

Soluble Salts Under Epoxy Coatings

Issues of Salt Ions On Surfaces Painted With
Epoxy Paint.

SNOPSIS:

Coating Pro magazine March 2008 "Soluble Salts and Specifications" - article on salt contamination on steel surfaces and its impact on Epoxy Paint topcoats.

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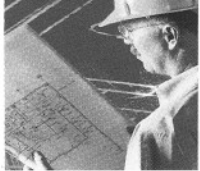


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Soluble Salts and Specifications

By James R. Johnson

Soluble salts are very much at the forefront of discussion in the coatings industry, but are often overlooked in specifications. In an effort to provide the industry with comprehensive information about soluble salts and corrosion prevention, CoatingsPro and ChlorRid are pleased to present the first in an on-going series of articles, "Salts 101."

Salts: The Economic Impact On Coatings

In 2002, the U.S. Federal Highway Administration released a major study which estimates the annual direct cost of corrosion at over \$150 billion, in 2007 inflation-adjusted terms. Over 88 percent of this cost, or an adjusted \$124 billion, is attributable to coatings. Proper surface preparation is a critical condition necessary for coatings to provide surface protection for an expected average of 14 to 15 years.

Salts are attributed as a major cause of premature coating failure, with claims from forensic failure inspections running over 60 percent. This means that salts left on the surface prior to coating have an economic impact of over \$74 billion per year. For the doubter, even if salt-related premature coating failures represent only five percent of the cause of the failure (and it is highly unlikely that it is this low), the economic impact is over \$6 billion per year.

What becomes obvious is that the economic penalty for not taking salt testing and removal into account is tremendous and it is a controllable variable. Whatever the number, would it not be in our best collective interest to save billions of dollars annually?



ABOVE ▲ Surface contamination by soluble salts has long been an issue for the corrosion industry. Lead-based paints used to be the first line of defense. A unique property of lead is that it reacts with soluble salts to form insoluble salts, thereby preventing those salts from causing or increasing corrosivity. But, of course, lead-based paints resulted in toxicity problems that outweighed their usefulness as anti-corrosives.

How Are Specifications Changing?

A few years ago specifications and surface preparation instructions rarely called for testing of salts or even for limiting them. Today, testing and allowable limits are included in a large percentage of specifications. In a few more short years, it is probable that most specifications will address salts in some manner. Asset owners are beginning to understand that salts are causing coating life spans to fall short of their intentions. Coating manufacturers are finding salts to be the cause of increasing warranty claims. Unaddressed salts are a major cause of expensive rework for coatings contractors. Consequently, coating professionals throughout the industry are

making changes in specifications.

For decades the coatings industry has worked with visual standards and visual comparators. As we begin to deal with soluble salts we enter the realm of the non-visible. Suddenly we are testing for and removing something that cannot be seen. This requires change, but human nature resists change, so such transition is not easy. Engineers, specifiers, and coating manufacturers frequently require testing and establish allowable limits; however there is resistance to change, so such efforts are not always successfully implemented. To provide a sound specification addressing salts, the specification writer should understand the significance of soluble salts, the problems caused by those salts and the appropriate methods

RIGHT ▶ The cleaner the surface, the better the coating performance — but some conductive materials have little effect on corrosion or coating performance, while other conductive materials can affect it to a great degree.

of testing, evaluating, and removing salts. Some specifiers are attempting to incorporate salt provisions into specifications without a good understanding of them and, consequently, many specifications still do not capture the essence of testing and decontamination that would effectively provide for intended or maximum coating performance.

Surface contamination by soluble salts has long been an issue for the corrosion industry; however, it was the banning of lead-based paints that caused closer scrutiny of salts with regard to coating service life and premature coating failures. A unique property of lead is that it is capable of reacting with soluble salts,



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All liquid-applied coatings are moisture-vapor permeable, which allows the salt on a substrate to "draw" moisture through the coating. This can cause the active corrosion of the substrate long before the protective coating fails.

forming insoluble salts, thereby limiting salts from causing or increasing the corrosivity of the immediate environment. The widespread use of lead-based paints gave us a sense of security but the legislated ban of such products requires reevaluation of surface preparation requirements. Also, as new "high performance" coatings are developed, film thickness is decreasing. The thinner coatings get, the more critical soluble salts become.

What Are Soluble Salts?

An explanation voiced in a NACE International committee meeting some years ago stated that anything conductive should be considered a salt.

Soluble salts are described in the Society for Protective Coatings (SSPC) Protective Coatings Glossary as — "An ionic chemical compound that dissolves in water to form a solution of positive and negative ions."

Coatings professionals have long realized that soluble salts are detrimental to the substrate and to coatings. Though they did not have the means to

perform the ion-specific testing that we do today, they realized that if a clean, uncontaminated surface were washed with de-ionized (DI) water, the water remained relatively non-conductive. But when contaminants were present, an increase in conductivity was observed. Since they did not have the means to identify specific ions, especially in the field, estimates were used to determine percentages of chlorides and other ions based on assumptions. That was the best they could do with the technology available at the time. Since then it has been found that these estimates are highly unreliable. Today we do have the means to identify and measure specific ions. Everything conductive is still frequently considered a salt; however, this conductivity could be comprised of hundreds of different constituents and not everything conductive is detrimental to coatings.

