Advantages of Stainless

The principal advantage of stainless, and the most frequently cited reason for purchase of this metal, is the ability to resist corrosion. Here are more details on this and other advantages of properly selected stainless alloys:

CORROSION RESISTANCE While incorrectly selected stainless alloys may pit or corrode under severe combinations of elevated temperatures and exposures to some types of chemicals, correct selection provides virtual immunity to corrosion.

ABILITY TO WITHSTAND SEVERE TEMPERATURES Stainless alloys generally have excellent strength and resistance to scaling at elevated temperatures. With proper selection, stainless can be used at temperatures up to 2200° F.. Stainless can also be used effectively at low temperatures, at which it has less tendency to become brittle than conventional carbon or alloy steel.

ASSURANCE OF PURITY Stainless is the logical product when chemical purity must be assured such as in pharmaceuticals or food manufacture, or when color balance may be affected by chemical changes such as in the textile industry. Stainless is inert to blood salts and natural tissues making it the perfect choice for surgical and medical instruments and appliances.

CLEANLINESS Stainless will not contaminate foods through deposition particles as in rusting, scaling, or flaking, since it is non-reactive in most chemical processing situations.

LOW MAINTENANCE Because of the high mechanical properties and resistance to corrosion exhibited by stainless, maintenance requirements are substantially reduced in most situations. Stainless surfaces are easier to clean, and provide a better appearance than alternative products.

HIGH SALEABILITY Stainless is viewed as a premium product because of the reputation this material has earned for good looks, toughness, and durability even under adverse conditions. Because of this, stainless is a highly saleable product, both to our customers and by them to the end user.

In summary, stainless alloys are a product at a surprisingly affordable price, and are unsurpassed where extra strength or corrosion resistance must be combined with an attractive appearance.

Metallurgy of Stainless

Many of the attractive properties of stainless are achieved through selective alloying of steel with chromium, nickel, and manganese. An understanding of how stainless is best applied must therefore begin with a review of some elements of stainless metallurgy.

Why Doesn't Stainless Stain or Corrode?

The "secret" of the ability of stainless to resist staining and corrosion is the addition of at least 10 to 12 percent chrome. When first exposed to air, this chrome forms a very thin, tough coating of chromium-rich oxide which protects the metal from further oxidation. This ability of chrome to impart corrosion resistance is further enhanced by the addition of small amounts of nickel, but the principal ingredient in corrosion resistance is the formation of a chromium-rich oxide layer.

FORMATION OF PROTECTION CHROME OXIDE FILM

As the chromium content of steel is raised still further, the alloy's ability to resist corrosion also increases. However, additions of chrome beyond the 10 to 12 percent level provide little extra resistance to corrosion, although resistance to scaling at elevated temperatures is improved.

EFFECT OF CHROME CONTENT ON CORROSION AND SCALING RESISTANCE

The chromium-rich oxide film which forms on the surface of stainless is invisible and extremely resistant to corrosion, but can be damaged in several ways with varying results:

SURFACE ABRASION If the surface of stainless is scratched, the film will ordinarily re-form instantly. However, anything which prevents oxygen from reaching the surface can accelerate corrosion.

TEMPERATURE CYCLING AT HIGH TEMPERATURES If stainless alloys, especially those with high coefficients of expansion, are subjected to intermittent or cyclic high temperatures, some corrosion resistance may be lost due to cracking and spalling of the oxide film.

REDUCING ENVIRONMENTS Gases or liquids which chemically combine with the oxygen in the oxide coating are said to be reducing in nature. Reducing environments can also destroy the oxide coating, causing an increased potential for corrosion.

STRESS CORROSION All metals, including stainless, are subject to increased risk of corrosion if they are simultaneously under stress and subjected to certain kinds of corrosive liquids, gases, or vapors.

GALVANIC CORROSION The corrosion potential of an assembly is increased when dissimilar metals are used together. When joining stainless to non-stainless metals through welding, riveting, or other methods, a weak electric current between the dissimilar metals is created increasing the corrosion of the more chemically active metal in the assembly.

