
Reichstag in Germany cleaned with Avesta Finishing Chemicals

THE IMPORTANCE OF SURFACE TREATMENT FOR STAINLESS STEEL

BY ANDERS BORNMYR

The effective cleaning of stainless steel surfaces, including weld seams and larger components, is essential in order to maintain their corrosion resistance. This paper gives you an introduction to:

- **the unique characteristics of various types of stainless steel,**
- **the importance of the passive layer,**
- **the most relevant cleaning methods to ensure lasting corrosion protection**
- **case studies from all over the world showing what we are able to do with our finishing chemicals.**

We also highlight the advantages of chemical cleaning and provide an overview of cleaning techniques as well as the complete cleaning lifecycle for stainless steel.

1 – AN INTRODUCTION TO STAINLESS STEEL

Stainless steel grades are a family of alloyed steels that are basically composed of iron (Fe) and Chromium (Cr), having:

- **a minimum of 12 % Cr**
- **a maximum carbon content of 1.2 %**
- **special properties such as corrosion resistance to specific media along with providing heat resistance. properties.**

Different alloys such as Nickel, Chromium and Nitrogen are added to iron during the production of stainless steel. Their content in a specific steel grade generally determines its corrosion resistance.

Nitrogen	increases the strength of austenitic and duplex steels and improves their resistance to localized corrosion.
Nickel	increases the resistance to general corrosion, increases impact strength and ductility.
Chromium	provides increased corrosion resistance and is the main alloy in stainless steel. It is responsible for the formation of the passive film.

Chicago Bean, Cleaned with Avesta Finishing Chemicals

Magnetism of Stainless Steel

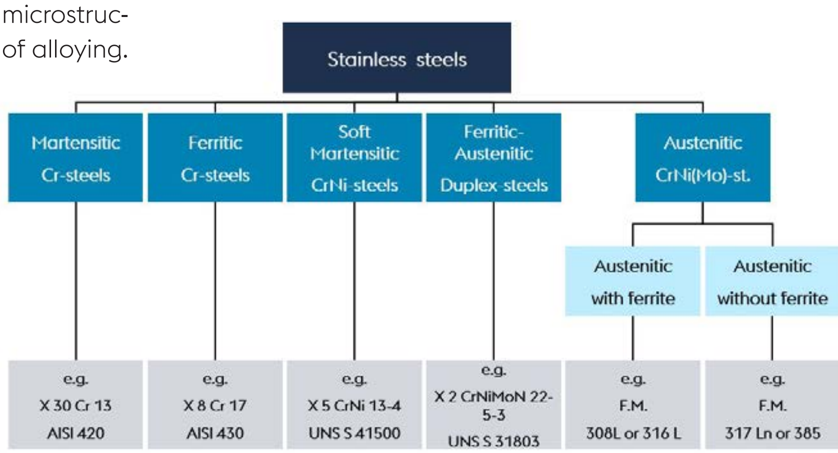
The addition of Ni as alloying element makes the stainless steel Non-magnetic. These 300 series stainless steels are also known as Cr-Ni steels or 18/8 as 18% Cr and 8% Ni were originally added. Therefore, stainless steels without Ni, also known as chromium steels or 400 series stainless steels, are strongly magnetic.

a) Different Types of Stainless Steels

There are many types of stainless steel grades available on the market, which vary in terms of strength, corrosion resistance and heat resistance. They are categorized into four main families according to their metallographic microstructure, which is determined by the type and level of alloying.

- **ferritic**
- **austenitic**
- **martensitic**
- **soft martensitic**
- **ferritic austenitic – duplex steels**

The various metallographic structures have a significant influence on the weldability of the respective steel.



a) How to define the corrosion resistance of stainless steels

Selecting the right corrosion resistant alloys is quite complex and depends on the specific application for which the materials will be used and the type of corrosive environment they will be exposed to. Test simulations of the field conditions are recommended in order to select the right alloys.

Let us discuss two common methods for defining the corrosion resistance of stainless steel.

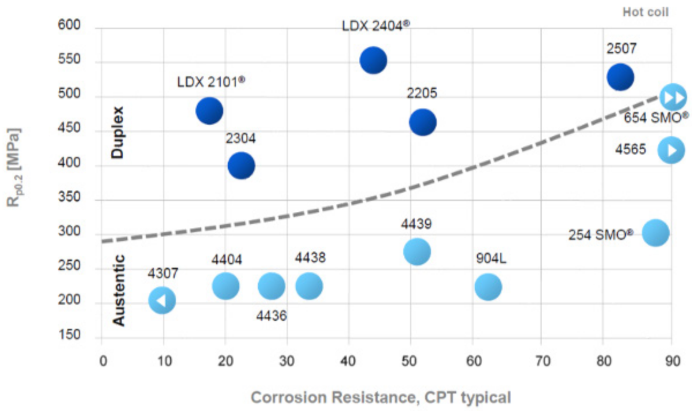
Pitting corrosion is often an important criterion when selecting components and materials for pipework. Studies have shown that pitting and crevice corrosion accounts for roughly 25 % of all corrosion damage. There are various methods for determining the corrosion resistance of stainless steel.

