



Rittal White Paper 104: Stainless Steel Enclosures in Industrial Applications

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Executive Summary

Stainless steel is a versatile material known primarily for its strength and corrosion resistant properties and utilized in the construction of enclosure solutions that satisfy applications across a broad spectrum of industries. While a wide assortment of different components are housed within these enclosures and placed in disparate environments, there are common criteria that must be considered to ensure that the proper stainless steel enclosure is chosen for a given application.

This paper explores some of the technical details of stainless steel that are crucial to the selection of industrial enclosures including composition, distinguishing properties of different grades, chemical resistances, suitable applications and general benefits offered by stainless steel when compared to carbon steel enclosures.

What Exactly Is Stainless steel?

By definition, stainless steel is a metal alloy containing at least 10.5% chromium by mass. In a process known as passivation, the chromium within the metal forms a very thin layer of chromium oxide when exposed to the oxygen in our atmosphere. This layer continually protects the metal beneath and spontaneously regenerates if the surface is scratched which is why stainless steel enclosures provide excellent corrosion resistance without the need for painting or any kind of surface treatment. It is because of this passivation that stainless steel alloys do not display the gross surface rusting common in carbon steel alloys. If the passivation layer is destroyed beyond repair, however, corrosion will occur in the form of localized pitting.

Grades

The American Iron and Steel Institute (AISI) first classified certain types of stainless steel as standard compositions and designated each type with a 3-digit number. AISI no longer maintains these standards, but the Society of Automotive Engineers International (SAE) and ASTM International (the American Society for Testing and Materials) have since filled this role. In addition, new designations were created utilizing the Unified Numbering System (UNS), which consists of one letter and five numerals and the DIN standard, established in Germany and common to Europe, which uses five numerals and no letters.

SAE grade 304 stainless steel is comprised of 18-20% chromium and 8-10.5% nickel. This is the standard type of stainless steel used in the enclosure industry—filling the widest range of applications. Limitations of type 304 stainless steel include use in outdoor applications near large bodies of saltwater where airborne salt can come into contact with the surface of the enclosure. A rule of thumb is that type 304 stainless steel should not be used within 5 miles of the coast, but the true distance at which corrosion can occur is dependent upon local weather patterns. Cold climate regions where chlorides are used as de-icing agents may also cause significant pitting in type 304 stainless steels. For these reasons, type 304 stainless steel is not recommended in these situations without a regular cleaning regimen.

Fortunately, many of the limitations of 304 stainless steel are not apparent with the second most common stainless steel, SAE grade 316. Generally 25-35% costlier than type 304, 316 stainless steel has a higher percentage of nickel and an alloy addition of molybdenum (2-3%). The molybdenum provides better resistance to pitting and crevice corrosion, particularly in chloride-rich environments. Type 304 stainless steel can resist corrosion in waters containing up to about 100 ppm chloride while type 316 stainless steel will exhibit this resistance up to 1000 ppm chloride. Often considered the standard marine grade steel, type 316 stainless will not resist prolonged exposure to seawater (19,000 ppm chloride) but is acceptable in applications where exposure is limited to occasional salt spray. Severe conditions such as tight spaces with low airflow, lower pH, or higher temperatures may cause the need for more stringent standards.

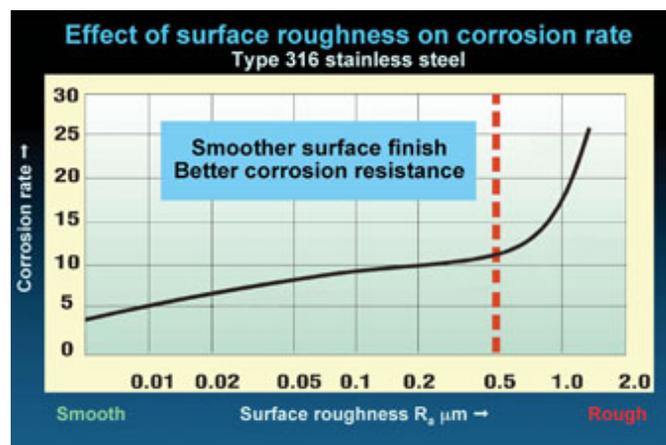
The 316L stainless steel commonly found in many enclosures has a lower carbon content (< .03%) than 304 or 316 making it more resistant to sensitization (grain boundary carbide precipitation), a byproduct of welding. Due to the extreme heat of welding, localized corrosion can occur in stainless steels in areas where the material has been welded, but the lower carbon content of type 316L prevents the carbide precipitation that can lead to weld decay and possible structural failure.

