# Stainless Steel

# Grade Datasheets


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**Atlas Steels**
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# FOREWORD

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# Stainless Steel Datasheets

## Austenitic Stainless Steels

| | |
|---|---|
| **301, 301L, 301LN** | High strength for roll formed structural components |
| **302HQ** | Low work hardening rate grade for cold heading fasteners |
| **303, 303Se** | Free-machining bar grades |
| **304, 304L, 304H** | Standard 18/8 grades |
| **310, 310S, 310H** | High temperature resistant grades |
| **316, 316L, 316H** | Improved resistance to pitting corrosion in chloride environments |
| **321, 321H, 347** | Stabilised grades for heavy section welding and high temperature applications |
| **253MA (S30815)** | High temperature resistant grade |
| **904L** | High resistance to general corrosion, pitting and stress corrosion cracking |

## Ferritic Stainless Steels

| | |
|---|---|
| **AtlasCR12** | Utility steel resistant to wet abrasion and mild corrosion |
| **AtlasCR12Ti** | Utility steel resistant to wet abrasion and mild corrosion – weld stabilised |
| **409** | Automotive exhaust grade – weld stabilised |
| **430, 430F** | Resistant to mildly corrosive environments |
| **F18S / 439** | Resistant to mildly corrosive environments – weld stabilised |
| **F20S** | A ferritic alternative to grade 304 / 304L – weld stabilised |
| **F18MS / 444** | A ferritic alternative to grade 316 / 316L – weld stabilised |

## Duplex Stainless Steels

| | |
|---|---|
| **2101** | Lean duplex – economical alternative to 304 and 316 |
| **2304** | Duplex alternative to grade 316 |
| **2205** | Standard duplex stainless steel - high resistance to pitting and stress corrosion |
| **2507** | Super duplex with very high resistance to pitting and stress corrosion |
| **2507Cu** | Super duplex with very high resistance to pitting and stress corrosion |

## Martensitic Stainless Steels

| | |
|---|---|
| **410** | Standard martensitic grade for low-duty hardened applications |
| **416** | Free-machining bar grade |
| **420** | Higher hardness martensitic grade for cutlery, cutting tools and dies |
| **431** | High hardness and toughness grade, primarily for shafting |
| **440A, 440B, 440C** | Very high hardness grades used in cutting tools |

## Precipitation Hardening Stainless Steel

| | |
|---|---|
| **630** | (17-4PH) High strength shafting grade |

Note that some of these stainless steel grades are commonly referred to by designations that are registered trademarks.

# Grade Data Sheet

# 301 301L 301LN

**Grade 301** is a high work-hardening rate austenitic stainless steel. It can be supplied with a tensile strength of up to over 1300 MPa in strip and wire forms, to produce tempers in the range of 1/16 Hard to Full Hard. The controlled analysis of Grade 301 enables it to retain sufficient ductility in conditions up to 1/2 Hard conditions to be roll or brake formed into aircraft, architectural and particularly rail car structural components. However, 3/4 to Full Hard tempers should be used whenever high wear resistance and spring features are required in components of simple form designs.

Grade 301L with low carbon is preferred for improved ductility or if heavy sections are to be welded, and another variant 301LN has a higher nitrogen content to compensate for the lower carbon.

ASTM A666 covers all three variants, and some are also included in Japanese specification JIS G4305 and Euronorm EN 10088-2.

## Corrosion Resistance

Corrosion resistance is similar to that of 304. Good resistance in applications involving external exposure to mildly corrosive conditions at ambient temperatures.

## Heat Resistance

Good oxidation resistance in intermittent service to 840°C and in continuous service to 900°C, although not usually chosen for this environment. Exposure to temperatures above about 400°C will result in progressive removal of work hardening effects; at approximately 800°C the strength will be similar to an annealed 301. In creep applications a work hardened grade 301 can even reduce to lower strength than an annealed 301.

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 1010-1120°C and cool rapidly. Use low side of range for intermediate annealing. This grade cannot be hardened by thermal treatment.

## Cold Working

Grade 301 and its low carbon variants are used where a high strength stainless steel is required. The grades work harden at the very high rate of approximately 14MPa/%Ra (14MPa increase in tensile strength for each 1% reduction of area of cold work), resulting in high achievable strengths from cold rolling and from roll forming. The strain-hardened austenite is at least partially transformed to martensite by this work. Despite the high strengths achieved there is still enough residual ductility to enable significant cold deformation. Although non-magnetic in the annealed condition, when cold worked the grades become strongly attracted to a magnet.

## Welding

Good characteristics suited to all standard methods. Grade 308L filler rod is recommended. Welds in Grade 301 must be annealed for maximum corrosion resistance; this is not necessary in 301L or 301LN. Welding and post weld annealing will both remove high strength induced by prior cold rolling.

Spot welding is commonly used to assemble cold rolled 301 components. The very small heat affected zone associated with this rapid welding technique results in little reduction of overall component strength.

## Typical Applications

Rail car structural components - often roll formed, brake pressed or stretch formed to profiles but also used flat. Airframe sections. Highway trailer components. Automotive wheel covers, wiper blade holders and clips. Toaster springs, stove element clips. Screen frames, curtain walls.

# Grade Data Sheet

# 301 301L 301LN

## Specified Properties

The properties for Grade 301 are specified for flat rolled product (plate, sheet and coil) in ASTM A666. Similar but not identical mechanical properties are specified in EN 10088.2 and JIS G4305 and in proprietary specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 301 | min. | - | - | - | - | - | 16.0 | - | 6.0 | - |
| | max. | 0.15 | 2.0 | 1.0 | 0.045 | 0.030 | 18.0 | | 8.0 | 0.10 |
| 301L | min. | - | - | - | - | - | 16.0 | - | 6.0 | - |
| | max. | 0.03 | 2.0 | 1.0 | 0.045 | 0.030 | 18.0 | | 8.0 | 0.20 |
| 301LN | min. | - | - | - | - | - | 16.5 | - | 6.0 | 0.07 |
| | max. | 0.03 | 2.0 | 1.0 | 0.045 | 0.015 | 18.5 | | 8.0 | 0.20 |

### Mechanical Property Specification (Grade 301 – other values for 301L and 301LN)

| Grade 301 Temper ASTM A666 | Tensile Strength (MPa) min. | Yield Strength 0.2% Proof (MPa) min. | Elongation (% in 50mm) (thick.>0.76mm) min. | Bend Test (1.27 - 4.76mm thick) | | Hardness Rockwell C (Note 2) |
|---|---|---|---|---|---|---|
| | | | | Bend Angle (°) | Factor (Note 1) | |
| Annealed | 515 | 205 | 40 | 180 | 1 | |
| 1/16 Hard | 620 | 310 | 40 | 180 | 1 | |
| 1/8 Hard | 690 | 380 | 40 | 180 | 1 | |
| 1/4 Hard | 860 | 515 | 25 | 90 | 2 | 25 – 32 |
| 1/2 Hard | 1035 | 760 | 18 | 90 | 2 | 32 – 37 |
| 3/4 Hard | 1205 | 930 | 12 | 90 | 3 | 37 – 41 |
| Full Hard | 1275 | 965 | 9 | 90 | 5 | 41+ |

Notes 1. Bend test is around a diameter of the Bend Factor multiplied by the steel thickness.
2. Hardness values are typical industry standard – there are no specified limits.

