Surface Preparation of Soluble Salt Contaminated Steel Substrates Prior to Coating

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Foreword

The subject of soluble salts on steel substrates and their effect on coating performance is an important and widely debated topic. The concentration at which soluble salts begin to have a detrimental effect on coating performance varies widely, depending on factors such as the type of service, coating thickness, generic coating type, and the presence of moisture.

This technical committee report is intended to provide information concerning the use of coatings in service environments where soluble salt contamination of the substrate is suspected. Ideally, it is desirable to have no soluble salts present on the surface to be coated; however, there is a cost associated with their detection,

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removal, and testing. These associated surface preparation costs provide incentive for risk assessment to balance the cost-to-benefit ratio of reducing or removing salts that may be present.

The purpose of this technical committee report is to increase the industry awareness of the following:

- The effects of various nonvisible soluble salt contaminants on a coating’s performance;
- An approach to risk assessment regarding the costs of soluble salt removal versus the risk of future coating failure;
- Identification of the indicators of salt contamination; and
- Various methods of salt contamination removal.

Coating manufacturers can provide recommendations regarding tolerable soluble salt levels based on coating type, service, and desired service life. With this information, the user typically makes a more informed decision regarding the most effective surface preparation methods.

The level of salt contamination that a specific coating system can tolerate in a given service environment depends on the type and severity of the environment, extent of surface preparation, coating material formulation, and a number of other parameters. Because of the variability of these parameters, numerical levels are not discussed in this report. Numerical levels of tolerable salt contamination are being addressed by ISO(1)/TC 35/SC 12/WG 5.1

The removal of visible contaminants such as iron oxides, previously applied coatings, dirt, oil, grease, water, or microbiological contamination is not covered in this report. Removal of these contaminants is covered in joint NACE/SSPC(2) surface preparation standards.2-7 These standards rely on a visual assessment of surface cleanliness. However, premature coating failures have been attributed to salt contamination even where surfaces have been prepared to appropriate visual standards.

This report is intended for use by engineers, specification writers, contractors, and anyone interested in reducing premature coating failures caused by nonvisible soluble salts. It addresses only chlorides, nitrates, and sulfates, because of insufficient research and data regarding other soluble salts. This report consists of the following sections:

- Introduction
- Effect of Salt Contamination on Coating Performance
- Risk Assessment
- Salt Contamination Sources
- Water-Soluble Salt Contaminants (Chlorides, Nitrates, and Sulfates)
- Recognition and Identification of Salt Contaminants
- Field Tests to Detect the Presence of Salts
- Salt Removal Methods
- Project-Specific Sampling Protocols and Acceptance Criteria
- References
- Appendixes:
  A. Area-Based Sampling Protocol and Testing
  B. Preparing a Specification
  C. Example Lining Specification

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(1) International Organization for Standardization (ISO), 1 ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland.
(2) The Society for Protective Coatings (SSPC), 40 24th Street, 6th Floor, Pittsburgh, PA 15222-46546.
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This technical committee report was originally issued in 1986 by NACE Task Group (TG) T-6G-22, "Surface Preparation of Contaminated Steel Surfaces," a component of Unit Committee T-6G, "Surface Preparation for Protective Coatings." It was revised in 2010 by NACE TG 142, "Surface Preparation of Contaminated Steel Surfaces." TG 142 is administered by NACE Specific Technology Group (STG) 04, "Coatings and Linings, Protective: Surface Preparation." It is also sponsored by STG 02, "Coatings and Linings, Protective: Atmospheric," STG 03, "Coatings and Linings, Protective: Immersion and Buried Service," and STG 43, "Transportation, Land." This report is issued by NACE under the auspices of STG 04.

NACE technical committee reports are intended to convey technical information or state-of-the-art knowledge regarding corrosion. In many cases, they discuss specific applications of corrosion mitigation technology, whether considered successful or not. Statements used to convey this information are factual and are provided to the reader as input and guidance for consideration when applying this technology in the future. However, these statements are not intended to be recommendations for general application of this technology, and must not be construed as such.

Introduction

Long-term coating performance is directly related to proper coating material selection, correct coating formulation, appropriate and adequate surface preparation, and satisfactory coating application. In addition, soluble salt contamination in the form of chlorides, nitrites, and sulfates sometimes has a deleterious effect on long-term performance of some coating materials in some exposure conditions. Coating specification writers, facility owners, and coating applicators have avoided problems by understanding when soluble salts could be an issue and the steps that could be taken to mitigate the consequences of salt contamination.

Soluble salts on a surface potentially affect the substrate or coating in two principal ways:

- By accelerating corrosion of an underlying steel surface. Dissolved salt solutions may accelerate oxidation of steel, resulting in undercutting of a coating system applied over that substrate. Corrosion can occur without the presence of any salts. Crevice corrosion, oxygen concentration corrosion, pitting, and general corrosion all occur without salt contamination in the presence of moisture on susceptible metal surfaces, such as steel. If salts are present, the rate of such corrosion accelerates.

