

Tea staining on Stainless Steel Surfaces

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Introduction

Tea staining of stainless steels is a relatively common occurrence in the coastal fringes of Australia, and wherever water which high in chlorides is used for washing down. Visually, it is a discolouration of the metal surface, which tends to follow the 'grain' of any surface finish. Although unpleasant to look at, it is not a serious form of corrosion, and in general does not affect the structural integrity, or longevity of the equipment. Aesthetically however tea staining is not ideal, and so the following is designed to help identify its causes and suggest remedies that have proven to be satisfactory in practice.

Stainless Steel

The term "stainless" steel derives from the development of the speciality steels for modern cutlery industry. It has now been adopted as a generic name for steels developed for any corrosion or oxidation (rust) resistant applications.

The corrosion resistant characteristics of stainless steels are a result of a chromium-rich oxide film that forms naturally on the metal surface. Although this film is extremely thin, it is chemically stable and 'self-repairing'. Other types of steel such as mild steel suffer from general corrosion where large areas of the surface are affected, but stainless steels, due to its oxide film, is normally resistant to this form of attack.

Common stainless steels used in the enclosure industry are 304 and 316. Both are iron alloys with additional chromium, and nickel. The nickel content in 316 grades is slightly higher than with 304 grades, and the chromium content is slightly lower. However, the most important difference is that the 316 grades have molybdenum as an additive, to improve its resistance to pitting corrosion, which is usually the result of chloride attack. B&R have standardized on the 316-grade material for the stainless range of enclosures due to this superior corrosion resistance, even though it is a higher cost material.

Tea Staining

The Australian Stainless Steel Development Association (ASSDA) has defined tea staining as the "discolouration of the surface of stainless steel ..." (1). This is obviously and by design a very wide description, and could be caused by many different things. In the US, for example, tea staining can also refer to iron oxide films caused by improper passivation, or sulphides in higher sulphur content grades such as 303.

For the purposes of this article, tea staining can be defined as the "discolouration of the surface of stainless steel as a result of chloride attack". As a first step it is useful to try to understand why, and in what circumstances tea staining can occur.



Figure 1 – Tea Staining

Tea staining of stainless steels is a phenomenon that occurs where water with a significant chloride content is in regular contact with the metal surface. This is a common occurrence along the coastal fringes of Australia, and in the interior where high groundwater salinity can occur. Along the coastal fringes, tea staining is rarely a concern unless the application is within about five kilometres from the sea, and as you get closer to the coast, the staining generally becomes progressively worse. Other factors such as wind exposure, higher temperatures and humidity can also increase the effect. Typical examples of tea staining are shown in figure 1.

Although this can look like quite a significant problem, the corrosion usually does not penetrate into the steel, and does not affect the structural integrity, or the longevity of the material.

How is tea staining caused?

Although research on the root cause of tea staining has been limited, with the notable exceptions of work by ASSDA, and an article by Sussex and Gouch (2) there seems to be little research on the root cause of tea staining. However the mechanisms involved can be inferred by the pattern of the corrosion, and known factors that can help counter the effect. One of the most common factors linked with tea staining is the surface finish of the material. Smoother, polished surfaces often do not show any signs of staining, so from this it can be said that grooves or troughs in the material are a root cause of the problem. Surface roughness (R_a) is measured in units of micrometers (μm), and is defined as the average deviation of the height of the surface from the mean height. This is shown in figure 2. Higher R_a values or irregular profiles are often associated with increased tea staining.

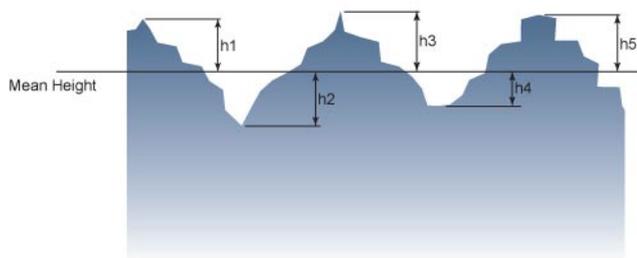


Figure 2 – Surface Roughness

It is reasonable to assume that the base cause of this corrosion is similar to that of many of the other common types of corrosion. The association of tea staining with proximity to salt water means that chloride attack is the most likely cause of the

problem. However you would not normally expect the low level of chlorides present in sea water, for example, to have such a dramatic effect. The reasons why this occurs can be deduced by the locations and one of the solutions to tea staining problems.

