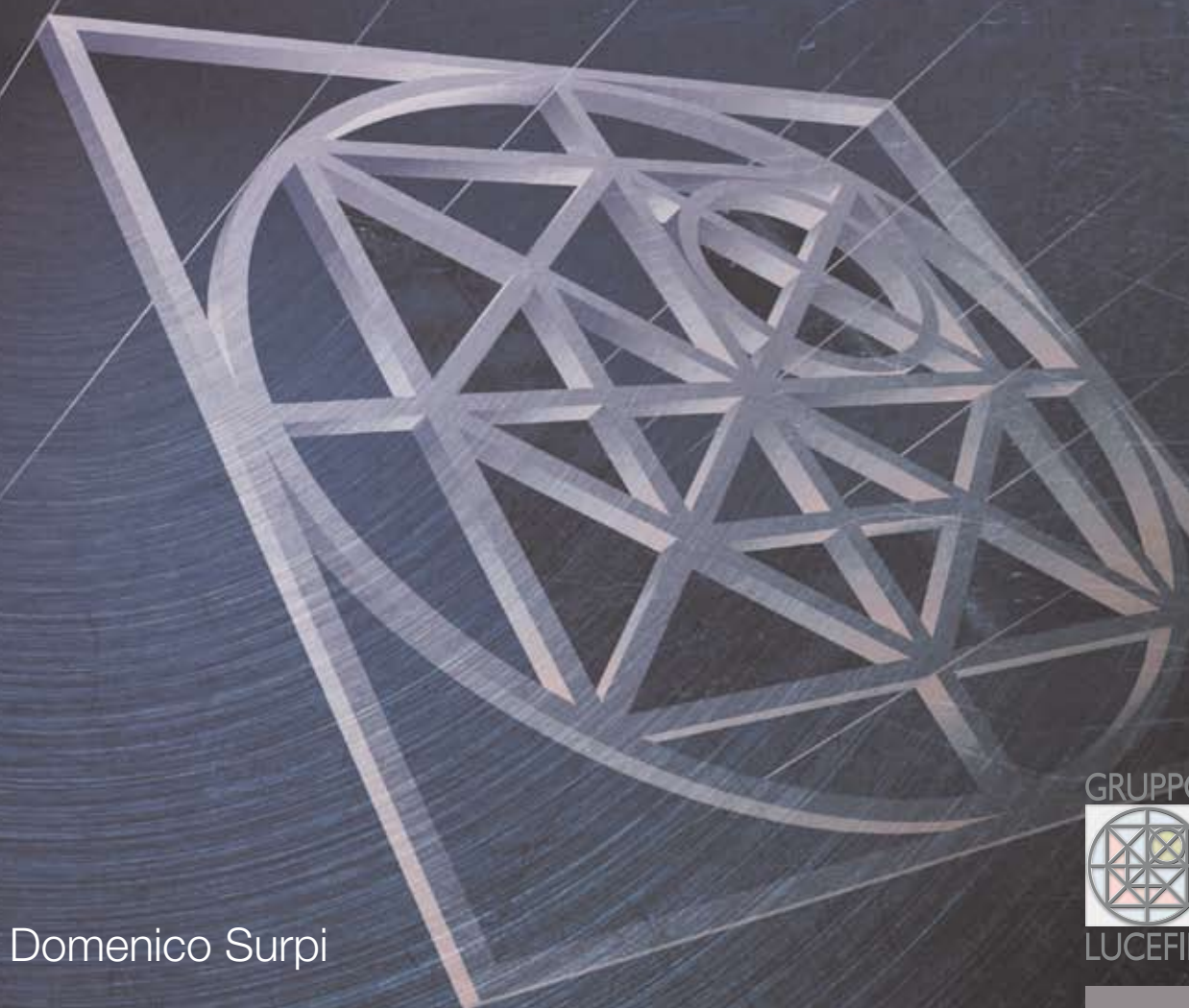


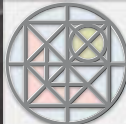
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Stainless steels
Rostfreie Edelstähle

On CD-ROM



Domenico Surpi

GRUPPO

LUCEFIN

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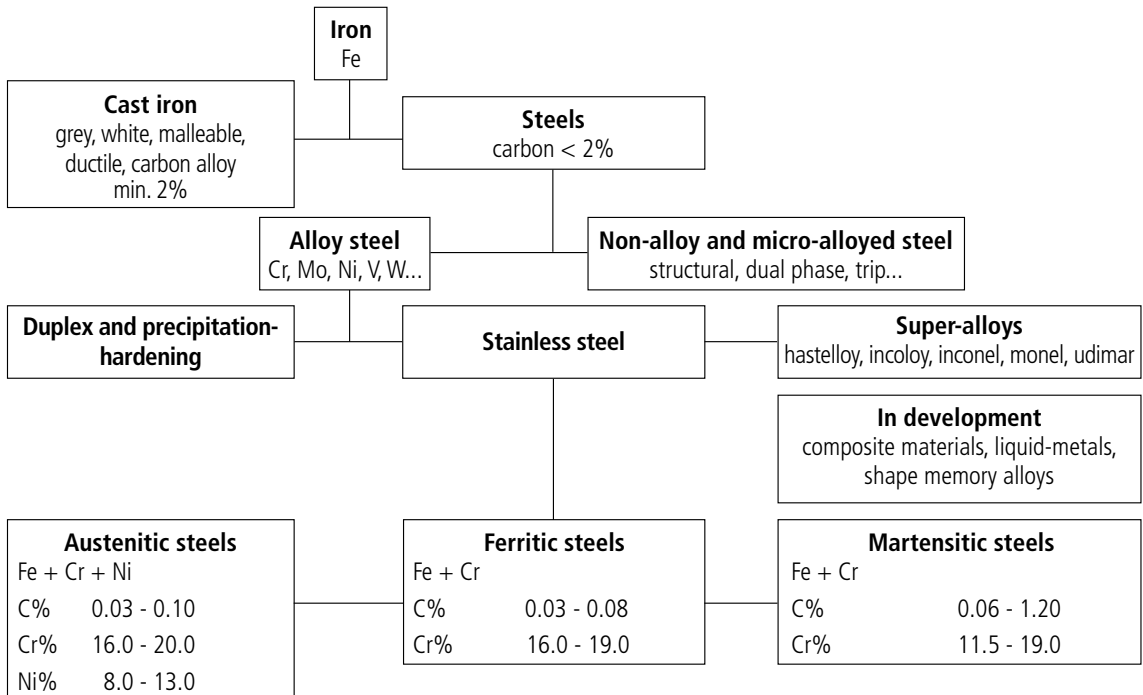
BASIC PRINCIPLES

Stainless steels are metals with high chromium content, used to prevent different types of corrosion. These metals and alloys have the defining characteristic of being resistant to both dry corrosion, through exposure to air or high temperatures, and wet corrosion. A distinction is made between dry corrosion (known as oxidation or high-temperature corrosion) and wet corrosion found in humid or wet environments.

Generally speaking, stainless steel is resistant to heat corrosion thanks to the formation, and further maintenance on site, of a fine, adherent and compact film of protective chromium oxide, which acts as a barrier and prevents any further attack on the base material. Wet corrosion is an electro-chemical process and stainless steel is corrosion-resistant thanks to the formation of a surface passivated film, though passivation only occurs when chromium content exceeds 10.5%.

In all types of stainless steel, this film must be continuous and adherent to the surface, it must not be porous or insoluble, and must be able to re-form if damaged when re-exposed to air or the effects of oxidizing environments. The structures of these metallic materials are of extreme importance, by which stainless steels are classified into the following types: **ferritic, martensitic, austenitic, austen-ferritic** and precipitation-hardening.

THE EVOLUTION OF IRON ALLOYS



The C - Cr - Ni values of stainless steels refer to those types included in the present catalogue



FERRITICS

Do not have critical temperatures and their structure is characterized by a high chromium and low carbon content. They are usable after recrystallization annealing. No matter what temperature this steel is heated to, its structure remains ferritic. After hot working, ferritic steels can be air-cooled as they do not harden and there is no serious risk of stress cracking.

Hot forming has an upper limit of 850-900°C as at around 1150°C there is a potential risk of grain growth which no heat treatment can reverse. To remedy such damage, the metal must be cold deformed to shatter the grain and then subjected to heat treating for recrystallization. The measured CR/C ratio ensures that the material does not have a transformation point: no heat treatment can alter its mechanical or physical properties.

CHARACTERISTIC PROPERTIES:

- C% 0.01 – 0.12 / Cr% 10.5 – 30.0
- corrosion resistance increases from moderate to good with an increase in chromium content
- good resistance to stress corrosion
- heat resistant to 1175 °C and scaling resistant to 750 - 800 °C
- limited mechanical characteristics, not improvable by heat treatment and barely improvable by cold-working; they cannot be hardened to the same extent as austenitics
- sharp decrease in toughness (Kv resilience) at temperatures near and below zero °C
- good resistance to wear
- good cold formability
- poor weldability, which can cause stress weakening

Their high magnetic permeability classifies these steels as ferromagnetics.

Free machining steels have a lower corrosion resistance than the same original steel type.

They are prone to embrittlement at, even at short exposure, to temperatures between 400 and 600°C; this phenomenon can be lessened by adding certain stabilizing elements during the melting phase.

CATALOGUE STEELS:

STEEL 1.4016 • EN X6Cr17 • AISI 430

Non-heat treatable.

Easily cold deformable to increase hardness, tensile and yield strength values.

It is advisable to preheat thicknesses of over 3mm to 100-300°C before cold rolling or drawing. Low-stress parts are generally used in an annealed condition, the ferritic structure is maintained at all temperatures.



Grinding and precise polishing can increase corrosion resistance.

Recommended for high-temperature applications and not recommended for use in environments with temperatures below 0°C because of embrittlement.

Uses: cutlery, domestic appliances (e.g. sinks and drums for washing machines and dishwashers), petrochemical and detergent industries, automotive industry trims, exhaust systems, containers for petrol, nitric acid plants, production of kitchenware, magnetic sensors, electro-injectors, containers for fuel, diesel combustion chambers, heaters, zips, ice-cream containers, equipment for nitrogen fixation, oil burners, industrial captor hoods, soot blowers, wire cloth, electromagnetic valves, plumbing pipes, bolts and screws.

Flat products are used for: roofing, gutters, drainpipes, flashing, load-bearing parts for roofs, paneling for elevators, AC; in the production of alternative energy as structure for solar panels and photovoltaic modules; thanks to excellent results from polishing, ideal for use in interior design applications.

STEEL 1.4105 • EN X6CrMoS17 STEEL AISI 430FMO

Non-heat treatable.

High sulfur content makes it suitable for automatic machine working.

To avoid the slight decrease in corrosion resistance which results from the addition of sulfur and sulfides a measured amount of molybdenum is added.

Good resistance to stress corrosion.

Uses: nitric acid and petroleum industries, architecture, decoration, automotive industry, nuts and bolts, magnetic brakes, bimetal thermometers (measuring temperature-humidity), screws, oil-burners, kitchenware, electromagnetic valves, plumbing components, injectors, furniture, mining industry, agriculture, landfill components, magnet rotors, solenoid electrovalves, temperature regulators.

Poor resistance to intergranular corrosion. Not recommended for pressure containers.

STEEL 1.4106 MOD • X2CrMoSiS18-2-1

Free machining steel, non- heat treatable.

Reduced corrosion resistance because of high sulfur content.

However, high molybdenum content means excellent resistance to acid and chloride corrosion.

Its particular chemical composition allows for excellent magnetic characteristics: silicon content gives high magnetic permeability and consistent electric resistivity.

Use: electrovalves for corrosive environments, pistons, earthing system components, sheathing, high-temperature pressure containers for corrosive environments, magnetic cores for transformers, dynamo poles, flow regulators, relays, parts for industrial and domestic ovens.



MARTENSITICS

So called because they are the only stainless steels to have critical temperatures (Ac_1 , Ac_3) and take on the martensitic structure after quenching.

The presence of chrome causes a significant movement to the right of the isothermal and anisothermal curves, consequently the structure can also be obtained through air-cooling.

As with heat-treatable steels, the best properties are obtained after quenching and tempering; however, care must be taken with the latter treatment as chromium carbide precipitation can affect corrosion resistance. Martensitic steels should not be used in an annealed condition.

CHARACTERISTIC PROPERTIES:

- C% 0.08 – 1.2 / Cr% 11 - 19
- moderate corrosion resistance: even exposure to urban-industrial atmosphere can damage the material
- good wear resistance
- low toughness especially at temperatures below 0°C
- poor weldability

Careful (mirror) polishing increases corrosion resistance.

Their high magnetic permeability classifies these steels as ferromagnetics.

Free machining steels have a lower corrosion resistance than the same original steel type.

CATALOGUE STEELS:

STEEL 1.4005 • EN X12CrS13 • AISI 416

Normally used in quenched and tempered condition as this increases its mechanical properties and corrosion resistance.

Low carbon content, sulfur added to increase workability.

Welding is not recommended: if unavoidable, use preheating and final stress relief. Quenching and tempering may modify mechanical characteristics according to application needs.

Use: turbines for energy production, hydraulic valves, fresh water motors and pumps, sports equipment, aggressive environments in chemical industry, screws, bolts, nails, pins, studs, valve stems, armaments, airplane parts, extinguishers, forged molds. Not suitable for wear or seizing risk applications.

STEEL 1.4006 • EN X12Cr13 • AISI 410

Suitable for quenching, stress-relief or tempering treatments.

It can be used in its annealed state. Suitable for cold drawing.



The highest levels of corrosion resistance are achieved after quenching and stress relief at 200°C and not over 430°C.

Tempering carried out at temperatures between 430 and 700°C causes a reduction in corrosion resistance. Optimum toughness properties are achieved with steels tempered at temperatures between 600 and 760°C.

Excellent deformability for hot rolled recrystallized or annealed materials, difficult to further deform (e.g. drawing or other) previously cold-deformed materials.

Uses: valve housing covers, lids, connectors, pump parts, flanges and fittings for petroleum and petrochemical industries, valve seats, shafts, rods, bolts, brackets, taps and fittings, spokes and rims for bicycles and motorbikes, gas burners, beaters for paper production, coal shoots-covers-bunkers, keys, micrometers, rifle parts, shears, lanterns, steam turbines, wire cloths, cupboards, interior decoration, diffusing bases, washing machines, exterior trim and decoration, water flush systems; in nuclear power stations as safety valves and control panels.

STEEL 1.4021 • EN X20Cr13 • AISI 420A

Normally used in quenched and tempered condition.

It has self-quenching properties (hardens when air-cooled).

Recommended for high-stress applications and low-corrosion environments.

Uses: mechanisms exposed to saline corrosion, cutlery, surgical and orthodontic materials, bearings when impossible to use rust-proof lubricant, hydraulic and gas turbines, agricultural and sports equipment, molds for glass, turbine blades, pump shafts, light weaponry, clamps and anchorage, valves, magnets, vegetable blenders; equipment to temper springs, in nuclear power stations as control rods.

STEEL 1.4028 • EN X30Cr13 • AISI 420B

High-hardness and good corrosion resistance after quenching and tempering.

Self-quenching.

Suitable for photochemical milling.

Excellent corrosion resistance after quench and stress relief at 200°C.

When the material is to be polished or photochemically milled it is recommended that a steel with S% 0.015 max. is used.

Uses: cameras, molds for glass, architectural design parts, kitchen knives, valve housings, conical valves, springs, screws, surgical instruments, molds for plastics, pump shafts, flanges and fittings.

STEEL 1.4031 • EN X39Cr13

Suitable for quenching and tempering.

Good resistance to heat and corrosion.



The highest corrosion resistance is achieved by low temperature (approx 180°C) quenching and stress relief. Welding is problematic and not advisable: if unavoidable, use pre-heating at 250-300°C and when welding is complete anneal immediately at 700-750°C.

Careful (mirror) polishing improves corrosion resistance.

For photochemical milling, it is advisable to use a steel with S% 0.015 max.

Uses: cutting blades for DIY, measuring instruments such as gauges, comparators, micrometers, molds for plastics, springs, surgical instruments, taps and fittings, pumps and filters for diesel engines, wear parts in drinkable water environments.

STEEL 1.4034 • EN X46Cr13 • AISI 420C

STEEL 1.4034 DE with improved workability

Suitable for quenching and tempering.

Welding is difficult and generally not recommended.

Good deformability in rolled state.

Highest corrosion-resistance is achieved by quenching and stress relief.

Good resistance to corrosion and heat.

Scaling resistant up to 650 °C.

Uses: containers for plants/vegetables, springs, molds for plastics, antifriction bearings, scissors and knives, mechanical industries, surgical instruments, scrapers, pump parts for diesel engines, fixers and fasteners, valve balls, automotive sector, domestic appliances, measuring tools (e.g. gauges and comparators).

STEEL 1.4035 • EN X46CrS13 • (AISI 420C+S)

High sulfur adding means excellent machinability.