Critical Pitting Temperature (CPT)

In this case, the critical pitting temperatures often give insight into the susceptibility of stainless steel to pitting corrosion. To determine the susceptibility of stainless steel to pitting corrosion, a very common method is to use various formulas to calculate the critical pitting temperatures.

Generally, it is assumed that susceptibility of stainless steels to pitting corrosion increases with temperature. The CPT value is largely determined by following international standards:

- **ASTM G48-03**
  (Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution)
- **ASTM G150-99**
  (Standard Test Method for Electrochemical Critical Pitting Temperature Testing of Stainless Steels)



Note: The standard procedures are suitable for ranking the susceptibility of stainless steel to pitting corrosion but not appropriate for predicting pitting corrosion of stainless steel under production.

PREN Value

The pitting resistant equivalent number (PREN) is also used to determine the corrosion resistance of stainless steel. There are different PREN formulas, with the results of the formulas usually starting with 16 and reaching values above 40. In general, the higher the number, the higher the corrosion resistance.

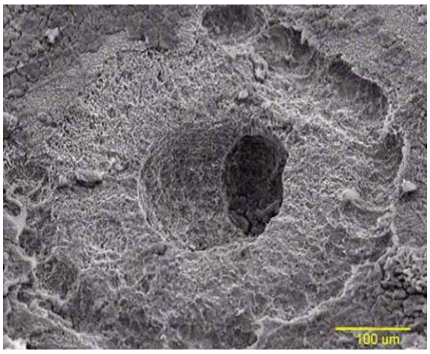
The pitting resistance equivalent number is a theoretical method of comparing the pitting corrosion resistance of various types of stainless steels based on the chemical compositions of an alloy.

The PREN cannot be interpreted as an absolute value.

2 – CORROSION OF STAINLESS STEELS

Corrosion is defined as an attack on a material by a chemical reaction, often electrochemical, with the surrounding medium. Pure physical or mechanical processes are not considered to be corrosion.

Passive layer and Corrosion Resistance

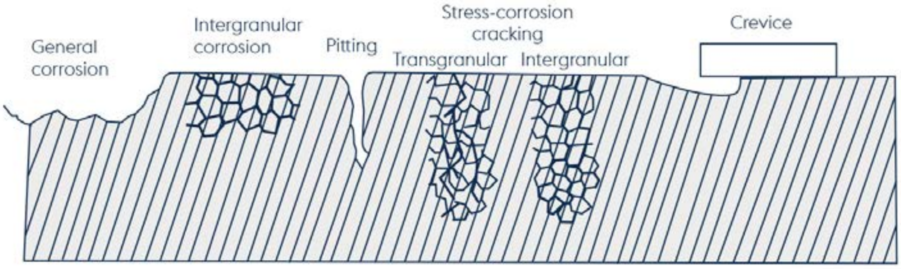


Stainless steel is protected against corrosion by its passive layer. The chromium in the steel reacts with the oxygen to which the steel surface is exposed, thus forming this invisible layer. If the layer is damaged, it heals spontaneously, provided the surface is clean.

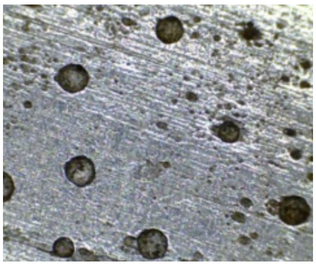
On a contaminated stainless steel surfaces, the deposits block this reaction. Chlorides can penetrate under the deposits leading to corrosion and rust. Thorough cleaning of the surface down into its pores significantly reduces this risk.

Types of stainless-steel corrosion

Most types of corrosion are "wet". Wet corrosion refers to corrosion in liquids or humid environments and also includes atmospheric corrosion. These are the most important forms of wet corrosion.