Clearly, the cleaner the surface, the better the coating performance — but some conductive materials have little effect on corrosion or coating performance, while other conductive materials

can affect it to a great degree. The prime detrimental salts most commonly encountered are chloride, sulfate, and nitrate, though specific industries may encounter others. These salts can be so detrimental that they can cause premature coating failure in as little as weeks in the right environment. Salts definitely can affect the overall life spans of coatings, even if the coating system survives beyond the warranty period.

The question industry is asking today is, "How much of what salt can be left on a surface and not significantly affect a coating's life span?" There are so many different coating systems available and so many different operating environments that a consensus number will probably never be attained. Best practices engineering dictates that the lower the number the less risk of premature failure and the highest probability of maximum service. As time progresses we are continually gathering more information as to what has and has not worked.

NASA engineers identified chlorides for their extreme corrosion effect in the

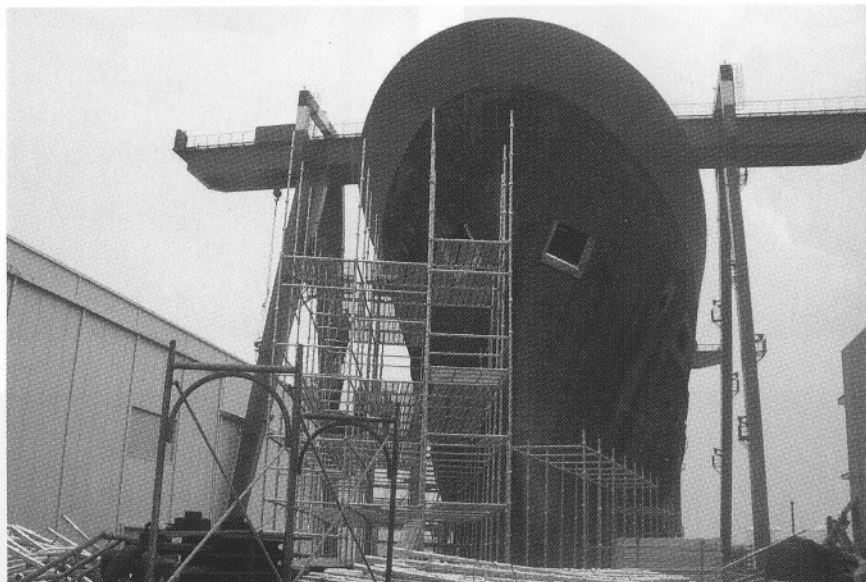
RIGHT ► To provide a sound specification addressing salts, the specification writer must understand the significance of soluble salts, the problems caused by those salts, and the appropriate methods of testing (photo at left), evaluating, and removing salts.

late 1970s and they established a chloride threshold limit of 5 micrograms per square centimeter ($\mu\text{g}/\text{cm}^2$) as the acceptable limit on surfaces prior to coating. Although there was no adequate, reliable, and accurate nondestructive test method for metallic surfaces, NASA held firm with their specification (KSC-STD-0001-D). Until recently they had to allow contractors variances to specifications because of the inability of contractors to meet the specification limits.

The US Navy started limiting chlorides in the early 1990s, setting limits of 10 $\mu\text{g}/\text{cm}^2$ for non-immersion service and 5 $\mu\text{g}/\text{cm}^2$ for immersion service. For various reasons, including premature failure, these limits were reduced to 5 $\mu\text{g}/\text{cm}^2$ for non-immersion service and 3 $\mu\text{g}/\text{cm}^2$ for immersion service. These lowered limits appear to be providing better results. Some state departments of transportation (DOTs) have used a limit of 10 $\mu\text{g}/\text{cm}^2$ but many are also still encountering unacceptable premature failures. Today, at least one state has adopted the US Navy standard as they find it is an achievable level and that coatings are performing as desired. The more knowledge the coatings and surface preparation industry gains about the direct relationship between salts and corrosion, the more they are beginning to realize how damaging salts are.

Where Do Salts Come From?

Our environment is filled with sources of salt contaminants, both natural and man-made. Chlorides from marine environments, water treatment, paper bleaching and deicing products are only a few of the many sources of chloride contamination to which steel surfaces and uncoated rebar in concrete become exposed. Sulfates are produced by natural sources and are generated from stack gas and diesel emissions (oxidized from sulfur dioxide) and nitrates from diesel and auto



emissions (oxidized from nitrous oxide). Converted to weak sulfuric and nitric acid in the atmosphere, when in contact with moisture, these are deposited on surfaces as acid rain. Chlorine and sulfuric acid are the two most widely produced and used chemicals in the world. Nitrogen fertilizers, in their manufacture, transport, use and runoff, result in oxidized nitrates, another salt, which is corrosive on metallic surfaces. Even without human intervention, nitrogen is in a constant cycle, alternating between soil and atmosphere. Nitrogen is constantly available in the atmosphere for deposition, and lightning readily converts atmospheric nitrogen to nitrogen oxides, which can form nitric acid.

