

COATINGS MANUAL HRSD

APPENDIX C

BASICS ON COATINGS CHEMISTRY: WHAT THE GENERIC TYPES MEAN PRACTICALLY

Introduction

Numerous different polymer based coatings are used for protective coatings. Polymers refer to compounds of high molecular weight derived from the addition of many smaller molecules or by the condensation of many small molecules along with the elimination of water, alcohol, or the like. The word polymer comes from Greek where poly means many and the word meros means unit, hence many units. Coatings are based on polymers such as epoxies, polyesters, vinyl esters, polyurethanes, polyureas, and others. In wastewater applications, the most common coatings systems are based on epoxy, polyurethane, vinyl ester, and acrylic polymers. Within these polymer choices exist numerous versions of each resin technology along with many varied modifications to each. This section of the coatings manual addresses the most widely used types of coatings used in wastewater environments and their relative performance related advantages and disadvantages.

Epoxies

Epoxies are without question the most widely used coatings in the wastewater field. Epoxy coatings are generally made through the reaction of phenols with acetone or formaldehyde. Those reactants are then further reacted with epichlorohydrin. The resultant materials are diglycidyl ethers of what are called Bisphenol A epoxies, Bisphenol F epoxies, or phenolic novolac epoxies. These resins are then crosslinked via polymerization reactions with various curing agents or blends of curing agents. A basic discussion of the three main types of epoxy resins and the major categories of curing agents follows below.

Bisphenol A Epoxies

These are the most commonly used resin for epoxy coatings. Bisphenol A resins are available in a large range of molecular weights. It is the reaction product of phenol and acetone. It is further reacted with epichlorohydrin. The resulting product is a thick liquid similar to honey in consistency. It is largely used for 100 percent solids coatings and flooring systems. Bisphenol A epoxy has good broad range chemical resistance, good physical properties, and is cured using a wide variety of curing agents at ambient temperatures. It is generally quite high in viscosity and this has historically limited its use in high filler loaded coatings. To reduce its viscosity for such uses, it has traditionally had solvents and diluents added to it. However, since the advent of strict VOC regulations, these additions have been replaced with reactive diluents, chemicals that dilute or lower the viscosity of the resin while going into the polymerization reaction. Reactive diluents can be helpful in reducing viscosity and enhancing other coating properties, but they can also reduce the chemical resistance properties and otherwise have detrimental affects on coating performance. In more recent years, some lower viscosity

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Bisphenol A liquid resins have been developed which do not require the use of diluents or solvents.

Bisphenol F Epoxies

These resins have lower viscosity than Bisphenol A resins and provide much better strong acid and strong solvent chemical resistance. Bisphenol F is formed by reacting phenol with formaldehyde. The resulting phenolic chemical is then reacted with epichlorohydrin to form the Bisphenol F liquid resin. These resins also cost a lot more money than Bisphenol A resins. With lower viscosity, the Bisphenol F resins can be used in highly filler loaded coatings without the use of solvents or nonreactive or reactive diluents.

Novolac Epoxies

Like Bisphenol F Epoxies, Novolac epoxies are resins which are also formed via the reaction of phenol with formaldehyde. In fact, Bisphenol F is the simplest form of Novolac resins. However, Novolacs have more reactive groups along their chemical backbone resulting in a more highly crosslinked polymer than either Bisphenol A or Bisphenol F epoxies. This much higher degree of chemical crosslinking or crosslink density produces coatings with much greater chemical and thermal resistance. Novolac epoxies do however require higher curing temperatures to achieve their maximum property development.

Novolac epoxies have a higher molecular weight than Bisphenol A or F resins. This results in higher viscosity and what is called higher functionality. Functionality is the term that refers to the relative number of reaction sites for the resin's chemical backbone. The higher the functionality of a resin, the greater its crosslink density. And crosslink density is what determines chemical resistance. For example, Bisphenol F resins have a slightly higher functionality than Bisphenol A resins. See Table I. This is largely why Bisphenol F resins have better resistance to a wider range of chemicals than Bisphenol A resins. Also, the chemical resistance of Bisphenol F resins is better due to its lower viscosity than Bisphenol A resins. This means that the use of fewer diluents or additives is required for viscosity reduction and those additives (as previously noted), also affect chemical resistance detrimentally. Due to this lower viscosity, Bisphenol F resins also remove the need for solvents from coatings. This reduces fire hazards and VOC.

Novolac epoxy resins have two distinct performance advantages over Bisphenol F resins. First, they have better chemical resistance due to their much higher functionality. See Table I. This produces very high crosslink density. And secondly, the large quantity of aromatic ring structures increase the heat resistance of Novolac epoxies when compared to Bisphenol F resins.

Please refer to Table 1 and Table III which compare the performance properties of the major types of epoxy resins.

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TABLE I

PROPERTY	EPOXY TYPE		
	BISPHENOL A	BISPHENOL F	NOVOLAC
Viscosity @ 25°C	11,000 to 15,000 cps	2,500 – 5,000 cps	20,000 – 50,000 cps
Molecular Weight	370	370	
Functionality	1.9	2.1	2.6 – 3.5

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TABLE II

PROPERTY	EPOXY RESIN TYPE		
	BISPHENOL A	BISPHENOL F	NOVOLAC
UV Light Resistance	1	1	1
Abrasion Resistance	3	3	3
Adhesion	3	3	3
VOC	2	3	3
Resistance to Moisture	3	3	3
Chemical Resistance	1	2	3

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Curing Agents for Epoxies

Due to ambient temperature curing requirements, almost all epoxy coatings must use amine based curing agents. While the selection of the epoxy resin generally establishes the limits on coating performance, the type of curing agent does affect coating properties in many ways. Within amine based curing agents, there are several classes that have differing effects on coating performance and application properties. These include the following:

- Aliphatic Polyamines.
- Polyamine Adducts.
- Polyamide/Amidoamines.
- Aromatic Amines.
- Ketimines.
- Cycloaliphatic Amines.

Aliphatic Polyamines

Aliphatic amines are multifunctional (meaning more than one reaction site per molecule). Aliphatic ethylene amines were the first curing agents or hardeners used in epoxy coatings. These hardeners provided high reactivity (fast cure) at ambient temperature and good solvent resistance due to high functionality. However, they are non-flexible and very prone to carbonation or blushing problems. As such, ethylene amines have largely been modified or blended with other hardeners to overcome these problems. Aliphatic amine cured epoxy coatings are used when strong chemical resistance is needed. They form tough coating films and the coatings have short pot lives and short cure times. These curing agents are very susceptible to what is called an “amine blush”. This involves reaction between the aliphatic amines and moisture and carbon dioxide resulting in formation of an amine carbamate. This happens during cure of the coating. This blush results in a hazy discoloration of the coating and the formation of an oily film on top of the coating that can act as a bond breaker for subsequent top coats.

