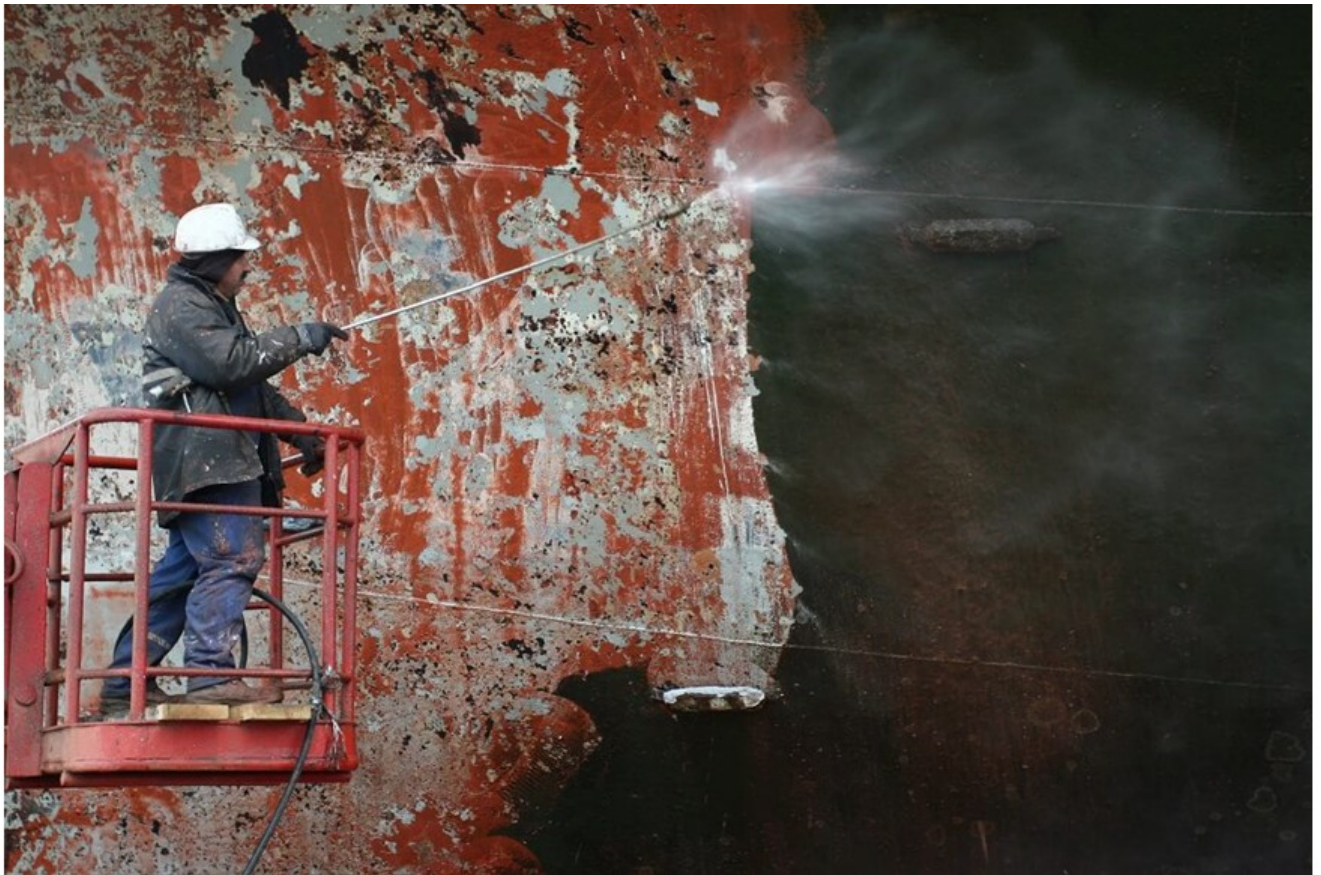


The Effects of Salt Contamination on Coating Performance

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Takeaway: *A substrate with no salt contamination at all is the best and most desirable condition. However, the upfront costs associated with salt detection and removal must be compared to the benefit that will be gained.*

The effect of [soluble salt contamination](#) on a [substrate](#) has been hugely controversial for decades. This controversy is mainly due to several factors that determine if salt contamination actually has an effect on the performance of [protective coatings](#). These factors could include, but are not limited to, the concentration of the salt contamination, the environment where the coated substrate will be exposed, the coating type and the [coating thickness](#).

