CHLOR*RID®

Product Information

CHLOR*RID International, Inc.

P.O. Box 908 Chandler, AZ 85244

800-422-3217 480-821-0039 fax 480-821-0364

www.chlor-rid.com

Email: info@chlor-rid.com

CHLOR*RID International, Inc.

FOREWORD

This booklet contains information regarding CHLOR*RID. The following, entitled APPENDIX, is especially informative because it offers an excellent explanation as to the corrosion activity of the soluble salt ion. Please read it carefully for a simple explanation.

The information included here has been gathered from various sources. If after reading the enclosed information you have questions or require further details, please contact our office via phone, fax or Internet.

P.O. Box 908 Chandler, AZ 85244
800-422-3217 480-821-0039 fax 480-821-0364
www.chlor-rid.com

Email: info@chlor-rid.com

APPENDIX

COMMENTS ON SOLUBLE FERROUS AND FERRIC SALTS

Although many ions can and do cause problems, the two most common in industry are ions or radicals formed from chlorine or sulfur. More sulfuric acid is produced and used than any other single chemical compound. Chlorine has many industrial uses, such as a bleaching agent, algecide and as a primary component in the chemical industry. It is not surprising that these ions cause most of the problems and are the most prevalent. Both the chloride radical Cl and the sulfate radical S04 are very active.

Current corrosion theory indicates that these radicals are not consumed in the corrosion reaction. These radicals react with steel to form an unstable iron compound that reacts further with oxygen. The second reaction replaces the radical with oxygen, allowing the formation of iron oxide, rust, and the original radical is regenerated. The regenerated radical is then free to react with more steel. This is a continuing and repeated cycle that only requires a minimum amount of oxygen to continue. A very small amount of these ions can corrode substantial amounts of steel.

These radicals, or ions, are non-visible to the eye and cannot be seen upon a surface. They are termed soluble salts, though they are not necessarily readily water-soluble. Also, they are hygroscopic and absorb moisture out of the air. The chemical compound on a soluble salt contaminated surface will absorb moisture from the air and will cause flash rusting to occur. The length of time needed for flash rusting to occur is dependent upon the relative humidity and the level of soluble salts upon a surface. High humidity and soluble salts levels will promote very fast flash rust, with the opposite true of low relative humidity and low soluble salt levels. With high humidity and high contamination levels, flash rust can occur in a matter of minutes, while low levels of humidity and low levels of soluble salts could allow many days to pass before flash rusting occurred.

On a contaminated surface, direct contact with water can cause almost instantaneous flash rusting. In such a situation, color change can often be seen to occur as a person is watching. If the temperature of a blast cleaned surface does not drop to the dew point, a truly clean surface, without soluble salt contamination, will not rust for hundreds of hours, regardless of the humidity level.

MARK M. MORRISON, PH.D.

Conductivity Measurements and Chloride Ion Concentrations

Conductivity measurements are often used to approximate the total dissolved solids concentration (TDS) and are often described in terms of sodium chloride concentration. However, only when sodium and chloride are the only tons present does conductivity directly correlate with sodium chloride concentration. Chloride, sulfate, nitrate, sodium, calcium, magnesium, ammonium, iron, sulfide, silicate, and other tons may be common contaminants on washed, blast-cleaned steel surfaces depending on the environmental exposure, water quality, and abrasive used.

Conductivity measurements do not directly measure chloride concentration, but rather express the ability of a solution to conduct electricity. This is due to all ions in solution.

Determination of these ions typically involves two steps, extraction and measurement. The extraction must be performed using high quality water to remove the ionic contaminants from the steel surface. Extraction methods include both laboratory methods, such as boiling the steel sample in water, and field methods, such as the swab test or Bresle→ sampler methods. The resulting solution contains whatever ions are solubilized in the extraction procedure.

The extract solution must be analyzed for chloride, sulfate, or other ions using methods which measure these ions directly. The concentration of the ion on the surface is then calculated in micrograms per square centimeter, based on the analytical result, the volume of the extract liquid, and the surface area tested.

Estimation of chloride concentration based on conductivity measurements will be erroneous unless the only conductive species are sodium and chloride ions.

Convenient field methods are available to determine chloride and sulfate ion directly. .A variety of laboratory methods are also available for determining ionic species in solution.

Studies by independent testing laboratories, including KTA-Tator, Inc. have shown that CHLOR*RID can decrease chloride and sulfate ion concentrations on steel surfaces, as shown by analytical determination of chloride and sulfate ions in the extraction fluid. But the solution from the extraction of these washed surfaces will be conductive, despite being relatively free from chloride and sulfate. Thus it is possible to have a "false positive" based on conductivity testing alone.

Mark Morrison is an independent consultant with experience in paint and coating testing, and was previously employed by KTA-Tator in the Gulf Coast Regional Office as Laboratory Director. Mark Morrison has a Ph.D. in analytical chemistry from the University of California, Riverside. Dr. Morrison may be contacted at 3618 Wells Mark Dr. Humble TX 77396 281-454-5091.

3618 WELLS MARK DR HUMBLE TX 77396-4010

PHONE: 281-454-5091

SALTS 101 – An Overview

Presented Courtesy of CHLOR*RID International Inc.

Introduction

Soluble salts are very much at the forefront of discussion in the coatings industry. There is much information available on the topic, but often is provided in small segments so a complete comprehension is not easy to grasp. It is the purpose of the following to provide an overview to assist in bringing those pieces together.

How are specifications changing?

As few as 4 or 5 years ago, specifications and surface preparation instructions rarely called for testing of salts or for limiting them. Today, testing and allowable limits are included in a large percentage of specifications. In a few short years, it is probable that most all specifications will address salts in some manner. Facility owners are beginning to understand how salts are causing coating life spans to fall short of their intentions and coating manufacturers are finding salts the cause of increasing warranty claims. Consequently, coating professionals throughout the industry are making changes in specifications.

"As we begin to deal with soluble salts, which are corrosive even at very low levels, we enter the realm of non-visible contamination."

For decades the coatings industry has worked with visual standards and visual comparators. As we begin to deal with soluble salts, which are corrosive even at very low levels, we enter the realm of non-visible contamination. As has been said many times, "Old habits die hard", especially in an industry steeped in perpetuation of established practices. Engineers, specifiers and coating manufacturers are now requiring testing and are setting allowable limits; however there is resistance to change, so such efforts are not always successful. To provide a sound specification for surface preparation, the specification writer must understand the significance of these salts, the problems caused by salts and the appropriate methods of testing, evaluating and removing salts. Some specifiers are attempting to incorporate salt provisions into specifications without a good understanding of the interaction of salts on metallic surfaces and, consequently, many specifications still do not capture the essence of testing and decontamination that would effectively provide for maximum coating performance.

Surface contamination by soluble salts has long been an issue for the corrosion industry; however, it was the discontinuance of lead-based paints that caused a renewed look at salts with regard to coating service life and their involvement with premature coating failures. A unique property of lead compounds is that they are capable of binding up soluble salts, thereby preventing 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 discontinuance of such products requires that we re-evaluate surface preparation requirements.

What are soluble salts?