Polyamine Adducts

Multifunctional (meaning more than one reaction site per molecule) aliphatic amines are partially reacted with epoxy resins to create amine adducts. The cured coating film (after the amine adduct is further reacted with epoxy resin in the coating) is similar to the aliphatic amine cured epoxy except the blushing problem is limited and reactivity is lower. The resulting coatings have longer pot lives and cure times as well. Generally, amine adduct cured epoxy coatings also have lower viscosities than aliphatic amine cured coatings.

Polyamide/Amidoamines

Polyamides and amidoamines (the low viscosity counterparts to polyamides) offer several advantages when compared to ethylene based aliphatic amines. This is due to the introduction of a fatty acid into the chemical backbone of the hardener. Polyamides and

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amidoamine curing agents are made by reacting aliphatic polyamines with fatty acids. The advantageous properties brought to coatings by polyamide and amidoamine curing agents include improved film flexibility, better wetting properties (and therefore adhesion), and good water resistance. Furthermore, these coatings are more tolerant of damp substrate conditions when applied without detriment to polymerization. As such, polyamide cured epoxy coatings do not develop amine blush problems. All of these advantages plus slower cure and longer pot lives come with lower functionality. Therefore, the chemical resistance of polyamide and amidoamine cured epoxy coatings (especially solvent and acid resistance) is greatly reduced when compared to amine cured epoxy coatings.

Aromatic Amines

Aromatic Amines are based on the presence of an unsaturated ring of carbon atoms in the molecule. Common aromatic molecules include benzene and xylene. As such, aromatic amines include an amine functional group attached to a benzene ring structure. The presence of the benzene ring structure greatly enhances chemical resistance. Aromatic amines react quite strongly and therefore accelerators need to be added to speed up the rate of reactions. For many years the widest used aromatic amine was Methylene Dianiline (MDA). It was used in some of the most chemically resistance lining products ever provided. It also gave great heat resistance, a long pot life, and good flexibility. Its use, however, due to toxicity issues has now been outlawed. Alternative chemistries have now been developed by coating formulators to replace the MDA-like performance.

Ketimines

Ketimines are aliphatic amines that have been reacted with ketones to produce what is called “blocked amines”. This means the amine is not able to crosslink with the epoxy resin until it is unblocked usually by the presence of water. The blocking provides longer pot lives to coatings and lower reactivity. Once the amine is unblocked, the coating film generally develops the same properties provided by the amine. The cure time for Ketimines is very slow. And because the Ketone solvent must come out of the film as a volatile, there is a lot of opportunity for solvent entrapment related problems like pinholes.

Cycloaliphatic Amines

This class of aliphatic amines is characterized by the presence of an amino group on the six carbon ring structure. These amines promote light stable coatings.

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They also produce coatings with enhanced heat resistance when compared to other aliphatic amines. They also produce coatings with better mechanical properties when compared to aliphatic amine cured or polyamide cured epoxy coatings. They are slower to react than aliphatic amines, but are faster than polyamides or amidoamines. Chemical resistance is very good compared to polyamides or aliphatic amines.

WHAT DOES ALL OF THIS MEAN TO ME?

Start by reviewing Tables III and IV below.

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TABLE III

CURING AGENT	PROPERTIES							
	Viscosity	Cure Time	Low Temp Cure	Color Stability	Water Sensitivity	Film Flexibility	Heat Resistance	Acid Resistance
Aliphatic Amines	Low	Fast	Moderate to Good	Good	Moderate	Poor	Moderate	Moderate
Polyamine Adducts	High	Moderate	Moderate	Moderate to Good	Moderate	Poor	Moderate	Moderate
Polyamides/Amidamines	High	Slow	Poor	Moderate	Moderate	Good	Poor	Poor
Aromatic Amines	High	Slow	Poor	Poor	Good	Moderate	Good	Good
Ketimines	Moderate	Slow	Poor	Moderate	Good	Good	Moderate	Moderate
Cycloaliphatic Amines	Low	Slow	Moderate	Good	Good	Poor	Good	Good

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TABLE IV

Coreactive Epoxy Coatings

Properties	Aliphatic Amine Cure	Polyamide Cure	Aromatic Amine Cure	Phenolic Modified	Silicone Modified	Coal Tar Amine Cure	Coal Tar Polyamide Cure	Water Based
Hardness/Strength	Hard	Tough	Hard	Hard	Medium-Hard	Hard (Brittle)	Tough	Tough
Water Resistance	Good	Very Good	Very Good	Excellent	Good-Excellent	Excellent	Excellent	Fair-Good
Acid Resistance	Good	Fair	Very Good	Excellent	Good	Good	Good	Fair
Alkali Resistance	Good	Very Good	Very Good	Excellent	Good	Good	Very Good	Fair
Salt Resistance	Very Good	Very Good	Very Good	Excellent	Very Good	Very Good	Very Good	Fair-Good
Solvent Resistance (Hydrocarbons)								
Aromatic	Very Good	Fair	Very Good	Very Good	Good	Poor	Poor	Poor-Fair
Aliphatic	Very Good	Good	Very Good	Very Good	Very Good	Good	Good	Good
Oxygenated	Fair	Poor	Good	Very Good	Fair	Poor	Poor	Poor
Temperature								
Dry	200 - 250 F	200 - 250 F	225 - 275 F	250 - 300 F	200 - 250 F	200 - 250 F	200 - 250 F	180 - 225 F
Immersed	130 - 150 F	120 - 160 F	180 - 200 F	200 - 250 F	NA	130 - 180 F	120 - 160 F	NA
Weatherability	Good, Chalks	Good, Chalks	Good, Chalks	Fair, Chalks	Very Good	Poor	Poor	Good
Aging	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Good
Best Characteristics	Corrosion Resistance	Water/Alkali Resistance	Chemical Resistance	Chemical Resistance	Water/Weather Resistance	Water Resistance	Water Resistance	Ease of Application
Poorest Characteristics	Recoatability	Recoatability	Slow Cure	Slow Cure	Recoatability	Black Color Recoatability	Black Color Recoatability	Proper Coalescence
Recoatability	Can Be Difficult	Can Be Difficult	Can Be Difficult	Can Be Difficult	Can Be Difficult	Can Be Difficult	Can Be Difficult	Can Be Difficult
Primary Use	Chemical Resistance	Water Immersion	Chemical Resistance	Chemical Lining	Weather Resistance	Crude Oil/Water Immersion	Crude Oil/Water Immersion	Atmospheric Corrosion