- As a cause of osmotic blistering. Blistering of a coating sometimes occurs when moisture permeates through the coating film and dissolves entrapped water-soluble salts beneath the coating. The coating acts as a semipermeable membrane between a dilute salt solution (the liquid outside the coating), and a concentrated salt solution (liquid with dissolved salts within the blister). Coating systems in immersion or wet environments are sometimes susceptible to osmotic blistering, and blistering may occur at the steel surface and between coats. Osmotic pressure beneath the coating, in excess of the bond strength of the coating, may cause blisters. Ultimately, corrosion sometimes develops within the blisters, depending on oxygen availability. Blistering of a coating system also occurs in the absence of soluble salts. Entrapped polar solvents and overdriven cathodic protection may draw moisture through a coating film to cause blistering.

The best life-cycle performance is usually achieved when the coating system is applied over an uncontaminated or less-contaminated surface. However, a level of nonvisible soluble salt surface contamination that does not significantly compromise a coating system's life-cycle performance may also exist. At this level, the additional cost of removal of the salt contamination sometimes is not warranted.

The owner or specifier sometimes conducts a risk assessment to evaluate the costs of soluble salt removal versus the risk of reduced coating performance. The owner and specifier often determine whether the increased performance anticipated by achieving a nonvisible soluble salt decontaminated surface is justified from a cost standpoint.
Effect of Salt Contamination on Coating Performance

Little definitive information is available regarding how the amount of salt contamination relates to coating performance. Difficulty in objectively evaluating the detrimental effects of soluble salts is caused in part by the diverse and variable resins, pigments, and coating materials available that may be formed into single-coat or multicoat systems. Other variables include the thickness of a given coat or coating system and the nature and range of severity of exposure environments. These variables combine to make it difficult to prepare a simple, convenient table or chart that establishes acceptable tolerance levels for a soluble salt beneath a coating.

Some coatings are more tolerant of the presence of water-soluble salts than others. For example, inorganic zinc-rich coatings and metallized coatings are generally considered to be more tolerant than organic coatings such as fusion-bonded epoxies and epoxy-phenolics.

The total thickness of a coating system usually has an impact on the ability of a coating system to tolerate the effects of salts on a surface. For a given coating system, thicker systems are typically more impervious to water, and therefore have a greater salt tolerance, than thinner systems.

Some soluble salt contaminants are more corrosive to steel than others. For example, nitrates appear to be slightly less corrosive than chlorides and sulfates at low concentrations, but not necessarily at higher concentrations. The effect of the cation (positive ion) typically is also considered. For example, for chloride salts, the order of corrosiveness (from most corrosive to least corrosive) to steel is: lithium chloride, sodium chloride, potassium chloride, and calcium chloride. The corrosiveness of a salt is, up to a point, directly proportional to the conductivity of the electrolyte formed when it dissolves (for sodium chloride, the maximum corrosiveness occurs when the salt solution is approximately 3.5 wt%). The conductivity of a given salt solution is a function of its ionic species.

The relative corrosiveness of salts to steel sometimes does not correlate with the effect of these same salts in compromising coating performance. Osmotic blistering of coatings is independent of the species of salt, and is entirely dependent on the number of ions in solution. For example, the solubilities in 100 mL of ambient water at 20 °C (68 °F) are: 87.6 g for sodium nitrate, 35.9 g for sodium chloride, and 19.5 g for sodium sulfate. Despite the dissociation of sodium sulfate into three ions, and sodium nitrate and sodium chloride into only two ions each, the lesser solubility of sodium sulfate results in less ions in solution. Therefore, of these salts, nitrates are expected to be most destructive with regard to blistering of a coating, even though they typically are the least corrosive salt to a steel surface at low concentrations.

To determine allowable levels of salts, users typically refer to the coating manufacturer’s product data sheet, or contact the coating manufacturer. Frequently, the allowable level of any salt is relative to the expected service life for the specified coating system in a particular environment. Contamination levels are most commonly measured in micrograms per square centimeter (µg/cm²) or milligrams per square meter (mg/m²).

Risk Assessment

The approach to risk assessment varies depending on a number of factors, not the least of which is the owner/specifier’s attitudes and concerns regarding the potential consequence of coating over a salt-contaminated surface.

In some service environments, salts may not be a problem. There may be no evidence of salt-induced corrosion or salt contamination. In general, coating systems in atmospheric exposures are more tolerant to soluble salt contamination that those in immersion service. In environments where salt-induced corrosion is seen, or where salt contamination is suspected, salts may be present. In these environments, testing is usually performed to ensure that unacceptable levels of soluble salt contamination are not present before any coating operations are performed.