An explanation voiced in a NACE (National Association of Corrosion Engineers, International) committee meeting some years ago stated that anything conductive should be considered a salt. Coatings professionals had long realized that salts were detrimental to the substrate and to coatings. Though they did not have the means for testing that we do today, they realized that if a clean uncontaminated surface were washed with DI (de-ionized) water that 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. Since then it has been found that these estimates are highly unreliable, but today we do have the means to identify and measure specific ions that are of primary concern. Everything conductive is still considered a salt; however, this conductivity could be comprised of hundreds of different chemicals and not all salts are detrimental to coatings.

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". 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 chlorides, sulfates and nitrates, 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. These 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 coating life spans?" There are so many different coating systems available and so many different operating environments that a consensus number will probably never be developed or standardized. 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 late 70's and they established a chloride threshold limit of 5 micrograms per square centimeter (↘g/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

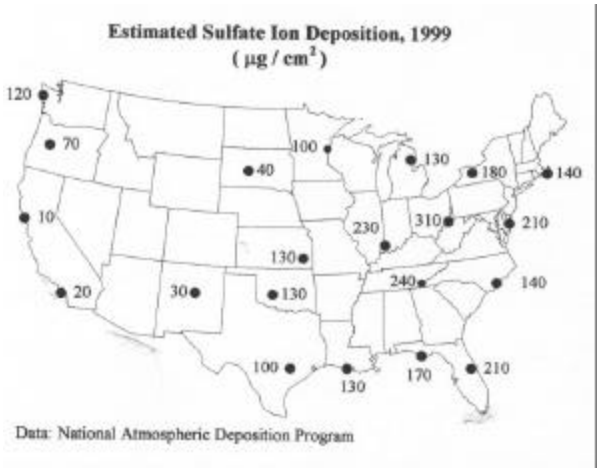

Figure 1

specification limits. The US Navy started limiting chlorides in the early 90's, setting limits of 10 ↘g/cm^2 for non-immersion service and 5 ↘g/cm^2 for immersion service. For various reasons, including premature

failure, these limits were reduced to 5 ↘g/cm^2 for non-immersion service and 3 ↘g/cm^2 for immersion service. These lowered limits appear to be providing satisfactory results. Many of the State DOT's have used a limit of 10 ↘g/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 knowledgeable the coatings and surface preparation industry is 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) (See Figure 1) 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 lightening readily converts atmospheric nitrogen to nitrogen oxides, which can form nitric acid.

A common practice is to acid etch concrete surfaces prior to applying coatings. If this is performed with hydrochloric acid, chlorides are left behind; etching with sulfuric acid leaves a sulfate residue. 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.

How do salts impact coating performance?

Salts left on a surface prior to the application of coatings can be the cause of several occurrences. Salts, as encountered in the coatings industry, are hygroscopic in nature, meaning they draw moisture. In this form, they achieve their highest level of chemical stability. As an example, in many households around the world, there are grains of rice or pieces of cracker in the saltshaker to absorb moisture. If these are not used, the salt will draw moisture from the air and cake. Salts, such as chlorides, sulfates and nitrates, do the same thing when left on a metallic surface. An active corrosion cell requires an anode, a cathode, a metallic pathway and an electrolyte (See figure 2).

Corrosion Cell Elements

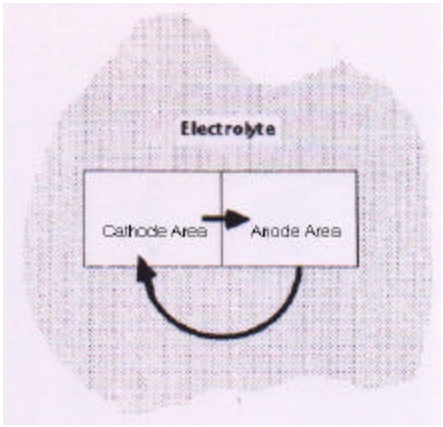

Figure 2

The surface of a piece of steel consists of many thousands of minute areas that are either anodic or cathodic to each other. The steel itself provides the metallic pathway. 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 of an active corrosion cell. All liquid applied coatings are permeable, thereby allowing the salt on a substrate to "pull" 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 forms an electrolyte behind the 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 (See figure 3). In nearly all cases, that paint was applied over salts. In immersion service and 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, producing weak acids. The weak acids, such as hydrochloric and sulfuric acids, will react with the concrete and cause it to deteriorate beneath the coating. These same 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 the probable contamination from the marine environment, so the specification required the surface to be washed with potable water and a salt remover added to the water. 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 between coats the surface had become recontaminated with salts.

Typical Chloride Induced Coating Failure

Figure 3

What about flash rust?

Virtually all rust on metallic surfaces is caused or induced by salt contamination. We have been taught to believe that whenever there is bare steel and humidity that there will be rust. This is so ingrained into our thinking that some have a hard time

believing that bare steel can be wetted and not rust. Take a clean uncontaminated steel coupon, abrasive blast it to a White Metal finish, hold it at a 45 degree angle, and pour DI (de-ionized) water over it. Even though it will be thoroughly wetted, it will not rust! Take the same piece of steel and pour tap water over it, and light flash rust will form, caused by the salt in the tap water. Pour salt water over the same panel and it will flash rust much more heavily (See figure 4). As stated by Dr. Gerald Soltz in his research work for the National Shipbuilding Research Program, in the executive summary, "Clean uncontaminated steel will not rust, even in 100% humidity, for thousands of hours." The old habit of "Blast it and paint it quick before it flashes" now has been found to often be inappropriate. If flash rust occurs to any great degree, contamination should be tested for, because the rust is the result of non-visible soluble salt contamination. Without some form of contamination, there will not be rust.

Salt Contaminated Steel Panels- Left to Right: Abrasive Blasted - Blasted & Water Washed - Blasted & Water Washed with Salt Remover

Figure 4

How do you identify and test for salts?

There are several common field methods to test for contamination and to determine contamination levels. None of the field test methods can measure the contaminants directly on the surface. The contaminants first must be extracted from the surface into a solution where they can be measured in parts per million (ppm). The ability of a certain method to perform this extraction is called the extraction efficiency, typically stated in the percentage of contaminants extracted from the surface versus the total on the surface. No method provides 100% extraction and the efficiency differs greatly from method to method. Once the contaminant is in solution, a variety of methods can be used to measure the ppm of a particular ion. This also varies from method to method, with different degrees of difficulty, accuracy and other limitations, such as the minimum detection limit. The chosen test method is, therefore, a combination of two separate critical steps blended in a single methodology. Whichever methodology is chosen, in order to have useful information, the ppm must be converted to micrograms per square centimeter ($\mu g/cm^2$), meaning a specific amount of salt over a specific area, a prime concern to adequate surface preparation. To perform this conversion, multiply the concentration of salts in solution (ppm) by the volume of extract liquid (milliliters) and divide that by the surface area sampled (square centimeters). The result is micrograms per square centimeter, expressed as $\mu g/cm^2$.

The Society for Protective Coatings SSPC-TU-4, Field Methods for Retrieval and Analysis of Soluble Salts on Substrates, notes two of the more common methods, the swab method and the adhesive cell method. Another choice is the CHLOR*TEST™, which has been introduced since TU-4 was published. The primary differences between the test methods are the degree of accuracy, lower limit of detection, ease of use and the degree of potential operator error. Errors usually occur because of complexity of procedures, operator accuracy in measuring and cross-contamination from reuse of components. Several things should be

considered when choosing a test method. No matter how cautious an operator is or how accurately he measures, he cannot overcome the accuracy, efficiency, limit of detection or other limitations of the test method.

