

# CLEANING STAINLESS STEEL SURFACES PRIOR TO SANITARY SERVICE

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# Cleaning Stainless Steel Surfaces Prior to Sanitary Service

Arthur H. Tuthill,<sup>1</sup> Richard E. Avery,<sup>2</sup> and Roger A. Covert<sup>3</sup>

## SUMMARY

This article describes practical procedures for cleaning stainless steel surfaces for use in the dairy, other food and beverage, pharmaceutical, and similar industries. Types of surface contamination that might occur, along with their prevention and removal are included. Also mentioned are various steps to be taken to obtain clean surfaces initially.

However, during shipment or as the material is fabricated into process equipment and during service use, surfaces may become fouled with many types of damage and foreign matter (11, 12). For stainless steel to perform well, all of this contamination must be removed. Table 1 summarizes the defects discussed in this paper and means for their removal.

## THE NATURE OF THE SURFACE OF STAINLESS STEEL

Before going into cleaning details, we need to consider the surface of stainless steel. When stainless steel is removed from the acid pickling bath and rinsed in water at the steel mill, a thin, adherent oxide film is formed instantaneously (Fig. 1). This film, typically 8 to 10 Angstroms ( $3$  to  $4 \times 10^{-8}$  inches) thick is a transparent chromium oxide also containing iron and nickel. It is the surface that we see and that the environment contacts. When properly formed and clean, it is quite inert under most conditions. In this state, the stainless steel is often said to be passive (5, 6, 7). Subsequent "passivation" treatments (8) are mainly cleaning procedures that do not induce passivity but may repair defects in the film and remove substances that could lead to damage of the protective film.

## INTRODUCTION

Because industries such as the dairy, other food and beverage, pharmaceutical, and biotechnology are always concerned with product purity, austenitic chromium/nickel stainless steels are often the materials of choice for process equipment, especially for surfaces in contact with products. However, to take full advantage of the excellent properties of stainless steel, the surface must be free of foreign and

contaminating deposits and defects (11, 12). These can be eliminated by recognizing their sources and by following good removal and cleaning procedures.

## SURFACE CLEANLINESS

The producers of stainless steel mill products, i.e., plate, sheet, strip, bars, and castings, make a concerted effort to deliver their products in a clean surface condition with the surface finish ordered.

Figure 1. Cross-section of stainless steel surface.



**TABLE 1. Surface defects and their removal**

<b>Defect</b>	<b>Removal techniques</b>
Dust and dirt	Wash with water and/or detergent. If necessary, scour with high pressure water or steam.
Loose iron particles and embedded iron	Immerse surface in 20% nitric acid solution. Rinse with clean water. Confirm removal with ferroxyl test. If iron is still present, immerse in 10% nitric-2% hydrofluoric acid solution. Rinse with clean water. Confirm removal with ferroxyl test. Remove all traces of ferroxyl test with clean water or dilute nitric or acetic acid.
Scratches heat tint and other oxidation	Smooth surface by fine grit grinding. Pickle surface with 10% nitric-2% hydrofluoric acid solution until all traces are gone. Rinse with clean water or remove with pickling paste. Wash with clean water or electropolish. Rinse with clean water.
Rust areas	Immerse surface in 20% nitric acid solution. Rinse with clean water. Confirm removal of rust and any under lying iron with ferroxyl test. Rinse with clean water or dilute nitric or acetic acid.
Rough grinding or rough machining	Remove by fine grit grinding.
Welding arc strike marks	Remove by fine grit grinding or weld over if in line of weld.
Weld spatter	Prevent from adhering with anti-spatter compound or remove by fine grit grinding.
Welding flux	Remove by fine grit grinding.
Weld defects	If unacceptable, remove by grinding and re-welding.
Oil and grease	Remove with solvent or alkaline cleaners.
Residual adhesives	Remove with solvent cleaner or remove with fine grit grinding.
Paint, chalk, and crayon	Scrub with clean water and/or an alkaline cleaner.
Sulfide inclusions	Pickle surface with 10% nitric-2% hydrofluoric acid solution or use a low sulfur stainless steel. Do not use S30300 (Type 303).
Process products	Scrub with clean water or steam or dissolve in suitable solvent.
"Rouge" deposits	Dissolve with moderate strength nitric, phosphoric, citric or acetic acid. Rinse with clean water.

