The Appropriate Application of Stainless Steel in the Weighing & Measurement Industry

This white paper is not inclusive and should not be used singularly as authoritative source material. Use this white paper as a catalyst to promote further research on the subject of proper stainless steel application in the marketplace. When the total life cycle costs are factored in, and your customer's application is fully understood, stainless steel often becomes the least expensive material option.

Contrary to conventional wisdom, all stainless steels are not alike. And, under the right conditions, stainless steel will rust. Plain carbon mild steel holds up well in most industrial environments. Well-known uses of stainless steel include applications set outside, in environments of wet or high humidity and in areas of varying temperatures (i.e., areas of extreme heat or cold for applications in the food, chemical or pharmaceutical industries).

Types 304 and 316 stainless steel are most commonly used in the industrial weighing and measurement industry. There are times when the use of other grades of stainless steel are a better long-term choice.

Properties of Stainless Steels

The advantages of stainless steel can be seen when compared to standard plain carbon mild steel. Although stainless steel has a broad range of properties, when compared with mild steel, stainless steel has a higher corrosion resistance, a higher cryogenic toughness, fire and heat resistance, a higher strength and hardness, hygiene, and a more visually attractive appearance, and overall lower maintenance needs.

Standard Classifications

The AISI three digit stainless steel numbering system (i.e., 304 and 316) is still commonly used. New grades are defined under the SAE system that uses a one letter and five digit UNS number. For example, under the SAE and ASTEM system, 304 stainless steel is now classified as S30400. Other designations include old BS and EN numbers like 304S31 and 58E.

Some grades are not covered by standard numbers and could be proprietary grades or named using standards for specialist products, such as welding wire.

Corrosion Resistance

All stainless steels are iron-based alloys that contain a minimum of approximately 10.5% chromium. The chromium in the alloy forms a self-healing protective clear oxide layer that gives stainless steels their corrosion resistance. The self-healing nature of the oxide layer allows the corrosion resistance to remain intact regardless of fabrication methods. Even if the material surface is cut or damaged, the surface will self-heal and corrosion resistance will be maintained.

Conversely, normal carbon steels may be protected from corrosion by painting or using other protective coatings such as galvanizing. Any modification of the surface exposes the underlying steel and as a result, corrosion naturally occurs. The corrosion of different grades of stainless steel will differ in various environments. Suitable grades depend upon the service environment. Even trace amounts of some elements can markedly alter the corrosion resistance. Chlorides in particular can have an adverse effect on the corrosion resistance of stainless steel. Steel grades that are high in chromium, molybdenum and nickel are the most resistant to corrosion.

Cryogenic (low temperature) Resistance

Cryogenic resistance is measured by the ductility or toughness at sub-zero temperatures. At cryogenic temperatures, the tensile strengths of austenitic stainless steels are substantially higher than at ambient temperatures. They also maintain excellent toughness.

Ferritic, martensitic and precipitation hardening steels should not be used at sub-zero temperatures. The toughness of these grades drops significantly at low temperatures. In some cases, this drop occurs close to room temperature.

Fire and Heat Resistance

Austenitic grades of stainless steel resist scaling and retain high strength at elevated temperatures. This is particularly so with grades containing high levels of chromium and/or silicon, nitrogen and rare earth elements (i.e., grades 310 and S30815).

High Strength

When compared with mild steels, stainless steels tend to have higher tensile strength. The duplex stainless steels have higher tensile strengths than austenitic steels. The highest tensile strengths are seen in the martensitic (431) and precipitation hardening grades (17-4 PH). These grades can have strengths double that of 304 and 316, which are the most commonly used types of stainless steels.

Magnetic Response

Magnetic response is the attraction of steel to a magnet. Austenitic grades are generally not magnetic, although a magnetic response can be induced in the low austenitic grades by cold working. High nickel grades, such as 316 and 310, will remain non-magnetic even with cold working. All other grades are magnetic.

Stainless Steel Families

Although the corrosion resistance of stainless comes from the presence of chromium, other elements are added to enhance different properties and alter the microstructure of the steel.

Stainless steels are grouped into families based on their metallurgical microstructure. The microstructure may be composed of the stable phase's austenite or ferrite; a "duplex" mix of these two; martensite; or a hardened structure containing precipitated micro-constituents.

Austenitic Stainless Steels

Austenitic stainless steels contain a minimum of 16% chromium and 6% nickel. They range from basic grades (like 304) to super-austenitics (such as 904L and 6% molybdenum grades). The properties of the steel can be modified by adding elements such as molybdenum, titanium or copper. These modifications enable the steel to be better suited for high temperature applications and increase corrosion resistance.

Most steels become brittle at low temperatures. However, the nickel in austenitic stainless makes it suited to low temperature or cryogenic applications. Austenitic stainless steels are generally non-magnetic and are not able to be hardened by heat treatment. These stainless steels rapidly work-harden with cold working. Although they work-harden, austenitic stainless is the most readily formed of the stainless steels.

Applications for austenitic stainless steels include kitchen sinks, roofing, gutters, doors and windows, food preparation areas, food processing equipment, heat exchangers, ovens, and chemical tanks.

