Electro-Cleaning

Technical Brief

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Stainless Steel Electro-Cleaning

Contents:

Introduction
Stainless Steel is often chosen for industrial and architectural applications because it withstands corrosion, is long lasting, easily fabricated, requires minimal maintenance and looks good.

Unfortunately exposure to many industrial environments can result in corrosion which typically occurs in weldments but can also be initiated in the parent metal in those areas which have not been thoroughly cleaned and passivated. In severe cases, pitting and even structural failure can occur if the corrosion is not adequately treated.

Our electrocleaning process utilizes an electric current in combination with a mild electrolyte, to preferentially dissolve the surface rust, iron contamination and inclusions instantly, leaving the stainless steel surfaces surgically clean. Additionally our process uniquely reforms the original protective chromium oxide layer, passivating the surface and improving its long term resistance to subsequent corrosion and staining.

Our latest developments in application technology have allowed us to treat stainless steel surfaces on site quickly and effectively, providing an economic, long term solution to corrosion. Figure 2.

Figure 2. Seaside balustrade cleaned using the Electropolsih process, giving long term corrosion resistance

The process is benign, safe to the materials being treated, safe for the operator and the environment. There are no noxious fumes and it is totally silent. Unlike traditional abrasive or acid cleaning methods there is no scratching, discolouration or etching of the surface.

At Electropolsih we are proud to have developed an effective cleaning solution for architectural stainless steel. Our process is now well proven on major infrastructure restoration projects. We have confidence in our ability to provide an excellent solution, backed with experience and friendly service.

Cleaning methods for stainless steels

The traditional methods of treating surface corrosion of stainless steels utilise either mechanical cleaning, application of various acid solutions or electropolishing (3). ASTM A380 and ASTM 967 standards provide a series of options for cleaning and passivation of stainless steel surfaces, including electrocleaning.

Mechanical cleaning

Mechanical linishing, buffing and polishing is generally slow, dirty, noisy, labour intensive and expensive. With sufficient time and effort, the surface can be highly polished but may not reflect the original finish. Following mechanical polishing, the corrosion resistance is initially lowered. Over time, the surface oxide will grow and passivate naturally in air and the corrosion resistance will gradually approach that of the original mill finish.

The corrosion resistance of mechanically linished finishes is generally lower than that of the annealed and pickled mill finish as they are severely cold worked in the surface layers, making them prone to attack and can retain corrosive material such as salt and dirt particles which readily initiate corrosion attack. Highly buffed surfaces however can result in better corrosion resistance than a linished mill finish.

Acid cleaning

Acid pickling and passivation(4) can be achieved by either immersing the component in a bath of mixed Nitric and Hydrofluoric acids for a significant time or applying commercially available “Pickling” or “Passivation” pastes. In general these solutions are highly effective in dissolving surface rust, iron contamination and oxidation products. Generally, acid pickling can return the corrosion resistance to the same level as the original parent metal.

Acid cleaning tends to etch the material surface unevenly and poses significant OH&S issues (14) along with EPA compliance costs and generally involves acid neutralisation and disposal.

In some cases nitric acid or milder citric acid solutions are used for “passivation” treatment, however citric acid is ineffective at removing heavier oxidation and corrosion products..

Electropolishing

Electropolishing is an effective method of surface cleaning, which also results in removing oxides and iron from the metal surface. It also preferentially dissolves iron and hence improves the Cr-Fe ratio of the surface layers. It alters the surface appearance by smoothing, “electrochemical polishing” of the surface significantly improves the corrosion resistance.

Whilst this process is very effective, it usually involves dismantling of the structure and removing it to a bath where the polishing process is carried out, generally making it relatively expensive for remedial treatments. Ideally electropolishing should be done immediately after fabrication but prior to the initial installation. On site electropolishing is possible but presents many logistical challenges and is quite expensive.

Electrocleaning

Electrocleaning is based on a similar process to electropolishing but it is portable and applied locally. This process has significant advantages over each of the above methods if applied correctly. Firstly, there is no dirt, buffing compounds or noise involved. The surface appearance is not altered by either mechanical abrasion, etching or polishing, it is simply returned to its original condition, clean and bright.

This process is very effective in passivating and also improving the corrosion resistance of treated surfaces. This process may be performed on site either during installation or as a remedial treatment.