Mechanical properties fixed by heat quenching and tempering treatments.

Sulfur content reduces corrosion resistance.

Welding is problematic because of high sulfur content and so is not advised.

Uses: pivot pins, small molds for plastics, cutting instruments such as razor blades, kitchen knives, scissors, scrapers, surgical instruments, worm screws, housing and track bearings, pin valves, nozzles. Not recommended for pressure containers for gas or liquids.

STEEL 1.4057 • EN X17CrNi16-2 • AISI 431

Usually used when quenched and tempered for high yield-strength and excellent impact resistance.

Quenching and tempering may modify mechanical characteristics according to application needs.

Good fatigue resistance.

Excellent deformability for hot rolled annealed materials, difficult to further deform (e.g. drawing or other) previously cold-deformed materials.



Excellent performance in sea water or salt environments.

Normally not used in applications where welding is necessary.

Uses: underwater equipment, piston rods, parts exposed to acidic water in mining, ship building, bolts for the starch and paper industries, valve parts, small propeller shafts for lakecraft, glass grinders, centrifuges for cheese-making and brewing, principally used for fixing devices; in nuclear power stations as core reactor pressure containers.

STEEL 1.4104 • EN X14CrMoS17 • AISI 430F

Free machining version of steel X14CrMo17.

Suitable for thermal quenching and tempering treatments.

Good resistance to medium corrosion (air, fresh water, nitric acid to 90% in cold and to 10% in heat, weak organic acids).

The added sulfur slightly decreases resistance to pitting and crevice corrosion.

Suitable for machining on production lines and at high-speeds

Not suitable for welding applications.

Uses: petroleum and nitric acid industries, exterior decoration for construction industry, decorative features on cars, bolts and screws, oil burner parts, cutlery, plumbing pipes, temperature regulators, temperature and pressure regulators, aeronautic parts.

Because of the high sulfur content (which may cause porosity inside the product) this steel is not recommended for pressure containers.

STEEL 1.4112 • EN X90CrMoV18 • AISI 440B

Highly wear-resistant and significant non-deformability.

By quenching and stress relief it acquires substantial hardness.

Good resistance in medium-corrosive environments when quenched and stress relieved at 300°C.

Because of high-quenchability, preheating and stress relief are necessary during welding.

Difficult to cold roll and draw.

Highest corrosion resistance obtained by tempering at temperatures below 430°C.

Uses: equipment for forming tin-plated strips, surgical instruments, bearings, parts for internal combustion engines, containers for food, knives, cold circular saw blades, tempered balls, permanent magnets, wear parts.

STEEL 1.4116 • EN X50CrMoV15

Low weldability because of its self-quenching properties.

Unsuitable for cold deformation. Excellent wear-resistance.

Highest level of machinability is obtained when the material is annealed using chipbreaking equipment.



Good resistance to oxidation and heat up to 760°C.

Uses: various cutting blades, cutting equipment, dishwasher-proof cutlery, molds and dies for synthetic resins, bearing nuts, balls, valve parts, measuring instruments, dies, surgical and orthodontic instruments, permanent magnets, pivot pins

STEEL 1.4122 • EN X39CrMo17-1

Heat quenching and tempering treatments give this steel excellent corrosion and wear resistance as well as anti-friction properties. Welding is not recommended: if unavoidable, use the TIG technique after preheating to 300-400°C.

Uses: compressor parts, bolts, valves for water steam, professional and surgical knives, molds for corrosive plastic materials and synthetic resins, high quality cutlery, pump parts, marine installations, studs, welding rod for hardfacing; in nuclear power stations as cores and pressure containers.

STEEL 1.4125 • EN X105CrMo17 • AISI 440C

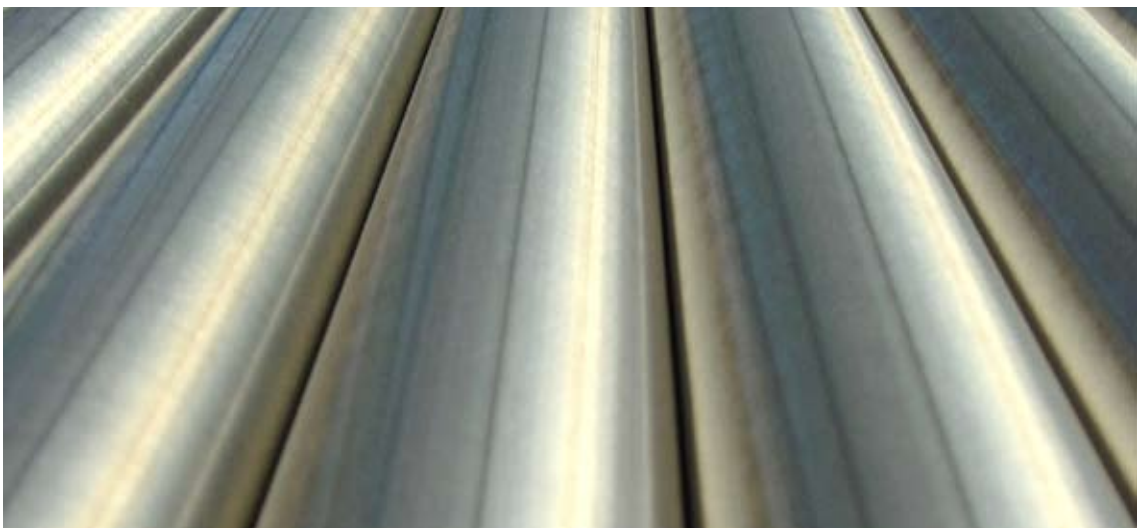
Suitable for quenching and stress relief to achieve high-hardness levels.

High wear-resistance.

Not to be used at working temperatures over 425°C as it is affected by tempering and corrosion resistance is compromised; noticeable oxidation at 750°C.

Welding is not recommended due to its high-quenchability: if unavoidable, preheat to 200-150°C and after welding anneal at 780°C.

Uses: special high-resistance knives, cutting discs, razor blades, surgical instruments, bearings, nozzles, valve and pump parts for oil wells, soot separators for diesel engines.



AUSTENITICS

The austenitic structure is stable at ambient temperature and characterized by the presence of chromium and nickel and a low carbon content. Austenitic steels are used in various aggressive environments and at high and low temperatures.

The most common heat treatment for all types of austenitic steel is solution heat treatment (water cooling from 1050°C).

The drawing process allows the desired degree of hardening, favoring yield-strength and tensile strength properties.

To aid this cold-working and not overdo hardening, the steel is treated with oxalates which act as a lubricant between the metal and die surfaces, thus reducing friction

Mechanical resistance can be increased through the addition of nitrogen and molybdenum.

A smooth, uniform surface (with very low surface roughness) significantly improves corrosion resistance.

CHARACTERISTIC PROPERTIES:

- C% 0.015 – 0.15 / Cr% 16.0 – 28.0 / Ni% 6.0 – 32.0
- molybdenum content gives high corrosion (crevice and pitting) resistance, however this can be compromised under stress in chloride environments
- high resistance to creep deformation
- good wear resistance
- high resistance to hot oxidation up to 925 °C and up to 1150 °C for the refractories (Cr% > 20, Ni% ~ 20, Si% > 1)
- good fatigue resistance
- the good ductability of these steels makes them highly suitable for cold forming
- good weldability
- very low magnetic permeability, such as that of a vacuum, allows stable non-magnetism

Free machining steels have a lower corrosion resistance than the same original steel type. The use of varnishes, including antifouling treatments, is not recommended and may be useless or even damaging; careful cleaning is recommended so as not to damage the passive film.

In the event of damage of the protective layer, pickling and/or passivation are recommended: the passive film will re-form quickly and efficiently.

Steels not prone to brittle fracture when solution-heat treated; they can also be used for applications at cryogenic temperatures (-160°C).



CATALOGUE STEELS:

STEEL 1.4301 • EN X5CrNi18-10

Free machining steel. In the stainless steel sector this is the classic 18-10.

Not quenchable, its R and Rp0.2 mechanical characteristics can be improved using draw hardening.

Excellent toughness at low temperatures. If welding for these purposes use E308 L electrodes.

Good corrosion resistance in solution-heat treated condition.

Avoid slow heating and cooling in the temperature range of 450° to 850°C to prevent chromium carbide precipitation (sensitization phenomenon).

Good weldability and drawing potential.

When ferrite content exceeds 1.5% there is a risk of breaking during drawing. To avoid this problem it is recommended that nickel content be kept at the highest levels permitted so as to keep ferrite levels below 0.5%.

Uses: pharmaceutical industry, chemical plants, oil industry, fabric production, dye-works, food production, jewellery, springs, architectural decoration, petrol tanks, car industry, heat exchangers, valves and nozzles, avalanche shelters; water sector (grids, sluice gates, self-cleaning and standard filters, sedimentors, agitators, sunken pumps, insufflators for oxygenation tanks, conveyors and ducts for sewage), medium and deep stamping; treatment plants for milk, cheeses, butter, fruit juices and distilleries; containers and equipment for cocoa processing; sound absorbing screens for use near railway lines and motorways.

Flat products are used for: roofing, guttering, drainpipes, flashing, windows and doors, load bearing roof structures, panels for elevators, road panels, gates, fencing, AC ducts, grilles and surfaces to be walked on, steam iron base plates; in nuclear power stations as flanges, springs, bolts, valves, tubes and boilers; in alternative energy production to make solar panels and dishes. Subject to intercrystalline corrosion when in sensitized condition (improvable by solution heat treatment), poor corrosion resistance in chloride environments.

STEEL 1.4305 • EN X8CrNi18-9 • AISI 303

Free cutting steel, used in solution heat treated and draw-hardened condition. Excellent toughness at low temperatures and good corrosion resistance in the absence of chlorides and reducing acids.

Acid attack creates pitting and crevice corrosion.

Lubricants normally used in general mechanics can be applied when turning or finishing.

Difficult to weld unless suitable methods adopted.

It becomes slightly ferromagnetic in proportion to amount of cold-hardening it undergoes.

Uses: screws, studs, nuts, bolts in mass production, connectors, pins, stay rods, bushings, fishing reels; furniture, domestic appliances, transport, electronic equipment.

STEEL 1.4306 • EN X2CrNi19-113

Chrome-nickel steel can be hardened through cold deformation, e.g. drawing or forming.

Unaffected by intergranular (intercrystalline) corrosion.



High nickel content produces high toughness at cryogenic (very low) temperatures.

The fatigue resistance of smoothed products in air is around 250 N/mm², this is lower in corrosive environments.

Not suitable to resist chloride corrosion. Avoid applications above 550°C.

Uses: dye-plants, paper, chemical, pharmaceutical, food, textile, nuclear, fertilizer and nitric acid industries; welding equipment, tanks, cryogenic equipment, cisterns.

STEEL 1.4307 • EN X2CrNi18-9

Not quenchable; mechanical properties can be improved by cold deformation.

In solution heat treated condition it is unaffected by intercrystalline corrosion.

Usually produced using calcium treatments to improve machinability.

Is slightly magnetized during cold deformation (drawing or cold rolling). Excellent drawability.

Easy to weld even without preheating and final stress relief.

Mechanical or chemical pickling of welding is recommended followed by passivation using 25% nitric acid.

Uses: containers and equipment for foods, textiles, oil industry, textiles and for cryogenic (low temperature) applications; coal hoppers, tanks for fertilizers; equipment for nitric acid production, containers for tomato concentrate, metal fabrics and meshes, architectural decoration, Ac ducts; in nuclear power stations as plating for welding and primary circuits.

STEEL 1.4310 • EN X10CrNi18-8 • AISI 302

It is one of the most widely used austenitic chrome-nickel steels; extremely strong and flexible, it is used under laminate conditions and is cold drawn. This steel is a version with a slightly higher carbon content compared to the 1.4301 type and has an excellent resistance to fatigue. Its resistance to corrosion is a bit higher than that of steel AISI 301.

The easy cold working greatly increases the hardness of this material but in the drawing phase, a possible increase of magnetism should be considered. When working it on machine tools, it is recommended to use chip breaker inserts because it has a remarkable plasticity.

Use: springs, watch components, connectors components, cages for animals, cooking equipment, for beverages, for bottling beer, outdoor architectural elements, boilers, washing machine drums, kitchenware, jewellery, pharmaceutical industry, food and dairy, gasoline tanks.

STEEL 1.4401 • EN X5CrNiMo17-12-2 • AISI 316

Used at high temperatures with good corrosion resistance to various acids, salts, sea water and chemical reagents. High molybdenum content allows its use in reducing environments and where good creep-resistance is needed. It resists localized (crevice and pitting) corrosion and in its sensitized state is relatively unaffected by intercrystalline corrosion. Heated materials in oxidating environments need to be chemically pickled to ensure the highest corrosion resistance.



Uses: chemical industry, food industry, artificial silk production, paper and cellulose production, photography, surgery, tanks for ships, cutlery, pharmaceutical production, automotive industry, plumbing, containers for food and beverage, guttering, heat exchangers and oven parts; rotors, pump shafts and diaphragms for desalination plants; steps, bridges and walkways; chimneys, containers for softening water, kettles, equipment for processing maize, vats for brandy; in the production of alternative energy as parabolic solar panels.

STEEL 1.4404 • EN X2CrNiMo17-12-2 • AISI 316L

Not quenched; its mechanical properties can only be improved using cold-deformation.

Suitable for intense cold deformation.

Good resistance to intercrystalline and salt water corrosion and to food substances.

Heated materials in oxidizing environments need to be chemically pickled to ensure the highest corrosion resistance.

Uses: particularly suitable for welding, chemical and food industries, production of artificial silk, flues and smokestacks, paper and cellulose, photography, surgery, tanks for ships, cutlery, chimneys, pharmaceutical industry, automobiles, plumbing, containers for food and drink, petrochemical vessels, parts which come into contact with sulfur dioxide, in depuration plants as flocculants doser and in incineration plants, fans, valves and nozzles, meshes, heat exchangers; in nuclear power stations as heat generators and pumps; used in jewellery and glasses production, although recent legislation has eliminated the use of nickel in situations where sweat is produced to be replaced by the less allergenic titanium alloy; in solar energy production to make accumulator tanks.

If parts have been welded, do not use for applications exposed to working temperatures over 400°C.

STEEL 1.4435 • EN X2CrNiMo18-14-3 • (AISI 316LMo)

Its structure is fully austenitic and after solution heat treatment, the ferrite content is less than 0.5%.

Similar to steel 1.4404 but with lower content of silicon and higher content of molybdenum.

Thanks to its fully austenitic microstructure, it can be easily cold formed and, with its higher molybdenum content, you can make equipment more resistant than with steel 1.4404.

Its totally austenitic structure, however, may be sensitive to the occurrence of hot cracking.

It can be welded with most welding processes: TIG, Plasma, MIG, SMAW, SAW, etc. using parameters that prevent the precipitation of carbides or nitrides and the formation of cracks.

The best results to prevent corrosion are obtained with polished surfaces.

Uses: like those of steel 1.4404 when higher mechanical strength is required.

STEEL 1.4541 • X6CrNiTi18-10 • AISI 321

Often called "refractory stainless steel".

Steel stabilized by the addition of titanium.



Good intergranular corrosion resistance.

If solution heat treated in oxidating environments, chemical pickling is necessary to obtain the highest corrosion resistance.

It cannot be sensitized.

Relative magnetic permeability at -196 °C ~ 2 μ r.

Very ductile steel.

Uses: in heat treatments for baskets, muffle furnaces, baths, crucibles, heating plates, grilles, chains, hooks, rollers, pistons, fans, nozzles for burners, screws and bolts;

aircraft collector rings, jet engine parts, boiler casings, shells for batteries, pressure containers, fire walls and doors, domestic boilers, manifolds.

Its good toughness at low temperatures makes it ideal for use in the production of industrial nitrate fertilisers.

STEEL 1.4567 • EN X3CrNiCu18-9-4 • (~ AISI 304Cu)

Copper addition stabilizes the austenitic stainless steel and makes it ideal for various cold deformation processes (hobbing, bending, drawing and machining). The copper content also increases corrosion resistance. Suitable for cryogenic applications.

Good for threading and boring in line with relative hardening.

Uses: automotive sector, chemical industry, food and beverage production, decoration, electronic components in ship-building, vineyards, wall hooks, cables, nails, wire mesh.

STEEL 1.4570 • EN X6CrNiCuS18-9-2 • AISI 303K

Free-cutting stainless steel, whose mechanical properties do not alter by quenching. High sulfur content can cause microcracking during cold deformation (drawing, forming etc).

Sulfur and copper addition increase the steel's machinability.

Copper addition increases resistance to corrosion caused by plastics.

Parts should be simply shaped so as to avoid the collection of corrosive agents.

Sensitization at temperatures in the 450 to 800°C range risks intercrystalline corrosion.