» Pitting corrosion
» Crevice corrosion
» General / Uniform corrosion
» Stress corrosion cracking
» Atmospheric corrosion
» Intergranular corrosion
» Galvanic corrosion



Pitting Corrosion

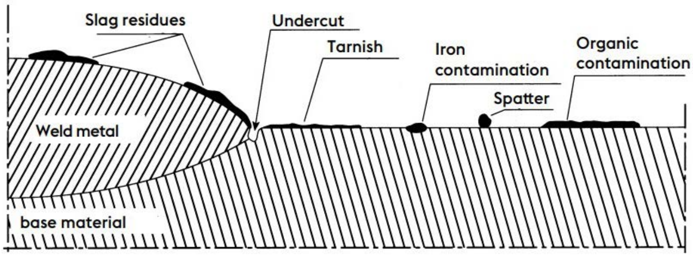
» Chloride attack of the passive layer (weak spots), displacement of oxygen
» No re-passivation due to the low-oxygen atmosphere.
» Accelerated corrosion due to potential gradient, decreasing pH value and increased chloride content.
» Pitting resistance is improved by an increased content of Cr, Mo and N.

Crevice corrosion

» Local surface attack on non-passivated or poorly passivated areas such as crevices, seals, deposits, dead spaces, threads.
» Passivation is prevented by insufficient oxygen diffusion.
» Can be partially controlled by avoiding such areas in the design and ensuring sufficient passivation.

Intergranular corrosion

» Corrosion in or adjacent to grain boundaries occupied by precipitates (grain disintegration).
» Formation of chromium carbides at the grain boundaries in the range of 500–800°C. This Cr-depleted fringe is susceptible to corrosion attacks.
» This can be counteracted by lowering the C content or the C-affine elements (Nb/Ti).