Passivation

Passivation is the process of forming a natural, protective, corrosion resistant layer on stainless steel surfaces. This is promoted by cleaning the surface of dirt, grease & oil, salts and iron contaminants. Water, detergents and mechanical cleaning techniques can readily remove dirt, oils and salts on the metal surface. Iron and iron oxides are not so readily removed with standard cleaning methods, hence pickling and passivating solutions containing phosphoric, citric, nitric and hydrofluoric acid are often used for this purpose.

The Electropolsih method results in a clean, fully passivated surface which is generally superior to that produced using conventional pickling or passivation solutions.

How our process works

The electrochemical cleaning process

The Electropolsih process involves applying an electric current through an electrolyte to the work piece in order to clean the metal surface, Figure 3. The electrochemical process itself is not new and is rather simple.

There are several techniques available utilizing either AC or DC current, generally with mild acids, but all have shortcomings with regard to performance and results. The most significant limitations are that they are relatively slow and ineffective on large surface areas, can result in local etching of the surface, depending on which acid is used.

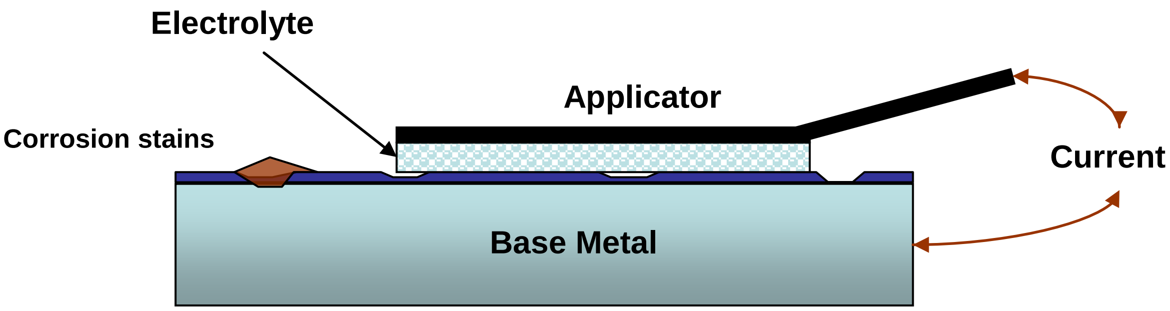

Figure 3. Electrochemical cleaning process

The Electropolsih process has involved significant development of each aspect of the process, especially the ability to clean large and complex surfaces quickly and efficiently without etching or visibly altering the surface condition.

What it does

Our process performs several functions in the one operation:

- Electrocleaning dissolves rust, stains and iron oxides from the metal surface
- Cleans but does not scratch, etch or polish the surface
- Dissolves non-metallic inclusions which act as pitting initiation sites
- The metal surface is thoroughly cleaned and is fully passivated.
- Microscopic smoothing of the metal surface:
    - Reduces the risk for further build up of surface contaminants which promote further corrosion
    - Increases the pitting corrosion resistance of the surface

Figure 4. Balustrades cleaned using the Electropolsih process.

What it does not do

Any pre-existing defects such as scratches or pits from prior corrosion, will be treated, but not removed.
Highly polished surfaces will be cleaned but not necessarily returned to the highly buffed original finish due to the corrosion processes involved in staining.

Testing method and environments

The ASTM standards A 380 and A 967 provide options for cleaning and passivation of stainless steel surfaces. Whilst they do describe various methods to be used and some simple evaluation tests, there is no specified criteria for the measurement nor required level of passivation or corrosion resistance of the cleaned surface.

In order to establish the efficacy of our process, we have employed the latest (1) electrochemical corrosion testing techniques. The critical pitting potential CPP technique has been utilised in our process development as well as on site determination of the corrosion resistance of each job both prior to cleaning and is also used as validation to confirm we have achieved a consistent and adequate level of passivation and corrosion resistance.

Corrosion testing and evaluation is carried out using a portable electrochemical potentiostat, which allows easy access to virtually any size object with various surface geometries even on-site. Determination of the pitting potential has been found (2) to be the most appropriate test method for standard stainless steel grades when compared with critical pitting temperature and critical chloride concentration methods.

The sensor makes electrolytic contact with the surface. Capillary forces cause electrolyte flow through a porous polymer pen.

By positioning the pen on the sample surface, electrolytic contact is established and electrochemical characterization is possible. The measured test area is 1.5 mm^2.

Fig 1: Electrochemical measurement of a stainless steel tube.

Electrochemical testing

Electrolytes of 1.0M and 5.0M NaCl solutions are prepared from distilled water and reagent grade chemicals. All potentials are referred to saturated calomel electrode (SCE). Prior to testing the surface is cleaned with ethanol. The surface is locally contacted by the electrolyte and is controlled by an electrochemical control unit.

