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304 Stainless Steel versus 316 Stainless Steel

Corrosion resistance of stainless steel varies by grade



[304 and 316 are the two most common grades of stainless steel](#)

Judging by the name, you might assume that stainless steel never stains—but you’d be wrong.

Stainless steel stains less easily than other iron-based metals, but it’s not literally “stainless”. Just like standard steel, stainless can get marked up by fingerprints and grease, develop discoloration, and eventually rust. The difference is resilience. Stainless steel can withstand much more time and abuse before showing signs of wear.

All steels have the same basic iron and carbon composition, but stainless steel also contains a healthy dose of chromium—the alloy that gives stainless steel its famous corrosion resistance.

And this is where things get complicated. There are multiple grades under the [stainless steel](#) umbrella, each with slightly different alloy composition, and therefore slightly different physical characteristics.

Stainless steel must contain at least 10.5 percent chromium. Depending on the grade, it may contain much higher chromium levels, and additional alloying ingredients like molybdenum, nickel, titanium, aluminum, copper, nitrogen, phosphorous and selenium.

The two most common stainless steel grades are 304 and 316. The key difference is the addition of molybdenum, an alloy which drastically enhances corrosion resistance, especially for more saline or chloride-exposed environments. 316 stainless steel contains molybdenum, but 304 doesn’t.

For outdoor furnishings like rails and bollards, stainless steel is an ideal corrosion-resistant material, but it will only withstand long-term exposure if the grade is appropriate for its

environment. 304 is an economical and practical choice for most environments, but it doesn't have the chloride resistance of 316. The slightly higher price point of 316 is well worth it in areas with high chloride exposure, especially the coast and heavily salted roadways. Each application for stainless steel has its own unique demands, and needs a stainless steel that's up to the task.

Natural corrosion resistance



[Iron oxide, also known as rust, is red and flakey. Stainless steel has a natural resistance to rust.](#)

Corrosion is a natural phenomenon. Pure elements always react with the surrounding environment, which is why so few elements are naturally found in their pure form. Iron is no exception.

In wet or humid conditions iron reacts with the oxygen contained in water to form *iron oxide*, also known as rust. The red flaky oxide deteriorates easily—exposing more material to corrosion. Iron and standard carbon steels are highly susceptible to this type of corrosion.

Stainless steel has the innate ability to form a passive layer that prevents corrosion. The secret?

Chromium.

The chromium found in all stainless steels reacts quickly with oxygen environments, much the same as iron. The difference, however, is that only a very fine layer of chromium will oxidize (often only a few molecules in thickness). Unlike flaky and unstable iron oxide, chromium oxide is highly durable and non-reactive. It adheres to stainless steel surfaces and won't transfer or react further with other materials. It is also self-renewing—if it's removed or damaged, more chromium will react with oxygen to replenish the barrier. The higher the chromium content, the faster the barrier repairs itself.

Once oxidized, or passivized, stainless steel typically rusts at a very low rate of less than 0.002 inches per year. When kept in its best condition, stainless steel offers clean and bright surfaces ideal for many building and [landscape designs](#).

304 Stainless Steel

Stainless steel provides an attractive, clean finish with low maintenance cost

304 stainless steel is the most common form of stainless steel used around the world, largely due to its excellent corrosion resistance and value. It contains between 16 and 24 percent chromium and up to 35 percent nickel, as well as small amounts of carbon and manganese.

The most common form of 304 stainless steel is 18-8, or 18/8, stainless steel, which contains 18 percent chromium and 8 percent nickel.

304 can withstand corrosion from most oxidizing acids. That durability makes 304 easy to sanitize, and therefore ideal for kitchen and food applications. It is also common in buildings, décor, and site furnishings.

304 stainless steel does have one weakness: it is susceptible to corrosion from chloride solutions, or from saline environments like the coast. Chloride ions can create localized areas of corrosion, called "pitting," which can spread beneath protective chromium barriers to compromise internal structures. Solutions with as little as 25 ppm of sodium chloride can begin to have a corrosive effect.

316 Stainless Steel



[Architectural features like this stainless steel railing are protected from oxidation in wet and salty environments.](#)

316 grade is the second-most common form of stainless steel. It has almost the same physical and mechanical properties as 304 stainless steel, and contains a similar material make-up. The key difference is that 316 stainless steel incorporates about 2 to 3 percent molybdenum. The addition increases corrosion resistance, particularly against chlorides and other industrial solvents.