This film, though thin, is extremely durable and continuously maintained in air or other oxidizing environments such as aerated water or nitric acid. When damaged in these types of media, the film immediately reforms. There is little difference in the composition and properties of the film on different grades of stainless steel, although certain alloying additions such as molybdenum can further stabilize the oxide and improve corrosion resistance.

### **SURFACE DAMAGE AND FOREIGN MATTER INTRODUCED DURING FABRICATION**

Surface damage, defects, and interfering substances such as dust and dirt, loose iron particles, embedded iron, heat tint and other oxidation, rust spots, grinding burrs, welding strike marks, weld spatter, welding flux, weld defects, oil and grease, residual adhesives, and paint, chalk and crayon marks may arise during fabrication of equipment (1). Some of these are depicted pictorially in Fig. 2. Most are unintentional or done through ignorance of their deleterious effects; nonetheless, they are potentially harmful to the protective oxide film. Once the film is damaged, weakened or otherwise altered, the substrate stainless steel may start to corrode. Corrosion will usually not occur over the entire surface, but at or adjacent to the defect. Such localized attack is usually pitting or crevice corrosion, both of which can be very deep and/or extensive where they occur, while the bulk of the surface remains unaffected (Fig. 3 and 4). A discussion of each of these problem-causing occurrences is given.

**Dust and dirt.** Fabricating is often done in dusty, dirty places where small airborne particles are common. These frequently settle on equipment surfaces. They can usually be removed by a water or alkaline chemical wash. However, tenacious deposits of dirt and grime may require high pressure water or steam cleaning.

Figure 2. Types of surface defects arising during fabrication.

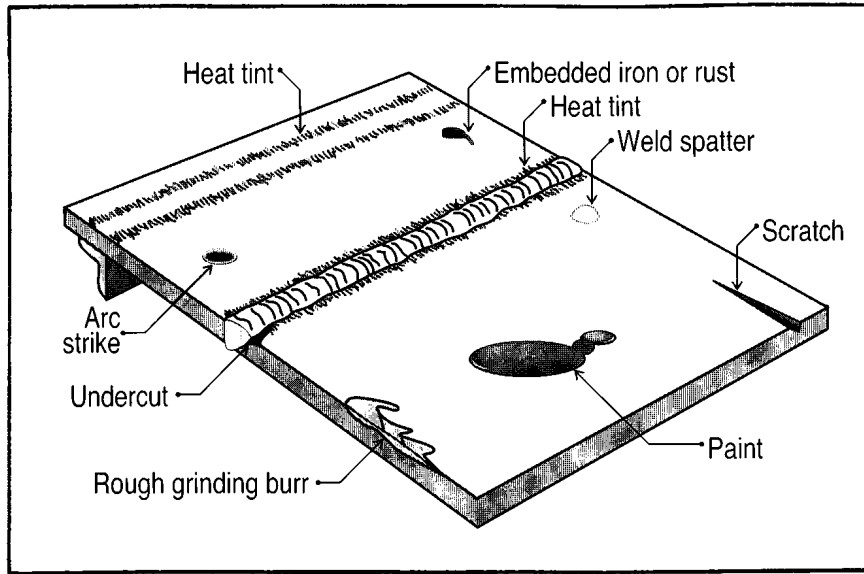


Figure 3. Pitting corrosion.

