Passivation:

Protecting Stainless Steel Food Processing Equipment

… and the Consumer

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Why do food processors need to go an extra mile in protecting their stainless steel equipment from corrosion? Aren't stainless steel's natural rust-inhibiting properties the reason for specifying it in the first place?

The case for extra caution is clear: because it comes in contact with the food supply of the nation and the world, food processing equipment demands the highest level of sanitation and cleanability.

However, during fabrication, stainless steel comes into contact with various iron tooling and shop contaminants. These may chip, gouge, smear and embed micro-particles of free iron, oxide scale, rust, metal chips or other deposits into its surface. **And those materials *do* rust.** If not removed, they'll degrade the natural corrosion-resistance that stainless steel is known and used for. The result is an unsanitary surface unsuitable for food-grade environments.

The industry can ill-afford to court food-borne bacteria. Our role in providing products to supermarkets and foodservice puts us in the front lines of public safety. According to the Centers for Disease Control (CDC), food-borne illnesses cause about 325,000 hospitalizations and 5,000 deaths every year in the United States. Product recalls cost us millions of dollars, including lawsuits, getting food off shelves and overhauling plants. This is economically devastating – not counting injured reputations and lost sales that are harder to put in dollar terms.

How Stainless Steel "Works"

Steels with more than 11% chromium naturally form an imperceptible and self-healing oxide surface film. Oxygen in the air combines with the chromium to form this microscopic layer (about 100,000 times thinner than a human hair) giving stainless steel its signature no-rust appeal.

While stainless is the preferred general-use metal for food-contact surfaces, not all grades are equal. Corrosion resistance varies with chromium level, and structural strength varies with nickel level. The American Iron and Steel institute (AISI) 300 Series Stainless Steel is typically recommended for food contact. 3A Sanitary Standards, long recognized as the authority for the dairy industry, call for 316 stainless steel for most surfaces.

Several methods have been developed to maximize the integrity of this material:

- **Electropolishing** can smooth and brighten the surface of stainless steel via immersing in an electrolyte bath and subjecting it to direct electrical current that dissolves metal ions and forms a film to block corrosion. The more reflective surface discourages food from sticking and improves cleanability.

- **Media Blasting** is a primary clean-up method used by fabricators to remove contaminants, though it does not restore the corrosion-resistant film. Obviously, the abrasive medium has to be iron-free – even sand is on the do-not-use list because it might contain iron and steel. According to the British Stainless Steel Association, fine glass beads are the preferred blast medium.

- **Pickling** (chemical descaling) is typically used to remove oxide layers and scale resulting from weld burn, heat-treating and other high-temperature operations. Chemically aggressive, pickling removes the surface layer and any contaminants in it – but, as a result, it can dull visual brightness to a degree. To develop full corrosion resistance, many sources suggest that pickling be used in tandem with **nitric acid-based passivation.**

Passivation: Preferred for Food Processing

Passivation is a post-fabrication procedure that **restores** stainless steel's natural non-corrosive properties. It changes stainless from an active state, in which it will corrode, to a passive state in which rust is resisted. It dissolves embedded iron and other surface contaminants and re-forms the thin, protective oxide surface film.

Proper passivation is integral to pharmaceutical, chemical, medical and aerospace manufacturing **– and a major advantage to food processing.** Sanitation failure can be catastrophic, with tremendous losses in product, sales, time and reputation. Food safety has both monetary and social value.

The Process

1. The first step in successful passivation is thorough cleaning to remove grease, lubricants, cutting fluids and shop debris. Typical methods include vapor degreasing, solvent cleaning and alkaline soaking. Thermal oxides may be removed by media blasting, grinding or pickling. It's important to remove all iron-containing fabrication residues to prevent localized corrosion sites.

   When a passivation provider skips the cleaning process, damage can be serious. This can range from residual grease, which causes bubbles that interfere with the passivation procedure, to chemical reactions with cutting fluid called "flash attack" that leads to a gray/black appearance and surface deterioration.

2. Passivation itself takes place by immersing the entire piece of equipment in a bath of nitric acid, nitric acid/sodium dichromate solution or, in some cases, citric acid – at a closely controlled temperature and for a closely controlled amount of time. **Total immersion** is the only way to passivate the entire product completely and cost-efficiently. Less effective and ultimately more costly methods include spraying down, wiping down or partial, specific local applications.

   Immersion requires investment in large-scale tanks and expertise in acid chemistry, and is best handled in-house at the fabrication site. Outside operations can be expensive in processing, shipping, handling and time. And incorrectly performed, measures to control corrosion can actually trigger it instead.

3. Acid immersion is followed immediately by one or more rinses – spray, immersion or a combination. Exposure to air following the acid bath and rinse contributes to the final corrosion resistance. Longer dry times and/or drying at high temperature allows the passive oxide layer to grow deeper into the metal.

4. Lastly, testing – including water immersion, high humidity, salt spray and copper sulfate methods – can determine success in removing free iron and other contaminants from the surface. Stainless steel fabricators who supply passivation will provide testing and verification, and in-house test kits are available for processor use as well.

The Benefits

- Performed correctly, passivated stainless steel exhibits:
- Maximum corrosion protection of all surfaces
- No rust discoloration
- Cleanability / reduced potential for food contamination
- Increased durability
- Decreased system downtime
- Meeting of cGMP surface quality requirements (if applicable)

Food Industry Standards

With the intent of laying out a body of sound sanitary principles, a number of organizations have developed standards for food equipment fabrication and manufacture. The most prevalent for passivation processes today are the voluntary consensus standards of the American Society for Testing and Materials (ASTM). For more information, refer to ASTM A967 “Standard Specification of Chemical Passivation Treatments for Stainless Steel Parts” at www.astm.org.