316 stainless steel is commonly used in many industrial applications involving processing chemicals, as well as high-saline environments such as coastal regions and outdoor areas where de-icing salts are common. Due to its non-reactive qualities, 316 stainless steel is also used in the manufacture of medical surgical instruments.

Alternative 300-series grades can contain up to 7 percent molybdenum. They provide even better chloride resistance, but such heavy-duty resistance is only necessary in industrial or high concentration exposure conditions.

Versatile applications



[Because of its material properties, stainless steel is the metal of choice in food processing environments.](#)

Both 304 and 316 stainless steels (as well as other 300-series grades) use nickel to maintain an austenitic composition at lower temperatures. Austenitic steels ensure a versatile balance of strength, workability, and corrosion resistance, making them ideal for outdoor architectural features, surgical instrumentation, and food processing equipment.

A large volume of stainless steel produced today (especially 316 stainless steel) can be found in products related to the food and beverage industries. Stainless steel is commonly found in commercial kitchens and food processing plants as it serves a variety of needs:

- It can be easily formed and fabricated into shapes needed to produce a variety of equipment and machinery, such as cooking tables, ventilation hoods, tanks, and hoppers.
- It is available in a wide range of decorative and polished finishes.
- It can withstand shock and abrasive conditions found in kitchens or food processing plants.
- It can be easily cleaned, and can withstand repeated washing with the many chemicals and detergents employed to meet public health demands.
- It does not react to the alkalis and acids found in milk, cooked foods, vegetables, and food additives.

The ultimate benefits of stainless steel include a long service life that will retain an attractive, clean finish. Properly cared for and [cleaned stainless steels present a low maintenance cost](#).

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Stainless Steel

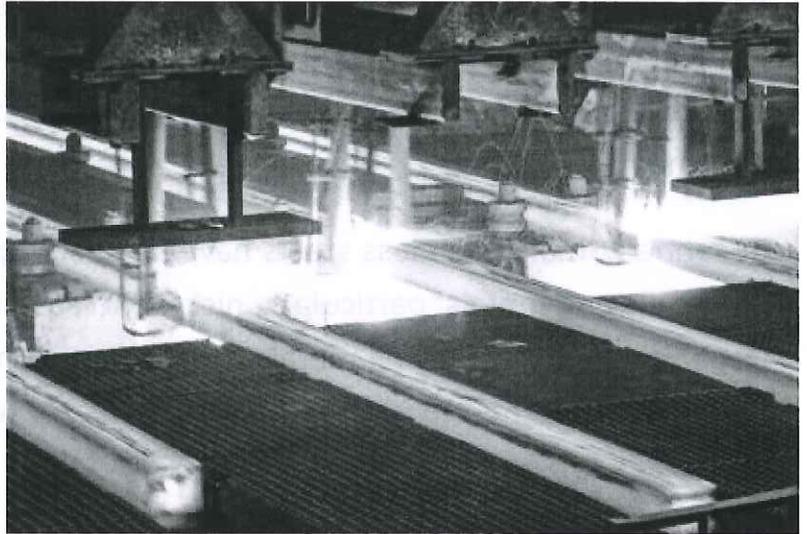
An introduction to wrought stainless steel properties and material selection

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Stainless steel is a group of ferrous alloys characterized by superior corrosion resistance. Unlike other ferrous alloys, they have a stable passivation layer that protects the steel from air and moisture. Stainless steels are suitable for wide-ranging outdoor, aqueous, food service, and high-temperature applications.

Stainless steels can be cast or wrought – this article focuses on wrought stainless steels.



Stainless steel is cast into blooms. Hot rolling will transform these long rectangles into wires and bars.

The Properties of Stainless Steel

Corrosion Resistance

Stainless steel is characterized by its resistance to corrosion. Resistance is not the same thing as invulnerability – given the right conditions, and adequate time, stainless steels will rust eventually. They will, however, take significantly longer to rust than other iron-based metals.

The corrosion resistance of stainless steel results from its chromium content: all stainless steels contain at least 10.5 percent chromium, but may contain significantly more depending on the application. Higher chromium content results in increased corrosion resistance.

When stainless steel is exposed to the atmosphere, the chromium combines with oxygen to form a thin, stable passivation layer of Chromium(III) Oxide (Cr_2O_3). The passivation layer protects the interior steel from oxidization, and quickly reforms if the surface is scratched.

The passivation layer that forms over stainless steel is different than plating. Other metals are commonly plated with white metals, including chromium and nickel, for surface protection. In those cases, the benefits of the coating are lost once a scratch penetrates the plating. Because stainless steel is alloyed with chromium, and not just surface plated, the passivation layer will reform no matter how deeply it is scratched.