Uses: all applications where there is the need for a corrosion resistance exceeding that of the basic ASTM 303 steel; high-speed mass production items such as pins, screws, nuts, rods, bushing.

STEEL 1.4571 • EN X6CrNiMoTi17-12-2 • AISI 316Ti

Titanium stabilized steel with good resistance to intercrystalline, uniform, localized, pitting/crevice corrosion. Efficient resistance to sensitization (limited chromium carbide formation) due to operating temperatures. Good mechanical properties at ambient and high temperatures with significant creep resistance.

Susceptible to severe oxidation at high temperatures in stagnant air environments.



Excellent for cold pressing and drawing.

Good weldability.

Uses: welded structures, maritime, petrochemical industry, food production, pharmaceutical sector, paper and textile production; heat exchangers for domestic and industrial ovens, coils for water heaters.

AUSTENITIC - FERRITICS (commonly referred to as duplex)

Containing chromium, nickel, molybdenum and nitrogen in appropriate proportions, they have a two-phase structure, consisting of austenite as "islands" surrounded by the ferritic matrix in almost equal parts. The main characteristics of these steels are excellent resistance to stress corrosion and a high yield strength.

The ferritic structure is more resistant to stress corrosion than the austenitic one and to general corrosion, so it is easy to see the industrial interest in these two-phase steels.

The chemical elements characteristic of this family are Cr, Mo (ferritizing) and Ni, C, N (austenitizing).

The nitrogen percentage of 0.10 to 0.20 also increases the stability of the austenitic structure during heat treatment, improves the mechanical strength and resistance to localized corrosion.

In the two-phase steels, there are two critical temperature intervals. One at 800°C (between 600 and 950 ~) which may cause a precipitation of carbides/nitrides and the other at 475°C when the ferrite can be enriched by chromium and, because its hardness increases, it becomes more brittle.

Toughness is also reduced by the oxygen content and the presence of intermetallic phases.

Duplex steels have a better fatigue behaviour than austenitic. This has been tested and confirmed by the Lf/R ratio between 0.5 and 0.6 for duplex steels and between 0.45 to 0.50 for austenitics.

(Lf = theoretical fatigue limit in rotating bending test and R = tensile strength of the material).

These steels are not suitable for heat treatment but can change the structure percentage with the solution heat treatment, e.g. by increasing that temperature a higher percentage of ferrite can develop at the end of quenching.

STEEL 1.4362 • EN X2CrNiN23-4 • UNS 32304

Steel used in environments subject to stress corrosion, cracking, pitting. Excellent mechanical strength obtained by adding nitrogen (N). Good toughness and ductility (midway between austenitic and ferritic steels). For hot forming, use $T \sim 0.6 \bullet T$ fusion, fine grain and low reduction speeds. It should not be used for prolonged periods at temperatures above 300°C because of the risk of loss of mechanical strength and the onset of embrittlement. Easily weldable, if you make sure to take all precautions necessary to avoid hydrogen absorption. An excellent surface finish (lapping with Ra 0.10 to 0.20 μm) has shown a significant increase in resistance to corrosion due to pitting.

Use: pressure vessels, hot water tanks, screws, fans, heat exchangers, waste water treatment, augers, mixers, paper and cellulose plants, bleach production, food and beverage industries, firebreak walls, offshore platforms.



STEEL 1.4462 • EN X2CrNiMoN22-5-3 • UNS 31803

Similar to steel 1.4362 but more alloyed with the addition of molybdenum (Mo). Its resistance to corrosion from pitting and crevices is equal to or greater than that of steel AISI 317L. It has more mechanical strength than austenitic steels. It is not immune to stress corrosion, but it is the most commonly used steel in engineering operations to withstand environments with sodium chloride and brine. It should not be used at temperatures above 340°C. The presence of molybdenum and nitrogen can cause difficulties in working it on machine tools. Its mechanical properties depend on the ferrite/austenite ratio and its toughness depends on iron levels. A higher percentage of ferrite corresponds to lower toughness and higher percentage volume of austenite corresponds to less mechanical strength. After cold working with reductions greater than 10%, it is recommended to perform a solution heat treatment. Like all duplex steels, this one also resists well at cryogenic temperatures (below -180°C).

Use: heat exchangers, acetic acid stills, combustion exhaust filters, pressurized chemical containers, industrial gas and oil equipment.

As a guide for use of stainless steels at low temperatures, the percentage of nickel (Ni%) found in the chemical analysis can be considered.

With Ni ~ 9% use at -196°C, with Ni ~ 3.5% use at -101°C, with Ni ~ 2.25% use at - 59°C.

As a guide for resistance to the formation of scales at high temperatures, refer to the content of Cr-Ni.

With Cr ~ 13%, use up to 760°C, Cr ~ 18% and Ni ~ 9%, use up to 850°C, Cr ~ 25% and Ni ~ 20% use up to 1150°C, Cr ~ 28% use up to 1175°C.

PRECIPITATION HARDENING STEELS

Often shortened to PH. Hardening is achieved after quenching through successive heating to not to high temperatures (480-600°C). Their main characteristics are good corrosion resistance with excellent mechanical properties. The chemical elements principally used to harden these steels are: titanium (Ti), niobium (Nb), nitrogen (N), aluminum (Al), and copper (Cu). PH steels also have martensitic, austenitic and semiaustenitic types. Given the cost of the raw material, PH steels are most cost effective in applications and sectors (aerospace and energy production) where high resistance and excellent elongation are needed.

e.g.: Martensitic type 17-4 PH after solution heat treatment and aging for one hour at 480 °C: R = 1250 N/mm²; A% = 13

OTHER STAINLESS STEEL CONSIDERATIONS

A certain level of decarburization may not be harmful to ferritics or austenitics but can be to martensitics; an increase in carbon is harmful to all types. When treatments are performed in the presence of gas, all necessary measures must be taken to avoid the absorption of hydrogen, because of its well-known embrittling effect. Ferritics and austenitics do not have critical temperatures and so cannot be quenched, their yield strength and tensile strength values can be changed through cold working. Martensitics have the best mechanical properties.



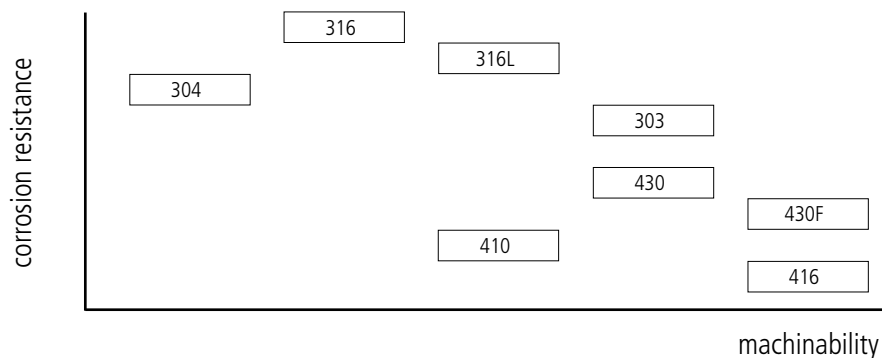
This table compares approximate characteristics of rolled products.

Steel type	R N/mm ²	Rp 0,2 N/mm ²	A %	Kv +20 °C J	Kv -150 °C J	Magnetic	Temperature resistance
Duplex	1070 - 1270	800	13	25		yes	good
Austenitics	500 - 700	220	50	140	100	no	good
Ferritics	450 - 650	280	22	25		yes	good
Martensitics	650 - 850	500	14	30		yes	average Cr% < 16 good Cr% > 20

Scale showing resistance to corrosion of different stainless steel types

Maximum				Minimum
Duplex	Austenitics	Ferritics		Martensitics

Table showing ratio of machinability - corrosion resistance



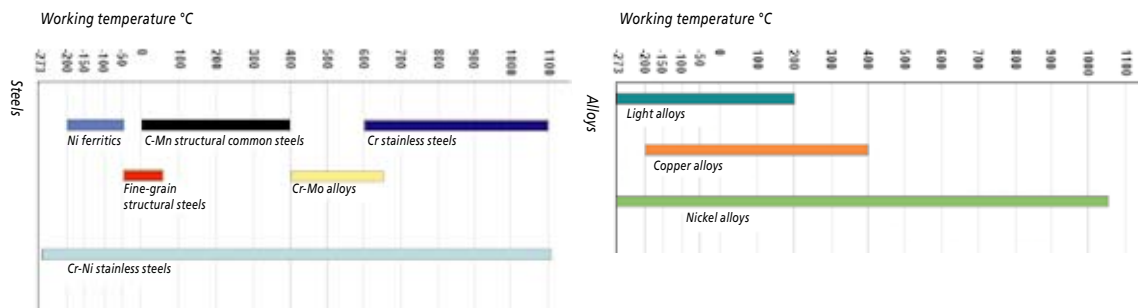
Classification of stainless steels

classification	UNS	AISI	EN	
500 series	S5xxxx		Xxx	Martensitic stainless steels
400 series	S4xxxx	4xx	Xxx	Martensitic and ferritic stainless steels
300 series	S4xxxx	3xx	Xxx	Austenitic stainless steels
200 series	S2xxxx			Austenitic stainless steels

The 200 series (Cr-Mn) is principally used in Asia where Ni is often replaced with high levels of Mn.

This particular chemical composition can cause the steel to be prone to cracking during cold drawing or hobbing.

Approximate fields of application of certain materials.



Intervals of use at high and low temperatures.



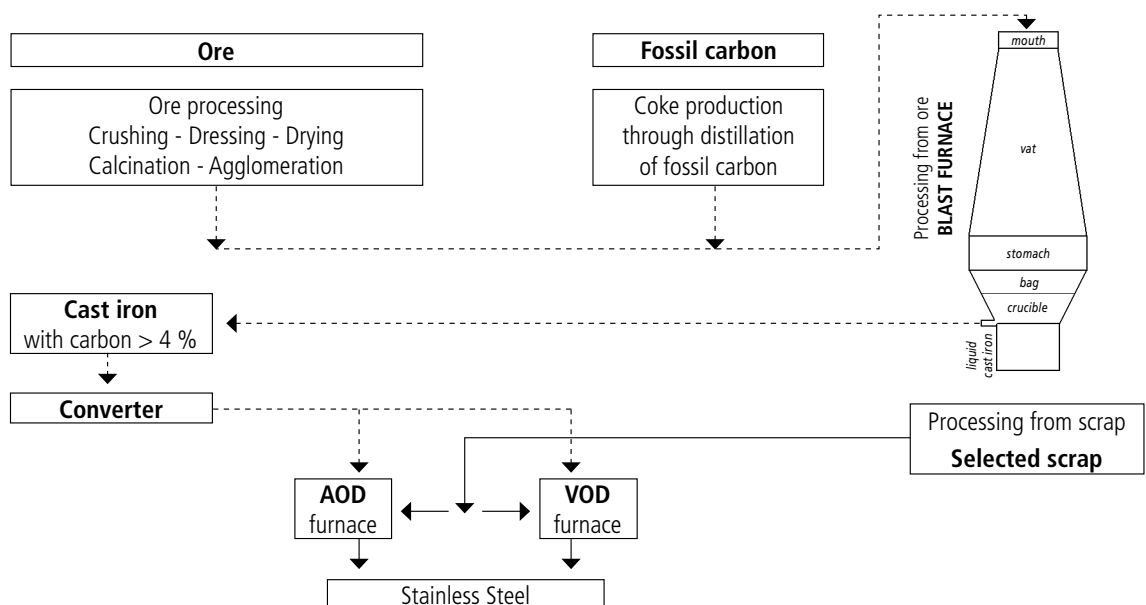
MELTING AND PRODUCTION OF STAINLESS STEELS

The discovery of the first materials able to resist attack from acids dates back to 1821 when iron oxides were mixed and fused with chromium. At the time, this alloy contained about 1.5% chromium and had an extremely high carbon content. With the arrival of the Bessemer furnace (1855), the Martin furnace (1865) and the Martin-Siemens furnace (1892) the mass production of chromium-carbon steels began. Only in 1895, did a handful of Swedish and German steelworks begin producing low-carbon iron-chromium alloys, which an ever-more refined electrosteel industry perfected over time. From 1904 to 1909 martensitic stainless steels were identified as being 13% chromium and ferritic stainless steels as being 17% chromium with carbon content from 0.12% to 1%. Again in 1909, the first austenitic steels made from iron-chromium-nickel alloys were being studied. In 1925, and using already tested technology, Italy began producing stainless steel.

ORE PROCESSING

Using a blast furnace cast iron is obtained with 4-6% carbon content, still in its molten state the material passes to the converter which reduces the content levels of phosphorous, sulfur, carbon, silicon and any other element with higher-oxidation than iron.

After dephosphorization, iron-chromium is then added and the material is transformed into chromium metal, the material is now chemically close to stainless steel. The liquid is then refined in an AOD vessel (fast, cheap process most often used for stainless steels) or using VOD (used by steel plants who not only produce stainless steel but also other alloys, tools etc). Through oxidation, usually in a vacuum, carbon is reduced to the levels desired. The final stages of chemical analysis are also carried out in these furnaces and by adding correctors (Cr, Ni, Mo, Ti, Cu, etc.) the definitive levels are reached. Using an AOD + VOD combination it is even possible to obtain steel with carbon levels of 0.005%.



SCRAP PROCESSING

The first stainless steels were produced using the same electric arc furnaces as conventional steels.

After melting common scrap, ferroalloys (iron-chromium) were added to the liquid bringing the chromium content to approximately 12%.

The amount of carbon was rather high, partly because of the three graphite electrodes that are released by this element.

Later, stainless steel scrap melted at high temperatures was used with a reduction from ferroalloys (iron-silicon and iron-chromium-silicon) through a process known as ex-furnace secondary metallurgy.

These methods were both time and energy intensive until 1960 when AOD and VOD processes were introduced.

AOD = Argon - Oxygen - Decarburization

VOD = Vacuum - Oxygen - Decarburization.

AOD PRODUCTION

Melting takes place in a traditional furnace; the molten metal is transferred to the converter, inside which the steel's chemical composition is refined through redox reactions.

Insufflation with argon and oxygen, through hot blast pipes, constantly mixes the molten steel and the redox reactions independently increase the temperature to approximately 1650°C.

The principal reaction is decarburization, during which excess carbon binds itself to oxygen and other insufflated inert gases to form carbon monoxide, this is then expelled bringing carbon levels down to about 0.015%.

The loss of chromium through oxidation is controlled through the regulation of proportions of oxygen and argon. After passing chemical analysis, the steel passes to continuous casting or ingot casting.

VOD PRODUCTION

Scrap melting is the same as in AOD, the only difference is that the molten steel is poured into a ladle which is then immersed into a tank, to create a vacuum with an initial value of 3 mbar which is then maintained at 0.6 mbar (millibar).

The vacuum enhances the decarburization reaction and prevents the overoxidation of chromium.

Argon is released through porous separators at the base of the ladle to keep the molten steel mixed.

Oxygen is introduced through a nozzle from above, this spreads over the surface of the liquid and speeds up the formation of carbon monoxide; this causes decarburization and brings carbon levels down to a limit of 0.015%.

When the desired carbon levels have been reached, the adjustment of the levels of other chemical elements can be carried out, for example the chromium content can be modified by adding iron-chromium.

One of the economic advantages of this process lies in the fact that the decarburization (oxidation of car-

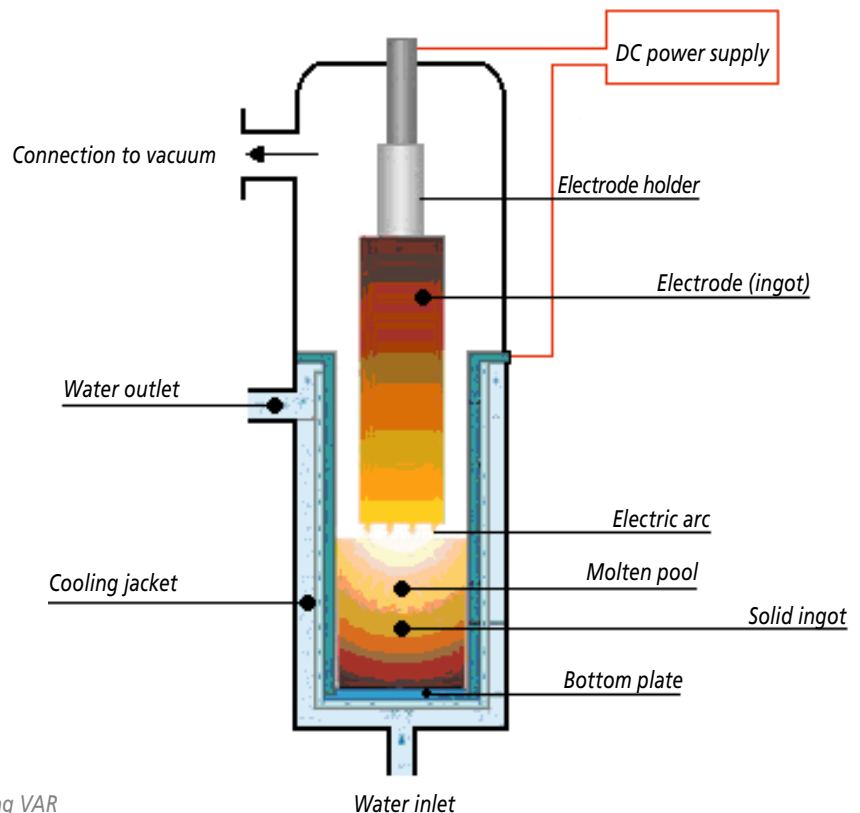


bon) reaction produces heat, meaning that less electricity is required to maintain the high temperatures needed for this process.