According to SSPC-TU-4, retrieval efficiency of the swab method is between 25 and 35%, as determined under controlled laboratory conditions. The same document reports the retrieval efficiency of the adhesive cell as 45 to 60%. The manufacturer of the CHLOR*TEST reports retrieval efficiency as 65 to 75%, as tested by an independent laboratory.

The swab method is extremely hard to perform on a vertical surface and all but impossible overhead. The other two methods can be performed in any direction. It is easy to see when critical areas are vertical or overhead surfaces, good quality assurance requires the appropriate method be used.

Another important variable that must be considered is the test limit of the kit, more specifically the lower limit of the method used to determine the concentration of salts in solution. This has typically been measured by titration strip or tube. One common titration strip has a lower limit of ~ 30 ppm, while a common titration tube has a lower limit of ~1 ppm. Since concern for soluble salts is generally in the lower concentrations, this lower limit comes into the equation, therefore, using certain kits can cause false negatives.

CHLOR*TEST
all test materials included and pre-Measured

Figure 5

Just as important, is that the specifier be aware of both extraction efficiencies and possible operator error from things such as cross contamination from test to test, inaccurate measurement of liquids and area, and overall complexity of the test procedures. Directions for performing these tests are included in SSPC document TU-4 and at www.chlor-rid.com. Those two references will provide the necessary information for an owner or specifier to determine which test method to require. Those same references can be very helpful and informative to the inspector or contractor so they would fully understand the requirements. The CHLOR*TEST kit is the only test method in which all required materials are supplied and are pre-measured for accuracy, with all components designed for one-time use to avoid cross contamination (See figure 5). This test is also the only method which does not require mathematical calculation to convert parts per million to micrograms per square centimeter.

In view of the variables involved in testing for soluble salts, it is reasonable to say that a correctly written specification should require that a specific test method be used and it should indicate the maximum test result allowable by that method. A specification could also be written to allow other methods to be used by specifying a multiplier for each of the various allowed methods, respective to the extraction efficiencies. A specification that simply says, for example, “chlorides are not to exceed 5 micrograms per square centimeter” leaves much to be interpreted. Does the specifier intend the test result to be a maximum of 5 micrograms? Can any method be used? It is easy to see how an inspector or contractor could be left in controversy by the specification. A specification should stipulate a particular test method, an acceptable test result and/or a factor (multiplier) to be used for different

test methods. The real life situation is that it has been determined that any amount of salt, particularly chlorides, sulfates or nitrates, is detrimental to the overall lifespan of the coating. The cleaner the surface, the more successful a coating is going to be. Since salts are a relatively new subject to many people, it is easy to understand that people are also not aware of the costs or methods of salt removal. Many specifiers fail to specify low allowable concentrations of soluble salts for fear of cost; others simply do not want to spend any additional funds whatsoever. When all costs of asset downtime, surface preparation, and coating application are factored into a cost analysis, the cost of a premature failure is exorbitant when compared to the costs of taking reasonable steps to identify the existence of and to remove soluble salts. Costs of surface preparation and coating application are generally estimated in dollars per square foot, while reasonable costs of soluble salts testing and removal are generally estimated at only cents per square foot.

How do you remove salts?

Removal of soluble salts can range from very easy to extremely difficult, depending on actual conditions, which can vary greatly. Consider just one very common salt, sodium chloride. The chloride ion is never found by itself. As it is commonly encountered in the coatings industry, the chloride ion is always coupled with something else. For chemical stability, the chloride (also applies to sulfate and nitrate ions) ion wants to attach to something, forming compounds such as sodium chloride, zinc chloride, lead chloride or ferrous chloride or any of several other combinations. When a coated surface becomes contaminated with sodium chloride, the salt lies on the surface. Due to the chloride ion's strong affinity for metals and its extremely small size (1 ↘g of $FeCl_3$ = ~ 3,686,600,000,000,000 molecules), even very small imperfections in the coating allow the ion to migrate to the metal surface. At the metal surface, with the chloride ion having its affinity for metals, it leaves the sodium and bonds with the metal surface for greater stability. The chloride ion forms an electro-chemical bond to the metal and that bond becomes extremely strong. That is why it cannot be simply washed off with a garden hose. Where the sodium chloride would have been relatively easy to remove from the surface of the coating, the chloride ion now has bonded with the metal surface and is far harder to remove. For example, most of the salts on the surface of a coating can be removed with low pressure water blasting, but salts that have attached and complexed with the metal substrate often cannot be removed with 40,000 psi Ultra High Pressure Waterjetting (UHP-WJ).

The chloride ion forms an electro-chemical bond to the metal and that bond becomes extremely strong."

Once these chloride ions form an attachment to the metal substrate, a very high level of energy is necessary to break that electro-chemical bond and remove them. That energy can be in the form of mechanical energy or chemical energy, or both. The properties of mechanical energy are widely known, but many coating professionals are unaware of the chemical requirements of a salt remover. For maximum effectiveness, a salt remover should have several distinct properties, as follows: 1) The pH should be below 7 to facilitate disbonding, but not cause a hydroxide layer to form which can mask remaining salts, as occurs with a high pH material; 2) It should be capable of being used with water that contains a fairly high level of salts, such as 600 ppm of chlorides, as is common with many water sources; 3) It should not leave any type of residue that will interfere with

adhesion of coatings; 4) Nor should it leave an inhibitor film that requires rinsing or removal prior to coating application. As has been stated, the mechanical energy of 40,000 psi alone often cannot do the work, but when combined with the chemical energy of a salt remover, such as CHLOR*RID®, a patented one-of-a-kind technology, the work becomes much easier. One form of energy assists the other, thereby providing the needed energy to complete the task. On an abrasive blast cleaned surface, chlorides can usually be adequately removed with the mechanical energy of a 3,000 psi pressure washer with the salt remover added, providing the chemical energy needed to perform the task. The mechanical action of water pressure is important for penetrating the crevices of the surface profile that exists on abrasive blasted metal surfaces. The action of a chemically balanced salt remover will take on the challenge of disbonding the chloride ion from the metal ion.

When discussing water on bare steel, the subject of flash rust invariably arises. Reviewing what was stated earlier, contaminants cause flash rust, so when the contaminants are removed the cause of flash rust is removed. Note: Since it is uncommon to totally remove all contaminants from all surfaces, there usually are some very low levels of salt contaminants remaining after decontamination. This is because of the irregular structure of the metal surface after abrasive blasting. When an abrasive blasted surface is viewed under magnification, it can be seen that the abrasive has impinged onto the surface, forming the valleys and peaks of the profile. Also visible at the same time is that succeeding abrasive grit has burred over the peaks and even created cave-like formations where one peak burrs over and meets another (See figure 6). To remove 100% of these incredibly small ions from such locations can be almost impossible. Even a very small amount of contamination can cause some flash rust, but it is typically very minimal and in most cases reblasting is not necessary. Some manufacturers of coatings, primarily for immersion service, do require a full white metal surface with no flash rust. In this case, it is usually necessary to perform a light sweep blast to remove any small amount of flash rust.