CREVICE CORROSION Anything which prevents the free circulation of gases or liquids across the surface of a stainless part can increase corrosion because it causes concentrations of ions on the surface. Crevices, sharp corners, or deposits of foreign material, as well as surface areas covered by packing material or gaskets can lead to corrosion of stainless under certain circumstances.

INTERGRANULAR CORROSION Chrome-nickel (austenitic) stainless alloys are subject to corrosion when the chrome in the alloy combines with carbon to form chrome carbides. If the alloy is heated within the temperature range of 800 to 1500° F. by welding or exposure to a high temperature environment, the chrome combines with the carbon to form chrome carbides. The chrome collects in the boundaries between grains, depleting chrome from the zone immediately adjacent to the boundaries.

INTERGRANULAR CORROSION

When the surface film is damaged and subject to corrosion, it is active. Usually, however, the film re-forms instantly, and the surface is again passive, that is, resistant to corrosion. If stainless surfaces have become active, a customer may wish to passivate them using some type of passivation process.

In most cases, this means cleaning the surface with a degreaser or dilute acid solution, such as 20 - 30% nitric acid. Passivation is any process which removes whatever foreign material is preventing the naturally occurring chromium oxide layer from re-forming. The most usual contaminants are iron or steel particles, lubricants, or dirt.

MAJOR ALLOYING ELEMENTS OF STAINLESS STEELS

While chromium is the major element giving corrosion resistance to stainless, nickel also contributes to both corrosion resistance and to improved mechanical and fabrication qualities. Manganese is used in some stainless alloys (Types 201 and 202) as a replacement for some of the nickel.

CARBON also plays a part in determining the mechanical properties and the corrosion resistance of stainless steel. Carbon plays roughly the same role in hardenable stainless alloys as it does in the non-stainless ferrous alloys. The higher the carbon content in hardenable stainless alloys, the harder (and more hardenable) the alloy. The effect of carbon on hardness is less pronounced in the non-hardenable stainless alloys. Carbon also increases the susceptibility of some alloys to intergranular corrosion when welded or when subjected to temperatures in the annealing range. Therefore, stainless containing increased carbon is more difficult to weld. To overcome these corrosion problems, reduced carbon content stainless alloys have been developed. Typical reduced carbon alloys include 304 ELC or simply 304 L, which is 0.03% maximum carbon, and 309 S and 310 S, each of which contains 0.08% maximum carbon.

Other elements are also added in small quantities to produce or improve certain qualities. Molybdenum is added to increase resistance to pitting-type corrosion and to improve general corrosion resistance to certain types of media. Maganese also improves the high temperature strength of stainless alloys. Silicon, above the amounts added to all alloys, increases oxidation resistance at elevated temperatures. Sulfur, and selenium are added to improve freemachining qualities, while columbium and titanium improve resistance to intergranular corrosion by stabilizing carbon. Because of environmental problems, lead is no longer added to stainless alloys to improve machinability.

MAJOR GROUPS OF STAINLESS ALLOYS

There are five major groups of stainless alloys, and they are commonly described by their composition, hardenability, and/or grain structure. The major types in each group are shown in the following figures:

CHROME, HARDENABLE, (MARTENSITIC) A group of alloys in which stainless properties are obtained primarily by the addition of chrome, which are hardened by heat treatment, and which, when examined under a microscope, have an overall martensitic grain structure. Because of their martensitic structure, these alloys harden very much like conventional steel alloys when subjected to heat treatment. The basic alloy in this group is Type 410. These alloys are widely used when strength, together with erosion and corrosion resistance, are required. Typical applications include coal chutes and bunker linings, jet engine rings, and steam turbine parts.