The next step is pouring the molten steel into molds for ingot casting or into baskets for continuous casting.

Other industrial processes for the production of stainless steels with specific properties (e.g. high purity) are:

- VIM vacuum induction melting
- VAD vacuum arc degassing used in conjunction with VOD for deep degassing (hydrogen < 1.2 ppm)
- VDG vacuum degassing with argon insufflation
- VAR vacuum arc remelting
- ESR electroslag remelting
- EBR electron beam remelting in a vacuum
- Combined processes VIM + VAR, VIM + ESR, ASLD + WIR, etc.



Outline of vacuum arc remelting VAR



CHEMICAL ELEMENTS

	carbon %	chromium %	nickel %
Austenitics	0,015 - 0,15	16,0 - 28,0	6,0 - 32,0
Ferritics	0,01 - 0,12	10,5 - 30,0	
Martensitics	0,08 - 1,20	11,0 - 19,0	

EFFECT OF ALLOYING ELEMENTS ON STAINLESS STEELS:

ALLUMINIUM

Increases resistance to oxidation at high temperatures, reducing oxide formation (scaling).

Combined with nickel it forms an intermetallic compound useful for precipitation hardening.

NITROGEN

Used in austenitic steels to prevent delta ferrites and stabilizes austenites. It increases tensile strength R and yield strength Rp. It raises yield strength limits in low-carbon steels. Undesirable in ferritic steels when it exceeds 10ppm. It increases resistance to pitting.

CALCIUM

Added to improve the machinability of steels (e.g. steel AISI 316L)

CARBON

When chromium content exceeds 10, carbon forms various types of carbides which are extremely useful for thermo-mechanical resistance, general corrosion resistance and intergranular corrosion resistance in particular. Lowers pitting resistance especially in sensitized states.

CHROMIUM

Steel acquires inoxidability when a solid chromium solution of over 10.5% is present in the matrix, which, absorbing oxygen, creates an extremely thin surface film capable of passivating the base metal and stopping corrosion. Excellent stabiliser for ferrites. It increases pitting resistance.

MANGANESE

Normally does not exceed 2% in stainless steels and so is not considered an alloying element.

MOLYBDENUM

When added to austenitics, it keeps the austenitic structure stable even at ambient temperatures.



Adding 2-3% of this element to austenitic steel AISI 304 increases the stability of the passivated film in high-chloride environments.

For applications involving contact with sulfuric, phosphoric or chloridric acids austenitic steels with a Mo content of up to 5% are used. Ferritising element. It increases resistance to crevice and stress corrosion.

With chromium it increases pitting resistance.

NICKEL

High levels of this element create ambient temperature stable austenitic alloys which have excellent ductility, high toughness even at cryogenic temperatures, good thermomechanical resistance, good weldability and good corrosion resistance in low-oxidating environments.

When Ni content is 4% a phase transformation occurs during heating when it is possible to perform martensitic tempering during cooling. When nickel content is below 20%, martensitic tempering is also possible through air-cooling.

Nickel content over 30% gives steel excellent resistance to stress corrosion.

It increases pitting resistance.

NIOBIUM

It creates stable carbides which improve mechanical resistance and creep resistance. Stabilizing element which prevents chromium carbide precipitation during heat treatments and welding.

RAME

In some cases it increases the efficacy of nickel. It increases the resistance of austenitic steels to corrosion even in the presence of 10% sulfuric acid at temperatures of 80%. It improves cold deformability of austenitic steels.

SILICON

Element which gives resistance to heat oxidation (scaling), often used in refractory steels (Cr > 20%, Ni ~ 20%, Si ~ 1% and generally higher carbon levels than in conventional stainless steels).

Its ability to melt in the matrix during the liquid phase, without creating carbides, improves resistance for hardening from solid solution. It reduces resistance to pitting corrosion, but increases it when combined when molybdenum is present.

It increases magnetic permeability and electrical resistivity.

SELENIUM

It can be used instead of sulfur as it has a more globular morphology which helps chipbreaking during machining. Not as detrimental to toughness and surface finishing as sulfur. It globulizes manganese sulfides



but because of high cost is only used in specific cases (e.g. when good transversal mechanical properties are needed). Given its high toxicity, its use is extremely limited and is now being discontinued.

SULPHUR

Added to improve chip breakability (e.g. in steel AISI 303) but it reduces corrosion resistance. It reduces friction between the machine and the chip preventing machine seizures.

TITANIUM

Stabilizing element which prevents chromium carbide precipitation during heat treatments and welding. It helps avoid intergranular corrosion.

TUNGSTEN

Added to certain austenitic steels to increase thermomechanical properties.

VANADIUM

It has the same characteristics as tungsten.



Graphite (carbon)



Titanium



Molybdenum



Chrome



Nickel



Sulfur crystals



Silicon



MACHINING AND SURFACE FINISHING

HOT WORKING

Forging and **Rolling** of martensitic and ferritic steels are performed at temperatures of between 900 and 1100 °C. More details can be found in the product specifications.

Ingots, blooms and billets are gradually reheated to approximately 800°C before reaching the pre-established temperature at which they should only be kept for very short periods.

It is recommended that the hot processing of ferritics be completed when the parts have a temperature of 750-700°C.

This hardening, and the recrystallization which follows, produce a fine granular structure.

The temperature for martensitics must not fall below 900°C, over that temperature the material must be cooled very slowly to prevent cracking.

Austenitic steels have lower thermal conductivity than ferritics and martensitics. To prevent cracking and hardening of austenitics, it is advisable to use longer reheating times and not to perform finishing at temperatures below 900°C. Do not perform repeated reheating in sulfurous or carburized environments.

For both groups it is advisable to avoid long intervals and repeated reheating at high temperatures as this causes grain growth and a loss of corrosion resistance.

Extrusion is generally carried out when simple rolling is not capable of producing the complex shapes needed.

The material is pressed and flows into the dies. The pressure used on stainless steels is greater than that used on other carbon or alloy materials of the same size.

The slugs, which are preheated in special furnaces using similar techniques to those used for forging and rolling, are then pushed by a punch into a container which has a liner and coating. The material to be extruded is covered with an anti-friction lubricant to aid smooth working.

In **powder metallurgy** the stainless steel is melted and then powdered into different size ranges of grain. These powders are mixed with alloying elements and then compacted at pressures of ~ 1000 bar and sintered at 1200- 1400°C.

COLD WORKING

Martensitic steels are sometimes cold molded but only for the purpose of producing shapes as their mechanical properties are not substantially altered through deformation. Martensitics principally react to quenching treatments.

Ferritics have low hardenability and so are more suited to compression and less to drawing.

Austenitic steels have the highest cold hardenability properties and their tensile strength and yield strength increases considerably while maintaining good elongation and resilience. However, these steels lose some toughness when sulfur or copper are added.



It should be remembered that the use of titanium and niobium carbides and the addition of non-metallic elements lowers the plasticity of stainless steels.

Another factor for consideration is the increase in magnetic permeability in proportion to an increase in the reduction ratio. This can be a drawback for non-magnetic applications.

After hot rolling, it is then possible to carry out **cold-rolling** (e.g. from wire rod in coils to flat coils or bars).

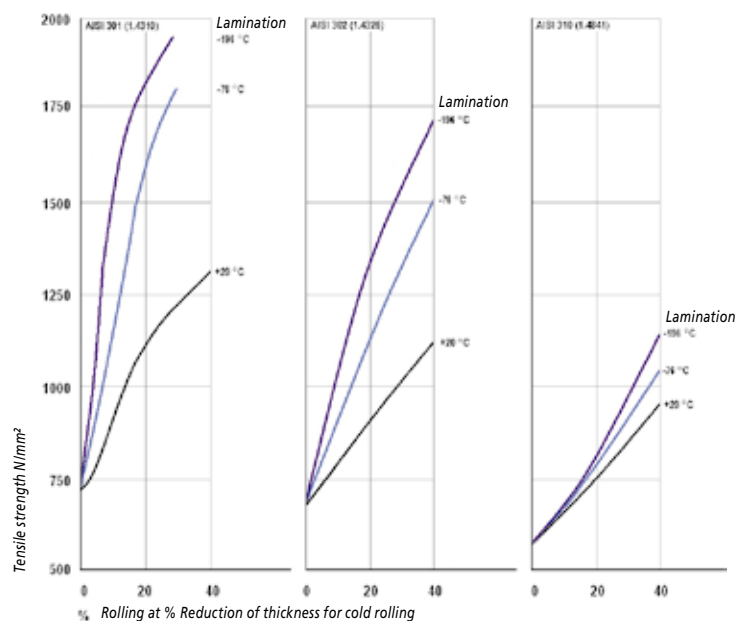
The starting material in ferritic or austenitic steel is softened appropriately (through annealing or solution heat treatment) and then chemically pickled. The maximum reduction for austenitics is 75% and for ferritics 85%.

If repeated rolling is necessary, ferritics first undergo recrystallization heat treatment and austenitics are solution heat treated. It is essential that materials and equipment are clean during these processes.

Lubricants suitable for use at high pressures are used and are often the same as those used for other carbon or alloy steels.

As is well-known, the undercooling of residual austenite at temperatures below 0°C can transform it into martensite. This process can be exploited in conjunction with cold deformation to increase the mechanical resistance of austenitic steels which in their solution heat treated state have only moderate yield- and tensile strength values.

Below are indicative graphs for some austenitic stainless steels.



*Variation in tensile strength from combined effect:
deformation from cold rolling and material temperature during pressing.*



Materials for **drawing** are treated and pickled in the same way as for cold-rolling.

The wire rod rolls or hot rolled bars undergo an oxalate treatment which works as an adhesion promoter for specific lubricating oils. Drawing speed must be lower than that of common carbon or alloy steels.

The reduction ratio varies from 20 to 30%, to a maximum of 50%, depending on the mechanical properties desired. It is useful to consult the hardening values included in some product specifications.

The main difficulties of drawing austenitics are related to the use of steels with a high-carbon carbon content, free machining steels with added sulfur and the embrittlement caused by the absorption of hydrogen during chemical pickling.

Through drawing it is possible to produce h10 and h11 tolerances. Using drawing machines specially designed for stainless steels, it is also possible to produce h9 tolerance profiles.

The drawn material is often ground to tolerances of h8, h7, h6, g... f... js. Type 1 cylindrical grinding is used: vitrified grinding wheels are used for polishing, while Bakelite grinding wheels are used for more heavy duty grinding to remove more material.

Thread rolling is used to shape screws and is mainly used on austenitic steels. It increases hardness, as well as straightening, smoothing, gauging and embossing the hardened steel according to the pressure exerted by the rollers. The lubricants used are oils or emulsions able to withstand high pressures.

In **embossing** the material is pressed between two dies to produce specific patterns or designs.

The starting material must be softened to the lowest possible hardness and be free of burrs, scratches, tarnishing etc..

Special attention must be given to the weight of the material be placed between the dies as it must correspond to the final volume of the part to be embossed. Lubricants are generally not used in embossing as any excess liquid may prevent the material from adhering properly to the die. Some specific products have been trialed by the sector.

Roll forming of stainless steels is mainly done using coiled steel. Different cold profiles or shapes are produced by feeding the material through stands of forming rolls and have excellent surface (often chrome) finishes. Abundant lubrication is needed, often in the form of emulsions suitable for high-pressure use. To avoid cracking defect, an appropriate bend radius must be used, particularly for materials which have already undergone extreme cold-hardening.

Austenitics are the most used stainless steels in roll-forming. When aesthetic considerations are of extreme importance, the steel coils are covered with a plastic film which is removed at the end of the process.

Austenitic stainless steels are also the most commonly used material in **Bending**, which can be perpendicular to the rolling direction (which is preferable) or parallel to the rolling direction.

When the steel is in a hardened state (cold rolled or drawn) preheating to around 200°C is recommended before proceeding to bending, using a specific bending radius. The edges of the sheets should be checked for defects or other possible causes of cracking.



All tool and machine surfaces must be in good order and free from rust so as to avoid causing galvanic reactions which can speed up the corrosion process.

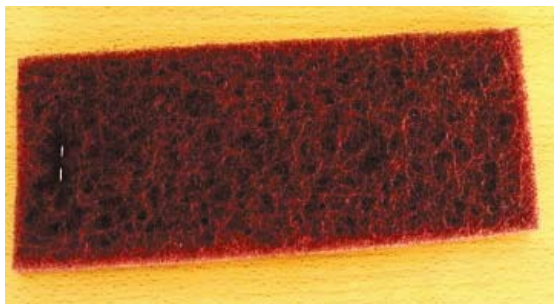
Abrasive or shot blasting is done using inert grains or small, high-hardness stainless steel balls. Blasting can be used, for example, to harden the surface layer of springs made from austenitic steels.

Grinding is a surface finish which removes extremely thin layers of metal from products using a bonded abrasive paste. The main function of grinding is the removal of harmful substances, such as oxides, and excessive roughness caused, for example, by welding. To avoid deformation of the material, grinding pressure parameters and the heat produced during the process must be monitored.

Polishing refers to finishing surfaces for aesthetic or decorative purposes. Generally speaking, the finer the grain of the abrasive, the smoother the finish. Fine grain types 320/400 are recommended for final finishing, and 36/60 grit for grinding hot rolled stainless steels. It should also be remembered that for repeated treatments, the speed of abrasive machines should be gradually lowered from coarse to fine.

Brushing is another abrasive treatment but is less aggressive than grinding and polishing. It is used to even out chrome surfaces, for example where there is a finely ground weld seam. Brushing is done using microfiber belts, pads or sheets.

Buffing is not intended to eliminate material but to smooth and shine the surface of stainless steel products. Buffing is done using cotton or felt mops, or using flap discs impregnated with abrasive pastes or liquids to enhance shine.



Microfiber for brushing.

For cleaning, descaling and passivation criteria see ASTM A 380.

For chemical passivation see ASTM A 967.



COLD ROLLING

Number of passes for austenitic or ferritic stainless steels starting from a 5mm thick hot strip

reduction		no. transformations (reductions)	further treatments	
from mm	to mm			
5	4	1	softening anneal	pickling
5	3	3 scale with first reduction greater than the other two	softening anneal	pickling
5	2	5 scale thickness reduction	--	pickling
The maximum total thickness reduction without intermediate softening treatments must not exceed 75% (austenitics) or 85% (ferritics) of the initial hot strip thickness				

Specific pressure needed for cold rolling according to thickness reduction applied

AUSTENITICS some types: AISI 301 - 302 - 303 - 304 - 316	Specific pressure N/mm ²	Reduction %
	880	0
	1000	5
	1120	10
	1150	15
	1250	20
	1310	25
	1440	30
	1500	35
	1630	40
	1690	45
	1760	50
	1870	55
	1930	60
	1980	65
	2030	70
	2060	75
	2125	80
	2190	85
	2220	90

FERRITICS some types: AISI 429 - 430 - 434	Pressure Specific N/mm ²	Reduction %
	815	0
	890	5
	1000	10
	1060	15
	1125	20
	1190	25
	1250	30
	1315	35
	1375	40
	1440	45
	1490	50
	1510	55
	1550	60
	1560	65
	1580	70
	1630	75
	1640	80
	1660	85
	1700	90

Cold rolling is performed on hot rolled strips which have been suitably softened (through solution heat treatment, recrystallization or annealing in accordance with the type of stainless steel used) and pickled.



SURFACE FINISHING

Operating parameters for electrolyte polishing

Bath composition	Cathode material	Tension ⁽¹⁾	Current density	Duration	Bath temperature °C
		V	A/cm ²	minutes	
300 cm ³ orthophosphoric acid 530 cm ³ glycerin 90 cm ³ water	Austenitic steel AISI 304	4 - 5	0.08	15	100
125 cm ³ sulfuric acid 650 cm ³ orthophosphoric acid 225 cm ³ water	Copper	8 - 15	0.08 - 0.20	5 - 10	85
110 cm ³ sulfuric acid 600 g. citric acid 250 cm ³ methyl alcohol or butyl, propyl or ethyl alcohol	Austenitic steel AISI 304	6 - 8	0.08 - 0.55	1 - 3	50 - 125

⁽¹⁾ per new bath

Approximate solutions for decontamination from traces of iron or contact contamination from other metals

Type of stainless steel	Volume %	Temperature °C	Time in minutes
austenitics, ferritics, austen-ferritics, precipitation hardening steels	Nitric acid (10 - 16)	25	10 - 60
AISI 400 series with Cr < 16% and free-machining steels	Nitric acid (8 - 12)	25	10 - 60

Solutions refer to mass concentration: nitric acid 67%.