## Physical Properties (Grades 301, 301L and 301LN - typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| All | 7900 | 193 | 17.0 | 17.2 | 18.2 | 16.3 | 21.5 | 500 | 720 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 301 | S30100 | 1.4319 | X5CrNi17-7 | - | SUS 301 |
| 301L | S30103 | - | - | - | SUS301L |
| 301LN | S30153 | 1.4318 | X2CrNiN18-7 | - | - |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted. Different comparisons apply to grades 301L and 301LN.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 301 / 301L / 301LN |
|---|---|
| 304 | Better availability, lower cost; the lower work hardening rate of 304 is acceptable. |
| 316 | Higher corrosion resistance needed; the lower work hardening rate of 316 is acceptable |

# Grade Data Sheet

# 302HQ

**Grade 302HQ** is a specialised wire grade with very wide usage for manufacture of stainless steel fasteners. The inclusion of 3% copper in the composition reduces the cold work hardening rate substantially compared to Grade 304. 302HQ is standard for manufacture of self-tapping screws and light machine screws; it is also used for some bolts, set screws, rivets and specialised fasteners. It has now totally replaced Grades 384 and 305 for cold heading applications, copper being a lower cost alternative to their high nickel contents.

The designation 302HQ is not standardised – ASTM specifications list the grade as UNS S30430, and alternative designations for the same grade include "XM-7", "304Cu" and "304HQ". The standard specification for stainless steel fasteners, ISO 3506, includes 302HQ as an acceptable composition for fastener grade "A2"; it is commonly produced in strength grades A2-70 and A2-80.

The stable austenitic structure makes 302HQ non-magnetic, even after substantial cold work, and also results in excellent toughness, even down to cryogenic temperatures.

## Corrosion Resistance

Equal to or exceeding that of Grade 304. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 50°C. 302HQ is considered resistant to potable water with up to about 200mg/L chlorides at ambient temperatures, reducing to about 150mg/L at 60°C. Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Good oxidation resistance in intermittent service to 870°C and in continuous service to 925°C. Continuous use of Grade 302HQ in 425-860°C range is usually safe (free of carbide precipitation) as the grade has a very low carbon content.

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 1010-1120°C and cool rapidly. This grade cannot be hardened by thermal treatment.

## Welding

Use Grade 308L rods or electrodes. Excellent weldability by all standard fusion methods, both with and without filler metals. Because of its applications this grade is not often welded. Exceptions are resistance butt welding to join wires together during wire manufacture, and when the grade is used to make stud welding fasteners. 302HQ is not specifically listed in AS 1554.6.

## Machining

302HQ is rarely machined, because of its form and likely products. The grade always has very low sulphur content as this aids formability, but unfortunately this also reduces machinability. Machining is certainly possible.

An Improved Machinability version of Grade 302HQ is produced, having a very high machinability. This version has a slightly higher sulphur content and is also calcium treated. This Improved Machinability grade (referred to as Ugima 4567) is available only to special order, but should be considered as an option where an "18/8" type grade needs to be both heavily cold formed and extensively machined.

## Cold Work Hardening

302HQ has the lowest work hardening rate of any of the common austenitic stainless steels. This results in a tensile strength increase of approximately 8MPa/%Ra (8MPa increase in tensile strength for each 1% reduction of area of cold work - this data from wire drawing). Even after substantial cold work this grade remains essentially non-responsive to a magnet.

For some high strength cold headed fasteners a slightly higher work hardening rate will be needed, so grade 304 or 304L (or the specialist grade 304M) will need to be used instead of 302HQ; these have work hardening rates varying between about 10 and 12.5MPa/%RA.

## Typical Applications

All severe cold heading applications, including self-tapping screws, roofing bolts, machine screws, bolts, set screws, blind rivets.

# Grade Data Sheet

# 302HQ

## Specified Properties

These properties are specified for grade S30430 wire in ASTM A493; wire is the only commonly available form for this grade. Properties of finished fasteners are covered by other specifications, such as ISO 3506-1 and 3506-3.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | Cu |
|---|---|---|---|---|---|---|---|---|---|---|
| 302HQ | min. | - | - | - | - | - | 17.0 | - | 8.0 | 3.0 |
| | max. | 0.03 | 2.00 | 1.00 | 0.045 | 0.030 | 19.0 | | 10.0 | 4.0 |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) max. | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) | Brinell (HB) |
| 302HQ annealed | 605 | - | - | - | - |
| 302HQ lightly drawn | 660 | - | - | - | - |
| Above values from ASTM A493 for diameters 2.5mm and above. Higher strengths can be produced by heavy cold work - this may be required for certain applications, which should be discussed with Atlas Technical Department. | | | | | |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 302HQ | 7900 | 193 | 17.2 | 17.8 | 18.8 | 16.3 | 21.5 | 500 | 720 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 302HQ | S30430 | 1.4567 | X3CrNiCu18-9-4 | - | SUS XM7 |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 302HQ |
|---|---|
| 304, 304L or 304M | A higher work hardening rate can be tolerated - or is needed. |
| 316L | Higher resistance to pitting and crevice corrosion is required in chloride environments; the higher work hardening rate of 316L is acceptable. |
| 430 | A lower cost is required, and the reduced corrosion resistance of 430 is acceptable. |

# Grade Data Sheet

# 303

**Grade 303** represents the optimum in machinability among the austenitic stainless steels. It is primarily used when production involves extensive machining in automatic screw machines. Machinability Rating (compared to B1212) is approximately 78%.

303 is also available as a "Ugima" Improved Machinability grade, with machinability even higher than that of the standard 303.

The sulphur addition which is responsible for the improved machining and galling characteristics of Grade 303 lowers its corrosion resistance to below that of Grade 304. As for other austenitic grades the structure gives 303 excellent toughness, although the sulphur in 303 reduces its toughness slightly.

Grade 303Se (UNS S30323) has a selenium rather than sulphur addition, improving the hot and cold forming characteristics over those of 303 and providing a smoother machined surface finish. The machinability rate is also slightly reduced compared to 303. Grade 303Se is not readily available in Australia.

## Corrosion Resistance

Good resistance to mildly corrosive atmospheres, but significantly less than Grade 304 due to the sulphur addition; the sulphide inclusions act as pit initiation sites. Grade 303 should not be exposed to marine or other similar environments, as these will result in rapid pitting corrosion. Because the sulphide inclusions in 303 are primarily aligned along the rolling direction the corrosion resistance is particularly reduced in cross-sections.