Chemical Analysis %

SAE	UNS	DIN	% Cr	% Ni	% C	% Mn	% Si	% P	% S	% N	% Mo
304	S30400	1.4301	18–20	8–10.50	0.08	2	0.75	0.045	0.03	0.1	-
316L	S31603	1.4404	16–18	10–14	0.03	2	0.75	0.045	0.03	0.1	2.0–3.0

Finish

Metals are finished not only for aesthetic purposes, but also to improve their corrosion resistant properties. Metal finishes are often designated by a system of numbers ranging from a No. 0 finish (scaled black finish; not suitable for end-use) to a No. 8 finish (highly polished, mirror-like finish). The No. 4 finish used for most stainless steel enclosures is a unidirectional finish with a maximum average surface roughness (R_a) of 0.64 micrometers (μm). It is considered a general-purpose finish with a visible grain that helps to minimize the reflection of light.



*Australian Stainless Steel Development Association (ASSDA)

In addition to surface finish quality, the grain orientation of a stainless steel enclosure can have a significant impact on corrosion resistance. A vertical grain orientation can help to provide an easier, more thorough cleaning since rainwater and gravity fed hose water will run parallel to the grains. By contrast, horizontal grain lines may retain corrosive contaminants, thereby expediting the corrosion process.

Applications

One of the most common applications for type 304 stainless steel is in the food and beverage industry because it gives users the ability to frequently wash the enclosure and surrounding environment without fear of rust. The ability to withstand the corrosive properties of the various acids found in meats, milk, fruits and vegetables makes 304 stainless steel enclosures ideal for housing controls used to operate the machinery found in food and beverage processing plants. Although type 304 stainless steel is effective in many food and beverage settings, if the

environment is overly chloride-rich or cleaning procedures involve the use of highly corrosive solvents, a switch to a stronger grade of stainless steel may be necessary.

As a general rule, type 316 stainless steel enclosures are more reliable in harsh chemical environments than other grades. The primary exception to this rule is exposure to nitric acids, which are principally used in the production of fertilizer and explosives. All stainless steel has some resistance to nitric acids, but in industries where nitric acids are prevalent, SAE 304 enclosures are usually preferred because of their superior resistance to this specific substance. Even though stainless steel will naturally self-passivate, the strong oxidizing nature of nitric acid is often used to encourage this process, thereby increasing the corrosion resistance of stainless steels.

Applications such as the treatments of waste and potable water are ideal for stainless steels. Type 304 stainless steel is sufficient in most areas, however some treatment plants use chlorine gas to disinfect water and use sulfur dioxide to then remove residual chlorine. Combined with the naturally humid environment of the plant, these gases are highly corrosive to stainless steels so the increased resistance of type 316L is required. In some cases, through an effort to be more environmentally friendly and reduce chemical usage, municipalities are turning to ultraviolet (UV) treatment to purify water. Type 304 stainless can be used in this application since there are no chemicals introduced to the surrounding environment of the enclosure.

Because 316 stainless steels are considerably more resistant to sulfuric acid solutions (<10%) and sulfur bearing gases, enclosures constructed of them are often found in industries that these substances are regularly found in. For example, this makes type 316 stainless steel enclosures a wise choice for use in many pulp mills.

Most of the pulp in the US is produced using either mechanical or chemical methods. The mechanical method (used to produce weaker paper such as newspaper) utilizes steam, pressure and high temperatures to break wood chips down into fiber. Type 304 stainless steel is often sufficient in pulp mills employing these processes. Higher quality pulp is produced using chemical processes such as the Kraft (sulfate) or sulfite processes where concentrated solutions of highly corrosive chemicals are used, necessitating the use of 316 stainless steel. If the pulp is going to be used to make white colored paper, it is then bleached with chlorine solutions, making the choice of type 316 stainless steel even more imperative.

The use of sulfur-based compounds is not limited to pulp and paper processing. They are also very prevalent in other industrial operations including the vulcanization process in the production of rubber, and the production of dyes and plastics. Type 316 stainless steel enclosures are ideal for applications in these industries as well.

Due to an increased resistance to chlorides, type 316 stainless steel is the preferred material of choice for food processing plants where enclosures could come into contact with highly acidic chemicals and concentrated chloride salts. Type 316 stainless steel enclosures are also recommended for marine applications such as shipping and offshore drilling and, not surprisingly, in salt mines. Basically, any application where high chloride levels are present or the corrosive environment will continually attack the surface of the enclosure, type 316 stainless steel is the metal of choice.