Approximate solutions for pickling

Type of stainless steel	Volume %	Temperature °C	Time in minutes
austenitics, ferritics, austen-ferritics, precipitation hardening steels	Nitric acid (10 - 25) Fluoridic acid (1 - 8)	25 - 60	5 - 50
AISI 400 series with Cr < 16% and free-machining steels	Nitric acid (10 - 15) Fluoridic acid (0.5 - 2)	20 - 50	5 - 20

Solutions refer to mass concentration nitric acid 67% and fluoridic acid 40%.

Some methods for cleaning stainless steel surfaces

Conditions	Detergent	Application	Notes
Not very dirty, regularly cleaned surfaces.	Soap and water or mild detergents.	With sponges, clean cloths, soft brushes. Rinse well.	On satin finishes only rub following the satin grain.
Moderately dirty, occasionally cleaned, surfaces.	As above, with possible addition of pumice powder. Chlorine-free commercial cleaners.	As above.	As above.
Very dirty surfaces in industrial environments.	Soap and water with added abrasive powders such as pumice or aluminum.	As above, persist on the most stained areas.	As above, do not use brushes or wire wool. If necessary use synthetic abrasive pads.



SEMI-FINISHED PRODUCT FINISHING

Rods, Wires, Bars and Sections UNI EN 10088-3

	Symbol (2)	Type of process route (1)	Surface finish	Product form			Remarks	
				A	B	C		
Hot formed	1U	Hot formed, not heat treated, not descaled.	Covered with scale (spot ground if necessary). Not free of surface defects.	x	x	x	Suitable for products to be further hot formed.	A = rods B = bars and section C = semi-finished products (1) Not all surface finishes and process routes are available for all steels. (2) First digit: 1 = Hot formed; 2 = Cold processed. (3) On ferritic, austenitic and austenitic-ferritic grades, the heat treatment may be omitted if the conditions for hot forming and subsequent cooling are such that the requirements for the mechanical properties of the product and the resistance to intergranular corrosion are obtained. (4) Type of cold processing, cold-drawing, turning, grinding, ..., is left to the manufacturer's discretion unless otherwise agreed.
	1C	Hot formed, not heat treated ⁽³⁾ , not descaled.	Covered with scale (spot ground if necessary). Not free of surface defects.	x	x	x	Suitable for products to be further processed, hot or cold formed.	
	1E	Hot formed, not heat treated ⁽³⁾ , not mechanically descaled.	Largely free of scale (but some black spots may remain). Not free of surface defects.	--	x	x	Suitable for products to be further processed, hot or cold formed.	
	1D	Hot formed, heat treated ⁽³⁾ pickled, coated (optional).	Free of scale (spot ground if necessary). Not free of surface defects.	x	x	--	Products used in their present condition or to be further processed (hot or cold).	
	1X	Hot formed, heat treated ⁽³⁾ rough machined.	Free of scale (but some marks left from machining may remain). Not free of surface defects.	--	x	--	Products used in their present condition or to be further processed (hot or cold).	
Cold processed	2H	Finishes 1C, 1D or 1X, cold processed ⁽⁴⁾ , coated (optional).	Smooth and matt or bright. Not necessarily polished. Not free of surface defects.	--	x	--	In products formed by cold drawing without subsequent heat treatment, the tensile strength is substantially increased, particularly in austenitic materials, depending on the degree of cold processing. The surface hardness may be higher than the centre hardness.	
	2D	Finish 2H, heat treated ⁽³⁾ , pickled and skin-passed (optional), coated (optional).	Smooth and matt or bright. Not free of surface defects.	--	x	--	This finish allows the restoration of the mechanical properties after cold processing. Products with good ductility (extrusion) and specific magnetic properties.	
	2B	Finishes 1C, 1D or 1X, cold processed ⁽⁴⁾ , mechanically smoothed.	Smooth, uniform and bright. Free of surface defects.	--	x	--	Products used in their present condition or intended for better finishing. In products formed by cold drawing without subsequent heat treatment, the tensile strength is substantially increased, particularly in austenitic materials, depending on the degree of cold processing. The surface hardness may be higher than the centre hardness.	
Special finishing	1G	Hot formed, heat treated ⁽³⁾ , descaled, rough machined ⁽⁴⁾ or shaved in the case of rod. Type of finish is left to the manufacturer's discretion.	Appearance bright, but not uniform. Free of surface defects.	--	x	--	Suitable for severe applications (extrusion and/or cold or hot heading). Surface roughness can be specified.	
	2G	Finishes 2H, 2D or 2B, centreless ground, mechanically smoothed.	Smooth, uniform and bright. Free of surface defects.	--	x	--	Finish for close tolerances. Unless otherwise agreed the surface roughness shall be Ra 1,2.	
	2P	Finishes 2H, 2D, 2B or 2G, centreless ground, mechanically smoothed.	Smother and brighter than finish 2B or 2G. Free of surface defects.	--	x	--	Products showing a well groomed surface appearance. Surface roughness shall be specified at the time of enquiry and order.	



COLD WORKING

Examples of problems occurring when using chip-removing cutting tools on stainless steel, possible causes and solutions.

DEFECT	CAUSE	SOLUTION
Plastic deformation	Insert temperature too high combined with high pressure.	Use a harder insert. Reduce speed. Reduce feed rate.
Built up edge	The material worked tends to stick to the insert.	Increase cutting speed or use an insert with positive rake angles.
Damage to the cutting tool	Insert not strong enough. Insert has weak geometric characteristics. BUE has formed.	Use a stronger insert. Use an insert with a stronger tool. Increase cutting speed or use an insert with positive rake angles.
Chip hammering	Il truciolo è troppo lungo e tende a piegarsi verso lo spigolo di taglio.	Slightly modify the feed rate. Use a different tool geometry. Change the setting angle of the support.

Machinability index for stainless steels (basic reference equal to 100 of steel AISI B 1112 - DIN 10S20)

AISI STEEL	STRUCTURE	MACHINABILITY INDEX
403	Martensitic	58
410	Martensitic	58
416	Martensitic	97 ⁽¹⁾
420 (C = 0.30%)	Martensitic	58
431	Martensitic	46
405	Ferritic	58
430	Ferritic	58
430 F	Ferritic	90 ⁽¹⁾
201	Austenitic	49
302	Austenitic	49
303	Austenitic	70 ⁽¹⁾
304	Austenitic	49
304 L	Austenitic	49
305	Austenitic	49
316 L	Austenitic	43

⁽¹⁾ Free-machining. Where possible, used hardened through cold plastic deformation (drawing) to aid chipbreaking.

Approximate values for centreless grinding of stainless steel parts

Steel	Hardness HB	Peripheral grinding spindle speed m/sec.	Peripheral piece speed m/min.	Grinding depth mm		Angle between axes	Peripheral speed driving grinder m/min
Martensitic	135 - 275	28 - 33	15	0,12	0,03	3°	30
Martensitic	> 275	28 - 33	15	0,12	0,03	3°	30
Ferritic	135 - 185	28 - 33	15	0,12	0,03	3°	30
Austenitic	135 - 275	28 - 33	15	0,12	0,03	3°	30
Precipitation hardened	150 - 200	28 - 33	15	0,12	0,03	3°	30
Precipitation hardened	> 200	28 - 33	15	0,12	0,03	3°	30
Grinding wheel with grain size 46 for roughing Resin grinding wheels for polishing		Grinding wheel with grain size 60 for medium grinding Coolant liquid: oil emulsion in water				Grinding wheel with size 70 for finishing	





WELDING

Approximate tension and current values for manual shielded arc welding

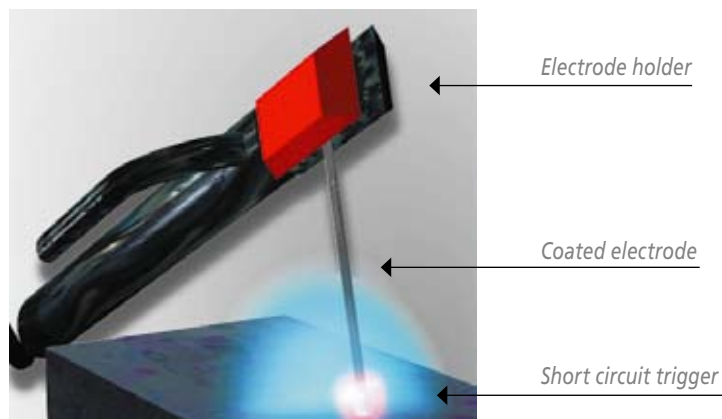
Electrode diameter mm	Tension V	Current intensity in A					
		Cr-Ni Electrodes Welding position			Cr electrodes Welding position		
		flat	vertical	overhead	flat	vertical	overhead
1,6	20 - 22	20 - 35	15 - 25	20 - 30			
2	20 - 23	30 - 50	25 - 35	30 - 45			
2,5	22 - 25	40 - 65	35 - 50	40 - 60	50 - 75	40 - 55	50 - 65
3,2	23 - 26	65 - 100	55 - 75	65 - 85	80 - 115	65 - 80	75 - 95
4	23 - 26	95 - 145	80 - 105	90 - 120	115 - 160	90 - 110	110 - 130
5	24 - 27	125 - 190	105 - 135	125 - 155	155 - 210	125 - 145	145 - 160
6	25 - 28	200 - 280					

Approximate parameter values for manual shielded arc welding

Electrode diameter mm	Thickness of material mm	Number of passes	Butt welding distance between edges mm	Average number of electrodes per metre of welding	
				butt n°	corner n°
1,6	0,8 - 1,2	1	0	5,5	8,5
2	1,5	1	0,5	3,7	6
2,5	2	1	0,8	2,9	4,8
3,25	3	1	1,5	2,9	4
4	5 ⁽¹⁾	2 ⁽²⁾	1,5	3,1	3,1
5	7 ⁽¹⁾	2 - 3 ⁽²⁾	1,5	4,1	4,1
5	10 ⁽¹⁾	3 - 4 ⁽²⁾	2	5	5,7

⁽¹⁾ For thicknesses of 4mm and over, the beveling of borders is advised when butt welding.

⁽²⁾ The use of a 1.6 or 2mm electrode is recommended for the first closure of the welding gap.



(Centro inox documentation)



Recommended types of stainless steel coated electrodes for the welding of stainless steels to other stainless steels, or to carbon- or alloy steels

[BIBLIOTECA TECNICA HOEPLI – 'GLI ACCIAI INOSSIDABILI' (STAINLESS STEELS) - FOURTH EDITION - G. DI CAPRIO]

HEAT TREATMENTS

For the families of stainless steels, which differ considerably from each other, it is important to know which features can be obtained with heat treatments and which ones are the most suitable for the desired purpose.

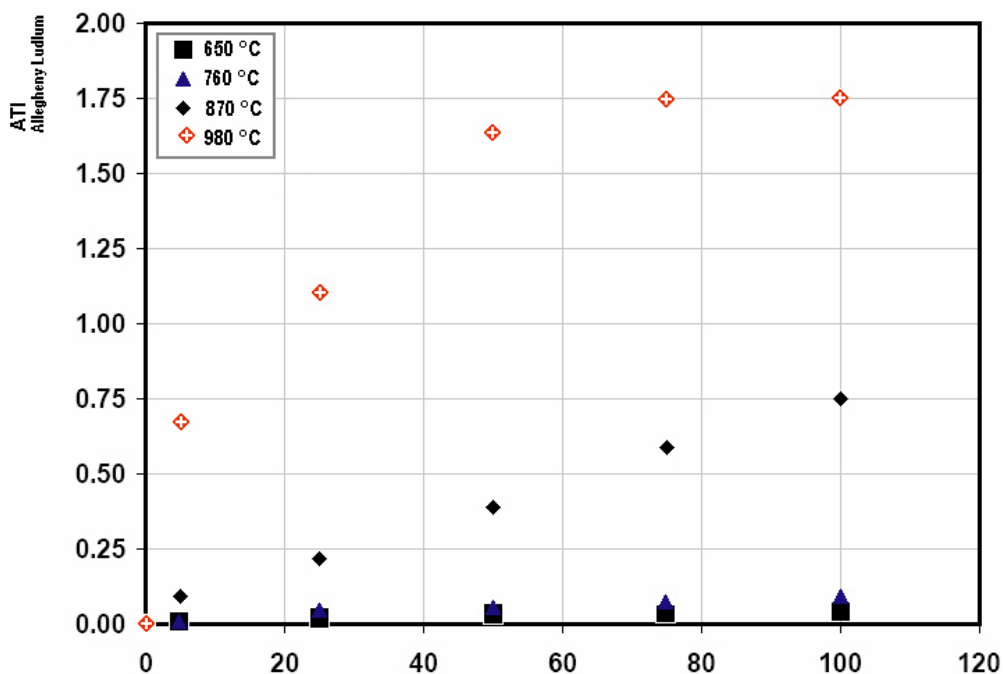
CONSIDERATIONS ON ATMOSPHERES IN THE FURNACE

In principle you can use any type of industrial furnace that runs on oil, gas, electricity, induction and radiant tubes. Flame-run furnaces (gas and oil) must be equipped with a shut-off system in order to prevent overheating or localized burning and the fuel must not be sulfurous.

All reheating furnaces must have a number of thermocouples designed to ensure full consistency between the set and actual temperature. This delta must not exceed 14°C and the qualification of the heat treatment system must be carried out according to API specification 6A.

OXIDATION UNDER HEAT

At temperatures above 250 to 300°C stainless steel materials begin to oxidize when they are treated or put into operation in atmospheres containing oxygen (air). In addition to yellowing, with an increase in temperature, the thickness of the oxide (scale/scab) also increases, with a subsequent loss of weight. The types of steel that are less affected by this effect are those that contain high percentages of chromium-nickel and stabilized steels.



A diagram of the rate of weight loss compared to the time of exposure of 316Ti steel exposed to various temperatures in air.



CONTROLLED ATMOSPHERES

The dry atmospheres inside the furnaces are generally composed of gases such as argon and nitrogen in order to prevent or minimize the addition of oxygen on the stainless product. In the absence of oxygen there will be no oxide formation and this will allow the steel to maintain its original gloss.

For treatments in inert or vacuum (controlled) atmospheres, it is advisable to clean the workpieces thoroughly with liquid or vaporized solvents.

CARBURIZATION

It is the enrichment of carbon that may occur on the surface when the material comes into contact with atmospheres or materials capable of releasing carbon. Carbon enrichment is generally damaging to all stainless materials and often deprives them of their original features.

DECARBURIZATION

A phenomenon that is just as damaging as carburization, it reduces the carbon content on the surface of the product and alters its natural characteristics. It does not damage ferritic and austenitic steels, but it is harmful to martensitic steels.

MARTENSITIC STAINLESS STEELS

1.4005 - 1.4006 - 1.4021 - 1.4028 - 1.4031 - 1.4034 - 1.4035 - 1.4057 - 1.4101 - 1.4112 - 1.4116 - 1.4122 - 1.4125

These are the only stainless steels that can change their mechanical properties when subjected to quenching treatment. They possess transformation A₁ and austenitizing points A₃ and for this reason they can increase their tensile strength values (R_N / mm²) and yield points (R_p 0.2 N / mm²) with a quenching heat treatment.

- A_c 1 temperature at which austenite begins to form, during the reheating phase
 - A_c 3 temperature at which the transformation of ferrite into austenite is complete, during the reheating phase
 - M_s temperature at which the austenite begins to change into martensite, during cooling, called martensite start
 - M_F: temperature at which the transformation of austenite into martensite is complete (martensite finish)
- Depending on the carbon and chromium content, you can obtain completely hardened structures composed of martensite, as in the case of steel 1.4021 (AISI 420) or from martensite + carbides, as in the case of steel 1.4125 (AISI 440C).

SOFTENING ANNEAL

This heat treatment, among the most economic, allows you to obtain material with easily chipped structures, and equally easily subject to cold plastic deformation.

For low-carbon-content steels, after a phase at standard temperatures for each type of steel, the cooling process can be carried out in still air.



The same operations apply to medium-carbon-content steels, but the hardness that can be obtained is greater than in the previous case.

For nickel containing steel it is possible to perform a double annealing phase, for example for 1.4057 the first annealing is carried out at 770°C and the second at 650-670°C. High carbon steels require annealing temperatures of 750-850° C which make it possible to obtain maximum hardness of 280 HB.

FULL ANNEALING

This type of heat treatment is performed when you want to achieve a high degree of cold deformation.

The temperatures are the standard ones reported in the product information sheets.