To reduce risk, some owners and specifiers desire to minimize any salt contamination prior to coating. Other owners and specifiers attempt to assess the risk associated with the presence of soluble salts to determine whether removal of the salts is necessary. Risk is a combination of the probability (or likelihood) of a hazard happening and the
consequence of that happening. A hazard is something that has the potential to cause harm or damage. To assess the risk, the hazard is identified, its probability is estimated, and the consequence is defined. In this case, the risk assessment involves identifying the potential hazard (the presence of soluble salts on the surface), estimating the probability (related to the quantity of soluble salts on the surface), and defining the consequence of the hazard happening (corrosion of the substrate or a premature coating failure). Such a risk assessment is used to quantify the risk associated with the presence of soluble salt contamination on the surface and to quantify the risk reduction associated with removal of the soluble salt contamination (reducing the probability and consequences of the hazard). The potential risk reduction (benefit) is then compared against the costs of removing the soluble salt contamination.

When assessing the risk associated with soluble salt contamination, these factors are typically considered:

- The service environment to which the substrate has been exposed;
- The service environment to which the substrate will be exposed;
- The coating system and coating thickness to be used;
- The method of surface preparation and degree of surface cleanliness prior to coating;
- Future accessibility and reparability; and
- The potential consequence (costs, time delay, etc.) of coating failures and substrate corrosion caused by salt contamination on the surface prior to coating.

**Salt Contamination Sources**

The most prevalent soluble salt surface contamination is the deposition of atmospheric contaminants on a surface to be coated. Salt contamination typically is prevalent in marine and chemical fume environments, and areas subject to acid rain and other airborne contaminants. However, a surface sometimes becomes contaminated by soluble salts in other ways.

Abrasives sometimes contain salt contaminants that, on impact, are embedded in the surface being cleaned. The abrasive typically becomes contaminated at the source of origin, by contaminated transport vessels or containers, through reuse, or in storage environments. All abrasives, on impact, embed to some degree, and generally, hard, brittle abrasives embed the most. After coating, the embedded, salt-contaminated abrasive particles sometimes cause problems.

Many specifications include testing of abrasives, prior to use, for water-soluble ionic contamination. For example, three SSPC abrasive specifications outline requirements for the selection and use of abrasives:

- **SSPC-AB 1** defines the requirements for selecting and evaluating mineral and slag abrasives used for blast cleaning steel and other surfaces for coating and other purposes.
- **SSPC-AB 2** defines the requirements for cleanliness of recycled ferrous metallic blast cleaning abrasives used for the removal of coatings, scale, rust, and other foreign matter from steel or other surfaces. Recycled ferrous metallic abrasives are intended for use in field or shop abrasive blast cleaning of steel or other surfaces.
- **SSPC-AB 3** defines the requirements for ferrous metallic abrasive for the removal of rust, mill scale, coatings, or other surface contaminants by blast cleaning. This specification covers previously unused abrasive material.

Chemical cargoes, and salt water in ballast tanks or other vessels, contaminate the vessel surface. The intentional spreading of salts for deicing purposes and the use of fertilizers containing nitrogen are also sources of salt contamination.

Examples of steel surfaces likely to be contaminated include, but are not limited to:
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- Storage tanks, railcars, piping, and process-handling vessels of all kinds, particularly if the contents of the vessel have the potential to leave salts on the steel surface. Contamination typically is found on internal or external surfaces of equipment of this type.

- Surfaces exposed to marine environments, road salts, acid rain, vehicle emissions, or heavy transportation industry environments;

- Surfaces externally exposed to industrial environments where fallout of salts or chemicals is prevalent;

- Corrosion pits or craters;

- Areas of failed coatings; and

- Combinations of any number of the above, which will exacerbate potentially corrosive conditions.

Water-Soluble Salt Contaminants (Chlorides, Nitrates, and Sulfates)

This report is concerned with chlorides, nitrates, and sulfates, which represent the largest and potentially most detrimental group of soluble salt contaminants. Common salt contamination sources are road deicing salts, fumes from vehicle emissions, sulfur dioxide (SO₂) combustion products from chimney fallout, marine environments, and acid rain. These soluble salt contaminants potentially contribute to corrosion of the substrate and reduce coating performance. These salts are frequently colorless and of small size (often only a few tenths of a millimeter) and therefore are not readily visible on a surface. In the presence of moisture they form an electrolyte, which accelerates corrosion. Salts are readily detectable with standard laboratory test methods such as energy dispersive spectroscopy (EDS) and the field techniques discussed in the section titled Field Tests To Detect the Presence of Salts.