Industries Using Stainless Steel Enclosures

Food & Beverage	General Food Processing	304 or 316 SS
	Milk & Dairy	304 or 316 SS
	Brewery and Wine	304 or 316 SS
	Bottling	304 or 316 SS
	Bakeries	304 or 316 SS
Chemical	Pharmaceutical	316 SS
	Petrochemical	316 SS
Marine	Offshore Drilling	316 SS
	Shipping	316 SS
Water	Waste Water Treatment	304 or 316 SS
	Potable Water Treatment	304 or 316 SS
	Desalination	316 SS
	Distribution	304 or 316 SS
Materials	Pulp	316 SS
	Paper	304 or 316 SS
	Rubber	316 SS
	Plastic	304 or 316 SS
Mining	Ore	304 or 316 SS
	Salt	316 SS
	Coal	304 or 316 SS

It is important to note that neither 304 nor 316 stainless steel will resist the chemical corrosion caused by hydrochloric acid. The acid will destroy the passivity, leaving the surface of the metal defenseless. The following chart shows how 304 and 316 stainless steels react with some of the chemicals present in common application environments.

Chemical Resistance Table

Chemical	304 SS	316 SS
Acetic acid (20%)	Good	Excellent
Citric acid	Good	Excellent
Fatty acids	Good	Excellent
Fresh water	Excellent	Excellent
Hydrochloric acid	Poor	Poor
Nitric acid	Excellent	Good
Phosphoric acid	Poor	Fair
Sea water	Poor	Fair
Sodium hydroxide	Good	Good
Sodium hypochlorite (<20%)	Fair	Fair
Sulfur dioxide	Poor	Excellent
Sulfuric acid (<10%)	Poor	Good

Variables Affecting Corrosion

Exactly how a metal will corrode in a given environment is often difficult to predict. Variables that can affect corrosion include the concentration and pH of the corrosive material and the temperature of the environment. The pH measurement scale is used to describe the strength of an acid or base. A pH of 7 is considered neutral while chemicals with pH values less than 7 are acidic and chemicals with pH values greater than 7 are basic or alkaline. Generally speaking, stainless steels will corrode when exposed to strong acids or alkalis but the overall effect of this corrosion is dependent upon the temperature at which the corrosive attack takes place.

It is important to differentiate the ability of a material to resist corrosion following prolonged contact and the ability of a material to resist corrosion resulting from occasional or possible accidental contact. For instance, the production of chloride-rich foods in direct contact with stainless steel will require the use of a stronger grade when compared to the requirements of an electrical enclosure, which may be unlikely to ever have direct contact with the corrosive material. Another possible issue, corrosive gases, poses a different set of challenges because the gases expand, continually corroding everything in the surrounding environment.

Each application will have unique circumstances requiring different levels of protection, but in the event of a corrosive attack, it is always better to have too much protection than too little.

Further Benefits

In addition to better corrosion resistance, stainless steel enclosures possess superior hygienic qualities when compared to their carbon steel counterparts. Bacteria and germs have difficulty adhering to and growing on stainless steel (provided that a sufficient finish is maintained) and the smooth, hard surface of stainless steel allows for a much easier, more thorough cleaning.

Other material properties of stainless steel enclosures offer advantages when compared to carbon steel models as well. A greater strength-to-weight ratio results in increased rigidity in larger enclosures, plus, stainless steels' superior hardness provides an increased ability to withstand damage.

When total life cycle costs are taken into consideration, stainless steel enclosure costs may be equal to, or in some cases, less than that of carbon steel. Although the acquisition cost of stainless steel is greater than that of carbon steel, this is often offset by lower maintenance costs and a greater life expectancy. Once the serviceable life of the enclosure is over, stainless steel also delivers yet another benefit versus carbon steel—a better return on scrap metal.

Conclusion

Stainless steel has proven to be a relatively low-cost material that can protect electronic equipment in a variety of different industries and application settings. The durability of stainless steel depends greatly on the steel grade, surrounding environment and surface finish. Type 304 stainless steel is the common solution for most environments where mild corrosion is a concern. Harsher environments will require the use of costlier type 316 stainless steel, but the chemical concentration and subsequent rate of attack should be carefully determined and monitored. A smooth finish with a vertical grain orientation and a regular cleaning regimen are vital to maintaining stainless steels' anti-corrosive and hygienic properties.

When specifying a stainless steel enclosure for any project, all of the factors covered in this paper should be carefully considered to ensure that the appropriate levels of protection are provided for installed equipment and the overall success of the application.

About the Author

Nathan Xavier is a Rittal Corporation Applications Engineer and has been with the company since 2007. He holds a Bachelor of Science degree in Mechanical Engineering and provides product management and customer-specific applications support relating to Rittal industrial enclosure and power distribution solutions.

The Rittal Corporation is the U.S. subsidiary of Rittal GmbH & Co. KG and manufactures the world's leading industrial and IT enclosures, racks and accessories, including climate control and power management systems for industrial, data center, outdoor and hybrid applications.

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