# What is Stainless Steel?

### Stainless Steel

In metallurgy, stainless steel, also known as inox steel or inox, is defined as a steel alloy with a minimum of 11% chromium content by mass. [1] Stainless steel does not stain, corrode, or rust as easily as ordinary steel (it stains less, but it is not stain-proof).[2] It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment to which the material will be subjected in its lifetime. Common uses of stainless steel are cutlery and watch cases and bands.

Stainless steel differs from carbon steel by the amount of chromium present. Carbon steel rusts when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide. Stainless steels have sufficient amounts of chromium present so that a passive film of chromium oxide forms which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure.

### History

An announcement, as it appeared in the 1915 New York Times, of the development of stainless steel.[3] A few corrosion-resistant iron artifacts survive from antiquity. A famous (and very large) example is the Iron Pillar of Delhi, erected by order of Kumara Gupta I around the year AD 400. Unlike stainless steel, however, these artifacts owe their durability not to chromium, but to their high phosphorus content, which, together with favorable local weather conditions, promotes the formation of a solid protective passivation layer of iron oxides and phosphates, rather than the non-protective, cracked rust layer that develops on most ironwork.

The corrosion resistance of iron-chromium alloys was first recognized in 1821 by the French metallurgist Pierre Berthier, who noted their resistance against attack by some acids and suggested their use in cutlery. Metallurgists of the 19th century, however, were unable to produce the combination of low carbon and high chromium found in most modern stainless steels, and the high-chromium alloys they could produce were too brittle to be practical.

In the late 1890s, Hans Goldschmidt of Germany developed an aluminothermic (thermite) process for producing carbon-free chromium. In the years 1904¨C1911 several researchers, particularly Leon Guillet of France, prepared alloys that would today be considered stainless steel.

Friedrich Krupp Germaniawerft built the 366-ton sailing yacht Germania featuring a chrome-nickel steel hull in Germany in 1908.[4] In 1911, Philip Monnartz reported on the relationship between the chromium content and corrosion resistance. On October 17, 1912, Krupp engineers Benno Strauss and Eduard Maurer patented austenitic stainless steel.[5]

Similar developments were taking place contemporaneously in the United States, where Christian Dantsizen and Frederick Becket were industrializing ferritic stainless steel. In 1912, Elwood Haynes applied for a U.S. patent on a martensitic stainless steel alloy. This patent was not granted until 1919.[6]

Also in 1912, Harry Brearley of the Brown-Firth research laboratory in Sheffield, England, while seeking a corrosion-resistant alloy for gun barrels, discovered and subsequently industrialized a martensitic stainless steel alloy. The discovery was announced two years later in a January 1915 newspaper article in The New York Times.[3] Brearly applied for a U.S. patent during 1915. This was later marketed under the "Staybrite" brand by Firth Vickers in England and was used for the new entrance canopy for the Savoy Hotel in 1929 in London.[7]

**Properties**

High oxidation-resistance in air at ambient temperature are normally achieved with additions of a minimum of 13% (by weight) chromium, and up to 26% is used for harsh environments.[8] The chromium forms a passivation layer of chromium(III) oxide (Cr2O3) when exposed to oxygen. The layer is too thin to be visible, and the metal remains lustrous. It is impervious to water and air, protecting the metal beneath. Also, this layer quickly reforms when the surface is scratched. This phenomenon is called passivation and is seen in other metals, such as aluminium and titanium. Corrosion resistance can however be adversely affected if the component is used in a non-oxygenated environment, a typical example being underwater keel-bolts buried in timber.

When stainless steel parts such as nuts and bolts are forced together, the oxide layer can be scraped off causing the parts to weld together. When disassembled, the welded material may be torn and pitted, an effect that is known as galling. This destructive galling can be best avoided by the use of dissimilar materials, e.g. bronze to stainless steel, or even different types of stainless steels (martensitic against austenitic, etc.), when metal-to-metal wear is a concern. In addition, Nitronic alloys (trademark of Armco, Inc.) reduce the tendency to gall through selective alloying with manganese and nitrogen.

**Applications**

Stainless steel's resistance to corrosion and staining, low maintenance, relatively low cost, and familiar luster make it an ideal base material for a host of commercial applications. There are over 150 grades of stainless steel, of which fifteen are most common. The alloy is milled into coils, sheets, plates, bars, wire, and tubing to be used in cookware, cutlery, hardware, surgical instruments, major appliances, industrial equipment, and as an automotive and aerospace structural alloy and construction material in large buildings. Storage tanks and tankers used to transport orange juice and other food are often made of stainless steel, due to its corrosion resistance and antibacterial properties. This also influences its use in commercial kitchens and food processing plants, as it can be steam cleaned, sterilized, and does not need painting or application of other surface finishes.

Stainless steel is also used for jewellery and watches. The most common stainless steel alloy used for this is 316L. It can be re-finished by any jeweller and will not oxidize or turn black.

