LIMITING CHLORIDE CONTENT IN BALLAST TANKS

Jeremy Jeffreys  
Metro Machine Corp.  
Norfolk, Virginia, USA:

Because of the increasing cost of high-performance coatings and the repair and overhaul of ships’ ballast tanks, strong emphasis has been placed on the initial surface preparation of a substrate. Blistering is one of the premier failures in salt water ballast tanks. For the most part, blistering occurs because of surface contaminants, such as chlorides, sulphates, and sulphites, which were not properly removed before the coating was applied. For this reason, reducing or eliminating these contaminants is sound practice to extend the life of the coating and, in the end, the substrate.

In my opinion, 5 micrograms per square centimetre (µg/cm²) as a general rule is a reasonable level, but as with all coatings, manufacturers should be consulted to determine the recommended limits for their products.

Ultra high-pressure (UHP) waterjetting at pressures above 30,000 psi (2,000 bar) is the best way to reduce chlorides to an acceptable level. UHP waterjetting also suppresses harmful airborne dust, which can be generated if dry abrasive blasting is used to remove hazardous coatings. Depending on the specification, if a surface-tolerant coating is being applied over the prepared substrate, flash rust may not be a factor. In this case, UHP waterjetting would be the way to go.

However, because of the high initial start-up cost and dangers involved with the use of UHP waterjetting in confined spaces such as ballast tanks (e.g., having to use a shorter wand and thus increasing the risk of injury to personnel), abrasive blasting may be the most economical way to prepare the substrate. In this case, I would recommend water washing at pressures of 3,000-12,000 psi (200-800 bar) before abrasive blasting.

Before water washing and abrasive blasting, preliminary chloride levels should be checked using either a blister patch titration kit or a chloride detection kit. When measuring for chlorides, it is a good idea to also measure for conductivity. (An acceptable conductivity limit in correlation to a chloride level of 5 µg/cm² is 100-120 microsiemens/centimetre [µS/cm]). Conductivity measurements can be used to estimate the total amount of soluble salts on the surface, but the measurement assumes that all salts present are sodium chloride. (The document, SSPC-TU 4, Field Methods for Retrieval and Analysis of Soluble Salts on Substrates, gives procedures for measuring soluble salt levels and conductivity and for estimating total salts based on conductivity readings.)

The use of high-pressure water washing or UHP waterjetting is recommended for removing marine fouling and soluble salts from the surface of the existing coating to ensure that they are not embedded in the substrate during abrasive blasting. In certain cases, little or no coating failure may be visible but contamination might still be present. In this case, a simple fresh water wash may be sufficient to remove non-visible surface contamination, but again it is recommended that a preliminary chloride and conductivity check be performed before abrasive blasting or UHP waterjetting.

A third method, steam cleaning, may be used if high levels of surface chlorides/conductivity remain after the initial blast. (This is a proven method of removing contaminants from previously blasted, pitted steel in ballast tanks.) Due to the expense of a second blast cycle, this process is recommended only when a surface-tolerant, high-solids epoxy coating system, which may be applied over damp surfaces, is used or when the coating is not scheduled to be applied for some time due to weld repairs. In the latter case, a second blast cycle should already be specified.

Chlorides are one of the primary contributors to coating failures in severe environments, which include submerged surfaces such as ballast tanks and ships’ underwater hulls. For this reason, removing soluble salts is a very important factor in obtaining a satisfactory service life from the coating system specified.

Continued
It should be relatively easy to attain the 5 µg/cm² level if a few facts are kept in mind. First, all the currently available methods to remove chlorides are wet methods, except one. The only dry method is repeated abrasive blasting. The problem with that method is that the user cannot know how many times it will have to be repeated to attain the required degree of cleanliness. Wet methods use two forms of cleaning action, mechanical and chemical.

Our firm has found a combination of wet and dry cleaning to be the most cost-effective method for meeting the allowable level of chlorides. Water alone will not remove the chloride, because the chloride ions become electrochemically attached to the substrate. We must also remember that some chlorides are beneath rust or a damaged coating layer and cannot be removed until exposed. I recommend pressure washing with fresh water to remove surface salts before using the selected wet or dry method.