Grade 303, like other common austenitic stainless steels, is subject to stress corrosion cracking in chloride containing environments above about 50°C.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Good oxidation resistance in intermittent service to 760°C and in continuous service to 870°C. Continuous use in the 425-860°C range is not usually recommended due to carbide precipitation - 303 usually does not have a low carbon content so is susceptible to sensitisation, which can lead to intergranular corrosion.

## Fabrication

As well as reducing the corrosion resistance, the sulphur additions in 303 also result in poor weldability and reduced formability compared to Grade 304. Sharp bends should not be attempted in 303. A practical compromise alternative may be a 304 Ugima Improved Machinability grade - this does not machine as readily as 303, but does offer better formability (as well as excellent weldability and significantly better corrosion resistance).

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 1010-1120°C and cool rapidly. This grade cannot be hardened by thermal treatment.

## Welding

Not generally recommended but, if unavoidable use Grade 308L or 309 electrodes. AS 1554.6 does not pre-qualify welding of 303. Welds must be annealed for maximum corrosion resistance, but even then poor mechanical and corrosion properties will result.

## Machining

A "Ugima" improved machinability version of grade 303 is available in many bar products. This machines significantly better even than standard 303, giving very high machining rates and lower tool wear in many operations.

For ultra-high machining rates there are also available special grade variants such as Ugima 303UX. This includes copper to reduce the work hardening rate, in addition to the usual high sulphur and Improved Machinability steel making practices.

## Typical Applications

Nuts and bolts. Bushings. Shafts. Electrical switchgear components. Gears. In general any component that is heavily machined and where the corrosion resistance and fabrication properties of 303 are viable.

# Grade Data Sheet

# 303

## Specified Properties

These properties are specified for long product (bar) in ASTM A582M. Similar but not necessarily identical properties are specified for other products such as wire and forgings in their respective specifications. Grade 303 is not produced in flat rolled products.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | Se |
|---|---|---|---|---|---|---|---|---|---|---|
| 303 | min. | - | - | - | - | 0.15 | 17.0 | - | 8.0 | - |
| | max. | 0.15 | 2.00 | 1.00 | 0.20 | - | 19.0 | | 10.0 | |
| 303Se | min. | - | - | - | - | - | 17.0 | - | 8.0 | 0.15 |
| | max. | 0.15 | 2.00 | 1.00 | 0.20 | 0.06 | 19.0 | | 10.0 | min |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) | Brinell (HB) |
| 303 | 650 typical | 300 typical | 45 typical | - | 262 max |

Note that ASTM A582 only specifies hardness – tensile properties included above are not guaranteed and for information only. Drawn bars, generally up to 25.4mm diameter, will have higher strength values. Proof (yield) stress values in particular will be significantly higher and the percentage elongation lower.

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 303 | 7900 | 193 | 17.3 | 17.8 | 18.4 | 16.3 | 21.5 | 500 | 720 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 303 | S30300 | 1.4305 | X8CrNiS18-9 | 2346 | SUS 303 |
| 303Se | S30323 | - | - | - | SUS 303Se |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 303 |
|---|---|
| 303UX | Ugima 303UX offers the highest machinability for long run repetition machining. |
| 304 | Better corrosion resistance, formability or weldability are needed, at the expense of lower machinability. Consider 304 Ugima. |
| 316 | Higher resistance to pitting and crevice corrosion is required, in chloride environments. A lower machinability can be accepted. |
| 416 | Even higher machinability than 303 is needed, and a lower corrosion resistance can be tolerated. Or hardening by thermal treatment is required, while maintaining a high machinability. |

# Grade Data Sheet

# 304 304L 304H

**Grade 304** is the standard "18/8" austenitic stainless; it is the most versatile and most widely used stainless steel, available in the widest range of products, forms and finishes. It has excellent forming and welding characteristics.

Grade 304L, the low carbon version of 304, does not require post-weld annealing and so is extensively used in heavy gauge components (about 5mm and over). Grade 304H with its higher carbon content finds application at elevated temperatures. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

Grade 304 can be severely deep drawn without intermediate annealing, which has made this grade dominant in the manufacture of drawn stainless parts such as sinks, hollow-ware and saucepans. For severe applications it is common to use special "304DDQ" (Deep Drawing Quality) variants.

## Corrosion Resistance

Very good in a wide range of atmospheric environments and many corrosive media. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 60°C. Considered resistant to pitting corrosion in potable water with up to about 200mg/L chlorides at ambient temperatures, reducing to about 150mg/L at 60°C. Consult Atlas Technical Assistance for specific environmental recommendations.

There is usually no difference in corrosion resistance between 304 and 304L.

## Heat Resistance

Good oxidation resistance in intermittent service to 870°C and in continuous service to 925°C. Continuous use of 304 in the 425-860°C range is not recommended if subsequent aqueous corrosion resistance is important. Grade 304L is resistant to carbide precipitation and can be heated into this temperature range.

Grade 304H has higher strength at elevated temperatures so is often used for structural and pressure-containing applications at temperatures above about 500°C and up to about 800°C. 304H will become sensitised in the temperature range of 425-860°C; this is not a problem for high temperature applications, but will result in reduced aqueous corrosion resistance.

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 1010-1120°C and cool rapidly. These grades cannot be hardened by thermal treatment.

## Welding

Excellent weldability by all standard fusion methods, both with and without filler metals. AS 1554.6 pre-qualifies welding of 304 with 308, and 304L with 308L rods or electrodes (or their high silicon equivalents). Heavy welded sections in Grade 304 may require post-weld annealing for maximum corrosion resistance. This is not required for Grade 304L. Grade 321 may also be used as an alternative to 304 if heavy section welding is required and post-weld heat treatment is not possible.

## Machining

A "Ugima" improved machinability version of grade 304 is available in bar products. "Ugima" machines significantly better than standard 304, giving higher machining rates and lower tool wear in many operations.

## "Dual Certification"

It is common for 304 and 304L to be stocked in "Dual Certified" form, particularly in plate, pipe and round bar. These items have chemical and mechanical properties complying with both 304 and 304L specifications. Such dual certified product may be unacceptable for high temperature applications.

## Typical Applications

Food processing, transport and storage equipment, particularly in beer brewing, milk processing and wine making. Kitchen benches, sinks, troughs, equipment and appliances. Architectural panelling, railings & trim. Chemical containers, including for transport. Heat Exchangers. Woven or welded screens. Threaded fasteners. Springs.