For low carbon steels with limited thermal conductivity, slow heating times are adopted and holding for at least 2 hours per inch of thickness. The subsequent cooling phase is performed at a speed of 15-25° C/h up to 590°C, and then in air until it reaches room temperature.

The same parameters as above can be adopted for medium-carbon steels.

This type of heat treatment should not be adopted for steels with nickel > 1%.

For high carbon steels, the temperatures are normally higher than those used in previously-mentioned types of steel. Cooling should be carried out in the furnace up to 790-760°C, followed by dwell time in proportion to the size of the workpiece and at a cooling rate of 15-25°C/h up to 590°C, and finally, discharge in still air.

ISOTHERMAL ANNEALING

The required temperature ranges are those reported in the product information sheets.

After the dwell time at temperature, controlled cooling is carried out up to 705-720°C for low carbon steels. The duration of the dwell time at these temperatures depends on the mass of the workpiece. After this second holding you can cool the piece in still air until it reaches room temperature.

The same parameters as above can be adopted for medium-carbon steels.

For nickel-containing steels that require very slow cooling isothermal annealing is usually not carried out.

For high carbon steels, temperatures are higher than those of other types and the hardness that you obtain is about the maximum you can possibly achieve with complete annealing.

QUENCHING

This heat treatment is applied to martensitic types of steel.

It consists of a controlled heating process up to the standard temperature for each steel, dwell time based on the mass of the workpiece and a rapid cooling phase to achieve the transformation of austenite into martensite.

Holding times at temperature vary from 30 to 35 minutes every 25 mm of thickness of the workpiece.

After quenching you must carry out a tempering process or a stress relieving phase according to the desired characteristics (mechanical, stainless, etc.).



In heat treatment jargon, quenching and tempering operations are described with a single word: hardening.

Water is almost always excluded as a means of cooling, because its severity can cause cracks. The most commonly used cooling methods are: humid and ventilated air, heated oil at 40-90°C and polymers.

Cooling severity should be kept low due to the fact that martensitic steels are often self-hardening.

During a slow preheating phase and prior to reaching the quench temperature, it is advisable to carry out dwell times at intervals at 740-760°C to homogenize the entire section of the workpiece, and remove any stress from cold hardening or heavy mechanical processes. Next, it is necessary to rapidly raise the level to the set temperature.

As with carbon and alloy steels, the rule that hardness increases in proportion to an increase in the percentage of carbon also applies to stainless martensitic steels.

Each carbon yield is associated with a quenching index. By way of some practical examples we can say that for 1.4006 steel the maximum diameter that can be fully hardened is 200 mm and with 1.4021 steel you can reach 300 mm.

In order to make sure that all of the austenite is then transformed into martensite it is useful to cool it, during the hardening phase, to a temperature of 180-200°C.

TEMPERING

This is performed on quenched material to provide stability to the structure of the material.

In martensitic steels tempering allows you to obtain good levels of tensile strength, yield points, elongation and sufficient toughness. Remember that austenitic steels have the highest levels of toughness.

Holding times at temperature vary from 50 to 60 minutes every 25 mm of thickness of the workpiece.

Usually you use long dwell times for low temperatures and vice versa with high temperatures.

For low and medium carbon steel you should not use tempering temperatures between 400 and 570°C, because they can lower the toughness and corrosion resistance. The most common temperatures range between 600 and 780°C. For high carbon steel (eg. cutlery), where the maximum level of toughness is desirable, you must run a stress relieving phase at 250°C.

The cooling phase following tempering is carried out in still air.

STRESS RELIEVING

Heat treatments performed at lower temperatures than those used for tempering, in order to eliminate any residual stresses due to cooling from quenching or to mitigate the negative effect of dissolved hydrogen in solid form in the material.

Temperatures range from 150 to 300°C and can reach 430°C in some cases.

This should be carried out immediately after quenching when the workpieces are still at 60-100°C.

You can use the tempering temperatures for the holding phase.



Still or forced air is used for cooling, and in some cases, oil or polymers.



ANNEALED STEEL 1.4006 X 500
slight grain-boundary carbide precipitation



HARDENED STEEL 1.4006 X 200
tempered martensite

FERRITIC STAINLESS STEELS

1.4016 - 1.4105 - 1.4106 MOD - ASI 430 FMo

It is not possible to improve the mechanical properties of this category through quenching.

The main treatment they undergo is recrystallization annealing.

These steels always have a stable ferritic structure at any temperature they are subjected to.

RECRYSTALLIZATION

An annealing treatment performed on ferritic steels in order to obtain a regular grain structure.

This process generally follows the process of cold working, it restores the plasticity and removes the hardening of the matrix provided by cold rolling or drawing.

Recrystallization is essential and must be carried out in intervals when performing numerous cold workings.

The holding time at the pre-set temperature is 1 hour per inch of thickness and controlled cooling is carried out up to 300°C, after which cooling can be completed with air.

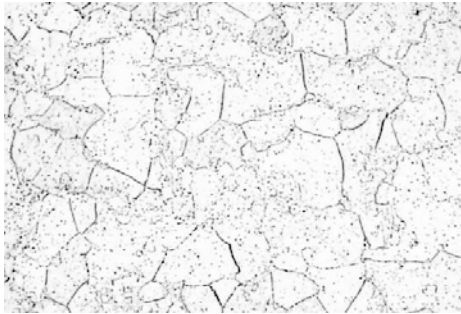
For the types of steel with a high chromium content (Cr% 20 ~) avoid holdings, even if limited, in the range between 570 and 400°C as it may cause embrittlement.

If such an incident should occur, repeat the treatment with rapid cooling up to a temperature of 300°C.

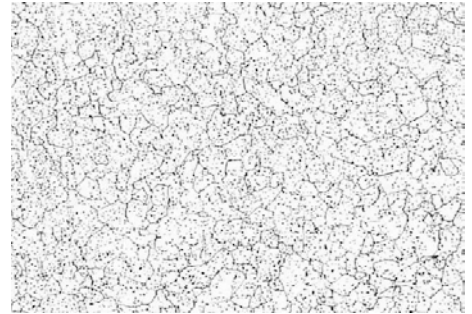
ASTM	N°	RECRYSTALLIZATION TEMPERATURE °C	COOLING
405	1.4002	810 - 700	air
409	1.4512	900 - 870	air
430	1.4016	810 - 700	air
430 F	1.4104	790 - 710	air
442	...	830 - 760	air
446	1.4762 ~	820 - 780	air



TYPICAL STRUCTURES OF FERRITIC STAINLESS STEELS



annealed steel 1.4016 x 200; ferritic structure with partial grain-boundary carbide precipitation



*annealed steel 1.4105 x 100
ferrite with 6-8 grain structure*

AUSTENITIC STAINLESS STEELS

1.4301 - 1.4305 - 1.4307 - 1.4401 - 1.4404 - 1.4541 - 1.4567 - 1.4570

These steels are not suitable for improving their mechanical properties through quenching, but they may have good tensile strength, yield point, elongation and toughness values after cold plastic solution and deformation (eg. drawing).

The materials of this family have an austenitic structure even at room temperature.

SOLUTION HEAT TREATMENT

This treatment is similar to quenching but much higher temperatures are used than those used for heat-treatable steels.

The temperature is generally greater than 1000°C (the standard temperature is 1050°C), in order to homogenize the structure of the material and spread the carbides throughout the matrix. Cooling is usually quick, with immersion in water in order to minimize the holding time in the range of 450-850°C, when carbide precipitation often occurs, also known as sensitization.

If the precipitated chromium carbides, during forging, hot rolling or welding, are not released into the solution to restore the correct percentage (min. 12%), it will be followed by loss of stainlessness.

Carbide precipitation occurs in the range between 450 and 850°C. With solution heat treatment, steel takes on a state of maximum softening and excellent plasticity.

Given the high temperature, which can cause undesirable effects on the surface and at the core of the material, we recommend short holdings of 3-5 minutes for every 3 mm of thickness. Solution heat treatment is repeated between cold workings, in order to allow the material to regain workability for elongation (deformation) without breaking.



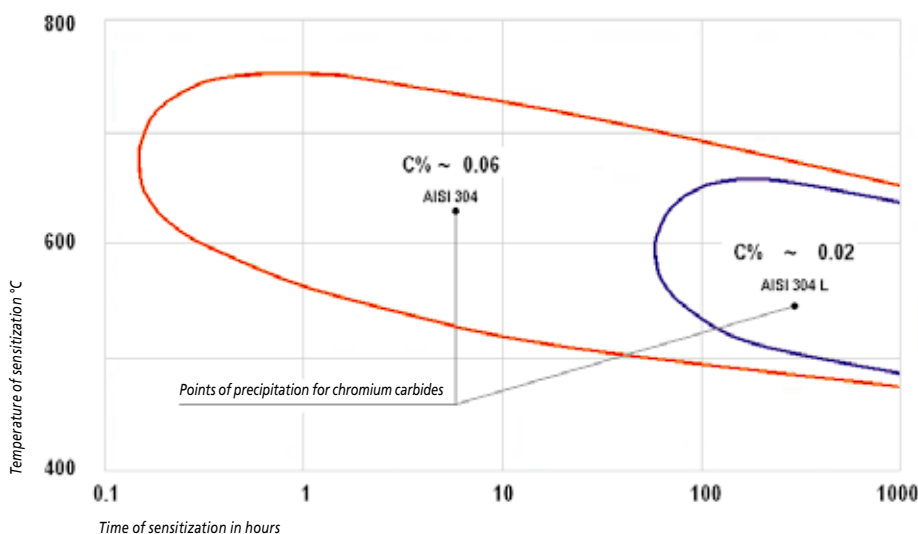
ASTM	SOLUTION HEAT TREATMENT TEMPERATURE °C	COOLING
201, 202	1120 - 1010	water
301, 302, 302B, 303	1120 - 1035	water
304, 305, 308	1120 - 1010	water
304L	1120 - 1010	water
309, 309S	1120 - 1035	water
310, 310S	1080 - 1035	water
314	1120 - 1040	water
316	1120 - 1035	water
317	1120 - 1065	water
316L, 317L	1105 - 1040	water
321	1080 - 905	water
347, 348	1100 - 980	water

SENSITIZING

This is not a quality heat treatment, and must therefore be avoided. It is used only for the purpose of verifying the tendency of a stainless steel to corrode on the grain boundary after heat treatment or welding.

As mentioned in the section on solution heat treatment, the depletion of chromium can occur between 450 and 850°C, if the steel lacks stabilizing elements (eg. Nb, Ti), various tests are performed at these temperatures. For stabilized steels the test temperatures range from 1250 to 1300°C.

To reduce the risk of sensitization low carbon steels are used in the L "low carbon" series (C% < 0.03, ex. AISI 304L, 316L...) and stabilized steels with Ti, Nb, Ta (eg AISI 321, 317).



*THE TREND
of the chrome
carbide
precipitation
phenomena
compared to
the percentage
of carbon
in austenitic
steels*



STRESS RELIEVING

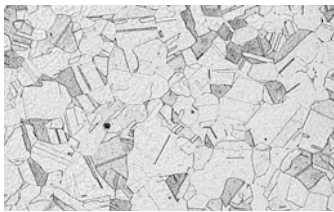
For austenitic steels this treatment is carried out at temperatures below 450°C for the reasons provided regarding chromium depletion. The heating is raised to approximately 350-430°C, with dwell times based on the thickness in order to even out the temperature of the entire mass which is then followed by air cooling. The result of this operation is to eliminate stress caused by mechanical and cold working, welding, severe cooling and to thereby avoid the development of stress corrosion.

All these stresses, if not reduced, can lead to the formation of cracks. Some texts use the term stress relieving at 800-850°C upon completion of welding, however "annealing" is the more correct term.

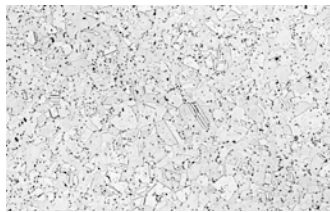
STABILIZATION

In short, it is similar to and generates similar effects to stress relieving, but is carried out at temperatures between 900 and 800°C (standard 885°C). With this treatment it is possible to prevent chromium-carbide precipitation and you obtain maximum corrosion resistance in austenitic steels.

Austenitic structures



rolled solution annealed steel 1.4301



rolled solution annealed steel 1.4305



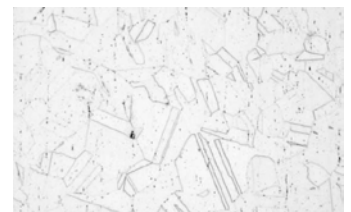
rolled solution annealed steel 1.4307



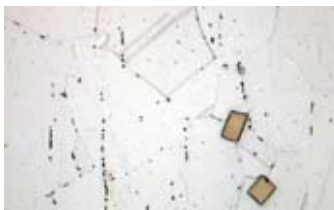
rolled solution annealed steel 1.4401



untreated rolled steel 1.4567



*rolled solution annealed steel
1.4541 x 200*



*rolled solution annealed steel 1.4541
structure with titanium
carbide-content. X500*



*steel 1.4401
rolled solution annealed steel,
and then drawn*



*steel 1.4404
rolled solution annealed steel,
and then drawn*



STAINLESS STEEL TREATMENTS IN CONTROLLED ATMOSPHERE

These are basically the annealing and solution heat treatment as described above but carried out in special furnaces that contain protected atmosphere composed of inert gases, and can prevent the oxidation that forms in standard oxygen circulation furnaces.

The atmosphere consisting of hydrogen can cause embrittlement in martensitic steels, particularly those with high carbon content, while the risk does not exist for austenitic steels, and is low for ferritic steels

SURFACE HARDENING TREATMENTS

Induction **surface hardening** can be carried out only on martensitic steels and the process is identical to that used for carbon and alloy steels.

The **case-hardening** process is not recommended, because an increase in carbon on the surface, decreases resistance to corrosion.

Given the high chromium content, nitration is possible as the formation of chromium nitrides can provide hardness values of up to 62-64 HRC. This hardness increases the wear resistance of martensitic, ferritic and austenitic stainless steels. For martensitic steels, nitration is performed on previously hardened material. No preliminary heat treatment is required for ferritic and austenitic steels. The methods are similar to those used for alloy steels. For ferritic and austenitic steels is known that hardening is also obtained through **controlled hardening** by cold plastic deformation, drawing, rolling, blasting or sandblasting. **Deposition processes** (PVD Physical Vapor Deposition and the less common CVD Chemical Vapor Deposition) are employed to increase the surface hardness, counter friction and develop excellent wear resistance.

n.	ASTM		feasibility	
1.4301	(304)	•	[]	◇
1.4401	316	•	[]	◇
1.4021	420A	•	[]	◇
1.4057	431	•	[]	◇
•	PVD ccoating with a coating temperature (layer) of 420-450°C TiN, TiCN		Thickness of the coating from 2 to 5 µm	
[]	PVD coating with a coating temperature of 280°C		Thickness of the coating from 2 to 5 µm	
◇	PVD coating with a coating temperature of 180°C		Thickness of the coating from 2 to 5 µm	
◇	CVD coating with a coating temperature of 90 to 130°C		Thickness of the coating from 6 to 10 µm	



GUIDING PARAMETERS FOR PLASMA CUTTING STAINLESS STEEL

Thickness	Speed	Nozzle diameter ⁽¹⁾	Current Flow	Power
mm	mm / s	mm	A	kW
6	86	3.02	300	60
13	42	3.02	300	60
25	21	4.00	400	80
51	9	4.08	500	100
76	7	4.08	500	100
102	3	4.08	500	100

⁽¹⁾ The plasma gas flow rate depends on the diameter of the nozzle and the type of gas used and varies from 47 dm³ / min for a diameter of 3.02 mm up to 94 dm³ / minute for a diameter of 4.08 mm.
The gases that are normally used are nitrogen and argon with additions of hydrogen of up to 35%



SURFACE TREATMENTS

All operations at high temperatures (forging, rolling, welding, heat treatments) create surface oxidation on carbon, alloy and stainless steel.

This layer of oxide, commonly called "scale" must be eliminated as it creates problems during molding and drawing, and more particularly it can deteriorate the corrosion resistance.

The best known cleaning systems are acid pickling, molten soda pickling, sandblasting and degreasing.

DEGREASING

Before proceeding to pickling and welding operations it is necessary to remove any grease or oil from the surface of the material. These compounds, which are used in deep drawing and drawing for example, can be removed with carbon tetrachloride, trichloroethylene or alkaline mixtures and fine abrasive powders.

At the end of the degreasing process you must rinse the material thoroughly.

SANDBLASTING

This technique is rarely used on stainless steel products, except for some cases of cast or forged workpieces with very adherent scale.

When this operation is essential, you must use very fine sand or grit, and then proceed with a decontamination-passivation treatment.

ACID PICKLING

Before proceeding with pickling, you must clean the workpiece thoroughly in order to remove all traces of insoluble matter, using special baths. We list a few by way of example.