It is well known that a substrate with no salt contamination at all is the best and most desirable condition. However, the upfront costs associated with salt detection and removal must be compared to the benefit that will be gained in having a salt-free substrate. In this article we will discuss the effect of various non-visible salts on coating performance, an approach to risk assessment regarding the cost of soluble salt removal versus the risk of future [coating failure](#), how to test for the presence of soluble salts, and some salt contamination removal methods that should be performed prior to coating application.

Effect of Salt Contamination on Coating Performance

Although it is well known that salt contamination has an effect on coating performance, a definitive value that precisely shows the salt concentration that will affect a given coating is not available. That can be attributed to the fact that coatings may contain several [pigments](#), [resins](#) and coating materials that can be formed into a single coat or a multi-coat system. In addition to this there are several other variables such as the coating system thickness and the environment to which the coated substrate is exposed. This combination of variables makes it difficult to develop a simple formula, chart or table that can predict an allowable salt concentration.

Salts can affect the substrate or the coating primarily in two ways:

1. By accelerating corrosion of the underlying steel surface. Dissolved salt solutions can accelerate the oxidation of steel, resulting in [undercutting](#) of the coating. Although corrosion can occur in the absence of any salts due to [crevice corrosion](#), [oxygen concentration cells](#) or [general corrosion](#), the presence of soluble salts increases the [corrosion rate](#).
2. As a cause of [osmotic blistering](#) (although osmotic blistering can occur in the absence of soluble salts due to entrapped polar solvents and over-driven [cathodic protection](#) systems). The presence of soluble salts can cause [blistering](#) of a coating when moisture permeates through the coating film and dissolves soluble salts in the entrapped water underneath the coating. In this case the coating acts as a [semipermeable membrane](#) between a dilute salt solution outside the coating and a concentrated salt solution underneath the coating. This difference in concentration will drive water to the higher concentrated salt solution, which will increase the [osmotic pressure](#) beneath the coating and eventually form blisters when the osmotic pressure increases beyond the [bond strength](#) of the coating. (Osmotic blistering is further examined in [The Role of Soluble Salts in Osmotic Blistering](#).)

It should be taken into consideration that the effect of salt contamination varies according to coating type:

- Some [inorganic](#) coating types such as [inorganic zinc rich coatings](#) and [metallized coatings](#) are considered more tolerant to salt contamination than [organic coatings](#) such as [fusion bonded epoxies](#) and [epoxy phenolics](#).
- The coating thickness impacts its ability to tolerate salt contamination. Thicker coating systems are more impervious to water than thinner systems, and therefore are more resistant to salt contamination than thinner coating systems.

Another aspect that should be taken into account is that some soluble salt contaminants are more corrosive to steel than other contaminants. For example, [nitrates are slightly less corrosive to steel than chlorides and sulfates at lower concentrations, but this is not the case in higher nitrate concentrations](#). In addition to this the effect of the cation (positive ion) should also be considered. For example, in chloride salts the order of corrosiveness from the most corrosive to the least corrosive is lithium chloride, sodium chloride and potassium chloride. The corrosiveness of a salt solution is directly proportional to the [conductivity](#) of the [electrolyte](#) formed when the salt dissolves, which is a function of the salt's ionic species.

