to application. Multi-component coatings have a limited pot life after mixing. Because pot life will vary with vehicle/resin type, the manufacturer's product data sheets should always be consulted.

5. Selection of Coating System

5.1 CLASSIFYING EXPOSURE ZONES: Successful corrosion protection utilizing a zinc-rich coating system is dependent upon the anticipated service in environmental exposure zones. Guidelines for the use of organic and inorganic zinc-rich coatings, either topcoated or untopcoated, are presented below based on the following SSPC classifications of exposure:

- 1A Interior, Normally Dry
- 1B Exterior, Normally Dry
- 2A Frequently Wet-Fresh Water
- 2B Frequently Wet-Salt Water
- 2C Fresh Water Immersion
- 2D Salt Water Immersion
- 3A Atmospheric Chemical Exposures (pH 2 to 5)
- 3B Atmospheric Chemical Exposures (pH 5 to 10)
- 3C Atmospheric Chemical Exposures (pH 10 to 12)
- 3D Chemical Exposure, Solvents
- 3E Chemical Exposure, Severe

5.2 GUIDELINES FOR USAGE: The untopcoated and topcoated inorganic and organic zinc-rich coatings are categorized as suitable (recommended), unsuitable (not recommended), or questionable for the exposure environments listed in Section 5.1. Questionable means that some products may perform satisfactorily, while other products may not, or that the environmental description is too variable to assure satisfactory coating system performance. Guidelines for the use of topcoated and untopcoated zinc-rich coatings in various environments are presented below and in Table 1.

5.3 USE OF UNTOPCOATED ZINC-RICH COATINGS

5.3.1 Untopcoated Inorganic Zinc-Rich Coatings: These coatings may be suitable for use in the following environmental zones: 1A, 1B, 2A, 2B, 3B, and 3D. These coatings are not recommended for the following environmental zones: 3A, 3C, and 3E. These coatings are questionable for use in environmental zones 2C and 2D. These coatings are suitable for application to uninsulated hot equipment with service temperatures up to 400 °C (750 °F).

5.3.2 Untopcoated Organic Zinc-Rich Coatings: These coatings may be suitable for use in the following environmental zones: 1A, 1B, 2A, and 3B. These coatings are not recommended for the following environmental zones: 2B, 2D, 3A, 3C, 3D, and 3E. These coatings are questionable for use in environmental zone 2C.

5.3.3 A one-coat zinc-rich coating system is described in SSPC-PS 12.01.

5.4 USE OF TOPCOATED ZINC-RICH COATING SYSTEMS: Zinc-rich primers are topcoated to provide extended exterior durability in severe exposures; to improve color, gloss, and other appearance properties; and to provide resistance to specific conditions such as highly acidic or highly alkaline environments.

5.4.1 Topcoated Inorganic Zinc-Rich Coating Systems: These systems may be suitable for use in the following environmental zones: 1A, 1B, 2A, 2B, 3B, and 3C. These systems are not recommended for environmental zone 3E. Some topcoated inorganic zinc-rich systems have demonstrated suitability for use in environmental zones 2C, 2D, 3A, and 3D. These systems are suitable for application to uninsulated hot equipment with service temperatures up to 400 °C (750 °F) when used with heat resistant topcoats.

5.4.2 Topcoated Organic Zinc-Rich Coating Systems: These systems may be suitable for use in the following environmental zones: 1A, 1B, 2A, 2B, 3B, and 3C. These systems are not recommended for environmental zone 3E. Some topcoated organic zinc-rich systems have demonstrated suitability for use in environmental zones 2C, 2D, 3A, and 3D.

5.5 VARIATIONS IN FORMULATION: These guidelines are based on the general characteristics of the different types of zinc-rich coating systems and exposure environments. Substantial formulation differences exist among zinc-rich coatings. The ability of a topcoated system to perform adequately is strongly dependent on the generic type and formulation of the topcoat (see Section 7.4). Therefore, the recommendations of the coating manufacturer regarding the use of a zinc-rich coating (organic or inorganic, topcoated or untopcoated) in a given environment should be solicited. This is particularly critical when considering use of a zinc-rich system in a questionable category.