The instrument runs polarization scans at a rate of 10 mV/s in order to determine the pitting potential. A typical calibration measurement is shown in Fig. 5. Running several calibrations results in the averaging of the instrument of the determined pitting potentials.

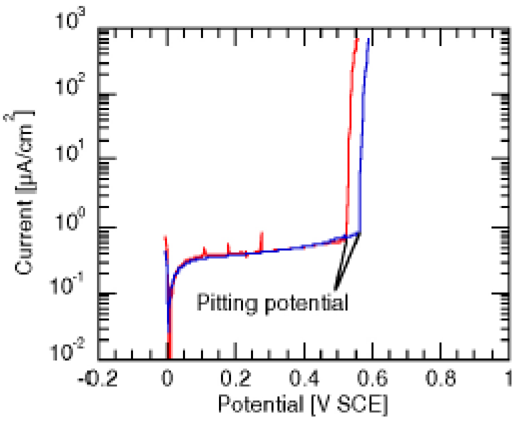

Fig. 5. Calibration scan determines pitting potential

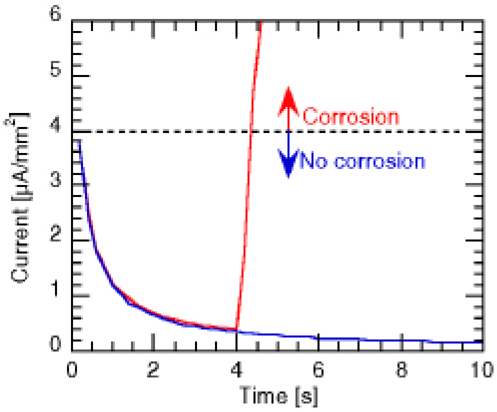

Fig.6. Corrosion current at the reference potential

Once calibration is completed, the instrument decreases the potential by 120 mV. By running potentiostatic tests for 10 seconds, the relative corrosion resistance is determined. Typical results are shown in Fig. 6.

If the current shows typical passive behaviour it can be concluded that the tested area exhibits a pitting potential that is comparable or higher than the area where the instrument was calibrated. If the current shows a strong increase, it can be concluded that pitting is initiated. Hence, the tested area exhibits a corrosion resistance that is significantly decreased compared to the area where the calibration was performed.

The above technique, as well as direct determination of the pitting potential have been used extensively in the determination of the appropriate processes for surface preparation, electrocleaning, neutralisation and rinsing.

Comparison with alternative cleaning methods

Utilising the electrochemical test technique described above, the effectiveness of several standard cleaning methods used on stainless steels has been compared. The results are summarised in Figure 7.

In this case, the alloy tested was grade 316L stainless steel with an original 2B surface finish. The tests were conducted at 20 deg C with a 5N NaCl solution. Acid cleaning was performed with 20% Phosphoric acid solution. Mechanical abrasive cleaning was performed with a Nylon pad and a domestic abrasive cleaner.