It should be noted that the corrosiveness of salts to steel isn't related to the effect that these salts have on the coating's performance. [Osmotic blistering of coatings is independent of the species of the salts and is related to the number of ions in the solution](#). For example, [the solubilities in 100 ml of ambient water at 20°C are 87.6 g for sodium nitrate, 35.9 g for sodium chloride and 19.5 g for sodium sulfate](#). Therefore, nitrates are expected to be the salt with the most destructive power with regards to blistering, although they are the least corrosive to steel at low concentrations.

To determine the allowable salt levels, [coating specification writers](#) are advised to check the coating manufacturer's [technical data sheet](#) or to contact the coating manufacturer directly. The allowable salt level is dependent on the expected service life for the specified coating in a particular environment. Salt contamination is usually expressed in ug/cm² or mg/m².

An Approach to Risk Assessment

As mentioned above, having a substrate with no salt contamination at all is the best condition to apply a coating. However, the extra costs incurred for salt removal and salt testing makes the decision to have an uncontaminated substrate more difficult and must be determined based on a risk assessment method. In the following sections we will briefly explain the meaning of a risk assessment and how it can be used as a decisive criteria for salt contamination removal and testing.

What is Meant by Risk?

Risk is a combination of the probability of a hazard occurring and the consequence or impact of this hazard. A hazard is defined as something that has the potential to cause harm or damage. To assess a risk, the hazard must be identified, its probability of occurrence must be estimated, and the consequence of the hazard occurrence must be defined. In our case, the risk assessment includes defining the potential hazard, which is the presence of soluble salts on the substrate. The probability of occurrence is estimated by defining the quantity of soluble salts on the surface. A consequence of the hazard occurring will be corrosion of the substrate or premature coating failure.

Making Use of a Risk Assessment

This risk assessment example could be used to quantify the risk associated with the presence of soluble salt contamination and to measure the reduction in risk associated with the removal of the salt contamination, which will reduce the probability and consequences of the hazard. The benefit of reducing the risk is compared against the cost of testing and removing soluble salts in order to obtain a proper decision with respect to the cost incurred in salt contamination removal.

The following factors must be kept in mind when assessing the risk associated with soluble salt contamination:

- The [service environment](#) to which the substrate has been exposed
- The service environment to which the substrate will be exposed (see [Defining Service Requirements & Environmental Factors for Coating Specification](#) for more information)
- The [coating system](#) and coating thickness to be used
- The method of [surface preparation](#) and degree of surface cleanliness achieved before coating
- The accessibility of the substrate and the ability to repair it later
- The consequence of coating failures and substrate corrosion (cost, time delays, etc.) if caused by salt contamination on the surface before coating

Testing for the Presence of Salt Contamination

Although contaminating salts are usually invisible, their presence and effect can often be visually detected. In this section we will be presenting how we can visually predict the presence of salt contamination on a substrate.

Bare Steel (New or Old)

[Visual observations](#) provide a preliminary assessment for the presence of soluble salts on a substrate. If there are unusual or unexplained rust patterns or [non-uniform rusting](#) then there is a possibility for the presence of soluble salts. [Pitted](#) areas of steel are the most vulnerable areas where salt contamination might be present. If the pitted areas develop [flash rust](#) after [abrasive blasting](#) and there are dark brown or black deposits in the bottom of the pits then there is a higher probability for the presence of salt contamination. (Recommended reading: [A Guide to Flash Rust Prevention and Protection](#).)

Moreover, if there is flash rusting on any abrasive cleaned steel without an obvious humidity source (higher than 60% relative humidity) or a source of water, then there is a possibility of salt contamination. (Also see [7 Things to Know About Flash Rust.](#)) It should be noted that uncontaminated steel will develop an even, light brown colored rust compared to contaminated steel where a dark or black appearance usually presents itself after abrasive blasting.

It should be also taken into account that the use of a dehumidifier may mask the presence of salt contamination on a substrate because the dehumidifier reduces the relative humidity considerably, thus increasing the time for flash rust to occur.