Surface defects

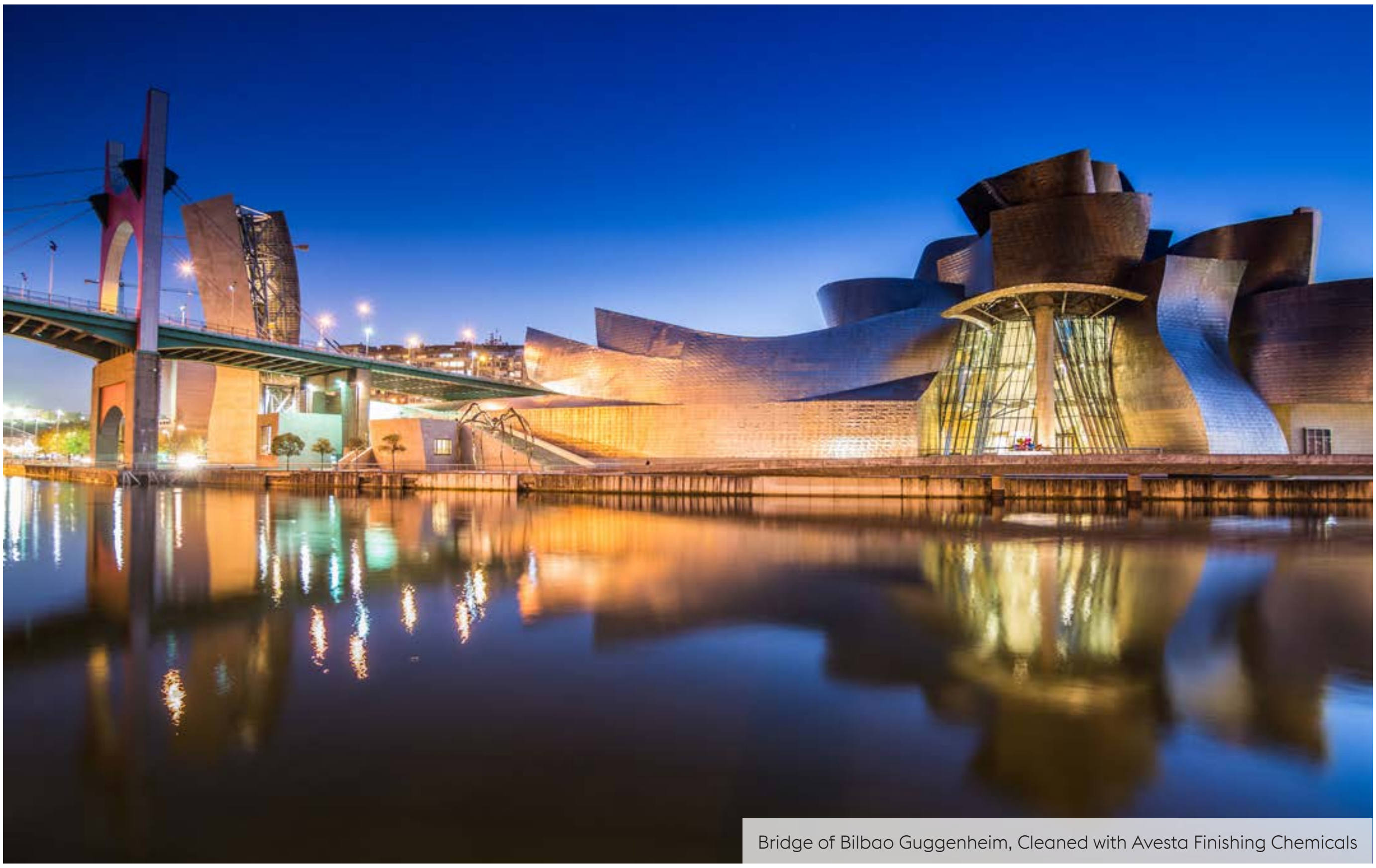
Surface Defects

» Heat tint and weld oxide scale
» Iron contamination
» Rough surface
» Organic contamination
» Weld defects

Defect		Problem occurring	Solution
	**Welding oxides**	Weld oxides have an impact on the passive layer.	Post weld cleaning is essential.
	**Iron contamination**	This problem occurs when carbon steel is used in the same workshop, and mixed in production.	Important: Stainless steel processing must be done in a separate workshop with the appropriately correct brushes in order to avoid any carbon contamination.
	**Rough surface**	The surface finish is damaged by welding, uneven weld beads and excessive grinding or blasting, which creates rough surfaces. Excessive grinding also creates high tensile stresses which promote stress corrosion cracking.	The end user can specify a surface finish that meets their design criteria and can dictate specific cleaning methods.

There is a maximum allowed surface roughness (Ra-value) for many applications:

Cleaning method	Typical RA value (µm)
Sand blasting/Bead blasting	1-6
Grinding 80 grit	1.8
Grinding 180 grit	0.8
Grinding 240 grit	0.4
Grinding 320 grit	0.3
Pickling	0.3-3
Electro-polishing	0.1-0.8



Bridge of Bilbao Guggenheim, Cleaned with Avesta Finishing Chemicals

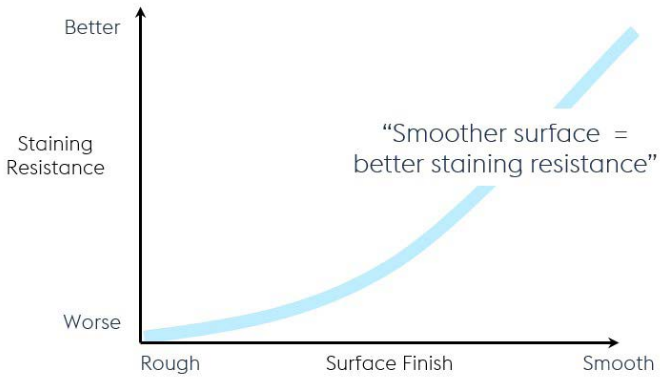
3 – SURFACE FINISH OF STAINLESS STEELS

When working with stainless steel, choosing the right surface finish is crucial for optimal performance. This decision involves several considerations that may vary depending on the specific stage of manufacturing and the intended application of the part.

Typically, manufacturers are seeking characteristics such as long lifespan, corrosion resistance, and minimal maintenance. The correct surface finishing ensures that stainless steel meets these expectations.

However, navigating the complexities of finishing processes can be challenging due to the different standards and designations that exist. The ASTM and EU standards, for instance, each have their own classifications for stainless steel surface finishes.

In general, a smoother surface tends to offer superior resistance to stains, which highlights the importance of understanding these finishing options.

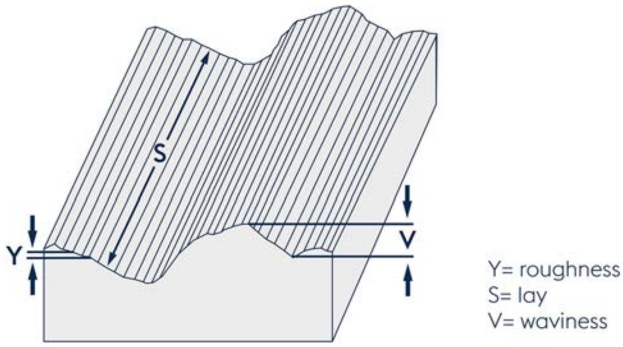


Surface Texture or Finishing Definition

Surface finish, also known as surface texture, is the condition of a surface, as defined by three characteristics: lay S, surface roughness Y, and waviness V.