# Grade Data Sheet

# 304 304L 304H

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M. Similar but not necessarily identical properties are specified for other products such as pipe and bar in their respective specifications. Minor changes to 304 and 304L composition limits were made in 2006-7 to harmonise with similar grades specified in ISO and European standards.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 304 | min. | - | - | - | - | - | 17.5 | - | 8.0 | - |
| | max. | 0.07 | 2.0 | 0.75 | 0.045 | 0.030 | 19.5 | | 10.5 | 0.10 |
| 304L | min. | - | - | - | - | - | 17.5 | - | 8.0 | - |
| | max. | 0.030 | 2.0 | 0.75 | 0.045 | 0.030 | 19.5 | | 12.0 | 0.10 |
| 304H | min. | 0.04 | - | - | - | - | 18.0 | - | 8.0 | - |
| | max. | 0.10 | 2.0 | 0.75 | 0.045 | 0.030 | 20.0 | | 10.5 | |

### Mechanical Property Specification (single values are minima except as noted)

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max |
| 304 | 515 | 205 | 40 | 92 | 201 |
| 304L | 485 | 170 | 40 | 92 | 201 |
| 304H | 515 | 205 | 40 | 92 | 201 |
| 304H also has a requirement for a grain size of ASTM No 7 or coarser. | | | | | |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 304/L/H | 7900 | 193 | 17.2 | 17.8 | 18.4 | 16.3 | 21.5 | 500 | 720 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 304 | S30400 | 1.4301 | X5CrNi18-10 | 2332 | SUS 304 |
| 304L | S30403 | 1.4307 | X2CrNi18-9 | 2352 | SUS 304L |
| 304H | S30409 | 1.4948 | X6CrNi18-11 | - | - |
| These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted. | | | | | |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 304 |
|---|---|
| 301/L | A higher work hardening rate grade is required for roll formed or stretch formed components. |
| F20S | Lower cost needed in thin gauge sheet and coil. Durinox F20S also has easier fabrication. |
| 303 | Higher machinability needed; lower corrosion resistance, formability & weldability are acceptable |
| 316 | Higher resistance to pitting and crevice corrosion is required, in chloride environments |
| 253MA | Better resistance high temperatures is needed. 253MA is optimised for temperatures to 1150°C. |
| 430 | A lower cost is required, and the reduced corrosion resistance and fabrication characteristics are acceptable. |

# Grade Data Sheet

# 310 310S 310H

**Grade 310** (UNS S31000) and its various sub-grades combine excellent high temperature properties with good ductility and weldability.

**Grade 310H** (UNS S31009) has a carbon content restricted to exclude the lower end of the 310 range, so is the grade of choice for high temperature applications.

**Grade 310S** (UNS S31008) is used when the application environment involves moist corrodents in a temperature range lower than that which is normally considered "high temperature" service. The lower carbon content of 310S does reduce its high temperature strength compared to 310H.

**Grade 310L** is a series of proprietary grades, generally with a 0.03% maximum carbon and sometimes used for very specific corrosive environments such as urea production.

Like other austenitic grades the 310 family have excellent toughness, even down to cryogenic temperatures, although other grades are normally used in sub-zero environments.

## Corrosion Resistance

The high chromium content - intended to increase high temperature properties - also gives these grades good aqueous corrosion resistance. The PRE is approximately 25, and sea water resistance about 22°C, similar to that of Grade 316. In high temperature service they exhibit good resistance to oxidising and carburising atmospheres. Resist fuming nitric acid at room temperature and fused nitrates up to 425°C.

The high carbon contents of all except 310L do make these grades susceptible to sensitisation and hence intergranular corrosion after elevated temperature exposure or welding.

310 is subject to stress corrosion cracking but more resistant than Grades 304 or 316. Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

310H has good resistance to oxidation in intermittent service in air at temperatures up to 1040°C and 1150°C in continuous service. Good resistance to thermal fatigue and cyclic heating. Widely used where sulphur dioxide gas is encountered at elevated temperatures. Continuous use in 425-860°C range not recommended due to carbide precipitation, if subsequent aqueous corrosion resistance is needed, but it often performs well in temperatures fluctuating above and below this range. Prone to sigma phase embrittlement in the temperature range 650 – 900°C.

Grade 310H is generally used at temperatures starting from about 800 or 900°C - above the temperatures at which 304H and 321 are effective.

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 1040-1150°C and cool rapidly for maximum corrosion resistance. This treatment is also recommended to restore ductility after each 1000 hours of service above 650°C, due to long term precipitation of brittle sigma phase.

These grades cannot be hardened by thermal treatment.

## Welding

Good characteristics suited to all standard methods. Grade 310S electrodes generally recommended for fusion welding. AS 1554.6 pre-qualifies welding of 310 with Grade 310 rods or electrodes.

## "Dual Certification"

310H and 310S are often produced in "Dual Certified" form – mainly in plate and pipe. These items have chemical and mechanical properties complying with both 310H and 310S specifications. Product complying with 310 only or dual certified 310 and 310S may have a carbon content below 0.04% which will not be acceptable for some high temperature applications.

## Typical Applications

Furnace parts. Oil burner parts. Carburising boxes. Heat Treatment baskets and jigs. Heat exchangers. Welding filler wire and electrodes.

# Grade Data Sheet

# 310 310S 310H

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M (310S and 310H) and ASTM A167 (310). Similar but not necessarily identical properties are specified for other products such as pipe and bar in their respective specifications.

### Composition Specification (%)

(single values are maxima)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 310 | min. | - | - | - | - | - | 24.0 | - | 19.0 | - |
| | max. | 0.25 | 2.00 | 1.50 | 0.045 | 0.030 | 26.0 | | 22.0 | |
| 310S | min. | - | - | - | - | - | 24.0 | - | 19.0 | - |
| | max. | 0.08 | 2.00 | 1.50 | 0.045 | 0.030 | 26.0 | | 22.0 | |
| 310H | min. | 0.04 | - | - | - | - | 24.0 | - | 19.0 | - |
| | max. | 0.10 | 2.00 | 0.75 | 0.045 | 0.030 | 26.0 | | 22.0 | |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max |
| 310 | 515 | 205 | 40 | 95 | 217 |
| 310S | 515 | 205 | 40 | 95 | 217 |
| 310H | 515 | 205 | 40 | 95 | 217 |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 310/S/H | 7750 | 200 | 15.9 | 16.2 | 17.0 | 14.2 | 18.7 | 500 | 720 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 310S | S31008 | 1.4845 | X8CrNi25-21 | 2361 | SUS 310S |

There are no known international specification equivalents to ASTM grades 310, 310H etc. These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted. Heat resistant grades have poor agreement between different specification systems.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 310 |
|---|---|
| AtlasCR12 | Heat resistance is needed, but only to about 600°C. |
| 304H | Heat resistance is needed, but only to about 800°C. |
| 321 | Heat resistance is needed, but only to about 900°C. Subsequent aqueous corrosion resistance also required. |
| S30815 (253MA) | A slightly higher temperature resistance is needed than can be provided by 310. Better resistance to reducing sulphide atmosphere needed. Higher immunity from sigma phase embrittlement is required. |

# Grade Data Sheet

# 316 316L 316H

Grade 316 is the standard molybdenum-bearing austenitic grade, second stainless steel in importance to 304. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. It is readily brake or roll formed, welded, soldered and cut by both thermal and mechanical methods. The austenitic structure gives excellent toughness, even down to cryogenic temperatures.

Grade 316L, the low carbon version of 316, is highly resistant to sensitisation (grain boundary carbide precipitation) and so is extensively used in heavy gauge welded components (about 5mm and over). Grade 316H, with its higher carbon content has some application at elevated temperatures, as does stabilised grade 316Ti. Nitrogen-strengthened versions also exist as 316N and 316LN. Only 316 and 316L are readily available in Australian stock.