Once salts adsorb onto a steel substrate, they may not be readily removed by water washing or completely removed by abrasive blast cleaning. Insoluble iron oxide and other corrosion products on previously corroded steel substrates sometimes cover salts. Most commonly these corrosion products occur over pitted areas, where salts sometimes concentrate. This often causes difficulties in adequately removing salts, and, in most cases, involves removal of the corrosion product first (e.g., by abrasive blast cleaning) to enable the salts to be flushed out of the corrosion pits.

Many soluble salt contaminants are hygroscopic. They absorb moisture from the atmosphere, yielding a surface that may not be visibly wet, but one that retains moisture. Moisture sometimes is absorbed at the surface of a soluble salt at temperatures above the dew point. Applying a coating over such salts, even at temperatures above the dew point, sometimes results in blistering and potential disbonding, corrosion, and premature failure of the coating system.

The salts of major concern when applying coating are the following:

Chlorides

The chloride anion (Cl⁻) occurs as a result of dissociation of chloride-containing salts, such as sodium, magnesium, and calcium chlorides. Chlorides from deicing salts are prevalent on roads and bridges in cold climates. Many manufacturing processes, such as the chemical process industry, mining and manufacturing, power generation, pulp and paper manufacturing, and other industrial production, generate or use chloride-containing salts. Chloride contamination is prevalent in numerous industries including salt refining, chlor-alkali production, and potash mining and handling, as well as in the petroleum industry. Industrial plants and equipment exposed to marine environments also are subject to chloride contamination from seawater, salt spray, and marine air with entrained salt. Food processing plants and equipment, particularly manufacturers of salty snack products and pickling operations, are also exposed to high levels of corrosive chlorides. Processing plants, water, and wastewater treatment facilities use
chloride-containing products for bacterial control. Each industry has its own particular conditions that sometimes contribute to salt contamination.

Nitrate

The nitrate anion (NO₃⁻) occurs as a result of dissociation of nitrate-containing salts such as sodium nitrate, ammonium nitrate, and other nitrates commonly found in the fertilizer industry, and as a result of some other manufacturing processes. The coatings industry has known for a long time that nitrates are a problem in fertilizer and munitions plants and equipment. A far more common source of nitrate contamination is nitrogen oxides (NOₓ) from vehicle and other combustion engine emissions, which contribute to the formation of acid rain. Fossil-fuel power plants also generate emissions containing NOₓ, contributing further to atmospheric contamination and acid rain. Lightning plays a major role in converting naturally occurring atmospheric nitrogen to NOₓ which are precursors to formation of nitric acid that is deposited by acid rain. Acid rain falls as dilute sulfuric and nitric acids; on water evaporation, the acid concentrates, leaving sulfates and/or nitrates behind. Nitrate contamination is commonplace, as confirmed by the U.S. Environmental Protection Agency (EPA).

Sulfate

The sulfate anion (SO₄²⁻) occurs as a result of combustion of coal and liquid hydrocarbon fuels, such as heating oil and diesel fuel, containing sulfur. Sulfur combustion products deposit as acid rain, even in nonindustrial areas, because of environmental fallout. In industrial areas, noticeable amounts of sulfur oxides (SOₓ) are found in the atmosphere, primarily from flue gas. This pollutant sometimes gives rise to a corrosive acid formation, culminating in the formation of various soluble sulfates that typically are not visible on an abrasive blast-cleaned surface. During the flue gas desulfurization (FGD) process, ferrous ions are readily formed on unprotected steel surfaces. The ferrous sulfate contamination is usually removed to prevent failure of coatings. Sulfuric acid, formed by the dissolution of sulfur trioxide (SO₃) in water, is a significant source of sulfate. Sulfuric acid can leave sulfate residues on surfaces, and fumes of sulfuric acid can cause similar sulfate deposition.

Recognition and Identification of Salt Contaminants

Although contaminating salts themselves are usually invisible, the effects of salt contaminants often can be detected visually. Such visual indicators provide a strong suggestion of the presence of a salt contaminant. This section discusses visual indicators that sometimes are predictive of the presence of salt contaminants.

Bare Steel (New or Old)

Visual observations provide useful clues regarding the presence of soluble salts. Unusual or unexplained rust patterns and nonuniform rusting suggest the possibility of salts. Pitted steel is typically of concern and salt contamination may be present when it flash rusts after abrasive blast cleaning or has dark brown or black deposits in the bottom of the pits. Any abrasive blast-cleaned steel that experiences flash rusting without an obvious water or humidity source (i.e., higher than 60% relative humidity) typically indicates the presence of a soluble salt. In dry weather, spraying the abrasive blast-cleaned steel surface with deionized water usually accelerates formation of iron oxide (rust) on the surface. Uncontaminated steel develops an even, light-brown-colored rust. Salt-contaminated areas take on a dark or black appearance. Contaminated areas typically are then identified and marked for further treatment (e.g., additional blast cleaning, steam cleaning, water washing, or treatment with a chemical salt remover). If the entire steel surface takes on an uneven or dark color, it is assumed that the entire surface is contaminated. When dark rusting occurs, testing usually is performed to determine the type and quantity of salts present. When decontamination is complete, the steel is then recleaned to the specified surface preparation requirement either by general cleaning or by spot cleaning. Sometimes, if the surface is not coated immediately after abrasive blast cleaning and rust-back occurs quickly, or rust-back occurs in some areas and not in others, salt contaminants are present.

