or

What Makes Stainless "Stain-less"

A common misconception about stainless steel is that is not affected by corrosion. While misleading, the phenomenal success of the metal makes this common belief understandable. One of New York City's most impressive landmarks is the stainless steel clad peak of the Chrysler Building. Built in 1930 of 302 Stainless, a recent inspection revealed no signs of corrosion or loss of thickness. The tallest manmade monument in the US, the St Louis Arch, is entirely clad in 304 stainless steel plates. Except for cleaning, the stainless exterior of this monument has required no corrosion maintenance. Closer to home, housewives work in stainless steel sinks that shine as bright as the day they were installed. Every day the average American will come into contact with numerous examples of the success of stainless steel. And while the name correctly signifies the rust resistant properties of the metal, "stain-less" is not 100% "stain-proof" in certain applications.

All metals except gold, platinum, and palladium corrode spontaneously

To understand the possibility of corrosion in stainless, we must first understand what gives it the ability to resist. Stainless steel is a family of alloy steels containing a minimum of 10-1/2% chromium. The chromium, when in contact with oxygen, forms a natural barrier of chromium oxide called a "passive film". Only microns thick, this invisible and inert film is self-repairing (according to worldstainless.org the chromium oxide film is 130 Angstroms in thickness, an angstrom being one millionth of one centimeter) Alan Harrison, with the British Stainless Steel Association's Stainless Steel Advisory Service, wrote us and advised he describes the thickness of the passivation as "about one ten thousandth of the thickness of a human hair"..

To ensure stainless steel is able to "self-heal" itself, it is necessary that a finished product, i.e. fasteners, go through a process upon the completion of their manufacturing process. The process, called "passivation", has become extremely controversial, and appears to have become less defined due to outside forces such as environmental regulations and high costs. The technical term and common usage are quite different. Technically, and still necessary to meet military and aerospace requirements, fasteners are submerged in a nitric acid solution. Also known as pickling, this acid treatment removes impurities from the manufacturing process, including oil and grease, and fine metal particles which have come from fastener tooling. Removing these exterior barriers or obstructions, the acid helps accelerate the formation of the chromium oxide film. In the US, the common use of this term among fastener manufacturers is simply a cleaning process. This can be done by different methods, from submerging in acid to dipping a finished product into a mix of cleaning fluid, and then leaving the fastener exposed to air. This "cleaning" can be fairly effective, or totally inadequate, depending upon the fastener manufacturer.

Types of Stainless Corrosion

According to the DOD *Technical Bulletin Corrosion Detection and Prevention* there are 8 separate types of corrosion, with only a few having a major impact on stainless steel. Please be advised the descriptions below are extremely brief and written in laymen terms. Before acting on any particular application, qualified advice particular to such application should be obtained.

1. *Uniform Attack* - also known as general corrosion, this type of corrosion occurs when there is an overall breakdown of the passive film. The entire surface of the metal will show a uniform sponge like appearance. Halogens penetrate the passive film of stainless and allow corrosion to occur. These halogens are easily recognizable, because they end with "-ine". Fluorine, chlorine, bromine, iodine and astatine are some of the most active.

2. *Crevice Corrosion* - this is a problem with stainless fasteners used in seawater applications, because of the low PH of salt water. Chlorides pit the passivated surface, where the low PH saltwater attacks the exposed metal. Lacking the oxygen to re-passivate, corrosion continues. As is signified by its name, this corrosion is most common in oxygen restricted crevices, such as under a bolt head.

3. *Pitting* - See Galvanic Corrosion. Stainless that had had its passivation penetrated in a small spot becomes an anodic, with the passivated part remaining a cathodic, causing pit type corrosion.

4. *Galvanic Corrosion* - Placing 2 dissimilar metals in a electrolyte produces an electrical current. A battery incorporates this simple philosophy in a controlled environment. The current flows from the anodic metal and towards the cathodic metal, and in the process slowly remove material from the anodic metal. Seawater makes a good electrolyte, and thus, galvanic corrosion is a common problem in this environment. 18-8 series stainless fasteners that work fine on fresh water boats may experience accelerated galvanic corrosion in seawater boats, and thus it is suggested you examine 316 stainless.