## Corrosion Resistance

Excellent in a range of atmospheric environments and many corrosive media - generally more resistant than 304. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 60°C. Considered resistant to pitting corrosion in potable water with up to about 1000mg/L chlorides at ambient temperatures, reducing to about 300mg/L at 60°C.

316 is usually regarded as the standard "marine grade" stainless steel, but it is not fully resistant to sea water. In many marine environments 316 does exhibit surface corrosion, usually visible as brown staining. This is particularly associated with crevices and rough surface finish. Consult Atlas Technical Assistance for specific environmental recommendations.

There is usually no difference in corrosion resistance between 316 and 316L.

## Heat Resistance

Good oxidation resistance in intermittent service to 870°C and in continuous service to 925°C. Continuous use of 316 in the 425-860°C range is not recommended if subsequent aqueous corrosion resistance is important. Grade 316L is more resistant to carbide precipitation and can be used in the above temperature range. Grade 316H has higher strength at elevated temperatures and is sometimes used for structural and pressure-containing applications at temperatures above about 500°C, but the titanium stabilised grade 316Ti is often a more appropriate choice.

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 1010-1120°C and cool rapidly. These grades cannot be hardened by thermal treatment.

## Welding

Excellent weldability by all standard fusion methods, both with and without filler metals. AS 1554.6 pre-qualifies welding of 316 with Grade 316 and 316L with Grade 316L rods or electrodes (or their high silicon equivalents). Heavy welded sections in Grade 316 require post-weld annealing for maximum corrosion resistance. This is not required for 316L. Grade 316Ti may also be used as an alternative to 316 for heavy section welding.

## Machining

A "Ugima" improved machinability version of grade 316 is available in round and hollow bar products. Ugima machines significantly better than standard 316 or 316L, giving higher machining rates and lower tool wear in many operations.

## "Dual Certification"

It is common for 316 and 316L to be stocked in "Dual Certified" form, particularly in plate, pipe and round bar. These items have chemical and mechanical properties complying with both 316 and 316L specifications. Such dual certified product may be unacceptable for high temperature applications.

## Typical Applications

Food processing equipment. Laboratory equipment. Architectural panelling, railings & trim. Boat fittings. Chemical containers. Heat exchangers. Screens for mining, quarrying & water filtration. Threaded fasteners. Springs.

# Grade Data Sheet

# 316 316L 316H

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M. Similar but not necessarily identical properties are specified for other products such as pipe and bar in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 316 | min. | - | - | - | - | - | 16.0 | 2.00 | 10.0 | - |
| | max. | 0.08 | 2.0 | 0.75 | 0.045 | 0.030 | 18.0 | 3.00 | 14.0 | 0.10 |
| 316L | min. | - | - | - | - | - | 16.0 | 2.00 | 10.0 | - |
| | max. | 0.030 | 2.0 | 0.75 | 0.045 | 0.030 | 18.0 | 3.00 | 14.0 | 0.10 |
| 316H | min. | 0.04 | - | - | - | - | 16.0 | 2.00 | 10.0 | - |
| | max. | 0.10 | 2.0 | 0.75 | 0.045 | 0.030 | 18.0 | 3.00 | 14.0 | - |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max |
| 316 | 515 | 205 | 40 | 95 | 217 |
| 316L | 485 | 170 | 40 | 95 | 217 |
| 316H | 515 | 205 | 40 | 95 | 217 |
| 316H also has a requirement for a grain size of ASTM No 7 or coarser. | | | | | |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 316 & 316L/H | 8000 | 193 | 15.9 | 16.2 | 17.5 | 16.3 | 21.5 | 500 | 740 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 316 | S31600 | 1.4401 | X5CrNiMo17-12-2 | 2347 | SUS 316 |
| 316L | S31603 | 1.4404 | X2CrNiMo17-12-2 | 2348 | SUS 316L |
| 316H | S31609 | - | - | - | - |
| These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted. | | | | | |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 316 |
|---|---|
| 316Ti | Better resistance to temperatures of around 600-900°C is needed. |
| 316N | Higher strength than standard 316. |
| 317L | Higher resistance to chlorides than 316L, but with similar resistance to stress corrosion cracking. |
| F18MS / 444 | Lower cost in thin gauge sheet and coil. F18MS (444) is a readily fabricated ferritic grade. |
| 904L | Much higher resistance to chlorides at elevated temperatures, with good formability |
| 2205 | Much higher resistance to chlorides at elevated temperatures, and higher strength. |

# Grade Data Sheet

# 321

**Grades 321** is the basic 18/8 austenitic steel (Grade 304) stabilised with Titanium. This grade is not sensitive to intergranular corrosion after heating within the carbide precipitation range of 425-850°C. 321 is the grade of choice for applications in the temperature range of up to about 900°C, combining high strength, resistance to scaling and phase stability with resistance to subsequent aqueous corrosion.

**Grade 321H** is a modification of 321 with a controlled higher carbon content, to provide improved high temperature strength.

A limitation with 321 is that titanium does not transfer well across a welding arc, so is not usable as a welding consumable. Grade 347 is therefore used - the niobium performs the same carbide stabilisation task but can be transferred across a welding arc. Grade 347 is therefore the standard consumable for welding 321. Grade 347 is only occasionally used as parent plate material.

Like other austenitic grades, 321 has excellent forming and welding characteristics, is readily brake or roll formed and has outstanding welding characteristics. Post-weld annealing is not required. Grade 321 also has excellent toughness, even down to cryogenic temperatures. Grade 321 does not polish well, so is not recommended for decorative applications.

Grade 304L is more readily available in most product forms, and so is generally used in preference to 321 if the requirement is simply for resistance to intergranular corrosion after welding. However 304L has lower hot strength than 321 and so is not the best choice if the requirement is resistance to an operating environment over about 500°C.

## Corrosion Resistance

Equivalent to Grade 304 in the annealed condition, and superior if the application involves service in the 425-900°C range. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 50°C. Considered resistant to potable water with up to about 200mg/L chlorides at ambient temperatures, reducing to about 150mg/L at 60°C. Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Good oxidation resistance in intermittent service to 900°C and in continuous service to 925°C. These grades perform well in the 425-900°C range, and particularly where subsequent aqueous corrosive conditions are present. 321H has higher hot strength, and is particularly suitable for high temperature structural applications.

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 950-1120°C and cool rapidly for maximum corrosion resistance.

### Stabilising Treatment

This treatment follows normal solution treatment. Heat to approx 870-890°C for 2 hours per 25mm of thickness and air cool. Stabilisation is recommended for most severe service conditions (above 425°C) and particularly for material annealed at the upper side of the annealing temperature range. The exact treatment must be agreed between supplier and purchaser.

### Stress Relief

Heat to 700°C for 1 to 2 hours and air cool.

These grades cannot be hardened by thermal treatment.