Coated Steel

A visual examination can also be used as a preliminary indicator for the presence of salts when evaluating a previously coated surface before abrasive blast cleaning. The type and degree of coating failure can be used as an indicator for the presence of salts. If the substrate's coating is intact and no rust spots are evident then there is a low probability for the presence of salts underneath the coating.

Field Tests to Detect the Presence of Salts

Several field tests are available that detect the presence of salt contaminants. However, the quantitative accuracy of these field methods and their effectiveness are yet to be established.

A problem that always exists in field tests is that although the measurement 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 other variables are also typical factors that affect the extraction of salts from a surface. No method exists that ensures total extraction of all salt contaminants on weathered substrates, especially within pits.

In the following sections we will present a brief description of some salt contamination field test methods. (Note: Additional information can be found in the article [Field Methods for Extraction and Analysis of Soluble Salts.](#))

1. Potassium Ferricyanide

This method is only a qualitative method to detect the presence of ferrous soluble salts on a substrate. It is done by applying a test paper over the misted surface to be tested. If a dark blue color appears then soluble salts are present.

2. Bresle Patch

This test method is commonly used in specifications referring to [ISO 8502-6](#) and [ISO/DIS 8502-9](#). In this method the following steps should be followed to perform a successful test:

1. Bresle patch shall be adhered on the substrate to be tested. The substrate must be clean and free from any adherent rust, dirt or moisture.
2. Remove the backing and the foam circle from the test cell. Adhere the cell firmly on the test area.
3. Insert the syringe needle into the spongy foam perimeter, and pull back the syringe to remove the air from the test area.
4. Inject the supplied reagent water into the cell.
5. Remove the syringe needle from the center of the cell, leaving it in the spongy perimeter. Gently massage the top of the cell for 10 to 15 seconds. Withdraw and reinject the water a minimum of four times.
6. Retrieve as much water as possible through the syringe and place it in a clean vial or tube.
7. Test the extracted solution using a conductivity meter or Kitigawa tubes or any other suitable method to measure the concentration of salts in the solution.

3. Sleeve Test

There are two variations in this method; one of them measures the salt concentration using a titration tube and the other uses a colorimeter to determine the results of the test.

In this method we perform the following steps:

1. Pour a pre-measured amount of the supplied solution into the sleeve provided in the test kit.
2. Adhere the sleeve onto the substrate where the test shall be done.
3. Hold the sleeve in an upright position in order to force the solution to flow over the substrate to be tested.
4. Massage the solution against the test surface through the test sleeve for approximately 2 minutes.
5. Remove the sleeve from the surface while retaining the solution inside the sleeve.
6. Follow the manufacturer's recommendations if you are using the titration tube or the colorimeter instrument.
7. The results from both test methods are presented in parts per million (ppm), which is equivalent to micrograms per square centimeter.

It should be noted that salt testing should be performed before surface preparation, after surface preparation and repeated if any salt removal attempts have been made. Keep in mind that salt testing should be performed as soon as possible after completing surface preparation to minimize the possibility of insoluble iron oxide re-rusting, which may reduce salt extraction efficiencies when testing a contaminated substrate.

Salt Removal Methods

Several methods are available to remove salt contamination before coating application. These methods include dry abrasive blasting, [wet abrasive blast cleaning](#), [water jetting](#), [chemical cleaning](#), [steam cleaning](#) and hand/power tool cleaning. Experience has shown that several cycles of cleaning are usually required in order to achieve a salt contamination level that lies within the tolerable levels advised by the coating manufacturer.

Conclusion

Having a substrate with no salt contamination is known to be the best method of ensuring a flawless coating that will perform its intended function for its design lifetime. However the extra cost incurred to test for salt contamination as well as the cost associated with salt removal makes the decision to have a substrate with zero salt contamination a little bit tricky. Therefore, asset owners of the substrates to be coated can use a risk assessment technique to determine if there is a necessity to have no salt contamination or if they can accept the risk of having some salt contamination and the subsequent risk of having the coating fail earlier than it is supposed to.