Annealed ferritic and martensitic steels.

A bath at 50 - 60°C or at room temperature, but for very long immersion times:

52% nitric acid (36° Bé)	100 liters
65% hydrofluoric acid,	10 liters
water	900 liters

For quick pickling or for materials which can be difficult to clean it is possible to use baths at temperatures close to boiling:

soda 20 %	by weight
Potassium permanganate 5%	by weight
water 75 %	by weight



Austenitic steels with low carbon content

A bath at 50 - 60°C or at room temperature, but for very long immersion times:

52% nitric acid (36°Bé)	100 liters
-------------------------	------------

65% hydrofluoric acid,	20 liters
------------------------	-----------

water	900 liters
-------	------------

When there is a risk of intragranular corrosion, it is advisable to keep the materials in the pickling baths for the shortest amount of time possible.

MOLTEN SODA PICKLING

It is sometimes carried out prior to acid pickling to facilitate the removal of the scale.

A) 15 minutes of immersion in a bath of molten soda heated to 450°C with the addition of sodium nitrate or potassium nitrate at 5 to 20%. At the end of immersion, cool it immediately and vigorously in water, then proceed to acid pickling.

B) A few minutes of immersion in a bath of molten soda heated to 370-380°C with the addition of sodium hydride at 1 to -2%. At the end of immersion, cool it immediately and vigorously in water, then proceed to acid pickling.

DECONTAMINAZIONE/ PASSIVAZIONE

These processes are commonly performed by immersion of stainless steel products in nitric acid.

Small contaminated residual particles are mainly caused by friction with non-stainless steel, cold shearing, metal brushes, and grinding wheels. Acid dissolves these contaminating particles that often cause localized corrosion.

A decontaminating bath may be used during cold processing that potentially generates ferrous residues.

The bath must be used at ambient temperature and immersion lasts several hours in the following solution:

52% nitric acid (36° Bé)	250 liters
--------------------------	------------

water	750 liters
-------	------------

thorough wash

This treatment is not recommended for stainless steel with sulfur addition; and is, therefore, replaced by cleaning with special pastes.

Whenever requested, this process must be performed immediately after pickling and rinse, or after polishing.

The same bath described in decontamination may be used for material immersion.





PASSIVATION

Recommended Nitric Acid Treatments for Different Grades of Stainless Steel.

Passivation, ASTM A 967

EN	UNS	NITRIC 1	NITRIC 2	NITRIC 3	NITRIC 4
AUSTENITIC					
1.4372	S20100		•	•	
1.4373 ~	S20200		•	•	
1.4310 ~	S30100		•	•	
1.4310 ~	S30200		•	•	
1.4301 ~	S30400		•	•	
1.4567	S30430		•	•	
1.4315 ~	S30451		•	•	
1.4303 ~	S30500		•	•	
1.4303 ~	S30800		•	•	
1.4828 ~	S30900		•	•	
1.4842 ~	S31000		•	•	
1.4841	S31400		•	•	
1.4401	S31600		•	•	
1.4404	S31603		•	•	
1.4401 ~	S31609		•		•
1.4541	S32100		•	•	
FERRITIC					
1.4002 ~	S40500	•			•
1.4512 ~	S40900	•		•	•
1.4001 ~	S42900	•			
1.4016	S43000			•	
1.4113	S43400	•		•	
1.4526 ~	S43600	•		•	
1.4749 ~	S44600			•	
FREE MACHINING					
1.4305	S30300	•			
	S30330	•			
	S30360	•			
	S34720	•			
1.4104	S43020	•			
	S44020	•			
MARTENSITIC					
1.4000 ~	S40300	•			•
1.4006	S41000	•			•
1.4005	S41600	•			
1.4021	S42000	•			
1.4057	S43100	•			•
1.4112	S44003	•			•
1.4125	S44004	•			•
DUPLEX					
1.4460 ~	S32900		•	•	
PRECIPITATION HARDENING					
1.4542	S17400	•			•
1.4568	S17700	•			•
	S35500	•			•

NITRIC 1	Solution contains 20 - 25% of nitric acid and 2.5% + 0.5 weight of sodium dichromate. Parts immersed for a minimum of 20 min at a temperature from 49 to 54 °C.
NITRIC 2	Solution contains 20 - 45% of nitric acid. Parts immersed for a minimum of 30 min at a temperature from 21 to 32 °C.
NITRIC 3	Solution contains 20 - 25% of nitric acid. Parts immersed for a minimum of 20 min at a temperature from 49 to 60 °C.
NITRIC 4	Solution contains 45 - 55% of nitric acid. Parts immersed for a minimum of 30 min at a temperature from 49 to 54 °C.



CORROSION

With exemption to gold and platinum, all metals are extracted in their raw state from different minerals and chemical combinations. The majority of these metal compounds are altered when in contact with water, vapor or atmosphere and they tend to regress to their original status.

Alloys, purposely studied to resist this alteration, are referred to as anti-corrosion stainless steel with passivation properties at contact with oxidizing agents.

Passivation is an extremely thin layer of adherent oxide (~ 0.01 micron) that spontaneously forms on the metal's surface, the same that delays corrosion and protects the base of stainless steel products. One of the elements most essential to the creation of the oxide layer is chrome – element that characterizes stainless steel. Its main property is to withstand dry chemical (oxidation) and wet (corrosion) attacks, both at room and high temperatures. Corrosion occurs when the oxide layer is attacked due to improper choice of materials in comparison to working conditions.

Passivation: property of some metals and alloys (stainless steel) to oxidize on the surface; the thin film protects the base metal against corrosion.

Corrosion: chemical-physical phenomenon that consists in the action exerted on metals by external agents. Corrosion can also occur as a result of galvanic treatment due to contact with materials having different electrochemical properties or when stressed, combined effect of a corrosive environment and mechanical stress in material tensile direction may induce fracture.

UNIFORM CORROSION

As understood from the term itself, this type of corrosion leads to a uniform loss of material across the entire surface. The effect is usually quantified in weight reduction in grams per hour per meter squared or annual thickness reduction. Laboratory tests and experiments have made it possible to calculate piece duration for a given corrosive environment and for the various types of steel. This type of corrosion rarely occurs in stainless steel.

CREVICE

Occurs in scarcely "oxygenized" zones and in the presence of aggressive substances. Crevice corrosion occurs when the metal touches chloride ion solutions. The fluid penetrates the miniscule gaps created by the surface contact between different pieces where it stagnates and develops corrosion.

PITTING

This phenomenon occurs in localized areas while the majority of the surface remains intact. This type of corrosion breaches deep into the metal with perforation of thin surfaces in extreme cases. Development of this type of corrosion cannot be measured through weight reduction due to its point



localization. Pitting corrosion occurs in solutions containing ferrous halogens, especially soluble chlorides, bromides and halides of heavy metals that tend to eliminate the passive oxide film and restore the surface to its active state; thus, allowing corrosion attack on the material. This effect is deceiving and dangerous because it eludes visual inspection.

The phenomenon's action takes place in two phases:

- 1) incubation where aggressive ions affect the passive film;
- 2) expansion of pitting by self-catalysis.

INTERGRANULAR CORROSION

Extremely dangerous corrosion by which non-low carbon, non-stabilized austenitic stainless steels are put at risk.

Individual cohesion of each grain is damaged by corrosion that, progressively moving along their edges, affects adhesion.

This type of defect is caused by modifications of the steel's structure and occurs during re-heating (from 400 to 900°C where grain-boundary carbide precipitation occurs) while undergoing specific procedures or operations such as welding. To avoid aggression by this type of corrosion, austenitic steels are always to be solution heat treated at 1,150-1,000 °C – temperature at which carbides are dissolved.

Niobium and titanium stabilized austenitic stainless steels or low-carbon steels are always used for parts with prolonged exposure to temperatures of 400-900 °C.

GALVANIC CORROSION

This phenomenon occurs when a stainless steel element that acts as a cathode is put into contact with metal contaminants, with other less noble metal (ex. aluminum, zinc, etc.) inside a sufficiently aggressive electrolyte (ex. marine environment). Galvanic conduction is more extensive for greater contact surface. This translates to the greater the stainless steel surface (cathode) in comparison to the less noble metal (anode).

STRESSED OR STRESS CORROSION

It acts through the formation of thin cracks that dig deep into the steel matrix.

Cracks may continuously develop across the entire surface of the piece.

This phenomenon occurs when the piece is continuously subject to a corrosive agent and stress (traction).

This type of corrosion is provoked, for example, by internal stress that is amplified by cold deformations of static loads. Typical environments able to cause this type of corrosion regard those containing concentrated alkaline solutions and chloride solutions. Under specific circumstances, even water and steam may generate a similar effect.



Stress corrosion is more common in austenitic and martensitic stainless steels. Ferritic and duplex stainless steel are less sensitive to this type of defect.

ATMOSPHERIC CORROSION

Corrosion due to atmospheric condensation on the metal surface.

CONTACT CORROSION

Localized corrosion that occurs in the contact area between two pieces of metal.

DRY CORROSION

Corrosion of a metal that occurs at high temperatures and lack of water or other solvents.

CAVITATION

Surface defect due to the action of moving gas or fluids. The formation of cavities is accelerated if the gas or fluid undergoes rapid pressure variation.

CORROSION CRATER

Surface cavity with depth equal to its transversal dimensions.

HYDROGEN PROVOKED STRESS CORROSION CRACK

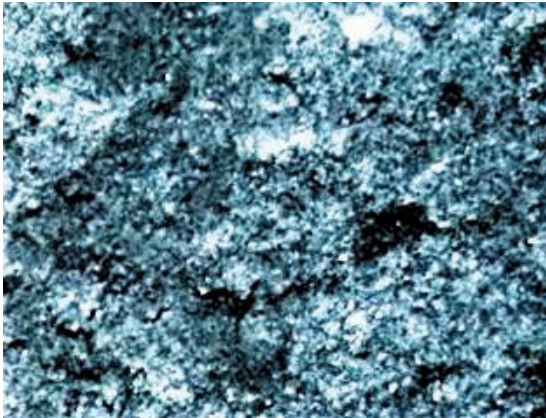
Crack provoked by corrosion that occurs in hydrogen provoked pressure.

STRESS CORROSION

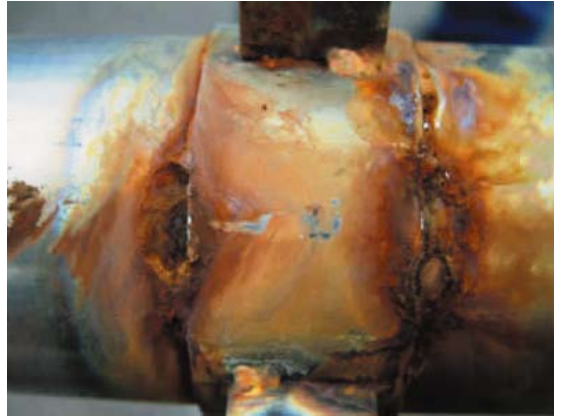
It comprises corrosion both due to self-stress and exertion of stress



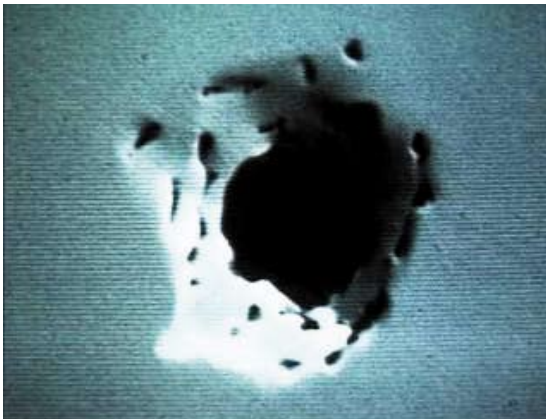
VARIOUS FIGURES OF CORROSION



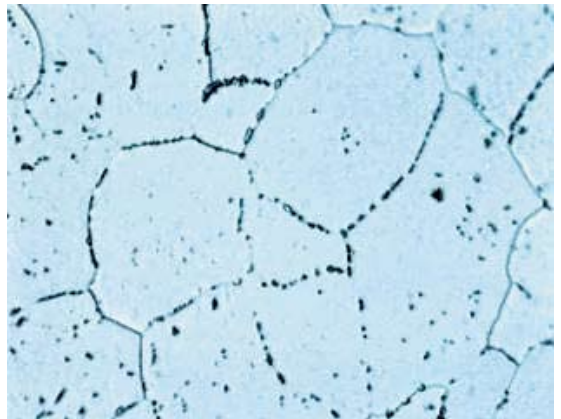
uniform



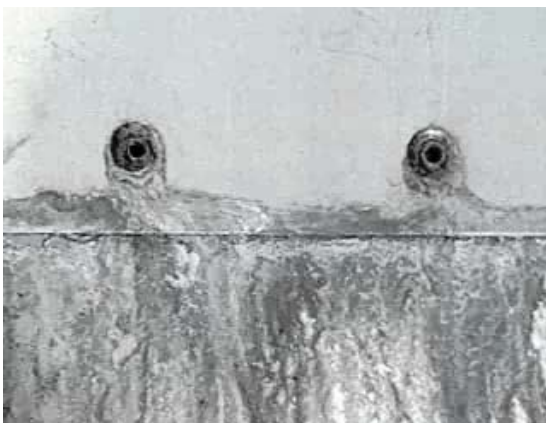
weld crevice



pitting



intergranular



galvanic



stress

SURFACE MAINTENANCE

[taken from Centro Inox – Italian Association for Stainless Steel Development]

LIMESTONE ENCRUSTATION

To remove limestone deposits due to hard water, use a multi-purpose cream applied with a soft cloth. Thicker deposits can be dissolved by submerging the piece in a solution of hot water and ¼ vinegar. Rinse thoroughly with a water and sodium bicarbonate solution, followed by clean water. Dry thoroughly.

OIL AND GREASE STAINS

Use a low potency detergent and plenty of hot water. Rinse with abundant clean water and dry thoroughly with a soft cloth. Use ethyl alcohol, acetone or other non-halogenated solvents for tough stains.

IMPRONT

Use a low potency liquid detergent mixed with water, rub with a soft cloth (ex. microfiber) and a glass cleaner.

FLAME RING

Use a cloth and a home multi-purpose cream detergent. Rinse under running water and dry with a soft cloth.

COFFEE OR TEA STAINS

Prepare a solution of sodium bicarbonate and boiling water. Immerge the stained vessel for 15 minutes and drain after removal. Rinse with care and dry with a soft cloth.

SURFACE SCRATHCES

Apply an appropriate stainless steel detergent/polish with a soft cloth.

TOUGH GRIME AND BURNT GREASE

Use a washcloth with a household multi-purpose cream detergent.

RUST STAINS (contamination)

Instead of stainless steel corrosion, rust stains may originate from steel tools of daily use that are left on a stainless steel surface for prolonged periods, or they may transfer ferrous particles. To remove these stains, apply a cream detergent with a soft damp cloth and rub delicately. Should the stain persist, apply a passivating or pickling solution for stainless steel.



NEVER USE an abrasive scourer, brushes or discs made of other metals or alloys (ex. common steel, aluminum, brass, etc.), or tools that previously worked on or cleaned other metals or alloys, which provoke unsightly rings aside from scratching the surface.

Stainless steel scourers and brushes are compatible given they cause no surface contamination, though care is required to avoid surface scratches.

NEVER USE hydrochloric acid (market available muriatic). It is also best to avoid contact with hydrochloric acid fumes that originate from, for example, floor cleaning. In general, avoid the use of detergents containing chlorides unless rapid contact and thorough water rinsing are foreseen. Never use bleach.

NEVER USE abrasive powder detergents that may damage the aesthetic aspect of surface finish (ex. gloss finish).

NEVER USE silver-cleaning solutions.



STORAGE

Almost all warehouses deal in various metals, going from carbon-based metals and alloys to stainless steels. Given the circumstances, methods for avoiding every possible product deterioration are necessary. The most frequent defects are caused by mechanical damage or rust.

- 1) Wherever possible, stainless steel wares must be protected by a layer of plastic film in order to avoid scratches or dents, as well as contact with non-stainless steels. This technique allows preservation of finishes and polish performed in the production plant.
- 2) The different types of materials must be stored at least on a family-basis method (ex. carbon with carbon, austenitic with austenitic), to avoid contamination by direct contact or ferrous dust deposit.
- 3) Forks, chains, trolleys, etc. must be coated in rubber, plastic or wood. Slings shall be composed of fiber ropes or harnesses, instead of steel chains. Tool, shears, transporters, presses and all equipment that has come into contact with carbon steel must be decontaminated of all residual ferrous powder before being used on stainless steels.
- 4) Stainless steel sheets and bars must not be stepped on by soles containing grease or metal powders pertaining to other steel categories.
- 5) If carbon steel supports are used during pack preparation, these must be insulated and must never touch stainless steel surfaces.