5.6 COATING HISTORY: Documented information with authenticated data detailing the history and exposure of the coating in terms of service life under specific conditions may be considered when preparing specifications for major projects. Details relative to surface preparation and application of coating should be supplied. SSPC-Guide 9 lists the type of data to be submitted. Additionally, or in lieu of suitable in-service field exposure or application histories as described above,

the coating supplier, the coating applicator, and the user may establish a criterion of performance agreeable to all parties.

6. Selection of Primer

6.1 PRIMER: The primer should be in accordance with SSPC-Paint 20 or SSPC-Paint 29.

6.1.1 Zinc-rich coatings are particularly useful for protecting steel surfaces in moist corrosive environments. These coatings are very resistant to high humidity and salt air, lasting many years. They galvanically prevent rust undercutting at small breaks in the coating system, often filling the breaks with protective deposits of zinc oxidation products, greatly extending coating life. Unless topcoated, they are unsuitable for acidic or alkaline service outside the pH range from about 5 to 10. Variations in properties of these coatings depend largely on the vehicle, whether inorganic or organic. The choice of the best coating for a specific end use should be made by a comparison of properties with the requirements of the service. Application and surface preparation constraints may limit the choice. The degree of corrosion protection desired may be a prime consideration. Zinc-rich coatings are characterized by their abrasion resistance, toughness of film, and galvanic action of the zinc.

6.1.1.1 For SSPC-Paint 29, the long-term corrosion resistance is assured by more rigorous performance tests than those required in SSPC-Paint 20. These include exterior fence tests as well as conventional laboratory accelerated testing. The field test consists of a 12-month fence test that may be extended to 30 months. The 12-month field test may be used as an interim qualification to allow for earlier procurement of the coating.

6.1.2 Inorganic: Inorganic zinc primers, while requiring more care in surface preparation and application compared to organic zinc primers, have a greater ability to withstand exposure to most solvents, oils, and neutral petroleum products. Some types of inorganic zinc primers require moisture to cure. Inorganic zinc primers have a tendency to mudcrack at heavier thicknesses, and dry spray may occur under certain ambient conditions. They function well up to 400 °C (750 °F) in dry conditions. In wet conditions, inorganic zinc-rich primers function well up to 50 °C (120 °F). Within the range of 50°C to 60°C (120 °F to 140 °F), performance depends upon formulation and the coating manufacturer should be consulted. In wet conditions above 60 °C (140 °F), zinc-rich primers are not recommended. Compared to organic zinc primers, inorganic zinc-rich primers generally exhibit more pinholing and bubbling upon topcoating.

6.1.3 Organic: Compared with the inorganic type, the organic zinc primers are generally more tolerant of surface preparation and are compatible with a wide variety of topcoats.

This type generally has fewer tendencies to mudcrack and to dry spray. Organic zinc primers generally provide less resistance to abrasion, solvents, and high temperatures than the inorganic. When left untopcoated, organic zinc primers may provide less galvanic protection than untopcoated inorganic zinc primers. This type combines the properties of the organic vehicle with the abrasion resistance and the galvanic action of the zinc pigment.

7. Selection of Topcoat

7.1 TOPCOATS: Suitable topcoating of the zinc-rich primer may provide additional service life. Topcoats should be formulated not only for environmental resistance, but also for suitable application (to minimize pinholing, bubbling, etc.) over a zinc-rich primer. Table 2 provides guidelines for topcoating zinc-rich primers in various environments.

7.2 IDENTIFY PRIMER: Proper selection of topcoats requires identification of the generic (chemical) type of primer. Often the specific product name is needed as well. First, determine the type of primer in accordance with Section 4.2. If the primer has already been applied, record the date of application, manufacturer's name, product identification, batch number, and manufacturing date. If the primer has been selected but not applied, record the name of the manufacturer and the product designation. It is good painting practice to obtain the primer, intermediate coat (if any), and topcoat from the same manufacturer.