## Welding

Excellent weldability by all standard fusion methods, both with and without filler metals. AS 1554.6 pre-qualifies welding of 321 and 347 with Grades 347 or 347Si rods or electrodes.

## "Dual Certification"

Plate is commonly dual-certified as 321 and 321H, suitable for high temperature applications.

## Typical Applications

Expansion joints. Bellows. Furnace parts. Heating element tubing. Heat exchangers. Screens for high temperatures. Spiral welded tube for burner pipes and flues.

# Grade Data Sheet

# 321

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M. Similar but not necessarily identical properties are specified for other products such as pipe in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 321 | min. | - | - | - | - | - | 17.0 | - | 9.0 | - | Ti=5(C+N) |
| | max | 0.08 | 2.00 | 0.75 | 0.045 | 0.030 | 19.0 | | 12.0 | 0.10 | 0.70 |
| 321H | min. | 0.04 | - | - | - | - | 17.0 | - | 9.0 | - | Ti=4(C+N) |
| | max | 0.10 | 2.00 | 0.75 | 0.045 | 0.030 | 19.0 | | 12.0 | | 0.70 |
| 347 | min. | - | - | - | - | - | 17.0 | - | 9.0 | - | Nb=10(C+N) |
| | max | 0.08 | 2.00 | 0.75 | 0.045 | 0.030 | 19.0 | | 13.0 | | 1.0 |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max |
| 321 | 515 | 205 | 40 | 95 | 217 |
| 321H | 515 | 205 | 40 | 95 | 217 |
| 347 | 515 | 205 | 40 | 92 | 201 |
| 321H also has a requirement for a grain size of ASTM No 7 or coarser. | | | | | |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 321 | 7900 | 193 | 16.6 | 17.2 | 18.6 | 16.1 | 22.2 | 500 | 720 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 321 | S32100 | 1.4541 | X6CrNiTi18-10 | 2337 | SUS 321 |
| 321H | S32109 | 1.4878 | X8CrNiTi18-10 | - | SUS 321H |
| 347 | S34700 | 1.4550 | X6CrNiNb18-10 | 2338 | SUS 347 |
| These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted. | | | | | |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 321 |
|---|---|
| 304L | The requirement is for resistance to intergranular corrosion, not high temperature strength |
| AtlasCR12 | Only mild "high temperature" environment is present… up to about 450 – 600°C. |
| 304H | Only mild "high temperature" environment is present… up to about 600 – 800°C. |
| 310 | The operating temperature is up to about 1100°C - too high for 321 or 321H. |
| S30815 (253MA) | The operating temperature is up to about 1150°C- too high for 321 or 321H. |

# Grade Data Sheet

# 253MA
## UNS S30815

**Atlas 253MA** is a grade combining excellent service properties at high temperatures with ease of fabrication. It resists oxidation at temperatures up to 1150°C and can provide superior service to Grade 310 in carbon, nitrogen and sulphur containing atmospheres.

253MA® is a trademark owned by Outokumpu Stainless AB. The standard grade designation covering this grade is UNS S30815. Other mills produce grades compliant with UNS S30815, including Sirius S15®.

253MA contains a fairly low nickel content, which gives it some advantage in reducing sulphide atmospheres when compared to high nickel alloys and Grade 310. The inclusion of high chromium, silicon, nitrogen and cerium contents gives the steel good oxide stability, high elevated temperature (creep) strength and excellent resistance to sigma phase precipitation.

The austenitic structure gives this grade excellent toughness, even down to cryogenic temperatures.

### Corrosion Resistance
Although not designed for aqueous corrosion resistance, the high chromium and nitrogen contents give the grade a pitting resistance approximating that of 316. 253MA does however have a high carbon content so is highly susceptible to sensitisation; this is likely to reduce aqueous corrosion resistance after high temperature service or fabrication.

Consult Atlas Technical Assistance for specific environmental recommendations.

### Heat Resistance
Oxidation - excellent resistance to air, at temperatures up to 1100°C. At high temperatures the steel quickly forms a thin, highly adherent and elastic oxide. This oxide gives good protection even under cyclic conditions, much better than is the case for Grade 310. Best resistance is under non-cycling conditions.

Carburisation - Under oxidising conditions this grade can perform well, but alloys with higher nickel content are preferred if the atmosphere is reducing.

Sulphidation - good resistance to sulphur-bearing gases in an oxidising atmosphere, even if only traces of oxygen are present. Reducing gases prevent the protective oxide forming.

253MA has high strength at elevated temperatures so is often used for structural and pressure-containing applications at temperatures above about 500°C and up to about 900°C.

253MA will become sensitised in the temperature range of 425-860°C; this is not a problem for high temperature applications, but will result in reduced aqueous corrosion resistance.

### Heat Treatment
#### Solution Treatment (Annealing)
Heat to 1050-1150°C and cool rapidly. It is recommended that the material be solution treated after 10-20% cold work to achieve maximum creep strength in service.

This grade cannot be hardened by thermal treatment.

### Welding
Excellent weldability by all standard fusion methods. AS 1554.6 pre-qualifies welding of S30815 with matching Grade 22.12HT rods or electrodes. Grade 309 fillers can be used if lower creep strength can be tolerated. Pure argon shielding gas should be used.

### Machining
As for other austenitic stainless steels, the machining requires sharp tools, slow speeds and heavy feeds.

### Typical Applications
Furnace components including burners, retorts, conveyor belts, fans, jigs and baskets, rollers, walking beams, radiant tubes, electric heater elements, refractory anchors, hoods, flues, grates, expansion bellows. Petrochemical and refinery tube hangers.

# Grade Data Sheet

# 253MA
## UNS S30815

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) as Grade S30815 in ASTM A240/A240M. Similar but not necessarily identical properties are specified for S30815 in other products such as pipe and bar in their respective specifications, and for Grade 1.4835 in specifications such as EN 10095.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Ni | N | Ce |
|---|---|---|---|---|---|---|---|---|---|---|
| S30815 | min. | 0.05 | - | 1.40 | - | - | 20.0 | 10.0 | 0.14 | 0.03 |
| | max. | 0.10 | 0.80 | 2.00 | 0.040 | 0.030 | 22.0 | 12.0 | 0.20 | 0.08 |

### Mechanical Property Specification (single values are minima except as noted)

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max |
| S30815 | 600 | 310 | 40 | 95 | 217 |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m3) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-600°C (µm/m/°C) | 0-1000°C (µm/m/°C) | at 20°C (W/m.K) | at 800°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| S30815 | 7800 | 200 | 17.0 | 18.5 | 19.5 | 15.0 | 25.5 | 500 | 850 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| S30815 | S30815 | 1.4835 | X9CrNiSiNCe21-11-2 | 2368 | - |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of S30815 |
|---|---|
| 310 | Carburising atmospheres require a higher nickel content |
| 304H | Lower cost alternative, with lower creep strength, for use up to about 800°C |
| 321H | Lower cost alternative, with lower creep strength, for use up to about 800°C |
| Nickel Alloys | Carburising atmospheres or temperatures above the 1100 - 1150°C maximum of S30815. |

# Grade Data Sheet

# 904L

**Grade 904L** is a non-stabilised low carbon high alloy austenitic stainless steel. The addition of copper to this grade gives it greatly improved resistance to strong reducing acids, particularly sulphuric acid. It is also highly resistant to chloride attack - both pitting / crevice corrosion and stress corrosion cracking.