One of the most common ways to prevent problems associated with tea staining is to ensure that the surface is washed regularly with fresh, clean water. This would infer that the corrosion is being caused not by the initial contact with salt water, but with deposits of salt building up on the surfaces. Figure 3 shows how the chloride concentration would build up in any surface troughs. On the left of the diagram the dry condition shows no salt deposition so when wet (the lower line) chloride concentration and therefore corrosion rates are low. As the water evaporates it leaves a deposit of salt in the trough, and the next time the surface becomes wet this deposit concentrates the chlorides naturally present, and increases the corrosive effects. Over time therefore the chloride concentration in these troughs can become high enough to cause corrosion. Note that this would be consistent with the effect that an increasing surface roughness will have on the tea staining effect, i.e. a deeper groove will trap more salty water, which will give a higher chloride concentration.

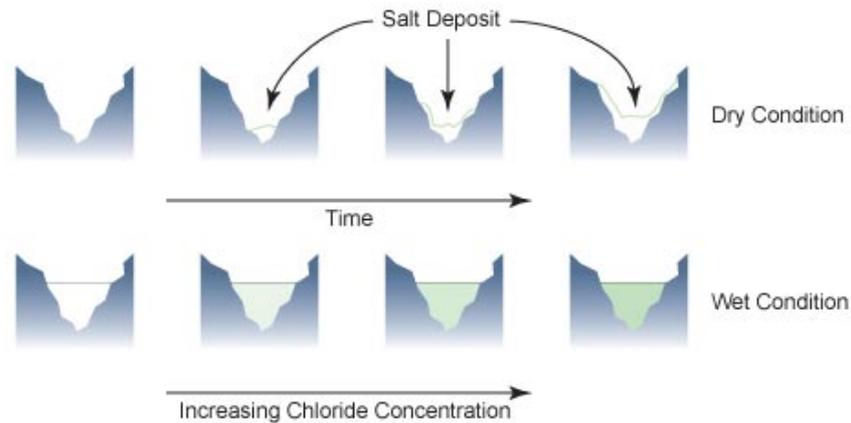


Fig 3 - Showing the increasing chloride concentration with time

The location of particular areas prone to tea staining also implies that higher temperatures and humidity have an effect, as does intermittent exposure (for example, spray from rough seas). High temperatures increase the rate of corrosion, but elevated humidity will increase the time taken for the water on the surface to evaporate, and hence increase the time that the higher concentration chloride solution will be in contact with the metal, and it is this contact with the solution that causes corrosion rather than with the resultant solids.

Intermittent exposure to salt water also seems to be another major factor, and it can be assumed that this is a two-fold problem. As shown above the cycle of water evaporation is required to deposit the salt on the surface, but also after a single 'wetting' as the water evaporates the results in increasingly high concentration of chlorides with time, and therefore an increasingly corrosive solution. Figure 4 shows this in more detail. As the salt water is originally washed into the trough the concentration is fairly low, but as the water begins to evaporate, it concentrates the

chlorides into an ever-decreasing volume of water. This makes the solution more corrosive as it evaporates, until salt solids are deposited.