Magnetism

The second defining characteristic of stainless steel is a lack of magnetism. Other ferrous (iron-based) metals such as carbon steel are magnetic at ambient temperatures. The magnetic attraction of these metals is due to their predominantly ferrite crystalline structure. Their structure phase changes to austenite when heated above 1340°F (730°C), causing them to become non-magnetic.

In contrast, many stainless steels have an austenite structure even at ambient temperatures. Some alloying metals, particularly nickel, increase the stability of the austenite structure. Depending on the alloying metals, stainless steel may be slightly magnetic, or not at all magnetic. As austenite wrought stainless steel is worked or heated, its non-magnetic properties can be reversed.

Mechanical Properties

Stainless steels possess a number of useful mechanical properties. As with corrosion resistance and magnetism, the relative strength of these properties varies by alloying metal content, making stainless steels an extremely versatile group.

Tensile Properties

The ability of stainless steel to withstand loads is measured with a tensile test. A representative tensile bar is subjected to pulling force, also called tensile loading. Upon failure, the following properties are measured:

- **Tensile Strength** – the force required to break the steel.
- **Yield Strength** – the force required to make the steel yield (stretch).
- **Elongation** (percent) – a measure of ductility (the ability to deform plastically), calculated by comparing the original length of a tensile bar with its full length after failure.
- **Reduction of Area** (percent) – a secondary measure of ductility, describing the difference between the original cross section of a tensile bar and its smallest cross section after failure.

Hardness

Hardness is the ability of a material to resist indentation and abrasion. It is a useful property because it can be measured by a number of different non-destructive tests, and is a good indication of tensile strength.

The two most common hardness tests are Brinell and Rockwell. In the Brinell test, a small hardened steel ball is forced into the steel by a standard load, and the diameter of the resulting impression is measured. The Rockwell test instead measures the depth of the indentation.

Toughness

The capacity of steel to yield plastically under very localized stress is toughness. A tough steel is resistant to cracking, making toughness a highly desirable quality in steel used in engineering applications.

The level of toughness is determined using a dynamic test: a sample bar is notched to localize the stress, then struck by a swinging pendulum. The energy absorbed in breaking the sample bar is measured by how much energy the pendulum loses – tough metals absorb more energy, while brittle metals absorb less.

Types of Stainless Steel

Stainless steels can be produced with five distinct crystalline structures: ferritic, austenitic, martensitic, duplex, and precipitation hardening.

Ferritic

Ferritic stainless steels contain iron, carbon, and between 10.5 and 18 percent chromium. They may contain other alloying elements such as molybdenum or aluminum, but usually in very small amounts. They have a body-centered-cubic (BCC) crystal structure – the same as pure iron at ambient temperature.

Due to their crystal structure, ferritic stainless steels are magnetic. Their relatively low carbon content produces correspondingly low strength. Other weaknesses of the ferritic type include poor weldability and reduced corrosion resistance. They are, however, desirable for engineering applications because of their superior toughness. Ferritic stainless steels are often used for vehicle exhaust, fuel lines, and architectural trim.

Austenitic

Austenitic stainless steels have a face-centered cubic (FCC) crystal structure; they are composed of iron, carbon, chromium, and at least 8 percent nickel. Due to their high chromium and nickel content, they are highly corrosion resistant. They are non-magnetic. Like ferritic stainless steels, austenitic stainless steels cannot be hardened by heat treatment. However, they can be hardened by cold working. The high nickel content in austenitic stainless steels makes them capable of functioning well in low-temperature applications.

The two most common stainless steels – 304 and 316 – are both austenitic grades; the primary driver behind the popularity of austenitic stainless steels is the ease with which they can be formed and welded, which makes them ideal for use in high-efficiency manufacturing.

There are many sub-groups of austenitic stainless steel, with wide variations in carbon content. The properties are further tuned by the addition of alloying elements such as molybdenum, titanium, and copper.

Austenitic stainless steels are frequently used to produce kitchen sinks, window frames, food processing equipment, ovens, chemical tanks, and outdoor site furnishings such as benches and bollards.

Martensitic

Martensitic stainless steels have a body-centered tetragonal (BCT) structure. They contain 12 – 18 percent chromium, and have a higher carbon content (0.1 – 1.2 percent) than austenitic or ferritic stainless steels. Like the ferritic BCC structure, BCT is magnetic. The major distinction is that martensitic stainless steel can be hardened by heat treatment because of their high carbon content. This makes it useful for a number of applications for which ferritic stainless steel would be unsuitable, including aerospace parts, cutlery, and blades.