EMPIRICAL FORMULAS

FOR STEEL GRADE CLASSIFICATION BY MICROSTRUCTURE

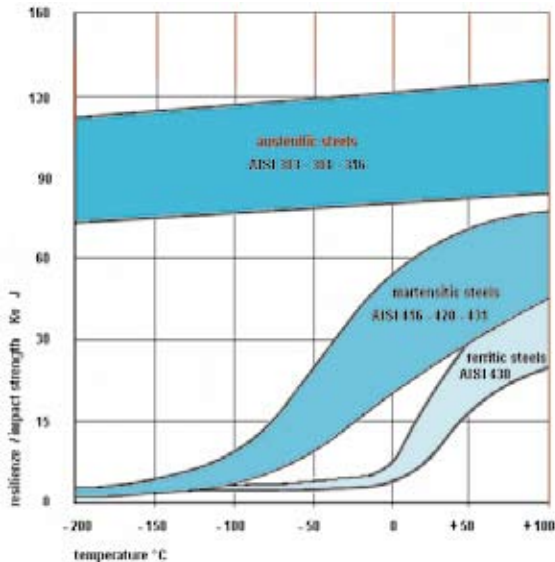
The formulae are used for characterisation of grades and classification into groups. They may be updated and harmonised with other formulae in use. The traditional groups for Ferrite, Martensite and Austenite are complemented with transition group marked in bold. The basis is the average chemical composition for the grade, i.e. (% min + % max)/ 2 .

MICROSTRUCTURE CHARACTERISTICS	FORMULAS AND PARAMETERS		RANGE OF APPLICATION	
FM Ferrite - Martensite- region in Schaeffler/de Long diagram	FM = (A – 1,2) / (F – 8) for F = min 8 where: F = 1,5Si + Cr + Mo + 2Ti + 0,5Nb A = 30C + 0,5Mn + 30N + Ni + 0,5Cu + 0,5Co		FERRITIC	Ferritic when: FM = 0,00 - 0,30
			MARTENSITIC	Ferritic-Martensitic when: FM = 0,30 - 1,00
MS Ferrite – Martensite transform Walker-Gooch	MS = 540 - 497C - 6,3Mn - 10,8Cr - 36,3Ni - 46,6Mo			Martensitic when: FM = 1,00 - 4,00
			Martensitic when: MS = 100 - 300	
MNA Martensite Number based on Md30 Angel-Nohara	MNA = 551 - 462(C+N) - 9,2Si - 8,1Mn - 13,7Cr - 29(Ni+Cu) - 18,5Mo - 68Nb		Austenitic-Martensitic when: MNA = 100 - 300	
MNK Martensite Number based on WRC-1992 diagram Kotecki-Siewert	MNK = 25 - F - 0,90A MNK = 21 - 0,90F - A MNK = 13 - 0,42F - 1,3A where: F = Cr + Mo + 2Ti + 0,7Nb A = 35C + 20N + Ni + 0,25Cu	for Mn = max 2,4% for Mn = 2,5 - 6,9% for Mn = min 7,0%	AUSTENITIC	Metastable austenitic when: MNA = 0 - 100 or MNK = (-2) - 0
MS Austenite – Martensite transform SINTEF Welding handbook 1997	MS = 502 - 810C - 13Mn - 1230N - 12Cr - 30Ni - 46Mo - 54Cu			Austenitic when: MS = (-1000) - (-10)
SM Solidification Mode based on WRC-1992 diagram Kotecki-Siewert	SM = F - 1,3A - 2,0 where: F = Cr + Mo + 2Ti + 0,7Nb A = 35C + 20N + Ni + 0,25Cu			Fully austenitic when: SM = (-30) - (-4)
FNA Ferrite Number based on complemented Schaeffler /de Long diagram ASME III div. 1 NB-2433	FNA = 3,34F - 2,46A - 28,6 FNA = 4,44F - 3,39A - 38,4 FNA = 4,06F - 3,23A - 32,2	for FNA = max 5,9 for FNA = 6,0 - 11,9 for FNA = min 12	DUPLEX	Austenitic when: FNA = (-40) - 20
	where: F = 1,5Si + Cr + Mo + 2Ti + 0,5Nb A = 30C + 0,5Mn + 30N + Ni + 0,5Cu + 0,5Co			Austenitic-Ferritic (Duplex) when: FNA = 30 - 50 or SM = 8 - 15
IMP Intermetallic Phases based on FNA equivalents and SINTEF Welding handbook 1997	IMP = F - 0,23A - 20,2 IMP = F + 1,25A - 32,8	for A = min 8,7 for A = max 8,6	Sensitive to formation of IMP when: IMP = 4 - 10	
PRE Pitting Resistance Equivalent Herbsleb (30N)-Truman (16N)	PRE = Cr + 3,3Mo + 16N	most common formulas for super-austenitic/ duplex/ferritic.	Resistent when: PRE = 40 - 60	
	PRE = Cr + 3,3Mo + 30N	also for austenitic steels with Mo > 3		



TRANSITION CURVES

The graph provides a behavioral scheme of steel resistance in Joule (mechanical force) determined with Kv resilience values at various temperatures for the three families of stainless steel.



documentation: Centro Inox

MECHANICAL PROPERTIES AT DIFFERENT TEMPERATURES OF SEVERAL AUSTENITIC STEELS

AUSTENITIC STEEL	TESTS AT °C	R _{p0.2} MPA / N/mm ²	R MPA / N/mm ²	A %	C %
304	24	227	586	60	70
304	-195,5	393	1416	43	45
304	-254	439	1685	48	43
304L	24	193	586	60	60
304L	-195,5	241	1340	42	50
304L	-254	233	1516	41	57
310	24	310	658	60	65
310	-195,5	585	1085	54	54
310	-254	796	1223	56	61
347	24	241	620	50	60
347	-195,5	284	1282	40	32
347	-254	313	1450	41	50

The temperatures -195,5 °C and -254 °C are defined as cryogenic (source: Key to Steel)

RESILIENCE TEST ON KV

AUSTENITIC STEEL	ENERGY ABSORBED (J)		
	24 °C	-195,5 °C	-254 °C
304	209	118	122
304L	160	91	91
310	192,5	121	117
347	163	89	77



COMPARISON TABLE

	TRAFITEC EN		USA UNS	USA AISI	CHINA GB	RUSSIA GOST	JAPAN JIS	INDIA IS	KOREA KS
m	1.4005	X12CrS13	S41600	416	Y1Cr13		SUS 416		STS 416
m	1.4006	X12Cr13	S41000	410	1Cr12	12Ch13	SUS 410	X12Cr12	STS 410
f	1.4016	X6Cr17	S43000	430	1Cr17	12Ch17	SUS 430	X07Cr17	STS 430
m	1.4021	X20Cr13	S42000	420A	2Cr13	20Ch13	SUS 420J1		STS 420J1
m	1.4028	X30Cr13		420B	3Cr13	30Ch13	SUS 420J2	(X30Cr13)	STS 420J2
m	1.4031	X39Cr13			4Cr13	(40Ch13)		(X40Cr13)	
m	1.4034	X46Cr13		420C		(4Ch13)			
m	1.4034	1.4034 DE							
m	1.4035	420C+S		(420C)					
m	1.4057	X17CrNi16-2	S43100	431	1Cr17Ni2	14Ch17N2	SUS 431	15Cr16Ni2	STS 431
m	1.4104	X14CrMoS17	S43020	430F	Y10Cr17		SUS 430F		STS 430F
f	1.4105	X6CrMoS17							
f	(1.4105)	AISI 430F Mo							
f	(1.4106)	1.4106 MOD							
m	1.4112	X90CrMoV18	S44003	440B	90Cr18MoV		SUS 440B		STS 440B
m	1.4116	X50CrMoV15			(7Cr17)	50Ch14MF	(SUS 440A)		
m	1.4122	X39CrMo17-1				40Ch16M			
m	1.4125	X105CrMo17	S44004	440C	108Cr17	95Ch18	SUS 440C	(X108Cr17Mo)	STS 440C
a	1.4301	X5CrNi18-10		(304)	0Cr18Ni9	07Ch18N10		X04Cr19Ni9	
a	1.4305	X8CrNiS18-9	S30300	303	Y1Cr18Ni9	12Ch18N10E	SUS 303		STS 303
a	1.4306	X2CrNi19-11		(304L)	022Cr19Ni10	(03Ch18N11)		X02CrNi19-10	
a	1.4307	X2CrNi18-9			00Cr19Ni10	03Ch18N11		X02Cr19Ni10	
a	1.4310	X10CrNi18-8	S30200	302	1Cr17Ni7	07Ch16N6	SUS 302	X07Cr18Ni9	STS 302
d	1.4362	X2CrNiN23-4	S32304		(S23043)	03Cr23N6			
a	1.4401	X5CrNiMo17-12-2	S31600	316	0Cr17Ni12Mo2	08Ch17N13M2	SUS 316	X04Cr17Ni12Mo2	STS 316
a	1.4404	X2CrNiMo17-12-2	S31603	316L	022Cr17Ni12Mo2	03Ch17N13M2	SUS 316L	X02Cr17Ni12Mo2	STS 316L
a	1.4435	X2CrNiMo18-14-3	(S31603)	(316L Mo)	00Cr18Ni15Mo3	03Ch17N14M3	(SUS 316L)	(X02Cr17Ni12Mo2)	(STS 316L)
d	1.4462	X2CrNiMoN22-5-3	S31803		(S22453)	02Ch22N5AM2	(SUS 329J3L)		(STS 329J3L)
a	1.4541	X6CrNiTi18-10	S32100	321	0Cr18Ni11Ti	06Ch18N10T	SUS 321	X04Cr18Ni10Ti	STS 321
a	1.4567	X3CrNiCu18-9-4	S30430	304Cu	06Cr18Ni9Cu3		SUS XM7		STS XM7
a	1.4570	X6CrNiCuS18-9-2	(S30331)	(303K)					
a	1.4571	X6CrNiMoTi17-12-2	S31635	316Ti	06Cr17Ni12Mo2Ti	08Ch17N13M2T	SUS 316Ti	X04Cr17Ni12Mo2Ti	STS 316Ti

m = martensitic

f = ferritic

a = austenitic

d = duplex



FIXING ELEMENTS (EN ISO 3506-1:2009)

part 1

bolts, screws and
stud bolts

part 2

nuts

part 3

screws and similar fasteners
not under tensile stress

part 4

tapping screws

Chemical composition %

GROUP	GRADE	C	SI	MN	P	S	CR	MO	NI	CU	REMARK
A austenitic	A1	< 0,12	< 1	< 6,5	< 0,20	0,15-0,35	16-19	< 0,7	5-10	1,75-2,25	b) c) d)
	A2	< 0,1	< 1	< 2	< 0,050	< 0,030	15-20	e)	8-19	< 4	f) g)
	A3	< 0,08	< 1	< 2	< 0,045	< 0,030	17-19	e)	9-12	< 1	h)
	A4	< 0,08	< 1	< 2	< 0,045	< 0,030	16-18,5	2-3	10-15	< 1	g) i)
	A5	< 0,08	< 1	< 2	< 0,045	< 0,030	16-18,5	2-3	10,5-14	< 1	h) i)
C martensitic	C1	0,09-0,15	< 1	< 1	< 0,050	< 0,030	11,5-14		< 1		i)
	C3	0,17-0,25	< 1	< 1	< 0,040	< 0,030	16-18		1,5-2,5		
	C4	0,08-0,15	< 1	< 1,5	< 0,060	0,15-0,35	12-14	< 0,6	< 1		b) i)
F ferritic	F1	< 0,12	< 1	< 1	< 0,040	< 0,030	15-18	e)	< 1		

b) sulfur may be replaced by selenium.

c) if the nickel content is below 8 %, the minimum manganese content shall be 5 %.

d) there is no minimum limit to the copper content, provided that the nickel content is greater than 8 %.

e) molybdenum may be present at the discretion of the manufacturer.

f) if the chromium content is below 17 %, the minimum nickel content should be 12 %.

g) for austenitic stainless steels having a maximum carbon content of 0,03 %, nitrogen may be present to a maximum of 0,22 %.

h) material stabilized with titanium or niobium

i) the carbon content may be higher where required in order to obtain the specified mechanical properties, but shall not exceed 0,12 % for austenitic steels.

Recommended steel types

	EN	AISI	production technique	applications
A1	1.4305	303	turning	wood screws, metal screws, tapping screws, nuts
A2	1.4567	304Cu	hot-forming / cold-forming, rolling	wood screws, metal screws, tapping screws, nuts
A3	1.4541	321	turning	linkages to high temperatures max 800 °C
A4	1.4401	316	hot-forming / cold-forming, rolling	wood screws, metal screws, tapping screws, nuts
A5	1.4571	316Ti	turning	linkages for marine applications
C1	1.4006	410	turning, pressing, rolling	viti autofilettanti ed a metallo
C3	1.4057	431	turning, cold-heading / cold rolling	metal screws, tapping screws, screw anchor
C4	1.4005	416	turning	metal screws, tapping screws, nuts
F1	1.4016	430	hot-forming / cold-forming, rolling	wood screws, metal screws, tapping screws, nuts



screw anchor type C1



screws



Mechanical properties

GRADE	PROPERTY CLAS	THREAD	HARDNESS			TENSILE STRENGTH	YIELD STRENGTH	ELONGATION	STATE OF SUPPLY
			HB	HRC	HV	R N/mm ²	RP _{0.2} N/mm ²	A ²⁾ %	
A1 - A2 A3 - A4 A5	50	< M39				> 500	> 210	> 0,6 d	softened
	70	< M241)				> 700	> 450	> 0,4 d	work hardened
	80	< M241)				> 800	> 600	> 0,3 d	high work hardened
C1	50		147-209		155-220	> 500	> 250	> 0,2 d	softened
	70		209-314	20-34	220-330	> 700	> 410	> 0,2 d	quenched and temp
	110 ³⁾			36-45	350-440	> 1100	> 820	> 0,2 d	quenched and temp
C3	80		228-323	21-35	240-340	> 800	> 640	> 0,2 d	quenched and temp
C4	50		147-209		155-220	> 500	> 250	> 0,2 d	softened
	70		209-314	20-34	220-330	> 500	> 410	> 0,2 d	quenched and temp
F1 ⁴⁾	45		128-209		135-220	> 450	> 250	> 0,2 d	softened
	60		171-271		180-285	> 600	> 410	> 0,2 d	work hardened

1) for elements with nominal diameter > 24 mm the mechanical properties shall be agreed in order

2) the minimum value is obtained by multiplying 0, .. for the nominal diameter of bolts, screws and studs

3) hardened and tempered at a minimum tempering temperature of 275 °C.

4) Nominal thread diameter < 24 mm.

ASTM A 193/A 193M

Hot-wrought alloy-steel and stainless steel Bolting Materials for High Temperature or High Pressure Service
Cover also screws and stud bolts.

GRADE	CLASSES
B7	... alloy steels AISI 4140/4142 quenched and tempered (EN 42CrMo4)
B8	1 stainless steels AISI 304 solution annealed (EN 1.4301)
B8M	1 stainless steels AISI 316 solution annealed (EN 1.4401)
B8	2 stainless steels AISI 304 solution annealed and cold working (EN 1.4301)
B8M	2 stainless steels AISI 316 solution annealed and cold working (EN 1.4401)

GRADE	SIZE	TENSILE STRENGTH MIN R N/mm ²	YIELD STRENGTH MIN RP _{0.2} N/mm ²	ELONGATION MIN A%	REDUCTION MIN C%	HARDNESS MAX HB
B7	< M64	860	720	16	50	321
	> M64 < M100	795	655	16	50	321
	> M100 < M180	690	515	18	50	321
B8 cl. 1	all	515	205	30	50	223
B8M cl. 1	all	515	205	30	50	223
B8 cl. 2	< M20	860	690	12	35	321
	> M20 < M24	795	550	15	35	321
	> M24 < M30	725	450	20	35	321
	> M30 < M36	690	345	28	45	321
B8M cl. 2	< M20	760	655	15	45	321
	> M20 < M24	690	550	20	45	321
	> M24 < M30	655	450	25	45	321
	> M30 < M36	620	345	30	45	321

Remark

Charpy impact test shall be made as agreed between the manufacturer and the purchaser



REFERENCE STANDARDS

UNI 6388/68 - ISO 286 bars tolerances

Dimensions and tolerances for steel rods for drawing and/or cold-rolling

UNI EN 10017:2005

Dimensions and tolerances of hot-rolled steel UNI EN 10059/10058

Dimensions and tolerances for hot-rolled round steel bars UNI EN 10060:2004

Dimensions and tolerances for hot-rolled hexagon steel bars UNI EN 10061:2004

Dimensions and tolerances for cold-processed steel products EN 10278

Surface classes EN 10088-3





Marzo 2011

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Progetto grafico: parlato**triplo** - Gianico (BS)
Stampa: la Cittadina - Gianico (BS)





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