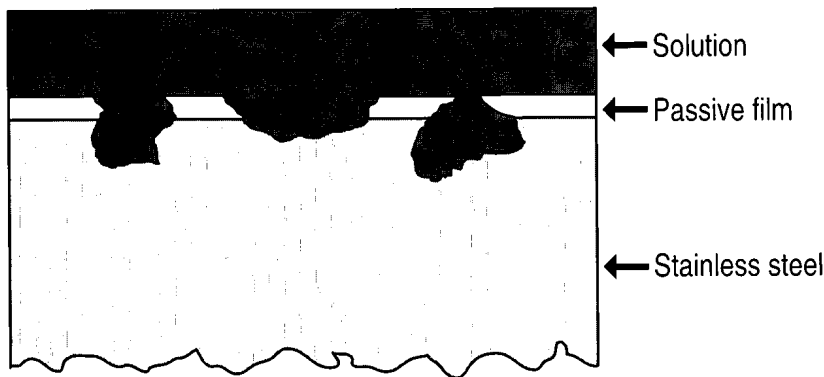
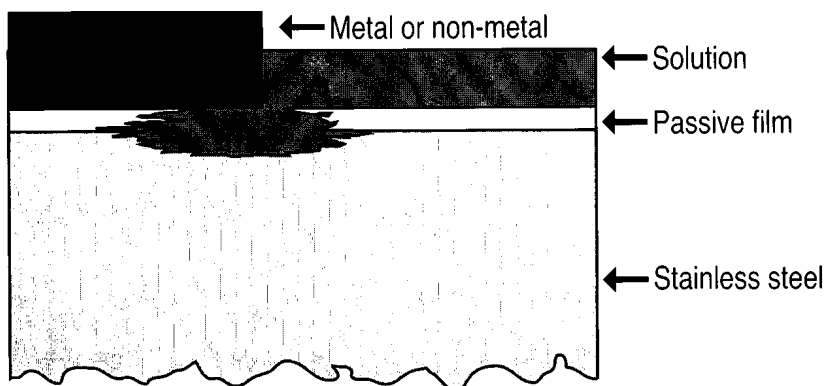


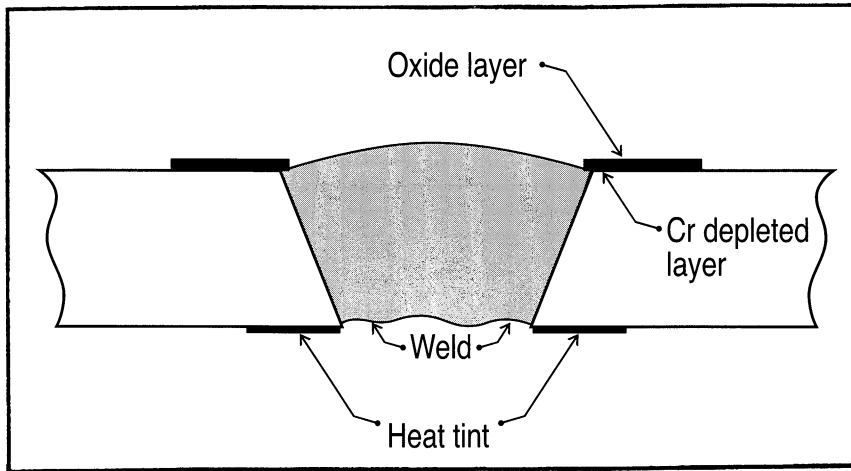
Figure 4. Crevice corrosion.



**Loose iron particles and embedded iron.** On any surface, free iron can rust and act to initiate corrosion of stainless steel. Therefore, it must be eliminated. Loose iron particles are usually removed with dust and dirt. However, some particles are more tightly adherent and must be considered as a form of embedded iron. Aside from dust, surface iron can arise from numerous sources. Among these are wire brushing with a plain carbon steel brush, blasting with sand, glass beads or other grit that has previously been used on plain carbon or low alloy steels or cast iron, or grinding these latter materials in the proximity of stainless steel parts and equipment. Iron is also easily embedded or smeared on surfaces during layout and handling unless stainless steel is protected from contact with steel wires, straps, slings, clamps, and table tops.