7.3 COMPATIBILITY CONSIDERATIONS: When topcoating zinc-rich primers, the topcoat is applied over zinc, not steel. Coatings based on drying oils, such as most oil and alkyd types, tend to react with the zinc metal to form zinc soaps, resulting in loss of adhesion and peeling of the topcoat. In general, coatings that have poor alkali resistance should not be applied directly to zinc-rich primers. Coatings with oil containing vehicles such as oil paints, alkyd enamels, vinyl alkyds of the oxidizing type, long oil silicone alkyds, and epoxy esters should not be applied directly to zinc-rich primers.

7.4 SELECT COMPATIBLE TOPCOAT: Table 2 lists combinations of commonly used zinc-rich primers and topcoats. For each combination, this table indicates the degree of acceptability, ranging from A (used directly) to E (not recommended). Although all of the generic coating types listed in Table 2, except alkyds, have been successfully applied as topcoats over zinc-rich primers, combining different manufacturer's products may adversely affect coating performance. The table reflects the application of the topcoat directly to the zinc-rich primer, not its use as a final coat in a multi-layered coating system. No coating should be applied to a zinc-rich primer unless recommended by the manufacturer for that purpose. If the primer

type has previously been identified, select a topcoat based on the information in Sections 5.4 through 5.6 and Table 2.

Other factors that may influence selection of topcoat and primer/topcoat combinations are: specific durability of topcoats in intended exposure environments, appearance of the finished coat, recoatability, heat resistance, and cost. Information on these factors may be found in the SSPC Painting Manual, Volume 1, Good Painting Practice, as well as other technical publications, and from coating manufacturers. The general appearance of a properly applied zinc-rich topcoated system is acceptable for typical industrial applications; however, an appearance as smooth as an automotive finish coat should not be expected. If the primer has not been identified, select a primer based on the information in Sections 6.1 through 6.1.3 and Table 2.

8. Surface Preparation of Steel Substrate

8.1 DEGREE OF CLEANING: Although blast cleaning to SSPC-SP 5 (white metal) may be preferred, it is also the most costly. In most cases, SSPC-SP 10 (near white) or, in some cases, even SSPC-SP 6 (commercial) may provide a satisfactory surface for these coatings. Table 1 provides minimum surface preparation guidelines for zinc-rich coating systems in various environments. Although this guide is written for blast-cleaned surfaces, under certain conditions other surface preparation methods can be used as a surface preparation for zinc-rich coatings if agreed upon by the contracting parties.

8.2 SURFACE PROFILE: Surface profile should be in the range of 25 to 90 micrometers (1.0 to 3.5 mils) unless requirements of the coating manufacturer are more restrictive. If the profile is too low, the adhesion of the coating may be compromised. If the profile is too high, the peaks may not be adequately covered.

8.3 SOLUBLE SALTS: Based on the coating system employed and the end use, it may be desirable to specify detection, measurement and removal of soluble salts. Field methods for detecting and measuring soluble salts are described in SSPC-Guide 15.

8.4 ADEQUACY OF SURFACE PREPARATION: The degree of deviation from the ideal surface preparation that zinc-rich coatings will tolerate without serious loss of their properties varies considerably from coating to coating. Therefore, adequate instructions from the manufacturer are essential and should be closely followed to ensure maximum performance. As a rule, organic zinc primers are more tolerant of residual rust and paint than inorganic zinc primers. Both types of zinc primers are more tolerant of surface contamination with soluble salts such as chloride and sulfate than their non-zinc counterparts.