It is important to remember that surface contaminating salts are not localized to coastal areas or locales where de-icing salts are used. Industrial and automotive emissions transform to acids, which can convert to surface salts. Salts are all around us and in so many products that we do not even realize their presence. Salts are so widely spread from so many diverse sources that virtually every surface is subject to salt contamination at some level.

RIGHT ▶ Some state DOTs have used a limit of $10 \mu\text{g}/\text{cm}^2$ of soluble salt, but many are also still encountering unacceptable premature failures. Today, at least one state has successfully adopted the US Navy standard.

Even accepted surface preparation methods can leave behind the beginnings of corrosion. A common practice is to acid-etch concrete surfaces prior to applying coatings. If hydrochloric acid is used in this process, chlorides may be left behind. Etching the substrate with sulfuric acid can leave a sulfate residue.

A Salty Impact On Coating Performance

Salts left on a surface prior to the application of coatings can be the cause of several occurrences. Soluble salts, as often encountered in the coatings industry, are hygroscopic, meaning they draw moisture to achieve their highest level of chemical stability. For example, in many households around the world there are

LEFT ◀ The US Navy started limiting chlorides in the early 1990s, setting limits of $10 \mu\text{g}/\text{cm}^2$ for non-immersion service and $5 \mu\text{g}/\text{cm}^2$ for immersion service. These limits were reduced to $5 \mu\text{g}/\text{cm}^2$ for non-immersion service and $3 \mu\text{g}/\text{cm}^2$ for immersion service.

grains of rice or pieces of cracker in the saltshaker to absorb moisture. Without the rice to absorb the moisture, the salt will draw the moisture from the air and cake. Salts, such as chlorides, sulfates, and nitrates, do the same thing when left on a metallic surface — they draw moisture.

An active corrosion cell requires four components: an anode, a cathode, a metallic pathway, and an electrolyte (a conductive liquid). The surface of a piece of steel consists of many thousands of minute areas that are either anodic (repellant) or cathodic (attractive) to each other. The steel itself provides the metallic pathway connecting them. Introduce a chloride ion into the equation — which will draw moisture from the air and become the electrolyte — and there are now all the components needed for an active corrosion cell.

All liquid-applied coatings are moisture-vapor permeable, thereby allowing the salt on a substrate to “draw” moisture through the coating, causing active corrosion of the substrate *long before* the protective coating fails.

The coating is applied, the salt ion draws moisture through the coating and provides an electrolyte behind the

▶ **FIELD CONTINUED ON PAGE 76**



► FIELD CONTINUED FROM PAGE 28

coating and an active corrosion cell is formed. The products of the corrosion cell activity are acidic and will corrode the metallic surface around the cell. We have all seen blistered paint which, when the blister is broken, exhibits rust on the backside. In nearly all cases, that paint was applied over salts. In immersion service and some atmospheric service, other than very dry environments, this same hygroscopic action will cause osmotic blisters.

The scenario is much the same with coatings applied to concrete. Salts left on the surface will absorb moisture through the coating, which will produce weak acids on the concrete surface. The weak acids will react with the concrete and cause it to deteriorate beneath the coating. These same acids/salts, in immersion or damp service, can also cause osmotic blistering of concrete coatings. These salt contaminants can also be introduced onto a concrete surface when etched by or exposed to hydrochloric or sulfuric acid.

Salts also can interfere with adhesion or bonding between coats. For example, at a lighthouse in the Florida Keys, the specifier was aware of probable contamination from the marine environment, so the specification required that the surface be washed with potable water into which a salt remover had been added. The surface was washed, the prime coat applied and left to dry overnight. The next day, an intermediate coat was applied. The

third day, a finish coat was applied. In a few weeks time the coating began blistering and peeling. It was not blistering from the surface, but from between coats. Subsequent investigation determined that in the time period in between the coats, the surface had become recontaminated with salts.

When it comes to salts, specifications have to be specific. Future articles will explore a variety of tests for determining the presence of, and methods for removing, soluble salts. Nature, time lapse, location, all are potential sources of soluble salts. And all can doom a project to premature coating failure and corrosion before anyone even steps onto the jobsite. The good news is that there are methods for combating salts and the opportunity to do so starts with the project specification. **CP**

JAMES R. JOHNSON has over 20 years experience in the fields of protective coating sales, application, and inspection. He served as a two-term Chairman of NACE STG-04 Surface Preparation Committee; Chairman of TG-142 joint NACE/SSPC task group on Decontamination of Contaminated Surfaces; and as Vice-Chairman of TG-288, NACE Task Group, Designating Non-Visible Contaminant Levels. He is a member of the joint NACE/SSPC task group on Wet Abrasive Blasting, as well as a member and previous Chairman of SSPC C.2.7 Soluble Salts Committee.

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