Procurement specifications and post-fabrication inspection can prevent and detect the presence of free iron. ASTM Standard Practice A 380 (3) describes the ferroxyl test for finding iron or steel particles on stainless steel surfaces. It should be used when maximum insurance against the presence of iron is required. If a positive test result is observed, surfaces should be thoroughly scrubbed with clean, pure water or nitric acid until the intense blue color is no longer apparent. As noted in A 380 (3), the test is not recommended for process surfaces of equipment that will be used for products for human consumption unless all traces of the ferroxyl test solution can be completely removed. A simpler test consists of exposure to water for 12 to 24 hours to see if rust spots appear. This test is less sensitive and, of course, more time consuming. It should be remembered that these are detection tests and not cleaning methods. Cleaning by the chemical and electrochemical techniques described later is necessary when iron is found.

**Scratches.** Scratches and other rough spots should be mechanically removed to prevent entrapment of process reactants or products and/or contaminants. For details, see

**Figure 5.** Cross-section of stainless steel weld.

the section on mechanical cleaning methods.

**Heat tint and other oxidation.** If stainless steel surfaces are heated to moderately high temperatures in air during welding or grinding, a chromium oxide heat tint develops on each side and on the under surface of welds and ground areas (Fig. 5). Heat tints are thicker than the protective oxide film and very visible. Their color depends on their thickness and varies from iridescent reds, blues, and violets to straw colors and browns. Thicker oxides are usually black. These result from higher temperatures or from moderate temperatures for prolonged times. When any of this oxidation occurs, the chromium content of the metal surface is reduced, resulting in areas of lower corrosion resistance. Thus, not only the heat tint and other oxidation should be removed, but also that portion of the underlying metal surface with reduced chromium.

**Rust areas.** Areas of rust are sometimes seen on stainless steel products and equipment before and during fabrication. This is usually an indication of a badly contaminated surface. Rust must be removed before putting the equipment into service. The ferroxyl and or water tests should be used to confirm that surfaces have been thoroughly cleaned.

**Rough grinding and rough machining.** Both operations leave

a rough surface that can include ruts, overlaps and burrs. Each can also deform the metal to a depth such that the damaged metal may not be removed by pickling, electropolishing or blasting. The roughened surface can act as a site for corrosion initiation and entrapment of products. Grinding with coarse abrasives should be limited to such operations as the removal of weld defects prior to rewelding or removal of excessive weld reinforcements. In the latter case, subsequent fine grinding is suggested.

**Welding arc strike marks.** When a welder strikes an arc on a metal surface, a rough defect is made. The protective film has been damaged and a potential corrosion site exists. The welder should strike the arc on the previous weld bead or on the side of the joint ahead of the weld and then weld over the strike mark.

**Weld spatter.** The tendency for weld spatter varies with the welding process. For example, gas tungsten arc welding (GTAW) or tungsten inert gas (TIG) processes are quite free of spatter. However, incorrect welding parameters with gas metal arc welding (GMAW) and flux cored arc welding (FCAW) can cause excessive spatter. When this occurs, adjustments are necessary. If there is concern over weld spatter, adherence of spatter can be eliminated by painting each side of the joint with an anti-spatter

compound prior to welding. This paint, with any weld spatter, is easily removed after welding with little or no damage to the surface.

**Welding flux.** Welding processes that employ a flux such as shielded metal arc, flux cored arc, and submerged arc may leave small particles of flux that are not removed in normal clean-up. These particles create sites for the initiation of crevice corrosion. Mechanical cleaning techniques are necessary for removal of residual flux.

**Weld defects.** Weld defects such as undercut, incomplete penetration, porosity, and cracks not only reduce the integrity of the joint but also act as locations for crevice corrosion. During product changeover cleaning operations, they also present problems by entrapping solids. Usually, these defects are repaired by re-welding or by a combination of grinding and rewelding.

**Oil and grease.** Organic materials such as oil, grease, and even fingerprints produce places where localized corrosion can start. Also, because such substances can act as shields, they interfere with chemical and electrochemical cleaning and must be completely removed. ASTM A380 has a simple waterbreak test to detect organic contamination. In it, water that is poured at the top of a vertical surface tends to "break" around areas of organic substances as it flows downward. Solvent and/or alkaline chemical washes will eliminate oils and greases.