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(3) U.S. Environmental Protection Agency (EPA), Ariel Rios Building, 1200 Pennsylvania Ave. NW, Washington, DC 20460.
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If soluble salts are allowed to remain on a surface, they sometimes combine with atmospheric humidity to form an electrolytic solution that potentially begins or accelerates the corrosion process. The rate or duration of time for rust-back to occur can be affected by the type and level of contamination and the humidity at the steel surface, which is influenced by the surrounding air temperature and the steel temperature. Dehumidification sometimes masks the presence of soluble salts by reducing the relative humidity, thus prolonging the time until rust-back occurs.

Coated Steel

Visual examination is often useful as an indicator when evaluating a previously coated surface prior to abrasive blast cleaning. The type and degree of coating failure sometimes indicates the possible presence of salts. In areas where the existing coating is tightly bonded and no rusting is taking place, it is unlikely the surface under the existing coating has been exposed to salts. Visible salt residues on the surface of an existing, unaffected coating are indicators that soluble salts are a concern when recoating.

Field Tests to Detect the Presence of Salts

Several recognized tests are available to detect the presence of salt contaminants. The quantitative accuracy of these field methods varies widely and their relative effectiveness has yet to be established. One problem in any quantification of contaminants on a surface is that, although measurements of salts in a solution extracted from the surface are accurate, the degree of extraction of the salts from a surface may vary considerably. The extent of soluble salt extraction from a surface depends on the initial concentration of salts on the surface, the extraction test method used, and the operation of the test procedure. The amount of rust remaining on the surface, the depth and configuration of any pitting, the type of extraction solution, temperature, and perhaps other variables are also typical factors that affect the extraction of salts from a surface. No method exists to ensure total extraction of all salt contaminants on weathered substrates, especially within pits.

Field test methods for soluble salts are described and explained in detail in SSPC-Guide 15.15 This guide describes the most commonly used field methods for the retrieval and analysis of soluble salts on steel and other nonporous surfaces. Laboratory methods are included only for situations when laboratory control is desired. However, the extracted solution sometimes does not represent the actual amount of salt ions on the surface even though the test kit can accurately measure the amount of salt ions in the extracted solution. This is because of difficulties and variability in extracting salt from a contaminated and/or pitted surface.

When coating work is to be performed in an environment where salts may be of concern, testing for salt contamination is often performed before surface preparation, after surface preparation, and again if any additional salt removal attempts have been made. Testing typically is undertaken at locations suspected of having salt contamination (see section titled Salt Contamination Sources). Typically, testing is performed as soon as reasonably possible after completion of surface preparation operations because insoluble iron oxide rerusting (i.e., rust-back) may reduce salt extraction efficiencies when testing a contaminated surface.

Salt Removal Methods

Salt removal methods include dry abrasive blast cleaning, wet abrasive blast cleaning, waterjetting, chemical cleaning, wet-heat/steam cleaning, and hand/power tool cleaning. Experience has demonstrated that these methods do not always remove salt contaminants to the specified level of cleanliness after a single cleaning. In some instances, repeated use of a single method, or a combination of cleaning methods, has been necessary.

In practice, final surface cleanliness prior to coating application is established by one or more of the contaminant tests, regardless of the removal method(s) used. Testing provides some assurance that soluble contaminants are at levels established by the coating manufacturer and/or specifier.

Dry Abrasive Blast Cleaning

Dry abrasive blast cleaning consists of a stream of abrasive particles impacting a surface at high velocity. Dry abrasive blast cleaning is an effective method for the reduction of soluble salt surface contamination. However,
although the surface may appear to be visually clean after abrasive blast cleaning, it may still be contaminated with nonvisible soluble salts. If detected levels of contaminants exceed those allowable in a specification, additional blast cleaning, or alternating cycles of dry abrasive blasting and salt-free water washing, is sometimes effective for suitable removal of contaminants. Wash water quality typically determines final results.

The following procedure has been used to reduce salt contamination:

(a) Abrasive blast clean to NACE No. 3/SSPC-SP 6, and remove abrasive and debris from the surface;

(b) Power wash with potable water at 17 to 20 MPa (2,500 to 3,000 psig), and allow surface to stay wet and flash rust overnight; and

(c) Abrasive blast clean to the final degree of cleanliness, usually NACE No. 2/SSPC-SP 10 or better.