There are several methods available to remove salts; only one of which is a dry method, the others all include the use of water. The dry method involves repeated abrasive blasting. A fine grit abrasive blast media is more effective at removing salts than coarse grit, so an engineered abrasive mix is sometimes specified (coarse abrasive to provide the necessary profile and fine abrasive for cleaning) but seldom can an effective job of removal be accomplished in a single abrasive blast. Typically a surface has to be abrasive blasted, allowed to rust back and then reblasted. In the corrosion or rust back cycle, a small amount of the salt ions get caught in the rust formed and, when the surface is reblasted, the small amount of salts in the rust is removed. It is not unusual to have to reblast a highly contaminated surface four to eight times to reach an acceptable level of cleanliness, particularly on highly contaminated surfaces such as those found in marine environments, pump bodies and water inlets. The rust back process can be actuated by atmospheric humidity or hastened by a water wash; simply add moisture and the salts will do the rest.

Magnified Blasted Surface
Photo Courtesy Dr. Lydia Frenzel

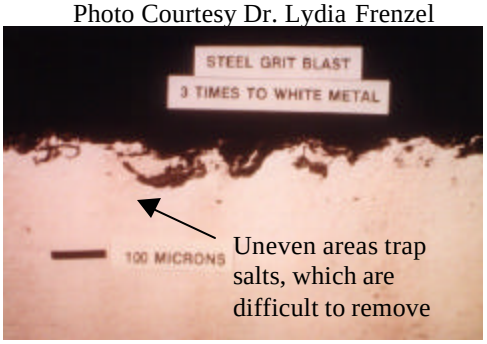

Figure 6

Of the wet methods, there are several choices, such as UHP-WJ, wet abrasive or slurry blasting, and dry blasting in conjunction with a water wash with a salt remover added, which sometimes requires a reblast as stated above. Other less common methods exist, such as specialty abrasives, but a particular type of abrasive alone will probably not remove all salts, though some abrasives do "scrub" the surface better than others. Reviewing the various options available, it can be determined which method will work best for a particular job.

UHP-WJ will usually, but not always, result in the desired level of cleanliness. If you want to be assured of attaining the desired cleanliness levels on a first time basis, add CHLOR*RID, a chemical salt remover to the water. This combines both mechanical and chemical energies, each assisting the other. This also allows the operator to proceed as fast as the visual work can be performed while being assured the non-visible contaminants will be removed. Maximum production can be achieved in this manner.

Wet Abrasive blasting, or slurry blasting, can remove chlorides, but may not attain the desired result in a single blast. A chemical salt remover, such as CHLOR*RID, can be added to the water, thereby combining chemical energy with mechanical energy. In every reported case, this method has resulted in chlorides being reduced to a non-detectable level with a single blast. A brush blast may be required to remove very light flash rust, usually quickly and easily accomplished. Wet abrasive blasting is not used frequently because "old habits die hard" and contractors are accustomed to dry abrasive blasting. Many contractors say that they do not want to make major equipment investments, not knowing the task can be accomplished with something as simple as a water ring, usually costing under $100.00, or an injector type nozzle, costing just slightly more, installed on their existing blast equipment. There are cleanup considerations, such as, wet abrasive does not sweep easily, but it can be vacuumed or shoveled much the same as dry. This method does offer greatly increased visibility which is a major consideration. Because wet abrasive blasting is almost dust free, environmental compliance is far less an issue. Since operators have better visibility, additional blast nozzles can be operated to complete a job more quickly. Because dust is not generated, it does not have to be removed, which results in a time and labor savings with a cleaner surface for coating adhesion.

The technique most commonly used is a dry abrasive blast of any rusted areas, sufficient to remove rust to an exposed bare steel substrate, such as would be provided by an Industrial Blast Standard. Depending on the extent of rusting, this could be either a spot blast or a blast over the entire surface. This blast is merely to remove any barrier materials, such as rust or damaged coating and to provide access to the chlorides so they may be removed. A pressure wash is then performed, usually a minimum of 3000 psi, with CHLOR*RID salt remover added to the water, again providing a combination of mechanical and chemical energy for removal. A final blast is then performed to the standard required by the specification. This same technique can also be performed by dry abrasive blasting to the standard required, then performing the pressure wash, with CHLOR*RID salt remover, followed by a brush blast to remove any excessive flash rust. Either method works well and can be relied on to achieve the desired result. These methods are very cost effective and cause no problems to cleanup, workers, or the environment. Each of the above is uniquely different and as each job is different, the option should be chosen that will provide the best result for each specific project.

Email info@chlor-rid.com
800-422-3217 / 480-821-0039
480-821-0364 Fax

In conclusion, our industry is changing. We, as a group and as individuals, are faced with change and challenge in order to keep up with technology. While we have relied on visible standards for surface preparation, we need to recognize that we must also be concerned about non-visible contaminants. This requires specific testing and to avoid premature failure of coatings, excessive soluble salt contaminants must be removed. There are numerous methods of removing soluble salts, most of which require the use of water and, when a wet method is allowed or used, removal is enhanced by the use of CHLOR*RID salt remover. It is possible to achieve a “non-detectable” level with the use of our product and in most cases it is economically viable. In almost all cases it is practical and cost effective to limit salts to levels such as are stipulated by the US Navy. A coating professional should also bear in mind that any amount of soluble salt contamination will have some adverse impact on the life span of any liquid applied coating.

The information provided above is a synopsis of the materials presented at CHLOR*RID International, Inc.’s Soluble Salt Training Sessions. We believe that education is beneficial to all coating professionals. Consequently our firm provides these sessions without charge. Anyone desiring to attend a full session, wanting to sponsor a session for their workgroup or for further information, please contact our office or visit our website. Additional educational and informational materials are also available on our website at www.chlor-rid.com

CHLOR*RID International Inc.

NON-VISIBLE SOLUBLE SALT CONTAMINATION OF STEEL SUBSTRATES

PREFACE

This document was drafted by a small, but diverse, group of coating professionals. From the outset, it was intended to be a "first for use by the Society for Protective Coatings, SSPC, and the National Association of Corrosion Engineers, NACE, in developi standard for testing and accepting steel surfaces that are contaminated with soluble salts.

This document has been given to SSPC and NACE for consideration. It is our intent that these groups will join forces to develop information into a joint NON-VISIBLE Standard or a Technology Update. It is published here as an interim documer CHLOR*RID International Inc. in the hopes of answering some of the many questions that we receive regarding salts. When interim document is superceded by publication of SSPC/NACE as a NON-VISIBLE Standard or Technology Update, it will bec obsolete.

PURPOSE

The purpose of this technical document is to increase industry awareness of an important part of protective coating technology: surface salt contamination recognition, levels of acceptance, area test procedures, and the preparation of specifications to mitigate the effects of soluble salts.

DEFINITION OF NON-VISIBLE SALTS

Non-visible soluble salt contamination is defined as any salt that remains on a surface after abrasive blast cleaning that cannot be seen with the unaided eye and that has a harmful effect on coatings or coating system performance. The terms salt, soluble salts, surface reacted salts, ferrous salts, surface reacted soluble salts, salt contaminants, non-visible salt and surface attached salts are sometimes used interchangeably. This document identifies several types of soluble salts, recommends levels of acceptance of two specific salts and recommends intervals for field testing of salts. Visible contaminants such as iron oxides, previously applied coatings, oil, dust, grease and water are considered in the visual surface preparation standards of SSPC/NACE.