**Residual adhesives.** Residual adhesives from tape and protective paper often remain on surfaces when they are stripped. If the adhesive particles are still soft, organic solvents will usually remove them. However, when exposed to light and/or air, adhesive particles harden and form sites for crevice corrosion. Fine-grit mechanical cleaning is then needed.

**Paint, chalk, and crayon marks.** The effects of these contaminants are similar to the effects of oil and grease. Scrubbing with a clean brush and either clean water or an alkaline chemical



cleaner is suggested. High pressure water or steam can also be used.

## **SURFACE DEFECTS CAUSED BY THE METAL STRUCTURE**

The surface imperfections discussed above have been caused by events that are due to outside sources, not to the stainless steel. Other defects can be attributed to the metal structure. Because of the ways metals are melted, poured, and cast before forging and/or rolling to shape, most alloys, including the stainless steels, contain solid, non-metallic inclusions. Other substances can also be forced into surfaces during forming operations. When exposed on the surface, some of these particles, especially sulfides, provide places where pitting corrosion can start. Normally these inclusions are removed during acid pickling, but in some cases when sulfur has been added for machinability, a sufficient number of particles remain to cause problems.

To minimize the occurrence of mill-related surface defects on finished equipment, the equipment manufacturer should visually inspect the as-received material and finished product surfaces for defects. The equipment purchaser should make a similar inspection. Minor or occasional defects can usually be removed by grinding with a fine grit abrasive. Sulfur-related defects are most often encountered with S30300 (Type 303), a free-machining grade of stainless steel commonly supplied as bar stock. To eliminate sulfide inclusions and stringers, a good choice is to use S30400/S30403 (Type 304/304L) or S31600/S31603 (Type 316/316L).

## **SURFACE DEFECTS AND "ROUGING" FROM PROCESS CONDITIONS OR OTHER SOURCES**

Dried process product deposits are examples of in-process surface contamination. In the food, beverage, and pharmaceutical industries, process equipment commonly has

multiple uses. This necessitates frequent cleaning between production of different products. Sometimes cleaning is incomplete and deposits of former products are left behind. These can act as locations for pitting and crevice corrosion. Thorough removal by scrubbing and/or dissolution is necessary on all surfaces.

Under certain incompletely understood conditions, but usually in high-purity, high-temperature water and steam environments, deposits known as "rouge" appear (9, 10). Much of the time, where they come from and why they form where they do is not clear. Some are loose and powdery, others tightly adherent to the surface. Even the name is a misnomer, for their colors vary widely; usually red or reddish-brown to orange, they have also been reported as gray, black, purple, blue, and even yellowish-green. Double layer "rouges" have also been found, with the layer next to the metal surface being black and the outer one reddish-orange. White particles are sometimes present. About the only agreement is that the "rouge" is primarily ferric oxide or a hydrated form of this substance. At least this is reasonably consistent with some of the observed colors, since iron oxides are usually rust colored ( $\text{Fe}_2\text{O}_3$ ) or black ( $\text{Fe}_3\text{O}_4$ ).

The source of the material for the "rouge" deposits is usually unknown (9,10). The "rouge" is not apparent on startup but can appear at any time from a few days to years after equipment is put in use. Sometimes it appears on all surfaces and at other times only in specific places. Corrosion at the site of the deposit apparently is not responsible. If in situ corrosion of embedded or particulate iron is the cause, then deposits should appear initially, not weeks or even years later. Some observers think that "rouge" originates from corrosion of steel or low chromium stainless steel in equipment such as steam generators and piping prior to the location of the deposit. Others think it comes from grinding and weld debris, heat tint, and other improperly cleaned areas. Impure

make-up and in-take water have also been suggested. Whatever the source, it appears that iron-containing material dissolves and is then transported as ions or colloids to an appropriate location where conditions are conducive to precipitation.