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Other Epoxy Coating Information

Solventless (100% solids) Epoxy Putties

Solventless epoxy coatings are formulated with liquid epoxy resins and liquid polyamide and amine curatives. The materials are bulked up to the consistency of putty by the judicious selection of thixotropizing agents and extender pigments. These 100% solids epoxy coatings are high build products that are typically applied at a thickness of 1/8 to 1/2 inch. The three most common uses of solventless epoxy coatings are (1) as patching putties for sealing over bolts, rivets and laps in tank lining work; (2) as splash zone compounds that can be mixed, applied and cured underwater; and (3) as monolithic surfaces for the protection of concrete floors and walls.

The water resistance of 100% solids epoxies is generally good but, the high filler content required for bulking and high film build, degrades the resistance to solvents (aromatics in particular) or strong acids that would otherwise be provided by the tightly crosslinked epoxy resin.

Fusion Bond Epoxy Powders (FBE)

Epoxy powder coatings provide performance that is similar to liquid applied epoxies. As one might expect, the powders are manufactured from high molecular weight, solid epoxy resins and solid, heat activated curatives (usually aromatic amines). The powders are made by two different processes; fusion followed by pulverization, or by dry grinding of the various ingredients in a pebble mill. Thin, decorative coatings are generally prepared by fusion and pulverization, whereas thicker (10-20 mils) protective coatings are made by the dry grinding process.

Powder coatings are applied by heating the item to be coated and dipping it in a fluidized bed of powder or by applying the powder with electrostatic spray. The surface must be heated above the fusion temperature of the powder and kept at that temperature for a sufficient period to allow the coating to flow, fuse, and cure into a smooth, continuous film. Some systems will cure in about 30 seconds at 450°F. Other systems may require as much as 30 minutes at 400°F. Fusion temperatures must be closely controlled to achieve good adhesion and other properties.

Epoxy powders are most often used as pipe coatings (ID and OD). These solventless coatings have an application and environmental advantage in that they can be applied with very little waste. The principal drawback with epoxy powders is that poor fusion may escape (visual) detection. Destructive evaluation may be necessary to confirm good coating quality and once damaged, these hard, slick films tend to be difficult to repair.

Water-Based And Water-Reducible Epoxies

Water-based epoxy coatings typically consist of an emulsion of epoxy resin in water as one component, and a dispersion or solution of polyamide coreactant in water and/or coupling solvent as the second component. Water-reducible or water-thinned epoxy coatings are not emulsion coatings, but have been designed to accept a small amount of water for thinning purposes. Both water-based and water-reducible epoxies have an advantage in that they can be applied directly over existing coatings (alkyds) that may be sensitive to the usual strong epoxy solvents (ketones),

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without causing lifting. Additional benefits are the decreased health and fire hazards, and the fact that water can be used for clean-up. Unfortunately, water-based and water-reducible epoxies do not generally provide performance comparable to their solvent-based kin with respect to chemical resistance.

Epoxy Esters

Single package epoxy coatings contain epoxy resin that has been modified by chemical reaction with drying oils which introduce significant polyester character and allow for "air drying" (oxidative curing). As a result, epoxy esters have properties which are intermediate between those of alkyds (polyesters) and those of "catalyzed" epoxies. Epoxy esters have somewhat better chemical resistance, but less weathering resistance than "straight" alkyd enamels. Epoxy ester paints provide alternatives to alkyds where better resistance to chemicals is required, and where the simplicity of a single-package product is desirable. Like the alkyds, epoxy ester coatings are not suitable for continuous immersion service or for use in alkaline environments. Also, most epoxy ester coatings do not meet current VOC regulations.

Coal Tar Epoxies

Coal tar epoxy (CTE) coatings are mixtures of thermosetting epoxy resin and thermoplastic coal tar pitch and are typically cured with amines, amine adducts or polyamide resins. The epoxy resin provides good adhesion, hardness and solvent resistance, whereas the coal tar pitch provides flexibility and greatly enhances resistance to water. Coal tar epoxies are often promoted as combination products that provide the best of both worlds, epoxy and coal tar pitch. Rather, coal tar epoxies are better thought of as compromise products.

Straight epoxies provide better adhesion to steel, and so polyamide epoxy primers are often used with coal tar epoxy topcoats, despite the fact that the coal tar epoxy can be self-priming. Straight epoxies also provide better resistance to hydrocarbon solvents and can withstand water and hydrocarbon immersion at much higher temperatures. Coal tar epoxy coatings are also widely used to protect buried pipe from soil corrosion. Amine cured coal tar epoxy (16 mils dft over 3-4 mils of a polyamide epoxy primer) has worked well on the exterior of cathodically buried pipe to temperatures as high as 200°F.

The principal disadvantages of coal tar epoxies are color, which is always black (or reddish-brown black), and their poor weatherability. Coal tar epoxies are often difficult to recoat and intercoat adhesion in multiple-coat systems or at touch-up areas is a concern. As a result, the use of self-priming, high build coal tar epoxy coatings that can provide from 12-20 mils or more in a single coat, have become popular. Coal tar has been identified as a carcinogen. For this reason, the old "black magic" coal tar epoxy coatings have seen diminished use in recent years.

Epoxy Mastics

The term "mastic" is widely used but it isn't definitive nor is it uniformly applied. In general, these are high solids epoxies that may be alternatively called "surface tolerant" or "maintenance"

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epoxies. The early versions were designed to penetrate wet rusty, poorly prepared surfaces. The focus was on developing good adhesion to marginally prepared surfaces and providing high build, on the order of 5-10 mils dft, in a single coat. Such a coating was designed to save money on labor costs with less surface preparation and fewer coats of paint.

These epoxy coatings employ polyamide resin curatives, and so they may also be called polyamide epoxies. (Polyamides are generally recognized as having better wetting characteristics than most other epoxy curatives.) Some formulations have contained a small amount of vegetable oil as a secret ingredient to better wet rusty surfaces but when these were applied over clean steel, the oil had no function and it tended to be displaced to the surface of the paint where it left a sticky film that trapped wind-blown debris and created a recoating problem.