Surface roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal flat form. It can be measured with an instrument in Ra (average roughness) values in micrometers (µm).

This means that a lower Ra value is better from the point of view of corrosion resistance.



Surface roughness

Finish	ASTM	EN 10088-2	Surface Finish	Typical Ra value (µm)
Hot Rolled A rough, dull surface produced by hot rolling to the specified thickness, followed by heat treatment and pickling. This surface, which is found on thicker sheets and plate, is slightly coarse with very low reflectivity. It is primary used for non-decorative purposes lie unexposed support systems and structural applications	No1	1D	Rough and dull	3,5-7,5
Colled Rolled A dull, cold rolled finish produced by cold rolling to the specified thickness, followed by heat treatment and pickling. The low reflective matt surface appearance is suitable for industrial and engineering needs, but less for aesthetic applications.	2D	2D	Smooth	0,4-1,0
Colled Rolled A bright, cold rolled finish commonly produced in the same way as 2D finish followed by skin passing. The most common surface finish. Good corrosion resistance, smoothness and flatness.	2B	2B	Smoother than 2D	0,1-0,5
Cold rolled BA finish produced by performing bright annealing in an inert atmosphere after cold rolling. A highly reflective finish, that will reflect clear images.	BA	2R	Smoother than 2B, bright and reflective	<1,0

4 – SURFACE TREATMENT OF STAINLESS STEELS TO AVOID CORROSION

As the demand for high-quality stainless-steel surfaces increases, selecting the appropriate cleaning and finishing methods is becoming more and more crucial. The higher the requirements for surface finish and resistance, the more important the choice of process to achieve the desired properties becomes.

Key factors to consider include:

» **Corrosion resistance**

» **Damage and contamination prevention**

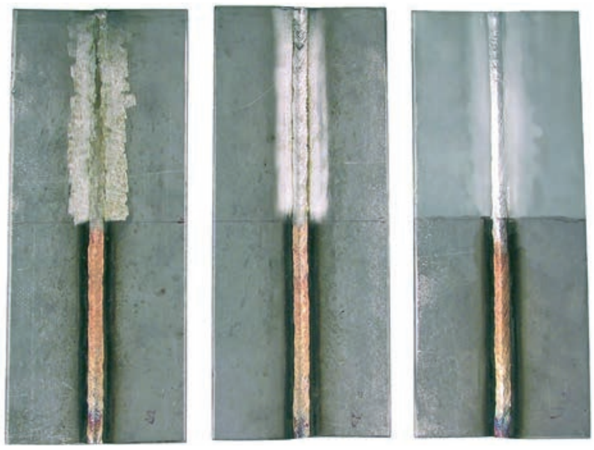
» **Visual appearance**

» **Meeting quality standards**

» **Adhering to environmental regulations**

Often, combination of different cleaning and finishing processes is required to achieve these goals. This is particularly important as stainless steel can be subject to various types of corrosion.

Effective cleaning plays a vital role in preparing the material and promoting the formation of a protective passive layer, which ensures long-term durability and performance.



Grinding Polishing Pickling

A) Chemical Surface Treatment

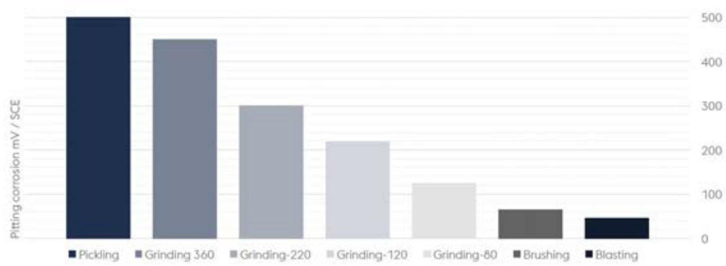
Chemical surface treatments of stainless steel consist of cleaning and degreasing, pickling, passivation, and electro-polishing. Various chemical and mechanical methods, and sometimes a combination of both, can be used to remove defects. While there are different methods of mechanical surface treatment, such as grinding, polishing or blasting this section focuses on chemical cleaning and its advantages.

Chemical cleaning usually provides superior results. This is because most mechanical processes tend to result in a rougher surface, while chemical methods reduce the risk of surface contamination.

It is important to know that Chemical Cleaning is regulated by local environmental and industrial safety regulations, but also by waste disposal regulations.

If you are interested in particular on safety of setting up a pickling workshop, please consult our technical team to reach out for support.