Several wet methods are available, such as ultra high-pressure (UHP) waterjetting, wet abrasive blasting, and dry blasting in conjunction with a water wash. The third method sometimes requires a reblast. Other, less common methods exist but for space considerations are not discussed here. If you review the options, you should be able to determine what will work for a particular job.

UHP waterjetting will usually but not always result in the desired level of cleanliness. It is more likely to attain the desired level of cleanliness on the first try by adding a chemical salt remover to the water. This practice combines mechanical and chemical actions. Typically, however, UHP waterjetting is not used in ballast tanks because of worker safety issues associated with such a powerful tool in a confined space, surface configuration, and other issues.

Wet abrasive blasting, or slurry blasting, can and will remove chlorides, but it also may not attain the desired result in a single blast unless a chemical salt remover is added to the water. A brush blast may be required to remove flash rust, but this is usually quickly and easily accomplished. Typically, wet abrasive blasting is not used in ballast tanks, primarily because of clean-up considerations. This method would work well if suitable clean-up means were used.

The technique we have seen used
most commonly is a dry abrasive blast of rusted areas sufficient to remove rust and expose the bare steel substrate, such as would be provided by a commercial blast (SSPC-SP 6, which is the equivalent of Sa 2). Depending on the extent of rusting, a spot blast or a blast over the entire surface may be needed. This blast is used to remove any materials over the chlorides—such as rust or a damaged coating—and to expose the chlorides so that they may be removed in the next step. After blasting, a pressure wash is performed, usually at a minimum of 3,000 psi (200 bar) and with a chemical salt remover added to the water. 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 pressure washing as described above, followed by brush blasting to remove excessive flash rust. Either approach works well and can achieve the desired result on the first try. This method has been found to work very well in ballast tanks. It is cost-effective and causes no problems for clean-up or to workers or the environment.

Because each job is different, we must choose the option that will work best for the project at hand.

Dr. G. Mills
G. Mills & Associates
Humble, Texas, USA, and
J. Eliasson
Stolt-Nielsen Transportation Group Ltd
Houston, Texas, USA:

To answer these questions, we must first look at how organic coatings applied to ships’ ballast tanks actually work. Organic coatings are not impermeable to the transmission of water and oxygen (i.e., they are not purely barrier coatings, as commonly thought). All organic coatings absorb, and allow transmission of, water vapour (the purest form of water) and oxygen to varying degrees through the paint film. Corrosion is an electrochemical process. This process requires a cathode, an anode, and a metallic electron pathway, all present in the steel itself, as well as an electrolyte external to the steel. The only component of the corrosion process that we can control with the use of organic coatings is the presence of the electrolyte. In fact, organic coatings work primarily by isolating the electrolyte from the steel surface. Furthermore, adherent organic coatings are very high in electrical resistance and serve to isolate the anode and cathode in the external corrosion circuit.

Continued
Pure water (water vapour) is not an electrolyte. In a properly formed ballast coating paint film, water vapour transmits through the film one molecule at a time to the steel surface. In theory, such pure water, after condensing at the steel surface, has such a high electrical resistance that it will not support corrosion. However, an electrolyte is formed when water is in the presence of any overcoated soluble salt. This electrolyte now provides the missing link of the corrosion cell, and corrosion may ensue. The rate of corrosion in the presence of oxygen (or other electron acceptor), with all other factors remaining equal, will increase as a function of salt concentration.

Blister formation, which is certainly a problem, depends on the salt content under the film and a number of other factors. The blisters are usually dome-shaped and may or may not be visible to the unaided eye. However, even if blisters do not form, the salt at the steel/coating interface will have a negative effect on the coating’s service life. Thus, removing as much of the salt content as possible before coating application is important.

The simplest method of removing salts from ships’ tanks already in service is by washing with fresh water at ~180-300 bar (2,700-4,500 psi). Pitted steel is harder to clean because of the tendency of the chloride salts to remain inside the pits. There are methods to address this problem, which is beyond the scope of our answer.