This document applies to non-visible soluble salt contaminants only.

INTRODUCTION

Premature failure of coatings and linings has often occurred after coating of steel that had been exposed to corrosion, either in service or in storage. Such failures were often blamed on errors in material selection, surface preparation, coating formulation or coating application. While all of these shortcomings can affect coating performance, there has been a growing awareness in recent years of another problem that may cause such failures: non-visible soluble salt contamination.

The NACE/SSPC joint surface preparation standards for abrasive blast cleaning are based on examination of the blast cleaned surface with the unaided eye. These standards do not address soluble salt contamination of the substrate and cannot provide assurances that a prepared surface is free of non-visible soluble salt contamination.

Soluble salt contamination has caused coating system failures, within a year of application or less, on the internal surfaces of saltwater tanks, ship ballast tanks, sulfur dioxide scrubbers, submerged piling and piping, submerged components of offshore drill rigs, and many other structures. Similar failures have occurred on surfaces exposed to marine environments, even though they were abrasive blast cleaned and carefully coated to exact specifications.

Soluble salt contamination on surfaces exposed to atmospheric conditions is particularly prevalent in rain protected areas, such as the underside of bridges or platforms because they are not routinely rinsed with rain.

A key factor in the cause of these coating failures is non-visible salt contamination that remains on the surface after abrasive blast cleaning. Judicious removal of non-visible salt contamination helps ensure maximum performance and longevity of the coating system.

The rate of corrosive attack or coating failure due to soluble salt contamination of the substrate is dependent upon many variables. One variable is the level of non-visible soluble salts on the surface. For any given combination of coating/lining, dry film thickness, application proficiency, and exposure, a higher contamination level will result in earlier or more extensive failure.

Abrasive Blast Cleaning has been an industrial method for surface preparation for over half a century. Competent coatings professionals now universally recognize the benefits and improved economics of abrasive blast cleaning. The cost of abrasive blast cleaning is now considered an essential element for many industrial-painting requirements. However, removal of non-visible soluble salts has an additional cost over and beyond that of abrasive blast cleaning.

GENERAL OVERVIEW

Contamination from Abrasives

Contamination may be deposited on the surface by the abrasives used for blast cleaning. The abrasive can become contaminated at its source, from contaminated transport vessels, containers, storage environments and from recycling or any combination thereof. Non-visible salt contamination can then be transferred to metal surfaces on impact. Some specifications now require testing of abrasives for chloride contamination prior to their use. *Reference:* SSPC AB1, Abrasive Specification No. 1, Mineral and Slag Abrasives. SSPC-AB 2 Specification for Cleanliness of Recycled Ferrous Metallic Abrasives; American Society for Testing Materials, ASTM D-1125, Test Method for Electrical Conductivity and Resistivity of Water; ASTM D 4940, Test Method For Conductimetric Analysis of Water Soluble Ionic Contaminants of Blasting Abrasives; MIL-A-22262, Abrasive Blasting Media Ship Hull Blast Cleaning.

Contamination from Exposure

Steel surfaces can be salt contaminated whether the steel is new or used, rough or smooth. New steel surfaces may become contaminated during manufacture, transportation, storage, or surface preparation. Used steel surfaces and coated surfaces may be contaminated by sea salts, road salts, air pollution (acid rain), fertilizer, process water and other exposures. For these reasons, all steel and coated surfaces prepared for coating, recoating, over-coating or coating repair should be tested for the presence of non-visible salt contaminants.

Examples of steel surfaces likely to have non-visible salt contamination include, but are not limited to:

1. Internal surfaces of storage tanks and process vessels of all kinds, particularly if the contained material is an aqueous liquid;
2. Surfaces exposed in or near marine environments;
3. Surfaces exposed to industrial environments;
4. Surfaces exposed to road salts;
5. Surfaces exposed to acid rain;
6. Weld seams;
7. Corrosion pits; and
8. Areas of failed coatings.

Problematic Effects of Soluble Salt Contamination

Soluble salt contamination accelerates the corrosion process. Corrosion rates of 15 to 25 mils per year have been documented for salt (chloride ion) contaminated surfaces. Most salt contaminants are hygroscopic; they absorb moisture from the atmosphere which promotes corrosion even though not wetted or exposed to water. When painted

over, they generate the osmotic pressure to pull moisture through a coating which promotes corrosion beneath an otherwise sound coating. When over-coating an existing coating, if salts are present, these same osmotic forces exist which may result in blisters, poor adhesion, peeling and delamination. These soluble salts are not consumed during the corrosion process, since they are regenerated in the presence of oxygen.[1]

The regeneration of the active salt ions makes the problem insidious. A small amount of one of the soluble salts beneath a coating on a metallic substrate can cause corrosion to occur and ultimately can lead to coating failure through disbonding, blistering and peeling. The rate of attack is dependent on several factors:

1. The amount and type of contaminant on the surface. Increasing levels of contaminant will accelerate the rate of attack.

2. The amount of available water (and oxygen). Increasing water and oxygen will accelerate the rate of attack.

3. The permeability of the coating. All coatings allow some water or moisture penetration. When this moisture reacts with the hygroscopic soluble salts, corrosion takes place even under coatings. Coatings or linings with less water permeability will generally experience a slower rate of attack than more permeable coatings.

4. Coating thickness. For any given level of permeability, increased coating thickness retards the movement of water through the coating. Thicker coatings (of the same material) permit less water migration than thinner coatings: reduced water migration results in reduced corrosive attack.

5. Time. Soluble salt contamination problems do not go away or get better over time. Extremely contaminated surfaces may promote coating failure in one year or less. Less contaminated surfaces may cause the same result, but only after several years of service.

6. Temperature and Pressure. Increasing temperature and/or pressure will increase the rate of water permeability through a coating resulting in increased rates of corrosion.

Recognition and Identification of Contaminants

Old and tightly bonded coatings are not likely to have underlying salt contamination. In areas where the coating is loose or missing, salt contamination is possible, especially if the surface has been in contact with chlorides, sulfates or nitrates. In maintenance painting, repeated coating failure in the same area may be an indication that soluble salt contamination exists. When coating failures continue even though surface preparation, paint selection and application are correct, soluble salt contamination should be suspected.

If flash rusting occurs on newly blasted steel, even though there is no precipitation, dew or condensation, it is likely that the surface is contaminated with hygroscopic soluble salts. These soluble ferrous salts promote rusting of even a dry surface by absorbing and holding the necessary moisture from the air. Blast cleaned steel that is free of moisture and soluble salt contamination may remain rust free for a very long period of time.[2]

NON-VISIBLE SALT CONTAMINANTS

Soluble salts such as chlorides, sulfates and nitrates represent the largest and potentially most detrimental group of non-visible salt contaminants. Fluorides and other halogens are also extremely corrosive but are not common in most environments; however, bromine is increasingly used as a water-disinfecting agent. This document is limited to addressing chlorides and sulfates because of insufficient research and data regarding nitrates and other soluble salts.

Chloride and sulfate salts are frequently colorless in a water solution and are therefore not readily visible when present in small quantities on a surface. However, even minute quantities are sufficient to initiate the cyclic reaction that can cause extensive, persistent corrosion and/or blistering under the protective coating system, often leading to coating system failure.