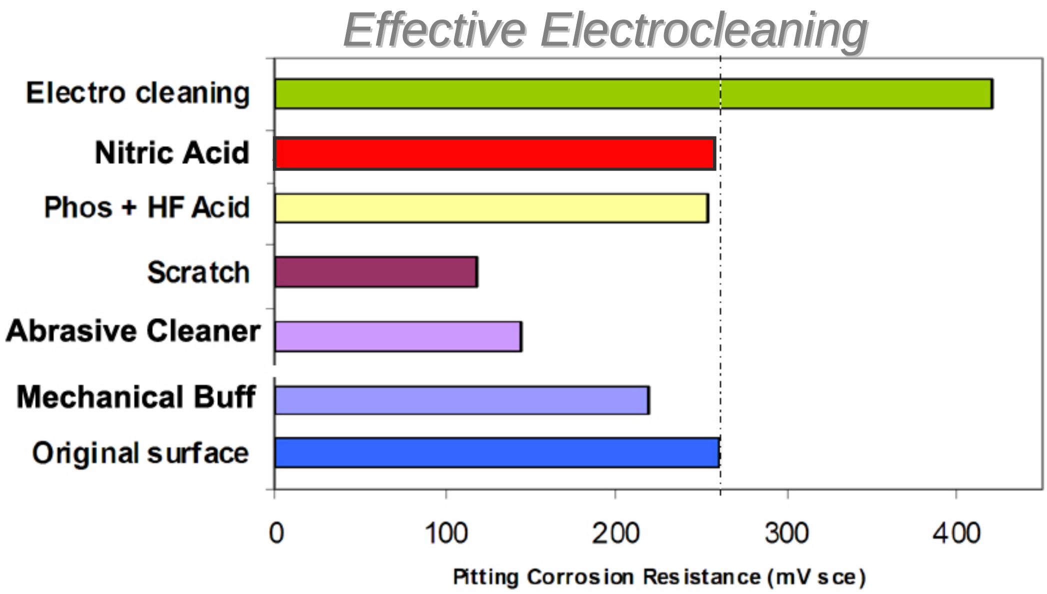

Figure 7. Comparison of the corrosion resistance of different cleaning methods.
Corrosion Resistance *(mV SCE, 5M NaCl, 20C, 316L 2B)*

<u>Cleaning of weldments</u>

Cleaning of stainless steel weldments is important in order to achieve adequate corrosion resistance after welding with particular emphasis being given to the Heat Affected Zones (HAZ). Methods such as mechanical and chemical cleaning are typically used. Electrochemical methods have also been employed where pickling pastes are considered dangerous for OH&S reasons.

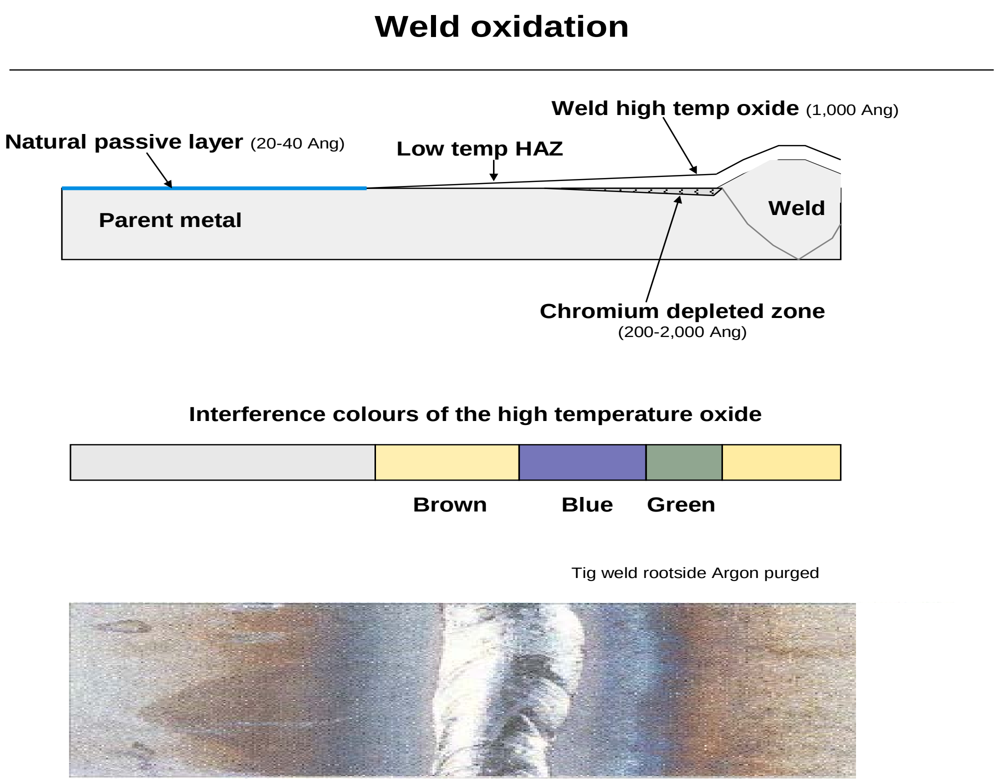

Figure 2. Surface oxidation, depleted zone and interference colours of stainless steel welds.

The high temperature heat affected zones (HAZ) of weldments are considered (1) to be chromium depleted, with an attendant reduction in corrosion resistance. The surface oxidation and chromium depleted zone and interference colours are represented in Figure 2.

Testing was conducted to identifying the corrosion resistance of the different parts of the weldment, using some common methods of treating the welds. The material tested was standard 2B mill finish grade 316L stainless steel.

- Mechanical cleaning was conducted by buffing using a 3M Scotchbrite pad.
- Acid cleaning was performed using pickling paste of 15% phosphoric acid and 0.9% Hydrofluoric acid.
- Electrocleaning was performed using the Electropolsih portable electrocleaning process.