Early versions contained flaking aluminum pigment to better limit moisture penetration into the film. Most manufacturers now provide this kind of workhorse "mastic" epoxy in several standard colors.

Like most thermosetting epoxies, these are packaged as two components that must be mixed just prior to use. Generally, these products are used as two component materials; however, some manufacturers provide a third component that may be referred to as a catalyst or an accelerator. This so-called "kicker" provides a faster cure at lower temperatures. However, these coatings are most useful as two component materials. With the addition of the catalyst third component, the pot life is shortened and the film gets harder faster but drying (solvent release) is unaffected. Also, curing is not more complete. The two coreactant components are balanced to react completely. This is why the mix ratio (A:B) is important and mixing of partial kits is not advisable. The catalyst reacts only with the epoxy resin component of the paint. If the balance of the two coreactants was correct to begin with, some of the polyamide resin must necessarily remain unreacted. The medium to long term result is that water resistance is compromised. In sum, the third component catalysts provide a limited benefit and a definite compromise. The third component catalysts or accelerators should only be added when work must be done at the lower application temperature limit of the coating or when work must be done near the water line on existing offshore structures.

Epoxy Phenolics

The addition of phenolic resins to epoxy systems enhances chemical, solvent and temperature resistance, but results in decreased flexibility and weatherability. As a result, epoxy phenolic coatings are used exclusively as high performance tank linings or immersion coatings usually. Phenolic-modified epoxy coatings are available as ambient-cured and bake-cured types. Ambient-cured epoxy phenolic coatings are manufactured by chemically reacting the phenolic and the epoxy resins. Curing is generally achieved by reacting the epoxide with aromatic amines. Some formulations of this type can provide excellent immersion service in oil and brine at temperatures as high as 250°F. Bake-cured epoxy phenolics are simple cold-blended mixtures of the two resins, catalyst and accelerator. A high temperature bake at 350-400°F is required to affect the cure. Formulations of this type can provide resistance to immersion conditions at temperatures as high as 300°F. The bake-cured epoxy phenolics are commonly used as high performance tank

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linings and for internal corrosion protection of down hole tubing in oil drilling and production operations.

Practical Application Information For Epoxy Coatings in Wastewater Applications

Here are some practical rules to follow:

- Polyamide cured epoxies are not suitable for H₂S conditions (headspaces) or to immersion service prior to secondary clarification. The polyamide curing agents have constituents in them that certain anaerobic and aerobic bacteria metabolize. These coatings do not perform well in grit facilities, primary clarification, or in aeration tanks typically.
- Use higher functionality resins with aliphatic or cycloaliphatic amine curing agents for high H₂S gas exposures where involved in aerated headspaces. These systems have higher crosslink density and therefore better permeation and sulfuric acid resistance.
- Use Bisphenol F epoxies with aliphatic or cycloaliphatic amine curing agents for steel for topcoats in primary clarifiers with a polyamide cured epoxy primer.
- For general purpose coating work including flooring where no aggressive chemical exposures occur, use Bisphenol A epoxies cured with aliphatic or cycloaliphatic amine curing agents.
- Use blended amine curing agents with Bisphenol F or Novolac or blended Bisphenol F and Novolac resins for concrete or steel where especially high H₂S gas and biogenic corrosion is known to occur. Also, make sure these coating systems are sufficiently thick (minimum 30-40 mils for steel and 60 mils for concrete over a filler/surfacer).
- For general weathering exposure, use polyamide or amidoamine epoxy coatings with an acrylic aliphatic polyurethane topcoat for U.V. light resistance. Otherwise, the epoxy coating will chalk.
- For interior, noncorrosive conditions, use Bisphenol A or Bisphenol F epoxies with polyamide or other non-blushing curing agent types.
- In secondary clarifiers, use polyamide or amidoamine cured epoxies like Bisphenol A or Bisphenol F for steel or concrete substrates.
- In anaerobic digester gas spaces like domes or in sludge holding tanks (where mixed primary, WAS (waste activated sludge), etc. sludges are present), use Bisphenol F or Novolac epoxies with aliphatic, cycloaliphatic, aromatic or blended amine curing agents.

Don't use coal tar epoxy coatings in high H₂S gas conditions and specifically don't use polyamide cured coal tar epoxy coating anywhere in the wastewater collection or treatment

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system where bacteria will come in contact with the coating, i.e. manholes, pump station wet wells, or in the treatment plant.

Other Generic Coating Types

Acrylics

Acrylics are available as emulsions (latex), lacquers, enamels and powders. The most common type of acrylic paint is latex. The weathering and oxidation resistance of acrylics is better than oil-based paints, alkyds, or epoxies because the chief components of acrylic polymers, acrylic and methacrylic acid, provide a polymer structure that has little tendency to absorb ultraviolet light. Acrylics are noted for their good color and gloss retention.

In light of the current trend toward tighter restrictions on volatile organic content (VOC), acrylic latex paints are finding increased use for mild atmospheric exposures (at the expense of solvent-based alkyds).

Solvent-based acrylics are referred to as lacquers (low volume solids) and enamels (higher volume solids). These are typically used when appearance is more important than corrosion protection. Shop application allows control of solvent emissions, including the collection and recycling of solvent. Solvent-based lacquers provide crystal clear films of which the hardness and flexibility may be varied within wide limits. Acrylic enamels (pigmented) are used for floor coatings, automobile topcoats, coil coatings, appliances, and metal furniture.

Acrylic resins are used to modify many types of coatings, including epoxies, silicones, urethanes, and vinyls, to achieve better appearance from these base polymers.

Alkyds

Alkyd coatings provide excellent weathering resistance in mild industrial atmospheres and can also withstand limited exposure to vapors, splash and spillage of many chemicals. Alkyd coatings maintain good adhesion, toughness and flexibility on steel at temperatures as high as 225°F, but will discolor at elevated temperatures. Good atmospheric corrosion protection coupled with low per gallon cost and ease of application make alkyd paints ideal for use on machinery, structural steel and tank exteriors. Alkyds are not suitable for use in severe marine atmospheric exposures or for use as tank linings.