Some firearms incorporate stainless steel components as an alternative to blued or parkerized steel. Some handguns, such as the Smith & Wesson Model 60 and the Colt M1911 can be made entirely from stainless steel. This gives a high-luster finish similar in appearance to nickel plating; but, unlike plating, the finish is not subject to flaking, peeling, wear-off due to rubbing (as when repeatedly removed from a holster over the course of time), or rust when scratched.

Some automotive aftermarket parts manufacturers use stainless steel only for the making of short shifters, shift knobs and Weighted Gear Knobs.

Uses in sculpture, building facades and building structures Stainless steel was in vogue during the art deco period. The most famous example of this is the upper portion of the Chrysler Building (illustrated to the right). Diners and fast food restaurants feature large ornamental panels, stainless fixtures and furniture. Owing to the durability of the material, many of these buildings retain their original appearance.

The forging of stainless steel has given rise to a fresh approach to architectural blacksmithing in recent years. The Gateway Arch (picture above) is clad entirely in stainless steel: 886 tons (804 metric tonnes) of 0.25 in (6.4 mm) plate, #3 finish, type 304 stainless steel.[10]

Type 316 stainless is used on the exterior of both the Petronas Twin Towers and the Jin Mao Building, two of the world's tallest skyscrapers.[11]

The Parliament House of Australia in Canberra has a stainless steel flagpole weighing over 220 tons. The aeration building in the Edmonton Composting Facility, the size of 14 hockey rinks, is the largest stainless steel building in North America.

**Recycling & Reuse**

Stainless steel is 100% recyclable. An average stainless steel object is composed of about 60% recycled material of which ≈40% originates from end-of-life products and ≈60% comes from manufacturing processes.[12]

**Types of Stainless Steel**

There are different types of stainless steels: when nickel is added, for instance, the austenite structure of iron is stabilized. This crystal structure makes such steels non-magnetic and less brittle at low temperatures. For greater hardness and strength, more carbon is added. When subjected to adequate heat treatment, these steels are used as razor blades, cutlery, tools, etc.

Significant quantities of manganese have been used in many stainless steel compositions. Manganese preserves an austenitic structure in the steel as does nickel, but at a lower cost.

Stainless steels are also classified by their crystalline structure:

**Austenitic**, or 300 series, stainless steels make up over 70% of total stainless steel production. They contain a maximum of 0.15% carbon, a minimum of 16% chromium and sufficient nickel and/or manganese to retain an austenitic structure at all temperatures from the cryogenic region to the melting point of the alloy. A typical composition of 18% chromium and 10% nickel, commonly known as 18/10 stainless, is often used in flatware. Similarly, 18/0 and 18/8 are also available. Superaustenitic stainless steels, such as alloy AL-6XN and 254SMO, exhibit great resistance to chloride pitting and crevice corrosion due to high molybdenum content (>6%) and nitrogen additions, and the higher nickel content ensures better resistance to stress-corrosion cracking versus the 300 series. The higher alloy content of superaustenitic steels makes them more expensive. Other steels can offer similar performance at lower cost and are preferred in certain applications.

The low carbon version of the Austenitic Stainless Steel, for example 316L or 304L, are used to avoid corrosion problem caused by welding. The "L" means that the carbon content of the Stainless Steel is below 0.03%, this will reduce the sensitization effect, precipitation of Chromium Carbides at grain boundaries, due to the high temperature produced by welding operation.

**Ferritic** stainless steels are highly corrosion-resistant, but less durable than austenitic grades. They contain between 10.5% and 27% chromium and very little nickel, if any, but some types can contain lead. Most compositions include molybdenum; some, aluminium or titanium. Common ferritic grades include 18Cr-2Mo, 26Cr-1Mo, 29Cr-4Mo, and 29Cr-4Mo-2Ni. These alloys can be degraded by the presence of chromium, an intermetallic phase which can precipitate upon welding.

**Martensitic** stainless steels are not as corrosion-resistant as the other two classes but are extremely strong and tough, as well as highly machineable, and can be hardened by heat treatment. Martensitic stainless steel contains chromium (12-14%), molybdenum (0.2-1%), nickel (0-<2%), and carbon (about 0.1-1%) (giving it more hardness but making the material a bit more brittle). It is quenched and magnetic.

**Precipitation-hardening martensitic** stainless steels have corrosion resistance comparable to austenitic varieties, but can be precipitation hardened to even higher strengths than the other martensitic grades. The most common, 17-4PH, uses about 17% chromium and 4% nickel. There is a rising trend in defense budgets to opt for an ultra-high-strength stainless steel when possible in new projects, as it is estimated that 2% of the US GDP is spent dealing with corrosion. The Lockheed-Martin Joint Strike Fighter is the first aircraft to use a precipitation-hardenable stainless steel - Carpenter Custom 465 - in its airframe.

**Duplex** stainless steels have a mixed microstructure of austenite and ferrite, the aim being to produce a 50/50 mix, although in commercial alloys, the mix may be 40/60 respectively. Duplex steels have improved strength over austenitic stainless steels and also improved resistance to localised corrosion, particularly pitting, crevice corrosion and stress corrosion cracking. They are characterised by high chromium (19¨C28%) and molybdenum (up to 5%) and lower nickel contents than austenitic stainless steels. The most used Duplex Stainless Steel are the 2205 (22% Chromium, 5% Nickel) and 2507 (25% Chromium, 7% Nickel); the 2507 is also known as "SuperDuplex" due to its higher corrosion resistance. Duplex stainless steels properties are achieved with an overall lower alloy content than similar performing super austenitic grades making their selection and use cost effective for many applications.