Ferritic Stainless Steels

Ferritic stainless steels include grades like 430 and contain only chromium as a major alloying element. The quantity of chromium present ranges from 10.5% to 18%. This family of stainless steel is known for its moderate corrosion resistance and poor fabrication properties. Fabrication properties can be improved by alloy modifications and are satisfactory in grades such as 434 and 444. Ferritic stainless steels cannot be hardened by heat treatment and are always used in the annealed condition. These stainless steels are magnetic and are not susceptible to stress corrosion cracking. Weldability is acceptable in thin sections but decreases as section thicknesses increase.

Applications for ferritic stainless steels include vehicle exhausts, fuel lines, cooking utensils, architectural trim, and domestic appliances.

Martensitic Stainless Steels

Martensitic stainless steels have a higher carbon and lower chromium content than ferritic stainless steels and include types 410 and 416. Hardened martensitic steels cannot be successfully cold formed. They are magnetic, have moderate corrosion resistance and poor weldability.

Martensitic stainless steels are typically used for cutlery (particularly knife blades), surgical instruments, fasteners, shafts, and springs.

Duplex Stainless Steels

Duplex stainless steels have high chromium and low nickel contents. This gives the duplex family microstructures that include both austenitic and ferritic phases. They include alloys like 2304 and 2205. These alloys are so named due to their respective compositions: 23% chromium, 4% nickel and 22% chromium, 5% nickel. By having both austenite and ferrite families in the microstructure, duplex stainless steels feature properties of both classes.

Although a compromise between the two "pure" types, duplex grades can offer some unique property solutions. This family of stainless steel is resistant to stress corrosion cracking, but not to the same level as ferritic grades. The toughness of duplex grades is superior to that of the ferritic grades, but inferior to that of the austenitic grades.

Most importantly, the corrosion resistance of duplex steels is equal or superior to 304 and 316 stainless steel. This is particularly so for chloride attack. Duplex grades are readily welded and have high tensile strengths.

Applications for duplex stainless steels include heat exchangers, marine applications, desalination plants, food pickling plants, off-shore oil, chemical, and petrochemical plants.

Precipitation Hardening Grades

Precipitation hardening grades contain both chromium and nickel. They develop very high tensile strengths with heat treatment. Precipitation hardening grades are usually supplied in a solution-treated condition that allows the steel to be machined. After machining or forming, the steel can be aged in a low temperature heat treatment process. As the heat treatment is performed at low temperatures, no distortion is induced in the work piece.

630 is the most common precipitation hardening grade. This grade is also known as 17-4 PH due to a composition of 17% chromium, 4% nickel, 4% copper and 0.3% niobium. The 300 series stainless is very corrosion resistant but is too hard to make into load cells. The 17-4 stainless that is used to manufacture load cells contains a great deal of iron and occasionally develops surface rust. The 17-4 is used for its spring or counterforce properties; not because of its desirable "stainless" characteristics.

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Precipitation hardening stainless steels are typically used for pulp and paper industry equipment, aerospace applications, turbine blades, nuclear waste casks, and mechanical components.

Grade selection

When selecting a particular grade of stainless steel, it is essential to consider the primary properties required, such as corrosion resistance and heat resistance. Important consideration must also be given to the secondary properties, like physical and mechanical properties. These properties will determine other factors, such as the ease of fabrication of any candidate grades. Selecting the correct grade will ensure the product will have a long and trouble-free life combined with cost-effective fabrication and installation.

Appendix A
Summary Table

TYPE	CHARACTERISTICS	CORROSION RESISTANCE	USES
AISI 303	Modified with selenium, sulphur, and phosphorous to improve machinability.	To atmospheric exposures, most organic and inorganic chemicals dyes, nitric acid and foods.	Aircraft industry
AISI 304	Low carbon stainless steel. Used where good corrosion resistance and mechanical properties are of great importance. Carbide precipitation is minimized during welding operations.	Good resistance to corrosion.	Food & beverage industry where high degree of sanitation and cleanliness is required.
AISI 304L	Variation of type 304. Low carbon content prevents carbide precip. 8000-15000 degree F	Same as 304 above.	Same as 304 above.
AISI 309	High strength. Welds are strong and ductile requiring no heat treatment.	Offers excellent oxidation resistance at extreme temps.	Aircraft heaters, heat treating equipment, annealing covers, furnace parts, heat exchangers, heat treating trays oven linings, pump parts.
AISI 310	This type used where strength, toughness, and resistance to corrosion and oxidation are essential.	More resistant to scaling and oxidation than 309.	Heat exchangers, furnace parts, combustion chambers, gas turbines, jet engines
AISI 316	Adds molybdenum.	Highly resistant to pitting, withstands corrosive actions of salts, acids and dyes.	Textile industries, process and pulp. Pumps, valves, textiles and chemicals.
AISI 316L	An extra low carbon version of 316 above. Avoids carbon precipitation when welding.	Same as 316 above.	Same as 316 above.
AISI 321	Similar to 304. Adds titanium. Intended for use in temps 8000 to 16000 degrees F.	Highly resistant to scaling, oxidation and corrosive elements.	Exhaust manifolds, boiler shells, fire walls, process equipment, pressure vessels.