Alkyd resins are essentially polyesters of alcohol and carboxylic acid monomers that are chemically combined with various drying, semi-drying and non-drying vegetable oils in different proportions. The polyester portion of the alkyd resin contributes hardness whereas the oil portion contributes good adhesion and flexibility. This allows for the rough classification of alkyd paints into short, medium and long oil types, depending on the quantity of oil used in the formulation. Short oil alkyds contain less than 40% oil; they are fast drying and provide the hardest, least flexible films. Long oil alkyds contain as much as 60-70% oil; they are relatively slow drying and provide the most flexible films. The high oil content promotes wetting of lesser prepared steel

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surfaces (hand or power tool cleaned). The wetting in turn, promotes the development of good adhesion by the dried film to these difficult substrates.

Alkyds are versatile resins that can be modified to enhance certain inherent properties. For example, the incorporation of phenolic, silicone and epoxy resins increases resistance to water, weather and chemicals, respectively. Modifying resins may be introduced by simple mixing, sometimes called "cold-blending" or by "cooking," which provides a chemical reaction and combination with the alkyd resin.

Alkyd coatings are single package products that dry by solvent evaporation and then cure hard by reacting with oxygen from the atmosphere (oxidative crosslinking). Because solvent must leave the film and oxygen must penetrate the coating to provide through-cure, the per coat thickness of alkyd coatings is generally limited to less than 4 mils. If the coating is applied at excessive thickness, solvent loss to the atmosphere is hindered. The coating skins over. Oxygen from the atmosphere does not penetrate all the way through the film thickness and the lower portion of the film remains soft and tacky. Thus, alkyds are generally employed as three or four coat systems to obtain adequate film build.

Alkyds have good color and gloss retention and a slow chalking rate during weathering exposure. Eventually, aging causes embrittlement and cracking. The oxidative process that is responsible for initial curing of the film continues with time and eventually becomes an aging process. This oxidative aging of alkyd coatings leads to the formation of organic acids, which may react with the substrate causing loss of paint adhesion. (For the most part, these acid degradation products are simple acids such as formic, acetic, and propionic, and not the original carboxylic acid monomers that were used to make the alkyd polymer.) Such acid formation within and beneath an otherwise intact alkyd coating is the reason for peeling failure on galvanized steel and concrete or other cementitious surfaces. Alkyds will initially adhere to galvanized steel and to cementitious surfaces, but they don't adhere well for very long, especially in damp exposure environments.

Chlorinated Rubbers

Chlorinated rubber (Neoprene or Hypalon binders) paints were formulated to be resistant to most inorganic acids, alkalis, salts, mineral oils, moisture and fungus growth. The low water absorption and low moisture vapor transmission rates of unmodified chlorinated rubber films makes these coatings ideal for atmospheric exposure in the marine environment. Chlorinated rubbers have also been used for aqueous immersion. Chlorinated rubber coatings are similar to solution vinyl copolymer paints in that they are single package, low-build, air-dry, thermoplastic coatings.

Chlorinated rubber paints were most widely used in marine, water, and wastewater applications. The solids content is low, typically around 30% solids by volume, and so multiple coat systems are required to achieve a reasonable film build of 10 or more mils. The solvent content of the paint is high and chlorinated rubber paints do not meet VOC restrictions. In some jurisdictions, chlorinated rubber paint may be used for specialty applications (e.g., swimming pools) where low quantities are needed, but in general these coatings are no longer in use due to a lack of VOC compliance.

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There is also a potential concern for old, existing chlorinated rubber paints. Polychlorinated biphenyls (PCBs) were sometimes used as plasticizers in chlorinated rubber paints. Some people have claimed that the PCBs in the old paint can pose an exposure risk to workers during paint removal (eg., by abrasive blasting).

Furans

The term furan is loosely defined and can be used to denote polymers that are based on furfural, furfuryl alcohol, or furan. Furan resins have been widely used in the fabrication of corrosion resistant processing equipment and in resinous cements. Furans are available as air-dried and bake-cured coatings. The baked versions have excellent heat resistance and may be used at temperatures up to about 375°F. Furans have excellent resistance to hydrocarbon solvents, organic acids, alkalies, and many inorganic acids, but they are not suitable for concentrated sulfuric acid (greater than 50%), hypochlorites (bleach), hydrogen peroxide, chlorine dioxide, chromic acid, and other oxidizing agents. Despite their excellent chemical, solvent, and temperature resistance, furan coatings are not widely employed because they are brittle, show poor adhesion to nonporous surfaces (such as steel), and show high shrinkage on curing.

Latex (Emulsions)

Latexes or emulsions consist of minute particles mechanically dispersed in a liquid in which they are not soluble. (A dispersion of a solid in a liquid is normally referred to as a suspension, but the paint industry refers to any dispersion of film forming substances in water as an emulsion.) Most emulsion paints rely on styrene-butadiene, vinyl or acrylic resins.

Latex paints provide many advantages from an application point of view. For example, water is the principal carrier solvent, and so water may be used as a thinner and for general clean up purposes. (Only small quantities of organic solvents are used.) Fire and health hazards are thereby minimized. Because water is the diluent, moist surfaces can be readily painted over. Wet surfaces are still a problem because standing or running water will prevent drying and may even re-emulsify the film.

The performance of an emulsion paint depends on the nature of the resin binder. In general, the dried paint film is somewhat porous and will "breathe" which may be desirable for use over concrete, masonry and other porous substrates. Acrylic and vinyl resins, PVDC (polyvinylidene chloride) in particular, provide dry films with good water resistance (low moisture vapor transmission rate, MVTR). These types provide the best atmospheric corrosion protection for steel.

Latexes are suitable for exterior exposure in mildly corrosive atmospheric environments. They are never used as linings for immersion service.

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Oleoresinous Paints (Oil-Based)

Oil based paints consist of a mixture of oils such as linseed, soy bean, castor or tung, which will convert to a solid film by chemical reaction with oxygen supplied by the atmosphere. Metallic driers are used to accelerate this crosslinking reaction. The dry films have little resistance to chemicals, are soft and have relatively high permeability to water vapor. This permeability makes drying oils a good binder for use in house paints, which if not somewhat permeable, would blister and peel due to moisture transport through the walls. Unmodified oil based paints provide inferior corrosion protection to steel and are not widely used by industry.

Phenolic

Phenolic resins may be blended with oils and alkyds to enhance the water resistance of these air-dried, ambient-cured paints. These are actually phenolic "fortified" coatings rather than "true" phenolics, which must be cured at elevated temperature. Phenolic fortified paints are low solids, low film build paints that are used in 3 or 4 coats for atmospheric protection.