Regardless of the reasons for the various forms of "rouge," they are contaminants that can not be tolerated in clean, sanitary systems (9, 10). Particles can break away from surfaces and introduce impurities into products. These same particles can clog filters and strainers. Localized pitting corrosion can initiate under "rouge". When found, it must be removed. Thin "rouge" deposits can sometimes be detected by wiping a clean white cloth or glove over the surface. A dark smudge will appear on the cloth. Acid cleaning techniques are usually required to remove "rouge". Moderate strength solutions of nitric, phosphoric, citric and oxalic acids have been used satisfactorily. Inhibited hydrochloric acid with and without ferric chloride has been tried, but there is always a risk of stainless steel corrosion in these media. Since "rouge" formation can be a recurring phenomenon, repeated acid cleaning is required each time deposits are found.

## **REMOVAL OF SURFACE CONTAMINATION: MECHANICAL CLEANING**

Mechanical cleaning techniques such as abrasive particle blasting, wire brushing and grinding are commonly used in fabricating shops. However, care must be used when employing these methods. When blasting, a clean abrasive, free of carbon or low-alloy steel or cast iron particles must be used. Clean glass beads are effective as are pieces of walnut shells. These latter types of media have the added advantages of not excessively roughening or deforming the surface as sand or other harder-grit particles may.

Wire brushing should be done only with brushes made with

stainless steel bristles. These brushes should not have been used previously on carbon or low-alloy steels, cast iron, or any materials other than a stainless steel alloy.

Clean abrasive disk and clean flapper wheel grinding are common methods used to remove heat tint and minor surface contamination and imperfections. Care must be taken, for, as in many grinding operations, these treatments can alter surfaces and affect corrosion resistance.

Grinding with hard grinding wheels deforms and changes surfaces to a greater degree than the techniques already discussed. Heavy grinding should be limited to grinding surfaces for welding and removing weld defects prior to re-welding. The high amount of deformation resulting from grinding can alter microstructure at the metal surface. Although this does not always affect corrosion performance, high stresses and possible surface cracking may lead to serious problems. Where practical, grinding should be limited to abrasive discs and flapper wheels instead of grinding wheels. Heavily worked surfaces should be removed by the chemical and electrochemical methods described in the next section.

### **REMOVAL OF SURFACE CONTAMINATION: CHEMICAL AND ELECTROCHEMICAL CLEANING**

Embedded iron, heat tint, the chromium-depleted layer under heat tint and oxides, the smeared/ altered layer left by mechanical cleaning operations, and sulfide inclusions can be removed by acid pickling, electrochemical dissolution or polishing. These processes remove, in a controlled manner, the affected areas, the thin oxide film, and a thin layer of metal under it. A thoroughly clean, defect-free surface results. The protective film reforms after exposure to air, aerated water or nitric acid.

ASTM Standard Practice A380 (3) gives a number of solutions for chemical cleaning and pickling. The most common ones are those

Nickel Development Institute containing nitric acid. The plain acid, at around 20% concentration, is very good for removing smeared and particulate iron. However, for removing heat tint and oxidation, a solution of about 10% nitric acid and 2% hydrofluoric (HF) acid is suggested. The HF addition is essential; without it, the stainless steel will not corrode and any chromium-depleted areas will not be removed. Pickling is usually done by immersion or by flushing piping systems with the appropriate acid solution. When equipment will not fit into tanks or is not amenable to flushing, commercial products known as pickle pastes can be used. These are applied to surfaces with a paint roller or brush. The coating is then removed by water after its active agents have reacted sufficiently. Since pickling solutions and pastes roughen surfaces if exposures are too long, the processes should be carefully controlled. Obviously, these techniques change surface appearance, but usually not in an unacceptable way.

In electrochemical cleaning or electropolishing, the stainless steel surface is removed through the application of a direct electrical current in a suitable electrolyte. Depth of metal removal can be controlled very closely. Unlike pickling, which roughens the surface, electrochemical processes tend to smooth or "polish" surface irregularities and dissolve many forms of defects. Sometimes, to achieve the required surface smoothness, a combination of mechanical polishing followed by electropolishing is needed. In the grinding step, metal particles can be embedded or entrapped in the surface. Controlled electropolishing will remove them and prevent future problems. There are many claims that the superior surface smoothness produced by electropolishing enhances corrosion resistance, but experience usually shows that cleanliness is a more important factor than surface roughness. The fact that electropolished surfaces are often easier to clean may account for the beneficial effects of electropolishing on

corrosion resistance. Electrochemical cleaning and polishing are usually done by immersion, which is not always possible with large, complicated equipment. If that is the case, hand-held devices such as that shown in Fig. 6 are available for use on local areas.