TABLE 2
ACCEPTABILITY OF PRIMER/TOPCOAT COMBINATIONS¹

Topcoat	Inorganic Zinc-Rich Primer			Organic Zinc-Rich Primer	
	Post Cure Water-Borne Type 1A ²	Self-Cure Water-Borne Type 1B ²	Self-Cure Solvent-Borne Type 1C ²	Thermoplastic (Solvent Evaporation Cure) Type IIA ²	Thermoset (Chemical Cure) Type II B ²
Vinyl	B	B	B	C	B
Epoxy ³	A	A	A	E	A
Water-Borne Acrylic	B	B	B	B	A
Chlorinated Rubber	B	B	A	A	A
Polyurethane ⁴	B	B	B	B	B
Polyurea ⁴	B	B	B	B	B
Phenolic	D	D	D	D	D
Silicone	A	B	A	B	B
Alkyd	D	D	D	D	D
Epoxy Ester	D	D	D	D	D
Silicone Alkyd	D	D	D	D	D
Oil Urethane	D	D	D	D	D
Oil Phenolic	D	D	D	D	D
Linseed Oil	D	D	D	D	D
Coal Tar Epoxy	B	B	B	E	A
Vinyl Alkyd	D	D	D	D	D

A Generally used directly on zinc with no difficulties.

B Some formulations can be used directly; others require a tie-coat.

C Lifting of zinc-rich primer is likely to occur unless well-aged or the primer is vinyl.

D Not recommended unless tie coat is added.

E Not recommended.

¹ These are general guidelines, not hard-and-fast rules. This list is not exhaustive. Always consult the manufacturer's recommendations.

² See SSPC-Paint 20 (Section 2.3).

³ Chemical cure such as epoxy amine, epoxy polyamide, epoxy polyamine, or epoxy phenolic.

⁴ Oil-free and alkali-resistant formulations.

9. Surface Preparation and Repair of Zinc-Rich Primer Prior to Topcoating

9.1 IDENTIFY AND REPAIR DEFECTS: The zinc-rich primer to be topcoated should be inspected for defects, and the defects should be repaired before the application of a topcoat. These defects include rust, low dry film thickness (DFT), high DFT, dry spray, mudcracking, foreign matter, and loose zinc salts. The coating manufacturer should supply recommended procedures for the repair of defects. Some general guidance is provided below.

9.1.1 Rust: Rust resulting from the corrosion of the steel substrate and loose deposits of rust stain should be removed. However, light adherent stain, resulting from rust running from adjacent rusted areas, need not be removed. As there are many different acceptable repair procedures, the manufacturer's recommendations should be considered.

9.1.2 Low Dry Film Thickness: The dry film thickness should be measured in accordance with SSPC-PA 2. Low dry film thickness should be repaired before topcoating, based upon the recommendations of the zinc-rich coating manufacturer.

9.1.3 Excessive Dry Film Thickness: Excessive film thickness above maximum acceptable levels should be repaired according to the recommendations of the zinc-rich coating manufacturer. This may involve removal of excessive thickness only or complete removal and reapplication of the coating. The amount of zinc-rich coating that is excessive is highly dependent on the formulation, the environment, the requirements for use, and the curing conditions. Based on a survey of suppliers, specifiers, and applicators, the most common value for maximum acceptable DFT is 125 to 150 micrometers (5 to 6 mils). For some zinc-rich coatings, the maximum DFT may be as low as 90 micrometers (3.5 mils), while for certain organic zinc-rich coatings a maximum DFT of 250 micrometers (10 mils) is acceptable. Consult the coating manufacturer's product data sheet for recommended DFT values.

9.1.4 Dry Spray: Paint that exhibits dry spray has been improperly applied. The dry spray should be totally removed. Depending on the extent of coating removal, the coating may have to be reapplied. It may be necessary to change types of thinners to retard solvent evaporation. A piece of wadded-up screen wire or screening attached to a wooden block may be used to remove dry spray. A wooden block may be shaped to fit the structural members involved. All dry spray should be removed.

9.1.5 Mudcracking: This condition usually results from excessive dry film thickness in a single coat. Mudcracking should be corrected according to the manufacturer's recommendations. This defect can occur anywhere, but it is most likely to occur at inside corners and fillet welds.

9.1.6 Microcracking: Microcracks that are visible only with magnification have no effect on performance.

9.1.7 Foreign Materials: Dirt, mud, grease, oil, and other foreign materials should be removed prior to topcoating. Usually detergent and solvent cleaning, in accordance with SSPC-SP 1, are sufficient. The manufacturer of the coating and the topcoat may be contacted for specific recommendations.