Martensitic stainless steels are highly useful in situations where the strength of the steel is more important than its weldability or corrosion resistance. Hardened martensitic steels can't be cold formed.

Duplex

Duplex stainless steels are the newest stainless steel type. They contain more chromium (19 – 32 percent) and molybdenum (up to 5 percent) than austenitic stainless steels, but significantly less nickel. Duplex stainless steels are sometimes referred to as austenitic-ferritic because they have a hybrid ferritic and austenitic crystalline structure. The roughly half and half mix of austenitic and ferritic phases in duplex stainless steels gives it some unique advantages.

Duplex grades are a compromise: they are more resistant to stress corrosion cracking than austenitic grades, tougher than ferritic grades, and roughly two times stronger than a pure form of either. The key advantage of duplex stainless steels is a corrosion resistance equal to – and, in the case of chloride exposure, exceeding – austenitic grades.

Another significant advantage of duplex stainless steels is cost efficiency – the strength and corrosion resistance of duplex stainless steel are achieved with a lower alloy content than equivalent austenitic grades.

Duplex stainless steels are regularly used to produce parts for chloride-exposed applications like desalination, food picking, and petrochemical.

Precipitation Hardening

Precipitation hardening stainless steels can have a range of crystalline structures, however they all contain both chromium and nickel. Their common characteristics are corrosion resistance, ease of fabrication, and extremely high tensile strength with low-temperature heat treatment.

Austenitic precipitation hardenable alloys have mostly been replaced by higher strength superalloys, however semi-austenitic precipitation hardenable stainless steels continue to be used in aerospace applications, and even applied to new forms.

Martensitic precipitation hardenable stainless steels are stronger than regular martensitic grades, are frequently used to produce bars, rods, and wire.

Stainless Steel Production and Processing

The manufacture of wrought stainless steel is a multi-step process: steel scrap is melted, then cast in a workable solid shape; the solidified steel is formed, heat treated, cleaned, and polished to meet the desired specifications. Finally, the finished stainless steel is packaged and shipped to manufacturers.

Melting and casting

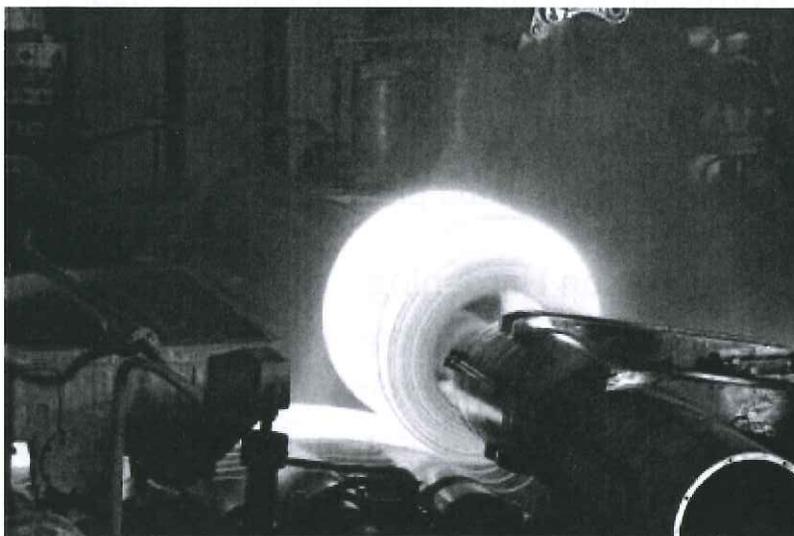
Steel and alloying metals are loaded into an electric arc furnace. Once in the furnace, the metal is heated to a specific temperature above its melting point, usually in excess of 2800°F. Because of the extreme temperatures, precision, and large volumes required for steel production, the melting stage generally requires 8 to 12 hours. Throughout this stage, steel technicians regularly check the bath temperature and chemical composition.

After the steel alloy is completely melted, the mixture is refined. Argon gas and oxygen are pumped into the furnace, where they convert some impurities to gas and cause others to form slag for easy removal.

The refined steel is cast into machine-ready forms, including blooms (rectangles), billets (round or square), slabs, rods, and tube rounds.

Forming

Hot rolling occurs above the recrystallization temperature of the steel. Most cast steel is formed by hot rolling: the slab, bloom, or billet is heated and passed through huge rollers, stretching out the steel into a longer, thinner form. Each slab is formed into a sheet, plate, or strip, while blooms and billets are formed into wires and bars.