### **PASSIVATION**

Passivation treatments for stainless steel have been mentioned before. ASTM A380 (3) describes a number of passivating solutions and methods. These are generally accepted as no more than moderate cleaning techniques. Whether they greatly improve corrosion resistance is open to question. They may help repair, but they do not significantly change the protective oxide film, nor do they remove any substantial amount of surface defects, depleted zones or other metal. They will often remove metallic and other soluble material adhering to machined or dirty stainless steel surfaces.

### **PROCUREMENT OF CLEAN STAINLESS STEEL EQUIPMENT**

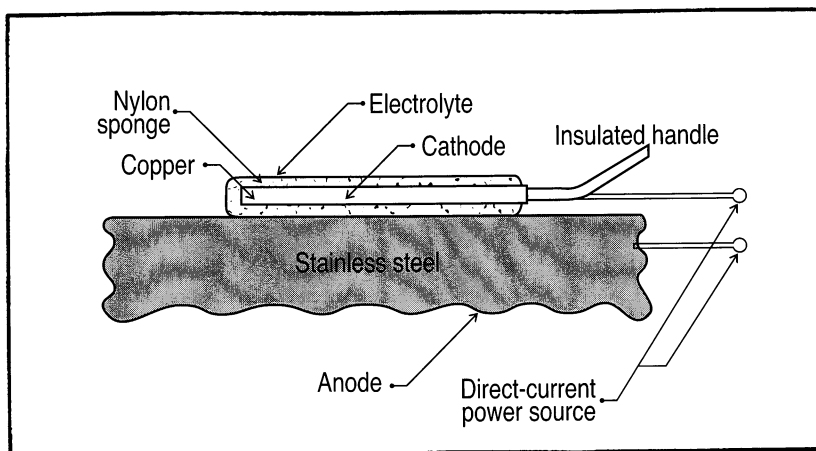
As mentioned before, many surface defects are introduced during fabrication and handling of materials and equipment. Through insistence on proper procedures and inspection in procurement documents, many problems associated with manufacturing errors and carelessness can be avoided. Where possible, "off-the-shelf" products should be subjected to the same stringent requirements as custom fabricated equipment.

Purchasing specification suggestions are as follows:

1. All surfaces to be in contact with process products must be free of oil, grease, fingerprints, crayon, ink marks, paint, tape and other substances containing organic matter. The water break test from ASTM A380 (3) should be required.
2. All surfaces must be free of iron contamination. The ferroxyl and/or water tests



Figure 6. Hand-held electropolishing tool.



from A380 (3) should be required.

3. All welds must be free of heat tint, other oxidation, weld spatter, welding strike marks, welding flux, and smeared layers from brushing and grinding. If visual inspection reveals these defects, appropriate mechanical, chemical and/or electrochemical treatments should be required.
4. All weld defects such as incomplete joint penetration, incomplete fusion, and cracks should be repaired by grinding and re-welding. Undercut and porosity, in excess of agreed-upon limits, should be repaired by grinding or by grinding and re-welding.
5. Closure of all openings after cleanliness has been achieved should be required. Require closures to remain in-place after final assembly and during shipment.
6. Equipment should be inspected at the supplier's site, prior to shipment, for compliance with 1, 2, 3, 4, and 5.