9.1.8 Cure Residue: To achieve satisfactory results when topcoating post-cured inorganic zinc coatings, it is important to clean the cure residue from the surface before applying topcoats. Normally, this is done by water washing and scrubbing.

9.1.9 Zinc Salts: Zinc-rich coatings, through natural reaction with the atmosphere, may form surface salts of zinc hydroxide, zinc oxide, and zinc carbonate, depending upon exposure. As an inorganic zinc coating weathers, the formation of tightly adherent zinc salts provides additional barrier protection to the substrate. Organic zinc coatings formulated above their CPVC may also weather to form tightly adherent zinc salts. For untopcoated atmospheric exposure service, tightly adherent zinc salts need not be removed. However, if the primer is to be topcoated, zinc salts should be removed by thorough washing with potable water and scrubbing with a stiff, non-metallic brush, because they could reduce adhesion of the topcoat. If pressure washing is used for washing, perform a trial over a test area to ensure the coating is not degraded or reduced in thickness. Low pressure water cleaning (LP WC), defined in SSPC-SP 12 as cleaning performed at pressures less than 34 megapascals (MPa) [5000 pounds per square inch (psi)], using potable water is usually sufficient.

9.1.10 Water-Soluble Salts: Washing or low pressure water cleaning reduces the amount of water-soluble salts (e.g., chlorides) on the surface, which may cause blistering if the surface is topcoated.

9.2 ENSURE ADEQUACY OF CURE: The film formation of most zinc-rich coatings includes solvent evaporation (drying) and chemical reaction (curing). To properly receive a topcoat, the primer should be adequately dried and cured. Typically, 90% or more of the solvent will evaporate within the first 15 minutes. Completion of the chemical reaction of curing may require weeks or months; however, the primer may be able to receive a topcoat in a shorter period than required for full curing. Because of possible delamination and zinc splitting, topcoating undercured inorganic zinc should only be performed in accordance with the manufacturer's recommendations.

9.2.1 Factors That Affect Cure: The following factors should be carefully considered prior to topcoating.

9.2.1.1 Humidity: Depending on the type of coating, the time to cure can be significantly altered by humidity conditions.

Many coatings (especially solvent-borne inorganic) do not cure below 40% relative humidity. For some coatings in low humidity environments, the application of a thin film of water after the initial drying can be used to promote curing mechanisms. In humidity over 90%, some water-borne inorganic zinc coatings do not properly cure. The manufacturer should be contacted regarding specific humidity requirements.

9.2.1.2 Temperature: The time to cure and the extent of cure for many zinc-rich coatings is also affected by temperature. The manufacturer should be contacted for specific recommendations regarding temperature for curing prior to topcoating.

9.2.1.3 Dry Film Thickness: For almost all zinc-rich coatings, thicker films require longer cure times. Solvent-borne inorganic zinc-rich coatings, especially the single-component types, are particularly sensitive to this effect.

9.2.1.4 Cure of Waterborne Inorganic Zinc Coatings: Trace amounts of alkalinity may remain within the film of all self-cured waterborne inorganic zinc coatings after cure. This alkaline residue can be detrimental to coating integrity when water is allowed to puddle on its surface, as trace amounts may concentrate in a drying puddle and result in high pH values that dissolve the coating film. Use only storage, shipping, and exposure configurations that prevent puddling or trapping of water on the coated steel. Thorough rinsing (after full cure) reduces the likelihood or scope of the problem.

9.2.2 Methods to Assess Adequacy of Cure: The recommendations of the zinc-rich coating manufacturers are the most important factors in determining the adequacy of cure of a zinc-rich coating. Some general methods for determining zinc-rich coating cure are listed below:

9.2.2.1 Solvent Rub: This method is only applicable to ethyl silicate inorganic zinc-rich coatings. As described in ASTM D 4752, a clean rag soaked in methyl ethyl ketone is rubbed over the coating 50 times. No residue, or only traces of residue on the rag, indicates adequate cure.