The primary food equipment sources are the National Sanitation Foundation (NSF) (www.nsf.org) and 3-A Sanitary Standards (www.3-a.org), which recommends that surfaces be passivated (via nitric acid or other strong oxidizing agents) after fabrication and updated regularly to maintain a passive oxide film. Underwriters Laboratories (www.ul.org) has become involved in food equipment standards as well.

Conclusion

Passivation of stainless steel processing equipment can play an integral role in system performance and, ultimately, food safety. By dissolving embedded iron and other surface contaminants, it restores the naturally occurring oxidation that makes stainless steel so corrosion-resistant in the first place. Performed under closely controlled conditions after fabrication and before potential contact with contaminants during shipping and installation, this is an ideal measure to protect not only the stainless steel, but food processors and – in the end – consumers of our value-added products.

Salt Spray Test

This test exposes metal to controlled corrosive situations at an accelerated rate to help demonstrate the impact of potential environmental conditions.

Fig. 1 – Two fabricated stainless steel panels – top half passivated;
lower half non-passivated

Operations performed on panels: welding, bonding, forming, punching, cutting, grinding

Shown after 2-hour exposure to 5% salt fog

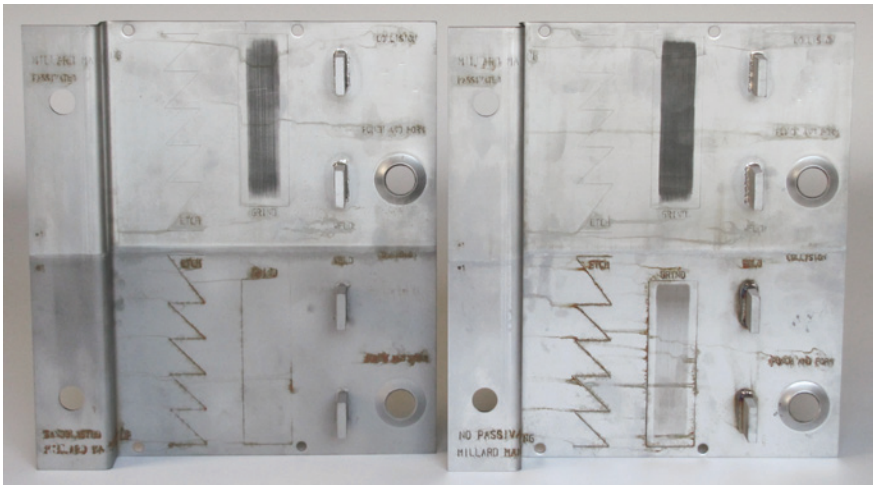

Fig 1

Passivation vs Non-Passivation

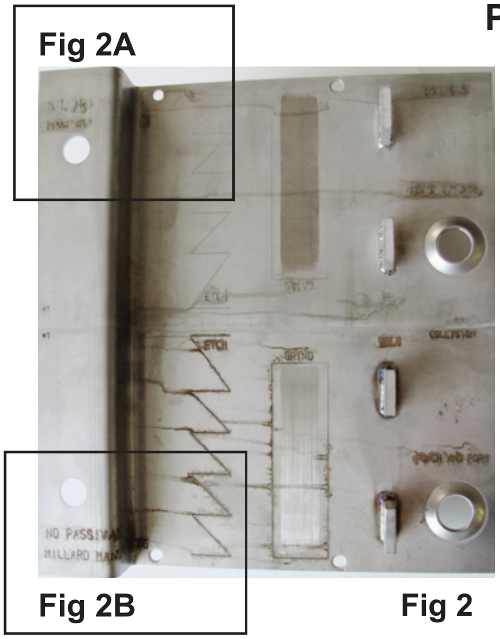

Fig 2A

Fig 2B

Fig 2

After salt spray testing:

Fig. 2 Top half: passivated
Lower half: non-passivated

Fig. 2A
detail, passivated panel

Fig. 2B
detail, non-passivated

Passivation vs Bead Blasted

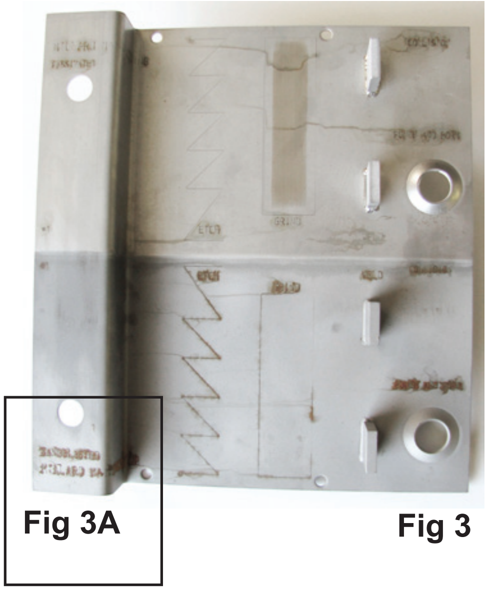

Fig 3A

Fig 3

After salt spray testing:

Fig. 3
Top half: passivated
Lower half: sand/bead blasted

Fig. 3A
detail, sand/bead blasted,
showing residual corrosion

Fig 4
Back of non-passivated panel;
shows corrosion where welding
was done on reverse side

Back View

*Testing performed to ASTM B17-11 z ASTM A967-13, Practice C Standards