Phenolics (Baked)

Straight phenolic resins are reaction products of phenols and formaldehyde. Baked-phenolic coatings are applied in multiple thin coats, typically 2-3 mils per coat. The paint film dries by solvent evaporation. A low temperature bake is generally required following each coat to ensure complete removal of paint solvents. A final high temperature bake at 350-400°F is required for full curing. High-bake phenolic coatings provide extremely hard, dense and smooth films. They are used exclusively as high performance tank linings and are the coating of choice for concentrated sulfuric acid and hot water. Straight phenolics have poor resistance to alkali and are difficult to repair when damaged.

Polyesters and Vinyl Esters

Polyester and vinyl ester linings are based on unsaturated thermosetting resins which are provided as pre-polymers that are dissolved in unsaturated monomers to form the resin. The monomer is typically styrene. Polymerization is catalyzed by the addition of a peroxide catalyst. This starts a free radical addition reaction that converts the liquid resin into a solid film.

Unsaturated polyesters are condensation products of polyhydric alcohols (e.g., ethylene, propylene, butylene glycols) and unsaturated polybasic carboxylic acids or acid anhydrides (maleic, phthalic, chlorendic. By proper selection of monomers and manufacturing techniques, many different resin types, showing wide variation in performance properties, may be obtained. Although performance varies considerably, the handling and curing requirements of unsaturated polyesters are very similar. With few exceptions, all are supplied as a solution of solid resin (and perhaps, fillers and pigments) in styrene (typically 40-55%), which acts as a solvent and as a crosslinking agent for the resin.

Peroxides (usually MEKP or BPO) are used as the catalyst (at a concentration of about 1.0%) for polymerization of the resin. Cobalt naphthenate or cobalt octoate, which is usually sold as a 6%

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solution in solvent is used as a promoter (at a concentration of about 0.1-0.3%) and dimethylaniline, which is available as a neat liquid, is used as an accelerator (at a concentration of only 0.1%). The accurate measurement of these small quantities of promoter, accelerator, and catalyst is crucial to proper curing. These are tiny quantities of low viscosity liquids that must be properly and thoroughly mixed into a viscous polyester resin. (The viscosity of the resin is generally similar to pancake syrup and these coatings are not to be thinned with solvent to provide for a more workable viscosity.)

Many packaged products are pre-promoted and pre-accelerated so that they require only the addition of a small amount of catalyst for curing. Some products require that the promoter and accelerator be added on site and thoroughly mixed into the viscous resin solution prior to the addition of the catalyst. **(Note: cobalt promoter should never be mixed directly with peroxide catalyst as a violent reaction can occur which may result in fire or explosion.)**

Vinyl ester resins are a type of polyester resin. The vinyl ester prepolymers are formed when epoxy resin (polyol) is reacted with acrylic or methacrylic acid which contains a vinyl group. Typically, Bisphenol A or Novolac epoxies are used. The Novolac based vinyl esters have better chemical resistance and heat resistance than the Bisphenol A based vinyl esters due to their higher reactivity.

Polyesters and vinyl esters cure quickly and are quite low in viscosity. They provide very good chemical resistance with polyesters being less resistant to strong acids than vinyl esters. Neither are particularly good in strong alkaline exposure, but both are generally resistant to solvents. Also, these lining systems are resistant to temperatures up to 212°F and 300°F dry. Polyesters and vinyl esters are widely used for tank linings, flooring systems and flake filled coatings.

These resins have high shrinkage and are extremely exothermic, meaning they give off a lot of heat of reaction. This means the resins are very brittle and must be reinforced to restrain the shrinkage. Also, these resins have a high thermal coefficient of expansion that further requires reinforcement.

Polyester and vinyl ester linings and coatings are also extremely moisture sensitive and temperature sensitive during curing. And while the styrene monomer largely is crosslinked into the film, the styrene vapors are extremely flammable and toxic during application and cure. Applying polyester and vinyl ester linings and coatings in confined spaces requires extreme safety precautions including respirator use and high air-change ventilation.

Polyurethanes

Polyurethanes are versatile polymers which provide products ranging from soft, thermoplastic elastomers to hard, thermosetting coatings and rigid insulating foams. The basic building blocks for polyurethanes are diisocyanates and glycols. Urethane coatings represent a unique variety of curing mechanisms and are classified by ASTM D 16 into six types as follows:

Type I - These coatings are characterized by the absence of any significant quantity of free isocyanate groups. The isocyanate component has been prereacted with oils to produce single

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package air-dry coatings that are commonly called "uralkyds." These oil modified urethanes provide an enhanced chemical resistant alternative to alkyd enamels, essentially equal to epoxy esters, for atmospheric corrosion protection.

Type II - These single package urethane coatings are cured by reaction with atmospheric moisture. The applied urethane prepolymer reacts with atmospheric moisture to form a substituted urea polymer network. The byproduct of this curing mechanism is CO₂ which escapes to the atmosphere. A minimum relative humidity of 30% is required to achieve a good cure. The per coat thickness must be kept from 1-4 mils to allow thru-cure and to avoid pinholing caused by the CO₂ escaping through the drying film.

Single package, moisture-cured polyurethanes are widely used as sealers for wood. The isocyanate is able to react with some of the hydroxyl groups provided by the cellulose, thereby providing a firm chemical attachment to the substrate.

Type III - These are single package heat-cured polyurethanes. The reactive isocyanate group is inactivated or "blocked," but becomes reactive when subjected to elevated temperatures.

Type IV - These are two package catalyzed polyurethanes. An isocyanate terminated prepolymer is cured by reaction with a catalyst at room temperature.

Type V - These two package ambient-cured polyurethanes are the most common urethane coatings. An isocyanate terminated prepolymer, which may be "aromatic" or "aliphatic," is cured by reaction with glycols (polyols). The polyol component of the coating usually consists of hydroxylated acrylic, polyester, or polyether resins. Aromatic polyurethanes provide excellent toughness and abrasion resistance but have poor weatherability.

Type VI - One package, nonreactive lacquer polyurethane with no reactive isocyanate groups. These cure via solvent evaporation only.