This grade is non-magnetic in all conditions and has excellent weldability and formability. The austenitic structure also gives this grade excellent toughness, even down to cryogenic temperatures.

904L does have very substantial contents of the high cost ingredients nickel and molybdenum. Many of the applications in which this grade has previously performed well can now be fulfilled at lower cost by duplex stainless steel 2205 (S31803 or S32205), so 904L is used less commonly than in the past.

## Corrosion Resistance

Although originally developed for its resistance to sulphuric acid it also has a very high resistance to a wide range of environments. A PRE of 35 indicates that the material has good resistance to warm sea water and other high chloride environments. High nickel content results in a much better resistance to stress corrosion cracking than the standard austenitic grades. Copper adds resistance to sulphuric and other reducing acids, particularly in the very aggressive "mid concentration" range.

In most environments 904L has a corrosion performance intermediate between the standard austenitic grade 316L and the very highly alloyed 6% molybdenum and similar "super austenitic" grades.

In aggressive nitric acid 904L has less resistance than molybdenum-free grades such as 304L and 310L.

For maximum stress corrosion cracking resistance in critical environments the steel should be solution treated after cold work.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Good resistance to oxidation, but like other highly alloyed grades suffers from structural instability (precipitation of brittle phases such as sigma) at elevated temperatures. It should not be used above about 550°C. 904L has design stress values in the ASME Boiler and Pressure Vessel Code to 371°C.

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 1090-1175°C and cool rapidly. This grade cannot be hardened by thermal treatment.

## Welding

904L can be successfully welded by all standard methods. Care needs to be taken as this grade solidifies fully austenitic, so is susceptible to hot cracking, particularly in constrained weldments. No pre-heat should be used and in most cases post weld heat treatment is also not required. AS 1554.6 pre-qualifies Grade 904L rods and electrodes for welding of 904L.

## Fabrication

904L is a high purity, low sulphur grade, and as such will not machine as well as other grades optimised for machinability. Grade 904L can however be machined using standard techniques.

Bending to a small radius is readily carried out. In most cases this is performed cold. Subsequent annealing is generally not required, although it should be considered if the fabrication is to be used in an environment where severe stress corrosion cracking conditions are anticipated.

## Typical Applications

Processing plant for sulphuric, phosphoric and acetic acids. Pulp and paper processing. Components in gas scrubbing plants. Seawater cooling equipment. Oil refinery components. Wires in electrostatic precipitators.

# Grade Data Sheet

# 904L

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240M. Similar but not necessarily identical properties are specified for other products such as pipe, tube and bar in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | Cu | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 904L | min. | - | - | - | - | - | 19.0 | 4.0 | 23.0 | 1.0 | - |
| | max. | 0.020 | 2.00 | 1.00 | 0.045 | 0.035 | 23.0 | 5.0 | 28.0 | 2.0 | 0.10 |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) |
| 904L | 490 | 220 | 35 | 90 | - |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (μm/m/°C) | 0-315°C (μm/m/°C) | 0-538°C (μm/m/°C) | at 20°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 904L | 8000 | 200 | 15.0 | - | - | 13.0 | - | 500 | 850 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 904L | N08904 | 1.4539 | X1NiCrMoCu25-20-5 | 2562 | - |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 904L |
|---|---|
| 316L | A lower cost alternative, but with much lower corrosion resistance. |
| 6Mo | A higher resistance to pitting and crevice corrosion resistance is needed.<br>A large range of super austenitic grades is available, with selection based on intended environment. |
| 2205 | A very similar corrosion resistance to 904L, with the 2205 having higher mechanical strength, and at a lower cost to 904L. (2205 not suitable for temperatures above 300°C, and not appropriate for difficult forming.) |
| Super duplex | Higher corrosion resistance is needed, together with a higher strength than 904L. |

# Grade Data Sheet

# AtlasCR12

This "utility stainless steel" is a fairly recent modification of 12% chromium stainless steel grades 409 and 410. It has been developed as a readily fabricated, low cost grade, exhibiting good resistance to wet abrasion and mildly corrosive environments. This grade is covered by Euronorm designation 1.4003 and also ASTM UNS S40977 / S41003.

## Corrosion Resistance

1.4003 is effective in many applications where carbon steel, galvanised, aluminised or painted steel or aluminium give unsatisfactory life. It is not attacked by strong alkalies, and often gives adequate resistance in mildly acidic conditions. Light surface rust can form in many atmospheres, making the material unsuitable for decorative applications.

1.4003 strongly resists chloride stress corrosion cracking, but is less resistant than 304 to pitting and crevice corrosion in chloride environments. 1.4003 is likely to resist water with chloride contents of up to 100 to 200 mg/L at ambient temperatures. The presence of sulphate or nitrate ions will reduce the corrosivity of chlorides. As the grade is not stabilised it can be susceptible to intergranular corrosion in certain circumstances. Consult Atlas Steels Technical Assistance for specific environmental recommendations.

## Heat Resistance

In air 1.4003 offers scaling resistance to 620°C continuous or 730°C intermittent, but if under stress the temperature should be limited to 450°C continuous or 600°C intermittent. 1.4003 suffers negligible embrittlement after extended exposure at temperatures of 450-550°C; it can be used safely at these temperatures without loss of room temperature impact resistance.

## Heat Treatment

Annealing - heat to 700-750°C, soak for 1½ hours per 25mm section. Air cool. The maximum temperature of 750°C should not be exceeded. Annealing should usually be followed by pickling and passivating.

This grade should not be hardened by heat treatment; quenching treatments may reduce the corrosion resistance and mechanical properties.

## Welding

1.4003 can be readily welded using similar techniques to austenitic stainless steels. Low heat input processes are preferred - particularly GTAW (TIG) and GMAW (MIG). Filler wire pre-qualified by AS 1554.6 (1.4003 referred to as "4003") is grade 309, but 309L, 309Mo, 316L and 308L have been successfully used. Argon plus 1-2% oxygen shielding gases are recommended. Discolouration of the weld should be removed by pickling, except possibly in wear applications; effective purging and use of backing gases is often a better option.

## Machining

1.4003 has a machinability similar to that of grade 430, ie about 60% of that of mild steel. The work hardening rate is lower than that of austenitic stainless steels, so reducing the need for special machining techniques.

## Finishes

1.4003 is available in standard HRAP (Hot Rolled Annealed and Pickled) finish in plate, and 2B or 2D in coil.

## Typical Applications

Mining and mineral processing and transport equipment. Sugar processing equipment. Furnace and oven parts.