Pitted steel generally is subjected to more abrasive blast cleaning repetitions or dry abrasive blast cleaning/water wash cycles to decontaminate the surface to acceptable levels. For pitted steel, a smaller particle size mix of abrasive can also be an effective means to scour the base of the pits. Fine abrasives scour a surface better than coarse abrasives.

**Wet Abrasive Blasting**

Wet abrasive blasting is similar to air-propelled dry abrasive blast cleaning except water is added to the air and abrasive stream at the nozzle. An advantage to using wet abrasive blasting is that potentially the water dissolves and dilutes soluble salts, promoting decontamination. The cleaned surface typically is tested to ensure contaminants are removed to the specified level.

After wet abrasive blast cleaning and confirmation of acceptable levels of soluble salts, it is common practice to perform a final rinse to remove any particulate matter that may remain on the surface. An inhibitor is sometimes added to the rinse water to deter flash rusting. **NOTE:** Owners usually require any inhibitor to be approved by the coating manufacturer prior to use to ensure that the inhibitor does not affect coating adhesion or performance. Inhibitors often mask detection of soluble salts. Consequently, soluble salt testing is usually performed prior to inhibitor application.

**Waterjetting**

Waterjetting is the use of high-pressure water at 70 MPa (10,000 psig) or greater to impact the surface to remove contaminants. NACE No. 5/SSPC-SP 12 states that waterjetting has been proven effective for reducing water-soluble surface contaminants. This standard also provides extensive information on waterjetting. Waterjetting is often more effective than dry abrasive blasting for cleaning contaminated surfaces when the contaminants are water-soluble salts. Fresh water, of suitable quality in the blast stream impinging at high velocity and with sufficient volume, dissolves and flushes away water-soluble salts.

**Chemical Cleaning**

Chemical cleaning involves the use of materials or agents, normally in liquid solution form, to dissolve or otherwise loosen and remove films, scales, and accumulations on a steel surface, thereby cleaning the surface. Although such cleaners may also remove salts, acids and salt-removing chemical cleaners are purposefully used for salt removal.

Dilute phosphoric acid products are sometimes used to pretreat steel prior to coating. The phosphoric acid reacts with the substrate to form iron phosphate. The chloride ion is displaced and can then be washed off, along with any excess acid. Chemical cleaning is often followed by a water rinse to remove unreacted acids or chemicals, and acid/chemical reaction by-products, from the surface.

Salt-removing chemical cleaners provide a chemical environment to remove chlorides and other corrosion-inducing anions. These cleaners have varying chemical functionality and range from acid to alkaline in pH. Assessment of
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their specific effectiveness can be determined by testing for salts before chemical cleaner application, and immediately after washing to remove salts and excess cleaner. The coating manufacturer can provide information on the compatibility of the cleaning chemicals with the coating to be applied.

Wet-Heat and Steam Cleaning

The application of heated pressurized water, or steam cleaning, is typically useful for the removal of salts, acids, alkalis, fatty acids, and oily contaminants.

NOTE: The surface cleaning methods described in the paragraphs titled Wet Abrasive Blasting, Waterjetting, Chemical Cleaning, and Wet-Heat and Steam Cleaning result in some degree of surface rust-back because of the use of water. Coating manufacturers typically provide guidance regarding suitable coating systems for use over steel surfaces with rust-back.

Hand and Power Tool Cleaning

Hand tool cleaning techniques include manual brushing, chipping, scraping, and wiping (SSPC-SP 216), and power tool cleaning techniques include power brushing and sanding (SSPC-SP 313). These methods are most often used for touchup and to prepare a relatively small surface area for coating. Used alone, these techniques do not remove salts satisfactorily from steel surfaces. They are often used with other cleaning methods such as water washing, steam cleaning, or chemical cleaning to obtain an acceptably cleaned substrate.

Project-Specific Sampling Protocols and Acceptance Criteria

There is no industry consensus for soluble salt sampling protocol, number of tests to be performed, or test locations. Test locations usually are selected based on service conditions, past coating performance, environmental exposure, prior corrosion, coating failure, and areas showing rust-back and other possible signs of salt contamination. Evaluators typically use their discretion and knowledge to select areas for testing that indicate the potential presence of salt contamination. The necessity for testing is generally based on the service expected and the existing condition of the substrate.

When developing a salt sampling protocol, areas where corrosion has taken place are usually tested, such as:

- Pitted areas;
- Moisture drain or drip points where higher salt concentrations potentially exist because of evaporation concentration;
- Surface areas known to be exposed to salts;
- Floor or horizontal areas where salt may concentrate, as opposed to walls, vertical surfaces, or overhead areas where salt solutions more readily drain; and
- Areas where rust-back occurs quickly or areas that rust back to a dark color rather than a light-brown color (see section titled Recognition and Identification of Salt Contaminants).