9.2.2.2 Coin Rub: Rub the coating with the edge of a coin; if the film burnishes, the cure is adequate. This technique, commonly encountered in the field, can be effective for determining cure of some, but not all, zinc-rich coatings. Because burnishing can occur on some under cured coatings and may not occur on other coatings where the cure is adequate, the coating manufacturer should be asked if this technique would provide an accurate determination of cure of a particular coating.

9.2.2.3 Pencil Hardness: The pencil hardness test (ASTM D 3363) covers a procedure for rapid determination of cure for inorganic zinc coatings by scratching with pencil leads of known hardness. Consult with the coating manufacturer to determine the necessary hardness for topcoating using this method.

9.2.3 Remediation of Undercured Inorganic Zinc Coating

9.2.3.1 If a solvent-borne inorganic zinc-rich coating is undercured due to insufficient humidity, proper curing may be achieved by curing at a high humidity level achieved through natural weather variations or artificial means, such as misting the primed surface with potable water. Misting with water is most effective if done soon after coating application. Misting may not result in successful cure of all formulations of solvent-borne inorganic zinc coatings. Hardness in particular may be affected. In a closed environment (e.g., a shop), means other than misting may be used to raise the relative humidity to a level high enough to promote curing.

9.2.3.2 Undercured water-borne inorganic zinc-rich coatings, Type IB, may achieve proper cure by lowering the humidity, raising the temperature, and increasing air circulation.

9.2.3.3 In the case of Type IA post-curing zinc-rich coatings, an acidic post-curing solution may be applied, followed by thorough rinsing.

9.2.3.4 If it is determined that the inorganic zinc-rich coating is not cured and cannot attain a satisfactory condition for topcoating, the zinc-rich coating should be removed and reapplied. This condition is generally due to excessive solvent retention or insufficient reaction of the vehicle with oxygen, moisture, or catalyst. The manufacturer should be contacted regarding specific requirements.

10. Coating Application

10.1 APPLICATION GUIDELINES: Follow the requirements of SSPC-PA 1 for general application guidelines.

10.2 APPLICATION OF ZINC-RICH COATINGS: Zinc-rich coatings vary in application characteristics, depending upon climatic conditions at the time of application. High substrate or ambient temperatures may result in a “dry spray” or porous coating, particularly with inorganic zinc. On windy days, over-spray may be a problem.

Many zinc-rich coatings, such as Type IB waterborne inorganics, Type II moisture curing polyurethanes or Type IC inorganic ethyl silicates, may not dry or cure properly at extremes of high or low humidity. Refer to the coating manufacturer’s written instructions for temperature and humidity requirements.

All zinc-rich coatings are preferably applied by spray, but may be brushed for small areas or to fill in irregularities. Brushing should be done with extreme caution to avoid zinc settlement. All zinc-rich materials may settle, and care should be taken to ensure they are thoroughly mixed before and during application. Thinning zinc-rich coatings usually accelerates the rate of settling. Exercise caution during work stoppages to prevent settling of zinc in hoses and equipment.

10.3 DRY FILM THICKNESS OF COATING: Due to the galvanic action of the zinc, these coatings can give satisfactory performance under mildly corrosive conditions with a one-coat application as little as 50 micrometers (2 mils) thick. The dry film thickness should be measured in accordance with SSPC-PA 2.

10.4 APPLICATION OF TOPCOAT: Zinc-rich coatings are topcoated to improve performance under more severe exposures. Special precautions in cleaning the prime coat prior to topcoating may be required, especially in moderate or severe chemical exposures. When self-coating inorganic zinc-rich coatings, solicit the manufacturer's instructions. Often, organic zinc-rich coatings or non-zinc-rich coatings are used in lieu of self-coating an inorganic zinc-rich coating. Consult the manufacturer to determine if a mist coat or a reduced coat is required. Paints meeting the requirements of SSPC-Paint 29 have topcoating properties comparable to paints meeting the requirements of SSPC-Paint 20.