Acrylic Aliphatic Urethanes for U.V. Resistance

Aliphatic-acrylic polyurethanes are thin film decorative coatings, typically providing only 1-4 mils dry film thickness per coat. This type of polyurethane can have exceptional color and gloss retention and is used exclusively for atmospheric (mostly U.V. light resistance) protection. The acrylic resins are commodity products based on hydroxyethyl and hydroxypropyl acrylate and methacrylate. (Acrylates provide more flexible films.) In general, any claims that one company's acrylic is much better than another's are unfounded. The real differences between products are due to the minor components (pigments, fillers, reactive diluents). In particular, small amounts of additives such as triazoles, benzophenones, and hindered amine light stabilizers (e.g., Ciba-Geigy Tinuvin 292) may double or triple gloss retention. These chemical additives are costly and proper inclusion in a polyurethane paint adds significantly to the cost (a few dollars U.S. per gallon). Choosing generically equivalent aliphatic acrylic polyurethane paints based simply on price runs the risk of getting an inferior product when the superior product was desired. Buying acrylic aliphatic polyurethane coatings is also difficult because many suppliers adulterate their coatings with alkyds; hence, it is difficult to compare apples to apples. Acrylic aliphatic polyurethane coatings are

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typically used as topcoats over epoxy intermediate coats to protect steel or other metal substrates from weathering or mildly corrosive environmental exposures.

Aliphatic-polyester polyurethanes are thin film coatings that provide harder, more chemically resistant films (with the exception of alkali resistance). Color and gloss retention, and impact resistance is less than with aliphatic-acrylic types.

Elastomeric Polyurethanes

Aromatic polyurethanes modified with hydrogenated castor oil are typically used to manufacture elastomeric polyurethane coatings. Most formulations on the market use Toluene Diisocyanate (TDI) reacted with polyols. These products provide good adhesion to steel and concrete when properly prepared. Also, these coatings or linings have good elongation and recoverable elongation properties. As such, these lining films can bridge minor crack movement in concrete substrates. However, the chemical resistance properties of elastomers are often lesser than more highly crosslinked harder, less flexible films. One generally gives up chemical resistance and permeability resistance properties for flexibility and elongation properties. Also, elastomeric polyurethanes are extremely moisture sensitive during application and curing. Therefore, substrates must be kept extremely dry during application. Furthermore, the application of two component elastomeric polyurethane coatings requires the use of specialized plural component spray equipment. Operating this equipment properly requires specialized training, etc. All of this higher technology permits more opportunities for application and mixing errors. Elastomeric polyurethanes are often hybridized or crosslinked with asphaltic resins or coal tars to create asphalt urethane elastomeric linings and coatings.

Moisture Curing Polyurethanes

These coatings fall into the categories of the Type II or Type IV polyurethanes as described above from ASTM D16. For weathering purposes, aliphatic polyurethanes are much better than aromatic polyurethanes. However for primers or intermediate coats, the aromatic polyurethanes are fine. All isocyanates react with any compound containing reactive hydrogen. This includes water or moisture found on substrates. As such, moisture cured polyurethanes provide excellent adhesion to steel and concrete substrates. This means these products are excellent for application over damp surfaces and when damp ambient conditions are present. This is not to say that these products should be applied over wet substrates. Reaction with moisture does produce carbon dioxide and extensive CO₂ formation can result in pinholing and foaming in the film. These coatings have fair resistance to acidic conditions, but are not recommended for high H₂S gas exposures. These coatings provide good abrasion resistance and other physical properties and are best utilized over steel substrates in wastewater applications.

Moisture curing polyurethanes are most widely used as primers for steel. They use up substrate moisture, adhere well, and are fast to recoat. These primers are more often than not pigmented with aluminum or micaceous iron oxide. These pigments are generally manufactured moisture free and lower the permeability of the coating film. Zinc is also used in moisture cure polyurethane coatings. See more on organic – zinc rich coatings later in this section of the manual.

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See Table V which compares the performance properties of various types of polyurethane coatings.

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Table V

Coreactive Polyurethane Coatings

Properties	Type 1 Oil Modified	Type 2 Moisture Cure	Type 3 Blocked	Type 4 Prepolymer Catalyst	Type 5 Two Component
Hardness/Strength	Very Tough	Very Tough Abrasion Resistant	Tough Abrasion Resistant	Tough Abrasion Resistant	Tough - Hard Rubbery
Water Resistance	Fair	Good	Good	Fair	Good
Acid Resistance	Poor	Fair	Fair	Poor - Fair	Fair
Alkali Resistance	Poor	Fair	Fair	Poor	Fair
Salt Resistance	Fair	Fair	Fair	Fair	Fair
Solvent Resistance (Hydrocarbons)					
Aromatic	Fair	Good	Good	Poor	Good
Aliphatic	Fair	Good	Good	Fair	Good
Oxygenated	Poor	Fair	Fair	Fair	Good
Temperature Dry	250 F	250 F	250 F	210 F	250 F
Weatherability	Good, Yellows	Excellent, Yellows	Good, Yellows	Good, Yellows	Excellent, Some Yellowing, Chalk
Aging	Good	Good	Good	Good	Good
Best Characteristics	Exterior, Wood Coating	Abrasion, Impact Low Temperature Cure	Abrasion, Impact	Quick Cure	Abrasion, Impact
Poorest Characteristics	Oil Base Chemical Resistance	Dependent on Humidity for Cure	Heat Cured	Chemical Resistance	Two Package, Moisture Sensitive, Slow Cure
Recoatibility	Fair	Difficult	Difficult	Difficult	Difficult
Primary Use	Clear Wood Coating	Abrasion Resistance, Floors	Product Finish	Abrasion Resistance	Abrasion Resistance & Impact, Exterior Finish

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Silicones

Silicone resins are hybrid polymers that consist of organic pendant groups attached to an inorganic quartz-like backbone of alternating silicon and oxygen atoms. This unusual polymer structure provides exceptional thermal stability and oxidation resistance. Silicones are essentially transparent to, and therefore resist degradation by, ultraviolet radiation from sunlight. Pure silicone paints are used on stacks, boilers and other exterior steel surfaces at temperatures ranging from 400-1200°F. Modified silicone paints have much lower resistance to elevated temperatures. Silicone coatings are used for atmospheric protection only.

High temperature, 100% silicone paints are single package paints that cure by heat-induced polymerization. These thin film paints dry quickly by solvent evaporation, achieving sufficient mechanical strength to endure the rigors of handling and transport; however, total cure is achieved only after exposure to temperatures in the 350-400°F range for approximately one hour. The coating on small items can be cured by oven baking. On large field structures, curing is achieved as the equipment is returned to its operating temperature. Although most high temperature silicone paints require ambient temperatures for application, special formulations are available that can be applied to steel as hot as 400°F.