Testing typically is performed until the tester is confident that specified contamination levels have been achieved, and that salt contamination is equal to or less than levels established by the coating manufacturer and/or specifier.

An example of an area-based salt sampling and testing protocol, based on the size of the structure to be coated, is presented in Appendix A. However, even when an area-based sampling protocol is used, it typically has been useful to sample selected potential problem areas as described above.
Appendix B discusses the preparation of a specification for assessing soluble salts, and Appendix C is an example of a specification for a lining system.

References


2. NACE No. 1/SSPC-SP 5 (latest revision), "White Metal Blast Cleaning" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

3. NACE No. 2/SSPC-SP 10 (latest revision), "Near-White Metal Blast Cleaning" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

4. NACE No. 3/SSPC-SP 6 (latest revision), "Commercial Blast Cleaning" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

5. NACE No. 4/SSPC-SP 7 (latest revision), "Brush-Off Blast Cleaning" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

6. NACE No. 5/SSPC-SP 12 (latest revision), "Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).

7. NACE No. 8/SSPC-SP 14 (latest revision), "Industrial Blast Cleaning" (Houston, TX: NACE, and Pittsburgh, PA: SSPC).


11. SSPC-AB 1 (latest revision), "Mineral and Slag Abrasives" (Pittsburgh, PA: SSPC).


13. SSPC-AB 3 (latest revision), "Ferrous Metallic Abrasives" (Pittsburgh, PA: SSPC).


15. SSPC-Guide 15 (latest revision), "Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates" (Pittsburgh, PA: SSPC).

16. SSPC-SP 2 (latest revision), "Hand Tool Cleaning" (Pittsburgh, PA: SSPC).

17. SSPC-SP 3 (latest revision), "Power Tool Cleaning" (Pittsburgh, PA: SSPC).

18. NAVSEA(4) PPI 63101-000 (latest revision), "Preservation of Ships in Service" (Washington, DC: NAVSEA).

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Appendix A: Area-Based Salt Sampling and Testing

This appendix is intended to provide supplementary information only, although it may contain mandatory or recommending language in specifications or procedures that are included as examples of those that have been used successfully. Nothing in this appendix shall be construed as a requirement or recommendation with regard to any future application of this technology.

NOTE: This appendix is an example of an area-based sampling and testing protocol. Other sampling and testing protocols (not based on area, or using different sampling areas and acceptance criteria) may be entirely suitable for a specific situation.

A1 The information contained in Tables A1 and A2 was derived from NAVSEA PPI 63101-000,18 NAVSEA Standard Item 009-32,19 and U.S. Army,20 U.S. Air Force (USAF),21 U.S. Naval Facilities Engineering Command (NAVFAC),22 U.S. Department of Transportation (DOT),23 National Aeronautics and Space Administration (NASA),24 coating manufacturers, and other asset owner requirements for soluble salt surface testing in both submerged and atmospheric applications.

Table A1

<table>
<thead>
<tr>
<th>Service</th>
<th>First 100 m² (1,000 ft²)</th>
<th>Next 300 m² (3,000 ft²) or part thereof</th>
<th>Remainder or part thereof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Immersion</td>
<td>5 tests</td>
<td>2 tests/100 m² (1,000 ft²)</td>
<td>1 test/200 m² (2,000 ft²)</td>
</tr>
</tbody>
</table>

(A) Areas of metal loss (active corrosion and pitting) may be indicative of salt contamination and are frequently targeted for testing.
(B) Welds may also be contaminated with salts and are frequently targeted for testing.
(C) Tests in the first 100 m² (1,000 ft²) are typically spaced 1 to 2 m (3 to 6 ft) apart.
(D) Tests performed after the first 100 m² (1,000 ft²) are typically spaced 2 to 5 m (6 to 15 ft) apart.

Table A2

<table>
<thead>
<tr>
<th>Service</th>
<th>First 5 Spot Repairs</th>
<th>Remainder of Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Immersion</td>
<td>1 test/1 spot</td>
<td>1 test/5 spots</td>
</tr>
</tbody>
</table>

A2 When developing acceptance criteria for a particular coating, project-specific factors such as stated in the first paragraph of the section titled Project-Specific Sampling Protocols and Acceptance Criteria typically are also considered. The following acceptance criteria were derived from the sources listed in Paragraph A1.

A2.1 Possible Acceptance Criteria for Table A1 Sampling Protocol:

(1) U.S. Army, Department of Defense (DOD), 1500 Army Pentagon, Washington, DC 20310-1500.
(4) U.S. Department of Transportation (DOT), 1200 New Jersey Ave. SE, Washington, DC 20590.
(5) National Aeronautics and Space Administration (NASA), 300 E St. SW, Washington, DC 20546-0001.
(a) Any one measurement not in compliance with the requirement of the specification is probable cause for failure of that area and additional salt removal is normally implemented.