10.4.1 The surface of the zinc-rich primer to be topcoated should be free of loose zinc salts, dry spray, foreign materials, and other defects described in Sections 9.1.1 through 9.1.9.

10.4.2 The primer should be dry. Consult the manufacturer's written recommendations for the amount of moisture permissible on the primer surface before applying any topcoat. Certain topcoats have a high sensitivity to moisture. For example, amine cured epoxy coatings may show large blisters if any moisture remains in the pores of the zinc primer at the time of topcoat application.

10.4.3 The primer should be adequately cured as described in Section 9.2, based on the requirements of the coating manufacturer.

10.4.4 Factors that affect the acceptability and performance of a topcoated zinc-rich primer include porosity of primer, extent of topcoat bubbling, and adhesion of topcoat. General guidelines are given below.

10.5 POROSITY OF COATINGS: A zinc-rich coating consists of particles of zinc metal bound to each other by a suitable inorganic or organic binder. The zinc dust content of the dry film may vary from 65 to 95 percent of the total weight. The small amount of binder results in a very high pigment volume concentration for both organic and inorganic zinc-rich coatings, resulting in a porous coating. Porosity becomes more pronounced if the zinc-rich coating is dry sprayed, the weather is hot, the equipment is improperly adjusted, or the applicator fails to apply the zinc-rich coating in a full wet coat. These conditions contribute to pinholing, bubbling, and cratering of the topcoat, the severity of which may vary with the type of binder used.

10.6 TOPCOAT BUBBLING AND PINHOLING

10.6.1 Origin of Bubbles and Pinholes: If the topcoat is capable of penetrating the pores and forming a film, this penetration may provide a base for initial adhesion. However, when organic topcoats and their solvents penetrate into the pores of the coating, they may also force air up through the wet film of paint. A bubble or crater results if the surface has "skinned over" (i.e., a semi-solid membrane has formed on the surface while the coating below is still liquid) or has lost its ability to flow. Pinholes may also occur under these circumstances.

10.6.2 Occurrence of Bubbles and Pinholes: Generally, the self-curing inorganic zinc coatings have a greater tendency to cause bubbling or pinholing in the topcoat than post-curing inorganic or organic zinc-rich coatings. High-build coatings specially formulated for application over zinc-rich coatings can reduce bubbling and other application problems. Low-build coatings, especially gloss or semigloss coatings, have a greater tendency for bubbling or pinholing. Generally, the tendency for bubbles and pinholes to form in the topcoat increases with greater thickness of the zinc-rich coating.

10.6.3 Repair of Bubbles and Pinholes: Bubbles, pinholes, or craters are unsightly and should be avoided using the methods in Section 10.7. They can be repaired by sanding the affected areas, then reapplying the topcoat. Sweep blasting can be effective. However, use of a relatively friable or less hard abrasive and/or reduced nozzle pressure will help avoid excessive ablation of the coating. If methods other than sanding are to be allowed, the contracting parties should agree in advance on the limits of the process and the type of abrasive. When properly repaired, bubbles and pinholes do not affect the performance of the system. If left unrepaired, the performance may be affected if the environment is characterized by aggressive chemical fumes or chemical contaminants, combined with high humidity and condensed moisture.

10.7 MINIMIZING BUBBLING AND PINHOLING

10.7.1 Some manufacturers recommend the application of a thin mist coat of the topcoat to reduce bubbles, pinholes, and craters, while others recommend a thinned coat (reduced coat) of the topcoat. Both are followed by a full wet coat of the topcoat. The application of the topcoat in two coats (a mid coat/full coat or a thinned coat/full coat) rather than a single heavy coat will reduce the chance of surface defects, such as pinholes and bubbles.

10.7.2 Other manufacturers recommend using a tie coat, such as a wash primer, to condition the substrate. The acid component of the wash primer reacts with the zinc and allows the wash primer to bond to the zinc-rich primer. This may be followed by a topcoat of any compatible type. Other specially formulated tie coats may also be used to promote adhesion for topcoats.