Comparison of different surface treatment methods – Pitting corrosion resistance:



Pickling

Pickling is the most common chemical process for removing oxides and iron contamination. In addition to removing the surface layer through controlled corrosion, pickling also selectively removes the least corrosion-resistant areas such as the chromium-depleted zones. Fume reduction during pickling is essential to meet requirements.

The toxic nitric fumes generated during pickling have a number of harmful effects on health and the environment. By using modern pickling products such as our BlueOne® pickling paste 130 pickling and RedOne® Pickling Spray 240, the toxic fume levels can be reduced by up to 80 %.

Passivation and Decontamination

This procedure is carried out in a manner similar to pickling. The passivator, which is applied by immersion or spraying, strengthens the passive layer. Since the passivator also removes free iron contamination from the surface, the treatment is more important after mechanical cleaning and processes where there is a risk of iron contamination. For this reason, the process can also be referred to as decontamination.

Electropolishing

Electropolishing normally produces a surface that ensures optimal corrosion resistance. No areas of lower corrosion resistance are selectively removed, rather micro peaks are polished from the surface. The material takes on a fine shine and, above all, an even micro-profile that meets extremely stringent hygiene requirements. For these reasons, electropolishing is normally used as the final treatment after pickling.

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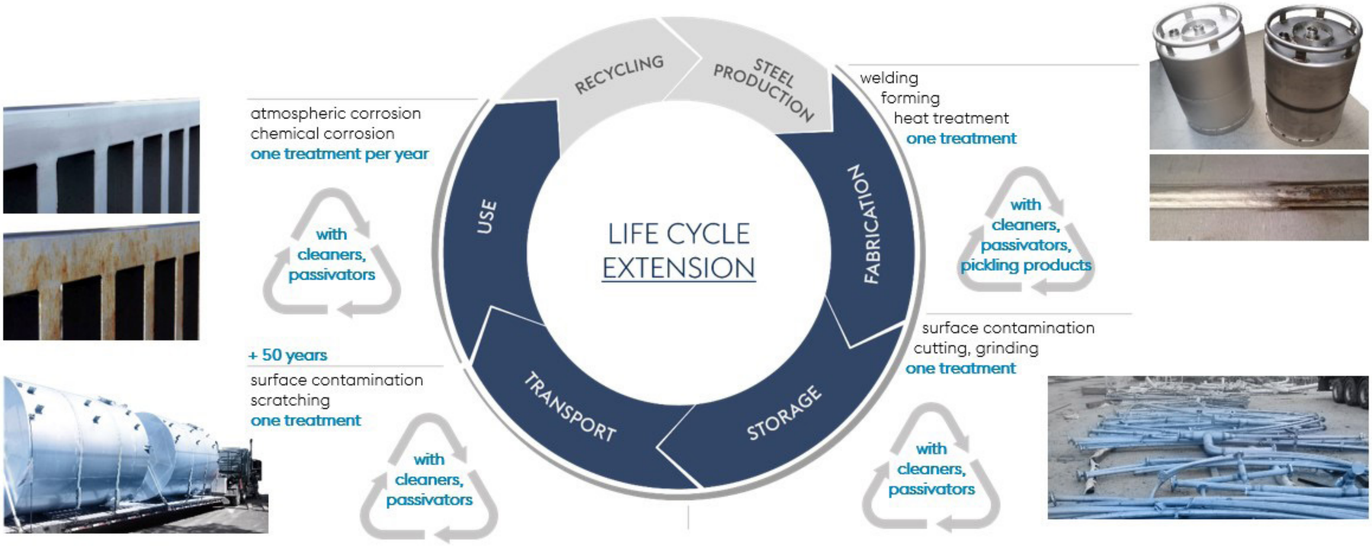


b) Cleaning Lifecycle

It is important to understand the cleaning cycle of stainless steel. During the four different phases of manufacturing, storage, the transport and the end use, stainless steel requires specific cleaning processes at different stages. Proper maintenance cleaning at the end of the cycle is crucial to extend the service life of a component.

FABRICATION

Stainless steel, which consists of forming, welding and heat treatment. To avoid corrosion, a pickling mechanism is recommended: pre-treatment is recommended prior to pickling, in which grease and organic contaminants are removed from the surface.

STORAGE

During the storage process, the previously cleaned objects may easily be contaminated with carbon steel. This risk is higher in a mixed production of stainless steel and carbon steel items. Carbon steel contamination: free iron particles must be removed immediately as this may otherwise lead to pitting corrosion.

TRANSPORT

During transport from the factory to the customer, the equipment may be exposed to chlorides coming from seawater during boat transport or road salt during winter road transport. Chloride problems such as airborne contamination, marine environment, chlorides from seawater, chlorides from road salt lead to localized pitting corrosion and surface rust. The chlorides must be removed immediately, otherwise they will rust very quickly and destroy the self-healing passive film on the stainless steel surface, leading to pitting corrosion.