CHROME, NON-HARDENABLE, (FERRITIC) A group of alloys in which chrome is the principal addition used to achieve stainless properties, with other additions (such as titanium or aluminum) used to achieve better fabrication properties or high temperature scaling resistance. These alloys have a ferritic grain structure when examined under a microscope, making them relatively soft in their commonly supplied condition. While the composition of these alloys make them non-hardening by heat treatment, they do work harden to some extent. The principal alloy in this group is 430. Typical application s include automotive and architectural trim and restaurant equipment.

CHROME-NICKEL, NON-HARDENING (AUSTENITIC) A group of alloys which contain both chrome and nickel, which are non-hardening by heat treatment, and which reveal an austenitic grain structure if examined under a microscope. While austenite is very tough, ductile, and quite strong as annealed, these alloys only develop their highest strength by cold working. Type 304 is the basic alloy in this group. A disadvantage is this group's susceptibility to intergranualr corrosion under certain temperature cycling conditions and during welding. These alloys are frequently produced with reduced carbon content (304L, 316L, 309S, 310S) or stabilized with columbium or titanium (321, 347) to prevent intergranular corrosion. Typical applications include beer and wine tanks, cryogenic vessels, and nuclear power equipment. The stainless screws found on Alumax Bath Enclosure products are typically made from this type of alloy.

CHROME-NICKEL, PRECIPITATION HARDENING (MAY BE MARTENSITIC, SEMI-AUSTENITIC, OR AUSTENITIC) This relatively recent development in stainless alloys consists of types which have two important things in common. Each contains both chrome and nickel and each hardens by transformation of the alloys grain structure to martensite during a relatively low temperature aging process. The amount of nickel in these alloys is adjusted, and other elements (such as copper or aluminum) are added to control the response of the alloy to heat treatment and to impart other qualities. The precipitation hardening alloys harden by transformation to the fully martensitic phase after heat treatment at only 900° F., rather than during a conventional heat treat cycle involving higher temperatures and a more abrupt quenching process. This relatively mild treatment and the composition of the PH grades produces a smaller and more predictable grain growth. It reduces stress, warpage, and rejection problems, allows work to be machined in the annealed state, and (after aging) results in a product with a high yield and tensile strength. Depending on the amount of nickel and other elements used, these alloys may appear as martensitic, semi-austenitic, or fully austenitic in the supplied state (before machining and hardening). The principal alloy in this group is 17-4 (AISI 630). Typical applications include aero-space structural components, landing gear covers, pump parts, shafting, and saws.

CHROME-NICKEL, DUPLEX, NON-HARDENING (50% FERRITE, 50% AUSTENITE) These stainless alloys feature a composition which results in roughly equal amounts of ferrite and austenite. Since the grain structure is a ferrite-austenite mix, these alloys do not harden appreciably with heat treatment, but do harden with cold working. These alloys, long popular in Europe and now more popular here, are characterized by excellent strength and corrosion resistance, as well as good fabrication qualities. The principal alloy in this group is 2205, and some typical applications include parts used in oil and has production and chemical processing equipment.

From the descriptions of the five major alloy groups, you may wonder why alloys are referred to by several different adjectives as well as by their Type number (such as Type 304, Type 410, etc.). The reason for this multiple way of describing alloys is that these alloys are generally ordered by composition and/or Type, with harenability an additional consideration. At the same time, the literature frequently describes these alloys in terms of their grain structure. Therefore, in order to understand both you must be able to understand how these classification systems relate to each other. Also, thinking of stainless alloys in terms of grain structure will help you to understand the behavior of some alloys when heat treated, welded, or otherwise fabricated.

CHROME-NICKEL, NON-HARDENING DUPLEX (FERRITE/AUSTENITE)
ALLOYS

In summary, then, there are five main groups of stainless alloys, each with a defined composition, hardenability, and grain structure. The "stainless" properties of each alloy in these groups is due primarily to the formation of a chromium-rich oxide layer, sometimes enhanced by selection additions of nickel. This protective layer is quite durable, but may be damaged in a variety of ways. While the chrome-oxide layer usually re-forms instantly, the "healing" process can be prevented by anything which reduces the flow of oxygen at the surface of the metal.