Although these contaminants are called water-soluble salts, they are not readily removed by water washing. They are difficult to remove due to their electrochemical attachment to the substrate. When discussing soluble salts on steel surfaces, a better terminology for soluble salts would be "surface reacted surface attached salts" (SRSAS). This new terminology would be more accurate and would negate the "Water Solubility Rules" because SRSAS's are not "common salts". By definition they are surface reacted and electrochemically attached to the substrate. Were they water soluble, a simple water wash would remove them and there would be neither worldwide attention nor concern given to this subject. When trying to remove salts from a surface, there are several variables to consider. Are the salts "free" (unreacted) or surface reacted surface attached (e.g. rusted steel)? Free salts are generally found on coated surfaces that have no metallic fillers in the coating. If salts are free, plain water may solubilize and remove them from the surface. If they are surface reacted surface attached, plain water will need more energy applied to counter the electrochemical bond to the surface to effect their removal.

NOTE: If salts are present on a surface, it may be beneficial to remediate them prior to surface preparation to avoid the possibility of "driving" them into the profile.

Consideration should be made to choose a cost effective, proven salt removal method that can demonstrate the removal of SRSAS's by quantitative analytical surface testing. See Appendix A for a more detailed discussion of SRSAS.

Chlorides

Chloride contamination occurs in numerous industries including salt refining, chlor-alkali production, power plants, mining, pulp and paper manufacturing as well as in the petroleum industry, from production through refining operations. Industrial plants and equipment exposed to marine environments are also inherently subject to chloride contamination from seawater, salt spray, and marine air with entrained salt. Hypochlorites, in the form of bleaches and cleaners, are a fairly specific type of chloride contamination and may contribute to surface contamination when used during or prior to surface preparation. Chlorides in road and street environments, where deicing salts are used, are also a contaminant source.

Testing through a National Shipbuilding Research Program[2] contract resulted in the following observations:

1. Chloride ion surface contamination levels below 0.25 ↘g $C1^-/cm^2$ (0.014 oz NaC1/1,000 ft^2) caused little or no visual substrate corrosion under clear epoxy, even after 4,500 hours immersion in pressurized seawater.
2. Increasing the chloride ion surface contamination levels from 0.25 to 8.0 ↘g Cl^-/cm^2 (0.014 to 0.44oz NaC1/1,000 ft^2) caused visible steel substrate corrosion reactions under clear epoxy in pressurized seawater immersion. The amount of underfilm corrosion that occurred was proportional to the amount of contamination placed on the substrate.
3. Chloride ion surface contamination levels of 8.0 - 16 ↘g $C1^-/cm^2$ (0.44 to 0.88 oz NaC1/1000 ft^2) caused steel substrate corrosion microblisters that could be seen under clear epoxy. The microblisters coalesced to form larger osmotic blisters, and underfilm corrosion blisters occurred in clear and coal tar epoxy.

Sulfates

In industrial areas, noticeable amounts of sulfur dioxide (SO_2) may be found in the atmosphere, primarily from flue gas, coal burning and vehicle emissions. Slag abrasives from high-sulfur coal may be another source of sulfates. Combined with atmospheric moisture, sulfates give rise to acid formation, producing a corrosive reaction that culminates in the formation of various soluble sulfates on the corroding surface. These salts are not readily visible on the surface and not easily removed by blast cleaning. Most blast-cleaning specifications do not address sulfates at this time.

Sulfate contamination levels that lead to blistering of coatings are higher than those for chlorides because sulfates are less reactive.[2] This fact has contributed to sulfates not being given the same level of attention as chlorides and until recently commercially available field test kits for extracting and titrating sulfates were not available.

Nitrates

Nitrates are less prevalent than either chlorides or sulfates. Their corrosive effect, though, may be significant. Nitrogen from fertilizer plants, in groundwater from cultivated field runoff, from auto and truck emissions, as well as industrial emissions, may oxidize to form unstable soluble salts (e.g. NO_3). Nitrate salts when in contact with a metallic surface will promote corrosion. The corrosion rate on steel, at a given level of contamination, may be near the same rate as chlorides because nitrogen has the same electronegativity as chlorine.

Acids

Acids such as sulfuric and hydrochloric, prevalent in weak concentrations in the environment, may penetrate most industrial and non-acid resistant type coatings. These acids may dissolve the coating, allowing direct reaction with metallic surfaces to produce iron salts. Coatings may progressively lose adhesion around the area of direct acid attack due to the blistering effect of iron salts formed under the edges of the coating. This leads to widening failure of the coating. The blistering around the edges of dissolved coatings may be much more rapid if the substrate surface already has residual soluble salts because exposure of the surface to moisture and air will promote disbondment of the coating.

Other

The list of non-visible salt contaminants is seemingly endless. Each industry may have its own particular conditions that contribute to surface salt contamination.

FIELD TESTS FOR THE PRESENCE OF NON-VISIBLE SALT CONTAMINANTS

There are several recognized tests for the presence of non-visible salt contaminants. Test procedures for sample extraction and for subsequent measurement of quantitative or qualitative results are described in NACE 6G186 Surface Preparation of Contaminated Steel Surfaces, SSPC TU 4, Field Methods for Retrieval and Analysis of Soluble Salts on Substrates, International Organization of Standards ISO 8502-5, Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 5: Measurement of chloride on steel surfaces prepared for painting (ion detection tube method), 8502-6, Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 6: Extraction of soluble contaminants for analysis -- The Bresle method, and 8502-11, Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 11: Field method for the turbidimetric determination of water-soluble sulfate.

NON-VISIBLE SALT LEVELS

Removal of soluble salts from blast cleaned surfaces adds to the cost of surface preparation. Since soluble salt removal does have additional costs, the degree to which removal is required (thus incurring additional surface preparation costs) has to be weighed against expected performance. These cost issues dictate that no single level of soluble salt contamination should be specified for all work. Just as there are several grades of abrasive blast cleaning, there needs to be various acceptable levels for soluble salt contamination, each being appropriate for the required coating service exposure and anticipated life.

There are no “industry standards” regarding acceptable levels of soluble salts. Guide Table 1 provides guidance in selecting acceptable levels of chlorides, broadly based on the U.S. NAVY’s acceptance criteria of 3 micrograms per square centimeter of chlorides for immersion service and 5 micrograms per square centimeter of chlorides for atmospheric service. The specifier should consult the coating manufacturer to determine that the soluble salt tolerance of the coating/coating system to be used corresponds with the in-service environment.

The responsibility of the specifier is to clearly state an acceptable level of non-visible soluble salt contamination. As a guide, wher White Metal Blast Cleaning or Near White Metal Cleaning is specified, and/or immersion service is anticipated (hot, cold or tepid), s a level within the top three (3) options. For Commercial Blast Cleaning, or when a lesser degree of cleaning is specified and atmospl service is anticipated, select a level within the top four (4) options. Above these levels of contamination, even the highest qu coatings/linings may be expected to fail prematurely.

For high performance coating work, such as ballast and cargo tanks, immersion service and underwater hulls “the goal should be between 1 µg and 2.0 µg chloride per square centimeter or lower if conditions permit”.[3] “Sulfates require

about ten (10) times the level of chlorides to induce osmotic blistering as the chloride ion in immersion service."[3] Based on this sulfate research, Guide Table 2 provides recommended acceptance criteria for sulfates.