USE

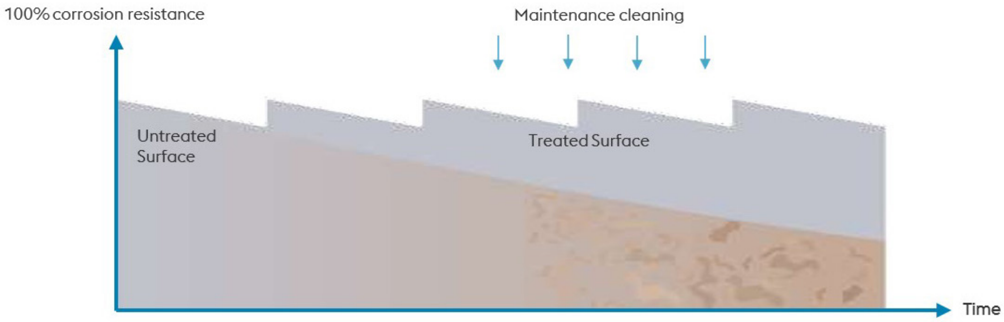
When used outside and during processing, stainless steel may be exposed to a wide range of potentially more aggressive environments, that can cause brown spots. These can be marine atmospheres, carbon steel, environments with industrial pollutants, salt spray from road salt, and atmospheric and traffic-related pollution.

We recommend preventive maintenance to avoid the risk of damage to the stainless steel caused by regular cleaning cycles. This maintenance cleaning should be carried out regularly and we recommend at least ONE treatment per year.

c) Cleaning Process with Finishing Chemicals

The cleaning process with finishing chemicals is critical and consists of following steps. Although the type of cleaning process may vary, the typical sequence of operations will be the same in most workshops:

1. Preparation
2. Degreasing
3. Rinsing 1
4. Pickling
5. Rinsing 2
6. Passivation
7. Maintenance Cleaning
8. Rinsing 3
9. Waste Water Treatment /Neutralization
10. Inspection



When cleaning stainless steel with finishing chemicals, clear instructions must be followed.

d) Pickling Methods and Their Usage

Product	Application	Results
Pickling Paste/Gel	For welding areas and small surfaces	
Spray	Larger surfaces, complex constructions, mixed materials, and carbon steels, such as the cleaning of pipes and tubes	
Immersion / Pickling Bath	Automated process, cost effective, complex constructions and tanks	

5 – AN INTRODUCTION TO SURFACE TREATMENT – CLEANING CASE STORIES

“Built to last – around the world architecture is considered the greatest art of mankind.“

Famous buildings, bridges and monuments make a difference, and they need to be maintenance cleaned in order to stay corrosion resistant. Here we want to highlight the importance of maintenance cleaning around the world.

Made of stainless steel, they reflects how we want the material to be :

- **We want stainless steel to stay corrosion resistant.**
- **We want stainless steel to stay clean.**
- **We want stainless steel to stay strong.**
- **But most of all, we want stainless steel to stay beautiful.**

Kuala Lumpur, Petronas Towers Cleaned with Avesta Finishing Chemicals

a) Buildings: Stainless steel is the preferred construction material thanks to its strength, beautiful finish, corrosion resistance, and fire resistance. In recent years, the use of stainless steel in buildings has increased , mainly due to its corrosion properties, leading to a long service life. (e.g. Petronas Twin Towers, Hearst Tower, Reichstag)

b) Bridges: They are unique in that they are exposed to highly corrosive sea water, heavy traffic and exacting aesthetic requirements. Bridges require high cleaning standards to meet public expectations. (e.g. Bridge of Bilbao Guggenheim)

c) Monuments: Many popular monuments are made of stainless steel because it is corrosion-resistant, beautiful and durable. (e.g. Chicago Bean)

d) Waterparks : The corrosion resistance of stainless steel offers a fantastic building material for waterparks parks and swimming pools. This is especially true for those building materials that come in contact with chlorinated water, or sea water if the pool is located at the seaside.

Need for maintenance cleaning: In addition, the hygiene and safety requirements in public facilities require the waterparks to be cleaned and maintained on a regular basis. We work with waterpark manufacturers who offer an annual cleaning service with our products.