Post weld cleaning

Corrosion tests were also conducted on weldments. The parent metal, low temperature HAZ, high temperature HAZ and weld metal, were tested after various forms of cleaning.

Automatic 316L MIG welds with argon purge on the root side were used. Tests were conducted on grade 316L, 2B material using a 1M NaCl test solution at 18 deg C. The test results are summarized in Figure 5.

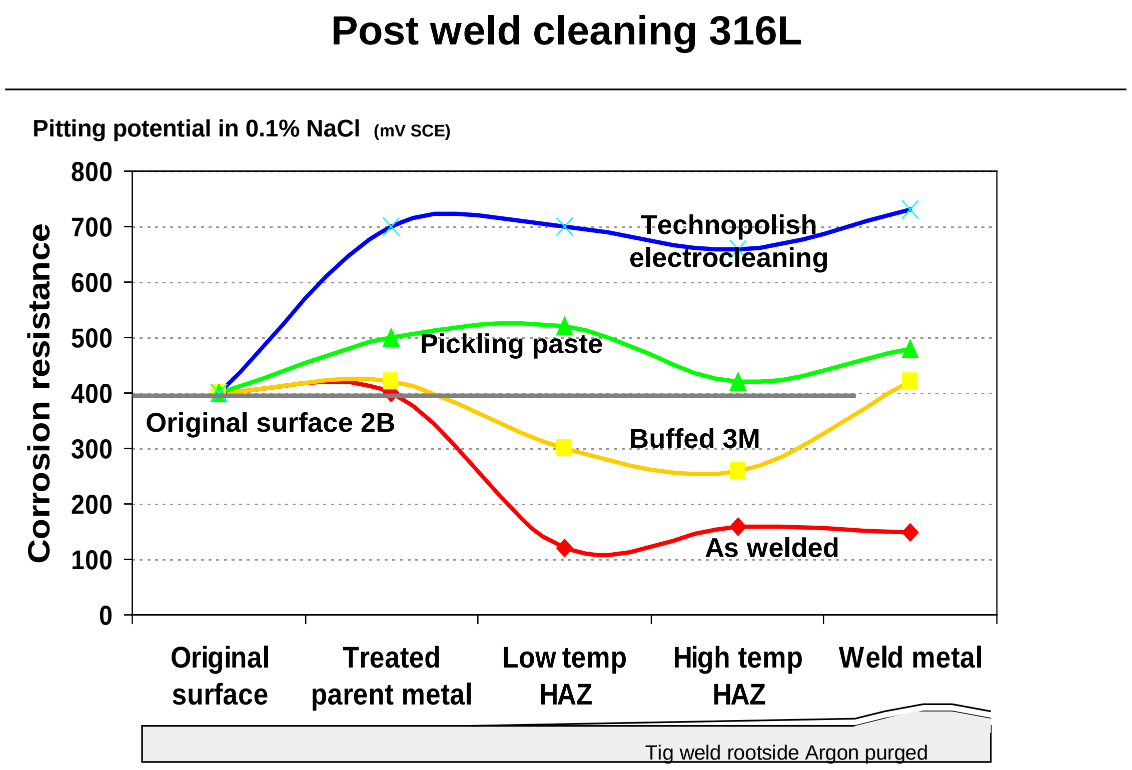

Figure 5. Effect of cleaning methods on a stainless steel weldment.

Pickling with commercial pickling paste significantly improves the corrosion resistance compared with that of the as-welded material. The electrocleaning process not only recovered, but can improve the corrosion resistance to a level above that of the original parent metal.

It is concluded that electrocleaning is at least as good as pickling and can even improve the corrosion resistance of weldments.

The Electropolsih advantage….

- Immediate, spectacular looking, long lasting results
- No messy abrasives or noise, No noxious fumes or smells
- Non abrasive, No scratches, No etching or staining
- Long term protection, with a maintenance guarantee
- Environmentally friendly solution
- All treated surfaces are fully passivated

It is fast and efficient when compared with pickling and suffers none of the drawbacks of the existing methods. The Electropolsih system offers significant operational cost savings as well as greatly reduced OH&S requirements.

Safe and environmentally friendly:
A key benefit of the Electropolsih system is that it is safe, cost effective and environmentally friendly. It uniquely addresses both OH&S and EPA compliance costs, as well as bath monitoring and maintenance costs.

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(9) Fabrication and Special Finishing Methods
(10) Preventing coastal corrosion - teastaining
(11) 304 grade stainless steel
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(13) 2205 grade stainless steel
(14) Acid scheduling

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