It is generally recognized that atmospheric service is not as severe an environment as immersion service. For the purpose of this document, immersion service is defined as, "Use of a coating under water or other liquid; in this service, the coating normally is called a lining". Atmospheric service is defined as, "Use of a coating with no exposure to under water/liquid environments not including exposure to rain, snow and dew".

Structures can be exposed to cyclic wet dry service, condensation and highly humid environments (e.g. rust belt areas, marine exposures, bridges exposed to road salts, oil and gas platforms above salt water, "sweating" vessels or pipes, high/low tide water exposures, buoys etc.). It is recommended that these environments be treated as immersion service. These environments, over time, will allow the concentration of salts to increase on a surface. Alternatively, in a drier service with less humid environments, the effects of salts are more limited due to the scarcity of moisture. It should be noted that, for maximum performance of any coating or lining system, there is no substitute for complete removal of salt contaminants.

The specifier should clearly stipulate the method of testing, the acceptable level of salt, the number of measurements (tests) to be taken, where they are to be taken, when they are to be taken (hold point) and the salt remediation method. Specifiers should be attentive to the fact that, when levels of salts are detected by the various field test kits or sample methods, they are likely to vary, depending on the efficiency of the extraction method. No field test extraction method is considered to retrieve 100% of the salts from a surface. The correction factor for extraction efficiency of a particular test method is at the discretion of the specifier. If a correction percentage for extraction efficiency is chosen, calculate the inefficiency and subtract it from the acceptable level then only specify the lower adjusted acceptable level. Extraction efficiencies of the different test methods are discussed in SSPC TU 4 "Field Methods for Retrieval and Analysis of Soluble Salts on Substrates."

The quantity of salt contamination on a surface is most often expressed in units of micrograms per square centimeter ($\mu g/cm^2$), a metric measure of mass per unit area.

GUIDE TABLE 1

Guide Levels	**Service**	
Non-visible chlorides (NVC)	**Immersion**	**Atmospheric**
NVC-0 Non detectable	Acceptable	Acceptable
NVC-1 1 or less $\mu g/cm^2$	Acceptable	Acceptable
NVC-3 3 or less $\mu g/cm^2$	Acceptable	Acceptable
NVC-5 5 or less $\mu g/cm^2$	Possible failure	Acceptable
NVC-7 7 or less $\mu g/cm^2$	Possible failure	Possible failure
NVC-10 10 or less $\mu g/cm^2$	Probable failure	Possible failure
NVC-15 15 or less $\mu g/cm^2$	Probable failure	Possible failure
NVC-20 20 or less $\mu g/cm^2$	Probable failure	Probable failure

GUIDE TABLE 2

Guide Levels	Service	
Non-visible sulfates (NVS)	**Immersion**	**Atmospheric**
NVS-0 Non detectable	Acceptable	Acceptable
NVS-5 5 or less $\mu g/cm^2$	Acceptable	Acceptable
NVS-10 10 or less $\mu g/cm^2$	Acceptable	Acceptable
NVS-15 15 or less $\mu g/cm^2$	Possible failure	Acceptable
NVS-20 20 or less $\mu g/cm^2$	Possible failure	Possible failure
NVS-25 25 or less $\mu g/cm^2$	Probable failure	Possible failure
NVS-30 30 or less $\mu g/cm^2$	Probable failure	Possible failure
NVS-50 50 or less $\mu g/cm^2$	Probable failure	Probable failure

Area Measurements for Conformance to a Salt Specification

Recommended area and length measurements are provided in units of lineal and square feet and lineal and square meters. While these units of area are not identical, it is considered that they are sufficiently similar to warrant the use of rounded numbers. The contract specification shall clearly delineate whether the unit of measure is English or Metric and the appropriate unit area should be specified.

IMMERSION SERVICE - *Recommended Number and Distribution of Measurements: New and Old Surfaces That Require Full Lining* ***(INTERNAL)***

Identifiable sections or components of a tank (e.g. floor, ceiling if present, and sidewalls of a tank or vessel) will be treated as separate areas of the structure. Alternatively, for rounded bottom tanks (vessels), treat the floor and walls as one area, and the ceiling as a separate area. Each area should be tested as follows:

1. In the first 1000 ft^2 (100 m^2) of area or part thereof make five (5) measurements, each spaced no closer than three (3) ft (1m) and no farther than six (6) ft (2m) apart. (5 tests floor + 5 tests ceiling + 5 tests walls = 15 tests)

2. For the next 3000 ft^2 (300 m^2) of area, make two (2) measurements in each 1000 ft^2 (100 m^2) of area or part thereof, spaced no closer than six (6) ft (2m) apart and no farther than fifteen (15) ft (5m) apart. (maximum 18 tests)

3. For the remainder of each area (floor, ceiling and side walls) make one (1) measurement in each 2000 ft^2 (200 m^2) of area or part thereof.

4. Any one (1) measurement not in compliance with the requirement of the specification shall be cause for failure of that specific test area and salt removal shall be accomplished. When salt removal is completed, re-measure beginning from the failed test area forward, with steps one (1), two (2) and three (3).

5. Tests shall be performed on metal loss areas when present. Metal loss areas are those areas that show evidence of corrosion or pitting. When metal loss areas are not evident, tests shall be sited adjacent to weld areas, if present. Otherwise, test sites shall be selected to be representative of the surface as a whole.

Example Table 3.

Ft^2 (m^2)	Floor Measurements	Ceiling Measurements	Wall Measurements
1000 (100)	5	5	5
2000 (200)	5+2=7	5+2=7	5+2=7
3000 (300)	5+2+2=9	5+2+2=9	5+2+2=9
4000 (400)	5+2+2+2=11	5+2+2+2=11	5+2+2+2=11
6000 (600)	5+2+2+2+1=12	5+2+2+2+1=12	5+2+2+2+1=12
8000 (800)	5+2+2+2+1+1=13	5+2+2+2+1+1=13	5+2+2+2+1+1=13
10000 (1000)	5+2+2+2+1+1+1=14	5+2+2+2+1+1+1=14	5+2+2+2+1+1+1=14
12000 (1200)	5+2+2+2+1+1+1+1=15	5+2+2+2+1+1+1+1=15	5+2+2+2+1+1+1+1=15
14000 (1400)	5+2+2+2+1+1+1+1+1=16	5+2+2+2+1+1+1+1+1=16	5+2+2+2+1+1+1+1+1=16

ATMOSPHERIC SERVICE – *Recommended Number and Distribution of Measurements: New and Old Surfaces That Require Full Coating (**EXTERNAL SURFACES AND STRUCTURES**)*

1. For the first 1000 ft^2 (100 m^2) of area or part thereof, make five (5) measurements each spaced no closer than three (3) ft (1m) apart and no farther than six (6) ft (2m) apart.

2 For the next 3000 ft^2 (300 m^2) of area make two (2) measurements for each 1000 ft^2 (100 m^2) of area or part thereof, spaced no closer than six (6) ft (2m) apart and no farther than fifteen (15) ft (5m) apart.

3. For the remainder of the structure make one (1) measurement for each 2000 ft^2 (200 m^2) of area or part thereof.

4. Any one (1) measurement not in compliance with the requirement of the specification shall be cause for failure of that area and salt removal shall be accomplished. When salt removal is completed, re-measure beginning from the failed area forward, with steps one (1), two (2) and three (3).