Silicone resins are blended with organic resins such as alkyds and acrylics to reduce cost and to enhance certain characteristics, but at the expense of a decrease in temperature resistance. For example, silicone acrylics are single package air-dry paints that provide good color and gloss retention to temperatures in the 350-400°F range. Similarly, silicone alkyds are single package air dry paints that provide good durability, color and gloss retention; however, the dry heat resistance is limited to only about 225°F.

Vinyls

Solution vinyl coatings are single package products that consist of high molecular weight copolymers of vinyl chloride and vinyl acetate, pigments, and fillers, dissolved in strong solvents. The large size and the chemical nature of the vinyl binder dictates that the applied coating will be low in solids, typically only 20-35% (by volume) and that the coating must then be applied in multiple thin coats, typically 1-4 mils each, to achieve adequate thickness. (Solution vinyls have been legislated out of existence due to their inherently high volatile organic content (VOC).)

Vinyl copolymer paints dry and harden by solvent evaporation only. There is no crosslinking mechanism as with alkyds and epoxies, for example. As a result, solution vinyl coatings are thermoplastic materials that have limited temperature and solvent resistance. However, vinyl coatings have good resistance to weather, mineral acids, alkalies and many chemicals. The extremely low permeability of multiple coat vinyl systems made them excellent for use as tank linings and marine coatings. The fact that vinyls are thermoplastic coatings that remain forever soluble in their own solvents was a benefit with regard to maintenance coating work because only minimal surface preparation was required; the new coat readily bonded into the previous coat. This description was kept in this manual because there may be existing vinyl coatings in some of the plants.

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Zinc (Inorganic)

The use of zinc-rich paints dates back to the 1940s. These primers are best known for their ability to provide galvanic protection to the steel substrate. Inorganic zincs also provide unsurpassed adhesion to properly prepared steel. Properly applied, the hard, durable film may be scratched or otherwise marred but, it will not lift, flake, or peel like ordinary paints.

During the first phase of their atmospheric exposure, inorganic zinc silicates act like a porous metallic electrode. The zinc content of the film is reduced during exposure, and the behavior of the coating moves gradually towards the typical characteristics of a barrier coating. Galvanic protection is predominant early and the zinc particles are anodically sacrificed in order to protect the steel. For this mechanism to take place, the zinc particles must be in electrical contact with one another and, in turn, with the base steel. The zinc concentration must be high, on the order of 75-95% by weight in the dry film. The galvanic or cathodic protection mechanism ceases to function in a short period of time but insoluble zinc corrosion products (zinc oxide and carbonate) may remain to seal up the porosity of the film, thereby creating an excellent barrier.

The silicate binder has excellent thermal stability and allows for atmospheric service up to the melting point of the zinc (750°F). The silicate binder also provides excellent resistance to hydrocarbons and so inorganic zinc coatings have been used extensively as tank linings for crude oil and for refined products. The development of high performance epoxy tank linings in recent years has brought about a decline in the use of inorganic zincs as tank linings. However, inorganic zinc primers still provide the best corrosion protection in neutral (pH 6-10) atmospheric exposures. The principal disadvantages of these coatings are that the best surface preparation is required and the metallic zinc pigment is attacked by both acids and alkalies.

Inorganic zinc primers are available as water or as solvent-based formulations, as one, two or three package products, and may contain anywhere from 60 to 90% zinc in the dry film. The variations are numerous but every inorganic zinc primer is aimed at achieving the same outcome – a rock hard quartz-like polymer filled with soft zinc metal. The differences in the various product formulations are important when consideration is given to how the coating will be applied. The application of some products is problematical under certain weather conditions.

For example, the original (standard) water based self-cured inorganic zincs had a ratio of 3:1 silicon to potassium. Drying occurs by evaporation of water. Curing involves absorption of atmospheric CO₂ in the remaining water solvent, forming carbonic acid (H₂CO₃) which reacts with the liquid potassium silicate and the powdered zinc metal to form the insoluble zinc silicate polymer and potassium carbonate. Drying may be slow under conditions of high humidity. These products may be modified to provide faster insolubilization, drying, and hardening, by the addition of small amounts of lithium silicate. The other major concern is that water has a high surface tension and the newly applied paint film may not wet out (fully contact) the steel substrate to obtain good adhesion. Common practice has been to specify the utmost in surface preparation, a white metal blasted finish (SSPC-SP5).

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These concerns for slow drying and poor wetting of steel substrates prompted the development of solvent based inorganic zincs. The lower surface tension of the hydrocarbon solvent system provides for easier application and easier wetting of the steel substrate. Most paint manufacturers recommend a near-white blasted finish (SSPC-SP10) and some allow a commercial blast finish (SSPC-SP6) for mild service exposure conditions. These products employ an organically modified silicate (TEOS – tetraethyl orthosilicate) which requires moisture from the atmosphere to cure. In doing so, ethyl alcohol is released as a by-product. These “alkyl silicates” require a minimum relative humidity for proper curing. After an appropriate air-dry time to allow for solvent release, cure may be accelerated by spraying the inorganic zinc coating delicately with a fresh water spray (mist).

A newer “high ratio” water based inorganic zinc has made significant inroads. The high ratio inorganic zincs have an approximate 5:1 ratio of silicon to potassium and this substantially increases the number of reactive hydroxyl groups on an individual silicate molecule. This greater reactivity accounts for more rapid insolubilization, faster cure, rapid hardening, and strong adhesion. The sum of these factors allows for the application of a topcoat sooner than for other inorganic zinc primers. The potential shortcomings of water as a high surface tension solvent remain but the slow dry aspect of earlier waterbased inorganic zincs has been overcome. Inorganic zinc rich coatings will rarely be used as part of this coatings manual for HRSD.

Zinc (Organic)

Organic zinc primers involve conductive metallic zinc pigment dispersed in a nonconductive, insulating polymeric hydrocarbon binder. High zinc pigment loadings are required to maintain contact between zinc particles to ensure electrical conductivity within the film and across the interface. The binders are most often epoxy (polyamide) or polyurethane.

In most respects, inorganic zincs are far superior to organic zincs. The inorganic films are harder, stronger, more adherent, have better resistance to abrasion, impact, heat and weathering. The advantages of organic zinc primers is that they are easier to apply and they are better suited for maintenance, touch-up coating conditions.