### SPECIAL CONSIDERATIONS FOR PLATE, PIPE AND TUBING, BAR, AND CAST PRODUCTS

These products present special problems when surface quality is

important. Comments on each are as follows:

1. **Plate.** Plate is considered to be material over 5 mm (3/16 in) in thickness. Although plate usually is supplied in the hot rolled and pickled condition, ASTM Specification A480/A480M (4) describes five finishes for plate products. The ground and polished No. 4 finish, which is produced by grinding with size 150 grit, is suitable for sanitary service. The others are normally too rough. They may also contain slivers and other defects which can be corrosion-initiation sites. Sometimes stainless steel mills can provide acceptable surfaces on plate without polishing, but special arrangements must be made.
2. **Tubing and Pipe.** Welded tubular products with a wall thickness of 5 mm (3/16 in) or less are made from sheet or strip. The original surface quality of this product form is usually quite bright and smooth. ASTM Specification A270 (1) is widely used where ease of cleanability is a requirement. Tubing made to A270 (1) is available with ground, polished or electropolished surfaces. Tubular products made to other ASTM specifications such as

A312/A312M (2) most often have a pickled surface.

Heavier walled tubular products are made from plate and have the same surface finishes as above. Again, the No. 4 finish should be specified when needed for sanitary service.

When tubular products and other components are joined by welding, it is essential that the inside surface be free of heat tint before equipment is put in service. Carefully controlled pickling can be used to remove this oxide. Some manufacturers produce tubing with interior surfaces electropolished after welding. Automatic orbital welding is an excellent technique that produces a smooth weld essentially free of heat tint.

3. **Bar.** For improved machinability, many stainless steel bar products are made from special high-sulfur alloys such as S30300 (Type 303). This leads to an increased number of normally globular sulfide inclusions that are elongated as the bars are formed. Because of their length, the inclusions may not be completely removed by pickling, especially on the ends. Also, machined parts are often not pickled as a standard procedure. This can lead to major problems, because exposed sulfides can act as sites for pitting to begin. The best practice is probably to use only the standard, low-sulfur alloys and accept higher machining costs.
4. **Castings.** Most of the common grades of stainless steels have cast counterparts. The composition of these may be slightly altered to ensure good castability, but their corrosion resistance is comparable. The major concern in using castings is that they usually have rougher and more

porous surfaces than wrought products. Also, there has often been considerable grinding and weld repair. It is important that users of stainless steel castings insist on good quality castings and demand the same cleaning procedures as those used on equipment fabricated from wrought products.

## CLEANING OF EQUIPMENT AFTER INSTALLATION AND OPERATION

Equipment often becomes dirty and contaminated during installation and operation. Precipitates, product deposits, dust and dirt, and other matter adhering to surfaces must be removed. Usual in-service cleaning procedures include all or some of the following:

1. Draining and rinsing with clean water.
2. Lancing with high pressure clean water.
3. Injection of low-and/or high-pressure steam.
4. Flushing with solvents or alkalis to remove oils, greases, and other organic substances. If alkalis or alkaline cleaners are used, a clean water rinse must follow.
5. Flushing with acids, followed by rinsing with clean water. If hydrochloric acid is used, extreme care must be taken, because residual chloride ions can promote pitting, crevice corrosion, and/or stress corrosion cracking.

## SUMMARY

1. Stainless steel forms a stable, self-protecting oxide film on exposure to air and/or aerated water. It is not necessary to use passivating treatments to obtain maximum corrosion resistance.

2. Common fabricating operations frequently damage and contaminate stainless steel surfaces. When this occurs, the surface must be cleaned by mechanical, chemical, and/or electrochemical techniques. After cleaning by these methods, the oxide film will reform spontaneously.
3. Machining and rough grinding often leave a layer of smeared metal on stainless steel surfaces. This should be removed by chemical or electrochemical processes.
4. Heat tints and thicker oxides from welding must be prevented or removed mechanically, chemically, and/or electrochemically.
5. Weld defects must be repaired by grinding and rewelding.
6. Surfaces after acid pickling are rougher than those after electrocleaning.
7. Acid pickling and electro-polishing are usually done by immersion. However, commercial pickle pastes and hand-held electro-cleaning tools may be used.
8. To ensure good surfaces, special attention is necessary during the procurement of plate and pipe products.
9. Because of the inherent roughness of castings, special care and procedures are necessary when cleaning them.
10. To ensure satisfactory surface cleanliness, cleaning procedures and specifications must be included in procurement documents. On-site inspection before shipment is recommended.

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