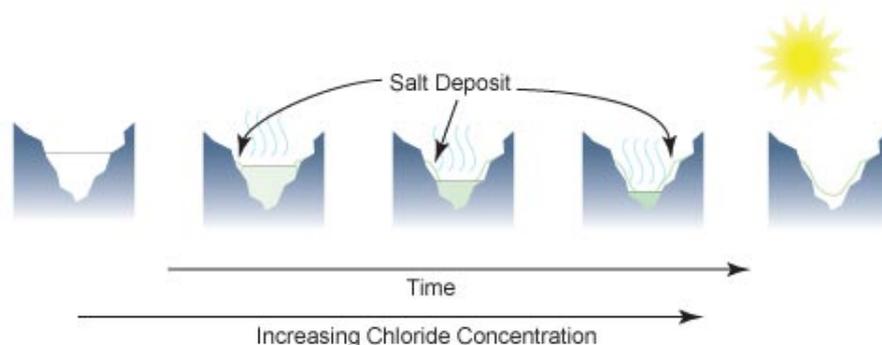


Fig 4 - Showing the increasing chloride concentration as the water evaporates over time.

Recommendation for minimising tea staining

B&R have put together the following list of factors that should be considered when specifying enclosures in areas close to the ocean, or where high levels of chlorides occur naturally, or are found in wash waters. This starts with basic initial material selections, and proceeds into maintenance of the equipment to ensure a long life, and therefore maximum value for the equipment.

Material Selection – Initial material selection for the enclosure is of critical importance to the longevity of the equipment. Stainless steel of grade 316 or above should be used as a minimum, as lower grades such as 304 are significantly less resistant to chloride attack due to the absence of molybdenum.

Surface Finish – The rule of thumb for surface finishes is that the smoother the finish, the better will be the resistance to tea staining. In the absence of any other treatments, B&R's experience has been that an N4 finish with a maximum R_a of 0.4 micrometre gives very satisfactory results. This offers a good level of protection in all but the most severe of cases, at a reasonable cost.

Cleaning – Regular washing with clean, fresh water or even rain water has a significant effect on reducing the incidence of tea staining in the environments that can cause concern (see above). Where tea staining still occurs despite regular washing, additional protection can be provided by the coating procedure detailed below.

Coating – Before coating can take place the surfaces must be thoroughly cleaned. If the metal has already experienced some tea staining then this must be removed with a suitable deoxidant such as a 2% solution of phosphoric acid (care should be taken to follow the manufacturers instructions when diluting and applying phosphoric acid). This is also safe for exposure to typical gasket materials. After leaving the deoxidant for a few minutes, some 'elbow grease' also needs to be applied, and the surface rubbed with a non-metallic cleaning pad in the direction of the grain of the material. Do not rub across the grain as this will burr the polish lines and dull the surface.

Generally after this process there should be no oxide stains visible on the metal surface.

The next step in the coating process is to ensure that any traces of the deoxidant are removed by rinsing with fresh water, cleaning the metal with a cloth, then repeating the process again. Ensure that the surface being cleaned is completely dry before proceeding to the next step.

The final step is a coating of a readily available clear nylonic polymeric resin such as Nycote. This can be purchased directly from B&R or from a reputable supplier. This coating is easy to apply, and is dry to the touch in 15 minutes, and suitable for handling in 1 hour (at 27°C).

Typical examples of applications both before and a significant time after coating applications are shown in figures 5 and 6.



Figure 5 – Tea Staining after treatment

Conclusion

Tea staining of stainless steel surfaces can be a problem where there are significant levels of chlorides in water that comes into contact with the metal surface. This can be around the coastal fringes of Australia, or in the interior where ground water contains significant chlorides. Although it does not look very pleasant it tends to be a surface phenomenon only, and does not affect the structural integrity or longevity of the material. The cause of tea staining has been examined in some details to help evaluate the potential remedies for the condition. Recommendations to help prevent tea staining include correct specification of the grade of stainless steel to be used, surface finishes to help reduce the problem, as well as maintenance procedures, and preventative coating treatments.



Figure 6 – Tea Staining after treatment

References

1. Australian Stainless Steel Development Association (ASSDA) Technical Bulletin, "Stainless Steel Tea Staining", No.2, July 2001.
2. Sussex, G., Gouch, A., Atmospheric Marine Behaviour of Stainless Steel, Corrosion and Materials Journal, Vol 27, No. 6, December 2002.