(b) When salt removal procedures are completed, a retest, beginning at the failed area, is generally performed.

A2.2 Possible Acceptance Criteria for Table A2 Sampling Protocol:

(a) If any one measurement is not in compliance with the requirement of the specification, all spots are typically considered contaminated and are recleaned.

(b) After soluble salt remediation, the typical procedure is to make one measurement on each of five different spot repair areas. Generally, when five consecutive measurements conform to the specification, the chosen cleaning procedure is applied to all remaining spots.

(c) For the remainder of the structure, the typical procedure is to take one additional measurement for every five spot repair areas. If any one measurement is not in compliance with the requirement of the specification, additional cleaning is normally performed. NOTE: Additional testing in a given area increases the statistical validity of the results.

Appendix B
Preparing a Specification

This appendix is intended to provide supplementary information only, although it may contain mandatory or recommending language in specifications or procedures that are included as examples of those that have been used successfully. Nothing in this appendix shall be construed as a requirement or recommendation with regard to any future application of this technology.

B1 Specification requirements regarding salt testing are usually driven by the specification writer's knowledge of salt test kits. Other considerations such as those listed below are normally taken into account.

B2 Some of the basic components of a specification associated with nonvisible soluble salts include, but are not limited to, such items as:

(a) Identify a field test kit or method for extraction and the method of analysis for each type of salt contaminant;

(b) Determine at what point in the project activity testing occurs, taking into consideration surface preparation methods and procedures;

(c) Choose the number of tests to be performed or a method for identifying the number and frequency of testing;

(d) Give guidance on or select test locations;

(e) State what level of soluble salt contamination is acceptable (see the product data sheet for the coating, or consult the coating manufacturer); and

(f) Indicate remediation method(s) and subsequent retesting for previously noncompliant surfaces.

B.3 Numerous sampling methods are described in SSPC-Guide 15. Each sampling and test method is different in operation, extraction efficiency, titration accuracy, and cost. Because each test method is different in the analysis of how to interpret and implement the results of the test, the specifier may want to incorporate the use of multiple test methods. For example: On large areas of flat steel that were previously coated prior to blast cleaning, a quick, less-
expensive qualitative test may be all that is used to cover large areas in a short period of time. Previously rusted areas may require more frequent testing and a quantitative result to determine the remedial action required.

B.4 Appendix C is an example of a portion of a written specification for a lining that incorporates these components.

Appendix B has been provided courtesy of the Salt River Project (SRP), 1521 N. Project Drive, Tempe, AZ 85281-1298.

Appendix C
Example Lining Specification

This appendix is intended to provide supplementary information only, although it may contain mandatory or recommending language in specifications or procedures that are included as examples of those that have been used successfully. Nothing in this appendix shall be construed as a requirement or recommendation with regard to any future application of this technology.

NOTE: This appendix is an example of a portion of a lining specification when it has been determined that salts on a surface prior to coating are of concern. Other specification formats and wording may be entirely acceptable.

The following is sample specification language for the portion of a written specification for testing for the presence of nonvisible salts.

1. Immediately prior to coating, surfaces normally are tested for [name(s) of salt] using [method]
2. Describe test protocol, number of measurements, etc.
3. Give acceptance criteria

Test surfaces immediately prior to coating for [chloride] [nitrate] [sulfate] salt contamination using the [____ Test Kit/Method for chlorides] [the ______ Test Kit/Method for nitrates] [the _______ Test Kit/Method for sulfates] [______ conductivity meter]. Tests shall be more concentrated 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. Areas of differing exposure such as the floor, ceiling, and sidewalls shall be considered separate areas. Each area shall be tested at the rate of _______ (specify test scheme). [One or more chloride measurements not in compliance with the specification acceptance criteria constitute evidence of excessive chloride contamination.] [One or more nitrate measurements not in compliance with the specification acceptance criteria constitute evidence of excessive nitrate contamination.] [One or more sulfate measurements not in compliance with the specification acceptance criteria constitute evidence of excessive sulfate contamination.] [One or more conductivity measurements greater than ___ µS/cm constitute evidence of excessive contamination]. Excessively contaminated surfaces shall be considered noncompliant and recleaned or washed or soaked with water or water modified with a soluble salt remover and allowed to dry. Reclean, and/or rewash and retest until all tests are compliant. Verify that prepared surfaces comply with the specified visual and written surface preparation standard. Label and record all test analysis devices and retain or photograph for test verification.

NOTE: ________, and [ ] denote choices available for selection by the specification writer.

Appendix C has been provided courtesy of the Salt River Project (SRP), 1521 N. Project Drive, Tempe, AZ 85281-1298, and modified for inclusion in this technical committee report.