Most cast steel is formed by hot rolling.

Cold rolling is used when more precise dimensions or a superior surface shine are required. It occurs below the recrystallization temperature of the steel. Cold rolling uses small diameter wheels with a series of supporting wheels to create smooth, wide sheets of stainless steel to close tolerances.

Heat treatment

Heat treatment strengthens rolled stainless steel by recrystallizing the deformed microstructure. Most stainless steel is heat treated by annealing – the stainless steel is heated to an exact temperature above its crystallization temperature, and slowly cooled under controlled conditions. This process relieves internal stresses and softens the stainless steel. The annealing temperature, time, and cooling rate all impact the properties of the complete steel.

Descaling

A rolled piece of stainless steel acquires a layer of oxidized “mill scale”, which needs to be washed away to restore a shiny surface finish. Mill scale is usually removed through chemical means like electro-cleaning and pickling.

In pickling, the stainless steel is submerged in a bath of nitric-hydrofluoric acid. Electro-cleaning makes use of a cathode and phosphoric acid to pass a current onto the stainless steel surface. Both processes effectively de-scale the surface. The de-scaled metal is finished off with a high-pressure water rinse, leaving a bright, shiny finish.

Cutting

Stainless steel is cut to a specified shape and size. Most cutting is done mechanically – the stainless steel can be sheared with circular knives, sawed with high-speed blades, or blanked with punches. Alternative methods such as flame, plasma, and waterjet cutting are sometimes used.

Finishing

Stainless steels can be made with a wide variety of surface finishes. The chosen surface finish isn't purely aesthetic – certain finishes make stainless steel more resistant to corrosion, easier to clean, or more readily used in manufacturing. The type of finish is determined by the intended application.

Surface finishes are the combined result of fabrication processes and finishing method. Hot rolling, annealing, and de-scaling produce a dull finish. Hot rolling followed by cold rolling on polishing rolls producing a bright finish, while a combination of cold rolling, annealing, and buffing with a fine surface creates a reflective surface.

An array of grinding, polishing, buffing, and sandblasting equipment is used in finishing stainless steel surfaces.

Work Hardening

Work hardening is the process of strengthening material through deformation. Stainless steels harden quickly overall, with the exact rate determined by the specific grade. Austenitic steels harden more readily than other grades.

Quality Control and Inspection

There are in-process controls throughout the manufacture and fabrication of stainless steels, but that isn't enough to meet international quality standards. Before being shipped, each batch of stainless steel must undergo chemical and mechanical testing to ensure that it meets the desired specifications.

Mechanical testing measures the physical ability of a stainless steel to withstand loads, stresses, and impacts. Mechanical tests include the tensile, Brinell, and toughness tests

described above in mechanical properties.

Chemical tests check the exact chemistry of a sample before certifying the stainless steel grade. Chemical tests are usually carried out by non-destructive spectrochemical analysis.

Corrosion resistance is of particular importance for stainless steels. Steel mills test and measure corrosion resistance with salt spray testing – the longer the steel remains unmarred by corrosion after exposure to salt spray, the higher the corrosion resistance.

Manufacturing

Stainless steels are a highly useful material used to manufacture a large range of products.

Most stainless steel is shipped to a manufacturer, where it undergoes further shaping, heat treating, machining, and welding to form a particular product. Stainless steels are frequently used to produce components for the automobile, ship, aircraft, and food service industries, among many others.

Stainless Steel Maintenance

Stainless steels have a well-deserved reputation for corrosion resistance. They will not rust as quickly or severely as conventional steels – but that doesn't mean they are completely immune to corrosion. Stainless steels can be corroded by long term exposure to damaging chemicals, grease, salt, moisture, or heat. The advantage of stainless steel is the ease with which stains can be removed and the passivation layer restored.



Steel sheet is shipped in large rolls.

Routine cleaning with soap and water will keep a stainless steel object attractive and in service for many years.

Lightly stained household appliances like kitchen sinks and refrigerator doors can be cleaned with a naturally acidic solution like vinegar or a mixture of lemon juice and baking soda.

Commercial and industrial parts usually need stronger treatment. An all-purpose lubricant like [WD-40](http://wd40.com) (<http://wd40.com>) is usually sufficient to clean away staining and restore the passivation layer. Stubborn rust spots can be treated with phosphoric acid based cleaners. After cleaning, the steel surface should always get a thorough rinse with clean water.

[Learn more about how to clean stainless steels.](#)

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