Unfortunately, from a practical perspective, there is no such thing as absolute cleanliness. Therefore, the economically sensible approach must be based on a balance between the cost to achieve reasonably obtainable limits and their relationship to coating longevity.

Reducing chloride levels to 5 µg/cm² or below is both feasible and economically viable, as illustrated by an example of a ballast tank that was not properly washed before the coating contractor began blasting. During the blasting, the tank partially flash rusted. Before it was reblasted, however, chlo-
ride levels were measured with Bresle patches. It was found that all surfaces with flash rust had chloride levels at or above 5 µg/cm². In another example involving many tanks with previously corroded steel, the surfaces had been properly washed and blasted with no flash rusting occurring.

There are other variables that influence the rate of flash rusting in addition to the amount of salt remaining on the steel’s surface. The major factor, and the one most often controlled, is the degree of humidity within the tank. While controlling humidity may minimise the formation of the visible corrosion product, the salts, not the corrosion product formed per se, present the problem jeopardising coating longevity.

Most paint manufacturers have set a maximum amount of permissible interfacial salt contamination. The most common value suggested is 5 µg/cm² with occasional higher and lower values. Five µg/cm² will probably be low enough to avoid catastrophic blistering failure within the guarantee period of the coating. But a level of 5 µg/cm² may also play a role in the more destructive, slow processes that lead to failure after the guarantee period has expired. Thus, the long-term concerns are usually the responsibility of the owner. Owners must decide what salt level they are willing to accept, based on cost, performance expectations, and the design service life.

For an intended 10-year service life when recoating a ship tank that has been in service, 5 µg/cm² is most probably reasonable. For ship new-buildings, where coating performance expectations are much greater, the amounts of salt remaining should, in principle, be much lower. In this case, 2-3 µg/cm² is easily obtainable and should be the norm.

Bjørn Erik Alveberg
Jak. J. Alveberg a.s
Østerås, Norway:
The key to obtaining such low salt levels is liberal use of fresh water, preferably fresh water from the vessel’s desalination plant. Not all water purchased in ports is free of chlorides. Thus, if purchased water is to be used, it should be checked for chloride content.

It is not important to use very high pressures in the cleaning process, as tests have shown that pressures in excess of 200–300 bar (3,000–4,500 psi) have very little positive effect, if any, on improving chloride removal. It is the quantity of water that counts. If the tanks are blast cleaned, the water cleaning should take place after the blasting as the final surface preparation before coating.

Continued
If the desired level of chloride removal has been achieved, the steel will remain grey for many hours after washing. In fact, if the steel turns brown, it is an indication that the chloride concentration on the surface is too high (generally >5 µg/cm²), and thus water washing must be repeated.

A study¹ published in 1991 by the U.S. Department of Transportation concluded that slight film surface roughening (micro blistering) due to underfilm corrosion could be observed under an epoxy coating when the chloride contamination exceeded 5 µg/cm² (or 82 mg NaCl/m²). It also found that chloride contamination levels below 0.25 µg/cm² on steel surfaces with an epoxy coating caused little or no visual corrosion of the substrate, even after 4,500 hours of immersion in pressurised sea water.

Under practical conditions, the requirement of 5 µg/cm² seems reasonable if an epoxy coating is to be used for the refurbishment work and a long-lasting result is expected. It should be noted that the Norwegian offshore specification, NORSOK M-501 (Rev. 4), Surface Preparation and Protective Coating, calls for a much lower chloride level. The requirement here is 20 mg NaCl/m², or approximately one quarter of the level indicated in the question.

1. U.S. Department of Transportation, Maritime Administration and U.S. Navy, in cooperation with the National Steel and Shipbuilding Company, San Diego, California; NSRP 0329 (June 1991).

---

Coming Up in Problem Solving Forum

• What coating problems are likely to be encountered in storage tanks that have dissimilar metal sides and floors?
• How do you decide what combination of heating, ventilating, and dehumidifying equipment you need to control the environment inside containment during winter?