**Stainless Steel Grades**

The SAE steel grades are the most commonly used grading system in the US for stainless steel. Other steel grades include the UNS grades.

**100 Series** - austenitic chromium-nickel-manganese alloys

· Type 101 - austenitic that is hardenable through cold working for furniture

· Type 102 - austenitic general purpose stainless steel working for furniture

**200 Series**- austenitic chromium-nickel-manganese alloys

· Type 201 - austenitic that is hardenable through cold working

· Type 202 - austenitic general purpose stainless steel

**300 Series** - austenitic chromium-nickel alloys

· Type 301 - highly ductile, for formed products. Also hardens rapidly during mechanical working. Good weldability. Better wear resistance and fatigue strength than 304.

· Type 302 - same corrosion resistance as 304, with slightly higher strength due to additional carbon.

· Type 303 - free machining version of 304 via addition of sulfur and phosphorus. Also referred to as "A1" in accordance with ISO 3506.[13]

· Type 304 - the most common grade; the classic 18/8 stainless steel. Also referred to as "A2" in accordance with ISO 3506.[13]

· Type 304L - same as the 304 grade but contains less carbon to increase weldability. Is slightly weaker than 304.

· Type 304LN - same as 304L, but also nitrogen is added to obtain a much higher yield and tensile strength than 304L.

· Type 308 - used as the filler metal when welding 304

· Type 309 - better temperature resistance than 304, also sometimes used as filler metal when welding dissimilar steels, along with inconel.

· Type 316 - the second most common grade (after 304); for food and surgical stainless steel uses; alloy addition of molybdenum prevents specific forms of corrosion. It is also known as marine grade stainless steel due to its increased resistance to chloride corrosion compared to type 304. 316 is often used for building nuclear reprocessing plants.[13]

· Type 316L - extra low carbon grade of 316, generally used in stainless steel watches and marine applications due to its high resistance to corrosion. Also referred to as "A4" in accordance with ISO 3506.

· Type 316Ti - includes titanium for heat resistance, therefore it is used in flexible chimney liners.

· Type 321 - similar to 304 but lower risk of weld decay due to addition of titanium. See also 347 with addition of niobium for desensitization during welding.

**400 Series** - ferritic and martensitic chromium alloys

· Type 405 - ferritic for welding applications

· Type 408 - heat-resistant; poor corrosion resistance; 11% chromium, 8% nickel.

· Type 409 - cheapest type; used for automobile exhausts; ferritic (iron/chromium only).

· Type 410 - martensitic (high-strength iron/chromium). Wear-resistant, but less corrosion-resistant.

· Type 416 - easy to machine due to additional sulfur

· Type 420 - Cutlery Grade martensitic; similar to the Brearley's original rustless steel. Excellent polishability.

· Type 430 - decorative, e.g., for automotive trim; ferritic. Good formability, but with reduced temperature and corrosion resistance.

Type 439 - ferritic grade, a higher grade version of 409 used for catalytic converter exhaust sections. Increased chromium for improved high temperature corrosion/oxidation resistance.

· Type 440 - a higher grade of cutlery steel, with more carbon, allowing for much better edge retention when properly heat-treated. It can be hardened to above Rockwell 55 hardness, making it one of the hardest stainless steels. Due to its hardness and relatively low cost, most display-only and replica swords or knives are made of 440 stainless. Available in four grades: 440A, 440B, 440C, and the uncommon 440F (free machinable). 440A, having the least amount of carbon in it, is the most stain-resistant; 440C, having the most, is the strongest and is usually considered more desirable in knifemaking than 440A, except for diving or other salt-water applications.

· Type 446- For elevated temperature service

**500 Series** - heat-resisting chromium alloys

**600 Series** - martensitic precipitation hardening alloys

· 601 through 604: Martensitic low-alloy steels.

· 610 through 613: Martensitic secondary hardening steels.

· 614 through 619: Martensitic chromium steels.

· 630 through 635: Semiaustenitic and martensitic precipitation-hardening stainless steels.

· Type 630 is most common PH stainless, better known as 17-4; 17% chromium, 4% nickel.

· 650 through 653: Austenitic steels strengthened by hot/cold work.

· 660 through 665: Austenitic superalloys; all grades except alloy 661 are strengthened by second-phase precipitation.

· Type 2205 - the most widely used duplex (ferritic/austenitic) stainless steel grade. It has both excellent corrosion resistance and high strength.

**Stainless Steel Finishes**

Standard mill finishes can be applied to flat rolled stainless steel directly by the rollers and by mechanical abrasives. Steel is first rolled to size and thickness and then annealed to change the properties of the final material. Any oxidation that forms on the surface (scale) is removed by pickling, and a passivation layer is created on the surface. A final finish can then be applied to achieve the desired aesthetic appearance.

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