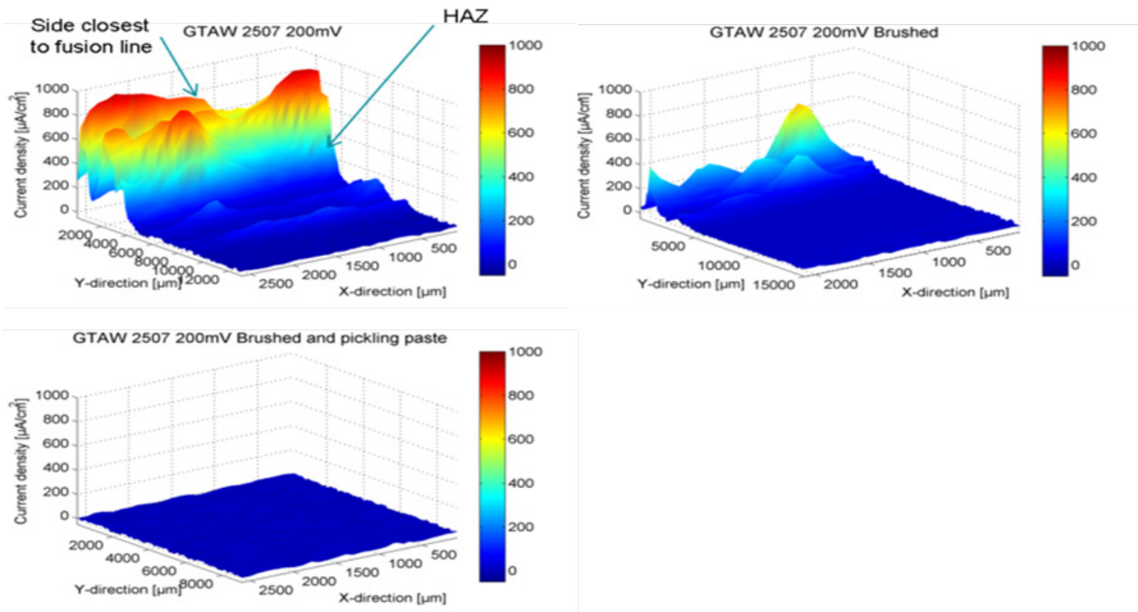
CONCLUSIONS

European Commission-funded JOINOX study, (2012-2016) provided a best practice guide for the post-weld cleaning of stainless steel, specifically aimed at preventing future corrosion. The outcome was clear: pickling is the most efficient method for cleaning welds to ensure corrosion resistance.

Mechanical cleaning methods alone, such as grinding or blasting, proved insufficient for removing the anodic activity that forms in the heat-affected zones.

The most effective approach was a combination of brushing and subsequent pickling, which consistently led to higher critical pitting temperature (CPT) values, using the selective vapor extraction technique (SVET).

Only pickling ensures complete corrosion resistance of the weld seam, i.e. mechanical means alone are not sufficient. Pickling is the most efficient method for cleaning large surfaces. In addition, pickling also provides an even and homogenous surface and guarantees a long-lasting and corrosion-resistant finish. Furthermore, iron impurities are also removed by passivation, which is an important choice after mechanical cleaning to properly restore the passive layer.



voestalpine Böhler Welding and the team of experts from finishing chemicals are at your side, providing you with guidelines for the best, safest and most effective treatment of stainless steel with our finishing chemicals and expertise.

ANDERS BORNMYR

GLOBAL PRODUCT MANAGER

SALES DEVELOPMENT SPECIALIST FINISHING CHEMICALS

voestalpine Böhler weldCare

Mr Anders Bornmyr is Global Product Manager and Sales Development Specialist of Finishing Chemicals for voestalpine Bohler weldCare, one of the world's largest manufacturers of refined finishing chemicals for the cleaning of stainless steel. As a senior member of the Global Product Management team, Anders is involved in new product developments, customized product applications and overall business strategy for the global finishing chemicals business.

Having traveled extensively and spent much time in the field, he has developed a greater understanding of the specialized requirements necessary in shipbuilding, repair and maintenance, as well as industrial vehicles and stainless-steel applications.

Operating out of Sweden, Malmö, from the worlds most modern and safe production plant for pickling products, with a start of production in December 2020, Anders and his team have made significant advancements in surface treatment technology driving enhancements in productivity together with cost saving initiatives to benefit both business partners and their end customers.

Anders with a M.Sc. has studied material science, chemical engineering and business administration at the Technical University in Gothenburg and in Karlstad, Sweden. He has more than 35 years of experience from working with surface treatment in the stainless steel industry. Anders oversees the most comprehensive portfolio of finishing chemicals in the industry for the cleaning, pickling and passivation of stainless steel.