The simplified galvanic series chart below will assist you in determining the potential electrical activity between 2 metals. Also included is a *Guideline for Selection of Fasteners based on Galvanic Action*

Galvanic Series of Metals and Alloys	
Magnesium	**Anodic More likely to be attacked**
Magnesium Alloys	
Zinc	
Aluminum 1100	
Cadmium	
Aluminum 2024-T4	
Steel	
Iron	
Cast Iron	
Lead-Tin Solders	
Lead	
Tin	**More Noble Cathodic**
Brass	
Copper	
Bronze	
Copper-Nickel Alloys	
Stainless Type 430 (Passive)	
Stainless Type 304 (Passive)	
Stainless Type 316 (Passive)	
Silver	
Graphite	
Gold	
Platinum	

More complete Galvanic Corrosion Chart

Guideline for Selection of Fasteners based on Galvanic Action

Fastener Metal

Base Metal	Zinc & Galvanized Steel	Aluminum & Aluminum Alloys	Steel and Cast Iron	Brass, Copper, Bronze, Monel	Martensitic Stainless (Type 410)	Austentic Stainless (Types 302, 303, 304, 305)
Zinc & Galvanized Steel	A	B	B	C	C	C
Aluminum & Aluminum Alloys	A	A	B	C	Not Recommended	B
Steel and Cast Iron	AD	A	A	C	C	B
Lead-Tin Plated Sheets	ADE	AE	AE	C	C	B
Brass, Copper, Bronze, Monel	ADE	AE	AE	A	A	B
Ferritic Stainless (Type 430)	ADE	AE	AE	A	A	A
Austentic Stainless (Type 302/304)	ADE	AE	AE	AE	A	A

A - The corrosion of the base metal is not increased by the fastener
B - The corrosion of the base metal is marginally increased by the fastener
C - The corrosion of the base metal may be markedly increased by the fastener material
D - The plating on the fastener is rapidly consumed, leaving the bare fastener metal
E - The corrosion of the fastener is increased by the base metal
Note - Surface treatment and environment can change activity
Source - "*Stainless Steel Fasteners A Systematic Approach To Their Selection" AISI 502-476-18M-CP*

5. *Intergranular Corrosion* - all austentic stainless steels contain a small amount of carbon. At extremely high temperature, such as welding, the carbon forces local chrome to form chromium carbide around it, thus starving adjacent areas of the chrome it needs for its own corrosion protection. When welding, it is recommended you consider low carbon stainless such as 304L or 316L.

6. *Selective Leaching* - Fluids will remove metal during a de-ionization or de-mineralization process. This usually happens inside a pipe and is rarely a fastener problem.

7. *Erosion Corrosion* - This corrosion happens when the velocity of an abrasive fluid removes the passivation from a stainless. Again, this is almost exclusively limited to pipe interiors and rarely a fastener problem.

8. *Stress Corrosion* - Also called stress corrosion cracking or chloride stress corrosion. Chlorides are probably the single biggest enemy of stainless steel. Next to water, chloride is the most common chemical found in nature. In most environments, the PPM are so small the effects on stainless are minute. But in extreme environments, such as indoor swimming pools, the effects can be extreme and potentially dangerous. If a stainless part is under tensile stress, the pitting mentioned above will deepen, and cracking may take place. If you are using stainless steel bolts under tensile stress, in an environment where chlorine corrosion is likely, you should examine the potential for stress corrosion cracking carefully.

According to a NACE International & CC Technologies study, corrosion costs the United States $276,000,000,000 annually. That's $276 billion and 4.2% of the nations GNP. In the power generation and transmission industry alone, it is estimated that nearly 8% of the typical electric bill is attributed to the cost of corrosion. It is unknown how many lives are lost annually due to corrosion but the number could be frighteningly high. Extreme examples thru the years include collapsed bridges and jet airliner crashes.

For additional reading on types of stainless, read FAA AC 43.13-1B Section 2 6-11 (document)

Methods to combat corrosion in stainless

Clean, clean, clean. A simplistic example of the effectiveness of cleaning is right in the house. A stainless kitchen sink can see some of the most hostile chemical attacks in a home. But the stainless stays bright. Why? Because the constant flow of fresh water and wiping down removes the harmful chemicals that if left unattended, could attack the stainless' passive film. The more hostile the environment, the more cleaning required. Cleanliness is essential for maximum resistance to corrosion.

Never use abrasive powders or materials on stainless. Always use a soft cloth. Mild detergents and soap can be used but those containing chloride detergents should be avoided.

Summary

No metal, except for gold and platinum in their natural state, are completely corrosion proof. But stainless steel has proven in thousands of applications, that it is one of the most economical solution's to combat the ever present elements that cause corrosion. Yet as its name implies - it is stain-less, not stain-proof

For additional reading we recommend the following sites with free pdf downloads
Materials Performance Supplement - Corrosion Costs and Preventive Strategies in the United States pdf

Photographs of Corrosion Types

Stainless Steel - Corrosion Resistance

Types of Stainless Steel Corrosion

Excellent article on Galvanic Corrosion with fastener samples

NST Center - (follow link) Technical Library - (follow link) A Corrosion Primer

Why Stainless Steel Pits - recent discovery from London

How to Passivate Stainless Steel Parts