10.7.3 DRY FILM THICKNESS OF TOPCOATS: The dry film thickness of the midcoat (if any) and the topcoat should be in accordance with manufacturer's guidelines. The dry film thickness should be measured in accordance with SSPC-PA 2.

11. Inspection and Repair

11.1 ADHESION OF TOPCOATED SYSTEMS: Three common methods of measuring adhesion of topcoated zinc-rich primer systems have been identified. However, no consensus for minimally acceptable adhesion ratings could be established for any of these methods. The user should consult the coatings manufacturer regarding appropriateness and interpretation of adhesion test results. The three methods for measuring adhesion are:

11.1.1 X-Cut Tape Test (ASTM D 3359 - Method A): An X-cut is made in the film to the substrate; pressure sensitive tape is applied over the cut, and then removed. Adhesion is assessed quantitatively on a scale of 0 to 5 by comparison with descriptions.

11.1.2 Cross Cut Tape Test (ASTM D 3359 - Method B): A lattice pattern with either 6 or 11 cuts in each direction is made in the film to the substrate, pressure sensitive tape is applied over this area, and then removed. Adhesion is assessed by comparison with descriptions and illustrations on a scale of 0 to 5. This method is not recommended for film thicknesses greater than 125 micrometers (5 mils).

11.1.3 Portable Adhesion Testers (ASTM D 4541): A dolly is glued to the coating surface, and then pulled off. The force required to remove the dolly, as well as the nature of the disbonding, are evaluated. This test provides a quantitative measure of the pull-off strength, but the significance of the adhesion values has yet to be established.

11.2 TOUCH-UP AND REPAIR OF TOPCOATED ZINC-RICH PRIMER: Touch-up and repair of topcoated zinc-rich primers may be required when the topcoat is damaged, when areas intended to be topcoated are missed, or when the total dry film thickness is insufficient. The methods of touch-up and

repair depend upon the specific generic type of the topcoat (e.g., epoxy, vinyl, or urethane) and the time interval between the original topcoating and the touch-up and repair operation. The new coating should be applied to provide uniform appearance with the existing coating, including feathering of edges. The surface may require cleaning by solvent, detergent, or pressurized water to remove dirt, grease, and other surface contaminants. Two-component, chemically curing topcoats may require mechanical abrading to provide adequate surface roughness, even when reapplied over the same generic type of coating. The topcoat manufacturer should be consulted for the procedures for specific coatings.

12. Environmental

12.1 VOC Content: Federal limits for VOCs in industrial maintenance coatings were published in 1998 and may be found at <http://www.epa.gov/ttn/atw/183e/aim/aimpg.html#RULE>. These limits apply to the coating at the time of application after thinning according to the manufacturer's recommendations. Many state and local governments and/or air quality management areas have more stringent VOC regulations than those in the federal rule. Information on the VOC content of each container before mixing or thinning is found on the container label and in the manufacturer's safety data sheet. The coating manufacturer's product data sheet usually provides information on the total VOC content of a coating after mixing and any recommended thinning.

12.2 LEAD LEVEL IN ZINC DUST: ASTM D 520 specifies three types of zinc dust for use as pigments in coatings. Type I is a general grade in which no maximum level of lead is specified. Type II is a high-purity grade with a maximum lead level of 0.01% by weight. Type III is the highest purity grade, with a maximum lead level of 0.002% by weight. Any grade of zinc dust can be used in the zinc coatings covered by this guide. However, it is important to note that if Type I zinc is used, it is possible to exceed the permissible exposure limit (PEL) for lead when the products are removed by abrasive blasting. For additional information relating the lead content of the coating to worker exposure to lead during blasting see Gary L. Tinklenberg, and Denise M. Doezema, "Health Concerns for Workers Using Zinc-Rich Coatings," *Journal of Protective Coatings and Linings*, Vol. 15, No. 5 [May 1998], pp 36-46. In addition to lead, cadmium and other toxic metals may pose a health hazard.