5. Tests shall be performed on metal loss areas when present. Metal loss areas are those areas that show evidence of corrosion or pitting. When metal loss areas are not evident, tests shall be sited adjacent to weld areas, if present. Otherwise, test sites shall be selected to be representative of the surface as a whole.

Example Table 4

Ft^2 (m^2)	# of Tests
1000 (100)	5
2000 (200)	5+2=7
3000 (300)	5+2+2=9
4000 (400)	5+2+2+2=11
6000 (500)	5+2+2+2+1=12
8000 (800)	5+2+2+2+1+1=13
10000 (1000)	5+2+2+2+1+1+1=14
12000 (1200)	5+2+2+2+1+1+1+1=15
14000 (1400)	5+2+2+2+1+1+1+1+1=16
16000 (1600)	5+2+2+2+1+1+1+1+1+1=17

REPAIR – *Recommended Number and Distribution of Measurements: Spot Repair for Used Surfaces (**ALL SERVICES**)*

A spot repair is considered a localized area of failed coating no larger than 200 ft^2 (20m^2). If spot repair consists of more than thirty percent (30%) of the total square footage (m^2) of a structure full lining or coating should be investigated.

1. Make one (1) measurement each, on 5 spot repair areas. If any one measurement is not in compliance with the requirement of the specification all spots are considered contaminated and require cleaning. If all measurements conform to the specification proceed to step three (3). (5 tests)

2. After soluble salt cleaning, make one (1) measurement each, on five (5) different spot repair areas. When five (5) consecutive measurements conform to the specification, that cleaning procedure shall be used on all remaining spots.

3. Thereafter, make one (1) additional measurement per 5 (five) spot repair areas. If any one (1) measurement is not in compliance with the requirement of the specification additional cleaning shall be accomplished followed by steps one (1), two (2) and three (3).

EXAMPLE OF A WRITTEN SPECIFICATION

Below are a series of suggested steps to successfully incorporate the issues discussed in this document. They are provided for guidance only.

- State that testing for soluble salts is required.
  - *Test all surfaces to be coated immediately prior to coating for chloride and sulfate contamination.*

- Identify one allowable test kit or method for each salt contaminant specified.
  - *Tests shall be performed using the _____ Test Kit for chlorides and the _____Test Kit for sulfates.*

- Provide a clear, descriptive statement that identifies the test location, the test rate, and the acceptance requirements. If a correction percentage for extraction efficiency is chosen, calculate the inefficiency and subtract it from the acceptable level then only state the lower adjusted acceptable level.
  - *Tests shall be performed on metal loss areas when present. Metal loss areas are those areas that show evidence of corrosion or pitting. When metal loss areas are not evident, tests shall be performed adjacent to weld areas, if present. Otherwise, test sites shall be selected to be representative of the surface as a whole.*
  - *The floor, ceiling and sidewalls of vessel interiors shall be considered three separate areas. Each area shall be tested at the rate of five tests for the first 1000 ft^2 or part thereof; two tests for each additional 1000 ft^2 for the next 3000 ft^2 or part thereof; and one test for each additional 2000 ft^2 thereafter or part thereof.*
  - *One or more chloride measurements greater than _____ micrograms per square centimeter ($\mu g/cm^2$) is evidence of excessive chloride contamination. One or more sulfate measurements greater than _____ micrograms per square centimeter ($\mu g/cm^2$) is evidence of excessive sulfate contamination.*

- State a remediation method for non-compliant surfaces:
  - *Excessively contaminated surfaces shall be considered non-compliant and washed with clean water or water modified with a soluble salt remover and allowed to dry. Re-test and/or rewash until all tests are compliant. Re-prepare washed and/or tested areas to specified visual standard. Label all test titration devices and retain for test verification.*

Sample Specification

"Test all surfaces to be coated immediately prior to coating for chloride and sulfate contamination using the _____ Test Kit for chlorides and the _____Test Kit for sulfates. Tests shall be performed on metal loss areas when present. Metal loss areas are those areas that show evidence of corrosion or pitting. When metal loss

areas are not evident, tests shall be performed adjacent to weld areas, if present. Otherwise, test sites shall be selected to be representative of the surface as a whole. The floor, ceiling and side walls shall be considered three separate areas. Each area shall be tested at the rate of five tests for the first 1000 ft^2 or part thereof; two tests for each additional 1000 ft^2 for the next 3000 ft^2 or part thereof; and one test for each additional 2000 ft^2 thereafter or part thereof. One or more chloride measurements greater than 3 micrograms per square centimeter ($\mu g/cm^2$) is evidence of excessive chloride contamination. One or more sulfate measurements greater than 10 micrograms per square centimeter ($\mu g/cm^2$) is evidence of excessive sulfate contamination. Excessively contaminated surfaces shall be considered non-compliant and washed with clean water or water modified with a soluble salt remover and allowed to dry. Re-test and/or rewash until all tests are compliant. Re-prepare washed and/or tested areas to specified visual standard. Label all test titration devices and retain or photograph for test verification."

There is no one best procedure of removing soluble salts; several factors should be considered:

1. The method used will be dependent upon environmental constraints, time, cost and available equipment. The added cost should be amortized over the expected life of the coating beyond the expected life of the coating if salt remediation were not accomplished.

2. Salts reside under the rust at the interface of the steel. This rust barrier must be removed to expose and remove the salts. The effectiveness of removing surface reacted surface attached salt is proportional to the amount of energy applied to remove them.

Salt removal may be accomplished in one or two steps:

A. TWO STEPS: Dry abrasive blast to remove the rust then wash (may incorporate salt remover) at sufficient pressure to remove the salts;
B. ONE STEP: Wet (slurry) abrasive blast (may incorporate salt remover) to remove both rust and salts;
C. ONE STEP: Wash at sufficient pressure to remove both rust and salts (may incorporate salt remover).

These methods require some change in thinking and diligence to incorporate them into a specification and a salt removal program.

DISCLAIMER

While every precaution is taken to ensure that all information furnished in this document is accurate, complete and as useful as possible. CHLOR*RID International, Inc. cannot assume responsibility nor incur any obligation resulting from the use of any materials, coatings or methods specified herein.

REFERENCES

1. M. Morcillo, S. Feliu, J.C. Galvan, and J.M. Bastidas "Some Obervations of Painting Contaminated Rusty Steel", Journal of Protective Coatings and Linings, September 1987

2. G.C. Soltz, "The Effects of Substrate Contaminants on the Life of Epoxy Coatings Submerged in Sea Water," National Shipbuilding Research Program Report, TASK No. 3-84-2, March 1991.

3. G.C. Soltz, "Understanding How Substrate Contaminants Affect the Performance of Epoxy Coatings and How to Minimize Contamination".

4. NACE 6G186, SSPC TU 4, ISO 8502-5 and ISO 8502-6

Calabrese, C., and J.R. Allen. "Surface Characterization of Atmospherically Corroded and Blast Cleaned Steel." *Corrosion* 34, 10 (1978): pp. 331-338.

Munger, C.G. ": Their Sulfides Affect on Coatings and Substrates." CORROSION/77, paper no. 1. Houston, TX: NACE, 1977.

SSPC 91-07 (latest revision). "Effect of Surface Contaminants on Coating Life." Pittsburgh, PA: SSPC.