# Grade Data Sheet

# AtlasCR12

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in Euronorm EN 10088.2 1.4003 and ASTM A240/A240M S40977 and S41003. Similar but not necessarily identical properties apply for other products (1.4003 bar is covered by EN 10088-3), but this grade is almost exclusively a flat rolled product.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.4003 | min. | - | - | - | - | - | 10.50 | - | 0.30 | - |
| S40977 | max. | 0.030 | 1.50 | 1.00 | 0.040 | 0.015 | 12.50 | | 1.00 | 0.030 |
| S41003 | min. | - | - | - | - | - | 10.5 | - | - | - |
| | max. | 0.030 | 1.50 | 1.00 | 0.040 | 0.030 | 12.5 | | 1.50 | 0.030 |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) | Yield Strength 0.2% Proof Stress (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell (HR) max | Brinell (HB) max |
| 1.4003 (1) | 450 – 650 | 280 (long), 320 (trans) | 20 | - | - |
| S40977 | 450 min | 280 | 18 | HR B88 | 180 |
| S41003 | 455 min | 275 | 18 | HR C20 | 223 |
| (1) Properties specified for cold rolled coil and hot rolled coil plate. Quarto plate has different values. | | | | | |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m$^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity at 100°C (W/m.K) | Specific Heat 0-100°C ( J/kg.K) | Electrical Resistivity (nΩ.m) |
|---|---|---|---|---|---|---|---|---|
| | | | 20-100°C (μm/m/°C) | 20-300°C (μm/m/°C) | 20-500°C (μm/m/°C) | | | |
| 1.4003 | 7700 | 220 | 10.4 | 11.2 | 11.9 | 25 | 430 | 600 |
| Source: EN 10088-1 | | | | | | | | |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 1.4003 | S41003 or S40977 | 1.4003 | X2CrNi12 | - | - |
| These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted. | | | | | |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 1.4003 |
|---|---|
| AtlasCR12Ti | Improved resistance to sensitisation and intergranular corrosion is needed. |
| 304 | Better corrosion resistance and fabrication properties are required. |
| Galvanised steel | A lower cost is required, and the reduced corrosion resistance and fabrication characteristics of galvanised steel are acceptable. |
| Weathering steel | A lower cost is required, and the reduced corrosion resistance and fabrication characteristics of weathering steel are acceptable. |

# Grade Data Sheet

# AtlasCR12Ti

This "utility stainless steel" is a proprietary modification of Grade 409 12% chromium stainless steel. It has been developed as a readily fabricated, low cost grade, exhibiting good resistance to wet abrasion and mildly corrosive environments; the titanium stabilised composition results in excellent resistance to sensitisation in welding, particularly of thin sections.

There are no national specifications or international specifications covering this grade. The designation "AtlasCR12Ti" is a registered trade mark of Atlas Steels.

## Corrosion Resistance

AtlasCR12Ti is effective in many applications where carbon steel, galvanised, aluminised or painted steel or aluminium give unsatisfactory life. It is not attacked by strong alkalies, and often gives adequate resistance in mildly acidic conditions. Light surface rust can form in many atmospheres, making the material unsuitable for decorative applications.

AtlasCR12Ti strongly resists chloride stress corrosion cracking, but is less resistant than 304 or 430 to pitting and crevice corrosion in chloride environments. AtlasCR12Ti is likely to resist pitting in water with chloride contents of up to 100 to 200 mg/L at ambient temperatures. The presence of sulphate or nitrate ions will reduce the corrosivity of chlorides. AtlasCR12Ti is titanium stabilised to be more resistant to sensitisation and intergranular corrosion compared to alternative grades such as AtlasCR12 (1.4003). Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

In air AtlasCR12Ti offers scaling resistance to 620°C continuous or 730°C intermittent, but if under stress the temperature should be limited to 450°C continuous or 600°C intermittent. AtlasCR12Ti suffers negligible embrittlement after extended exposure at temperatures of 450-550°C.

## Heat Treatment

**Annealing** - heat to 700-750°C, soak for 1½ hours per 25mm section. Air cool. The maximum temperature of 750°C should not be exceeded. Annealing should usually be followed by pickling and passivating.

This grade should not be hardened by heat treatment; quenching treatments may reduce the corrosion resistance and mechanical properties.

## Welding

AtlasCR12Ti is resistant to the sensitisation and intergranular corrosion that can occur in welding of unstabilised stainless steels. It can be welded using similar techniques to austenitic stainless steels. Low heat input processes are preferred - particularly GTAW (TIG) and GMAW (MIG). Filler wire recommended is grade 309L; this over-alloyed grade is important for welding AtlasCR12Ti to other steels, but 316L and 308L have also been successfully used when welding AtlasCR12Ti to itself. Heat inputs should be controlled to 0.5 to 1.5kJ/mm. Argon plus 1-2% oxygen shielding gases are recommended.

Discolouration of the weld should be removed by pickling, except possibly in wear applications; effective purging and use of backing gases is often a better option. Standard stainless steel pickling pastes can cause higher attack than they do on austenitic grades; these should be used with caution.

## Machining

AtlasCR12Ti has a machinability similar to that of grade 430, ie about 60% of that of mild steel. The work hardening rate is lower than that of austenitic stainless steels, so reducing the need for special machining techniques.

## Finishes

AtlasCR12Ti is available in standard No1 ("HRAP" – Hot Rolled Annealed and Pickled) finish in sheet, plate and coil down to 3mm thickness, and as cold rolled 2B finish in lighter gauges.

## Typical Applications

Mining and mineral processing and transport equipment. Rail wagons for coal and iron ore. Sugar processing equipment. Furnace and oven parts.

# Grade Data Sheet

# AtlasCR12Ti

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil). Similar but not necessarily identical properties apply to other products such as pipe and bar, but this grade is almost exclusively a flat rolled product.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | Ti |
|---|---|---|---|---|---|---|---|---|---|---|
| AtlasCR12Ti | min. | - | - | - | - | - | 10.50 | - | - | 4(C+N) |
| | max. | 0.030 | 2.00 | 1.00 | 0.040 | 0.030 | 12.50 | | 1.50 | 0.6 |
| These properties are specified for the proprietary grade AtlasCR12Ti. There are no national or international specifications covering this grade. | | | | | | | | | | |

### Mechanical Property Specification

| Grade | Thickness (mm) | Tensile Strength (MPa) | Yield Strength 0.2% Proof Stress (MPa) | Elongation (% in 50mm) min | Hardness Brinell (HB) max | Impact Energy (J/cm²) |
|---|---|---|---|---|---|---|
| AtlasCR12Ti | <3 | 460 min | 280 min | 18 | 220 | - |
| | 3 – 4.5 | 460 min | 300 min | 18 | 220 | - |
| | >4.5 – 12 | 460 min | 300 min | 20 | 220 | - |
| | >12 | 460 min | 300 min | 20 | 250 | - |
| These properties are specified for the proprietary grade AtlasCR12Ti. There are no national or international specifications covering this grade. Special properties are available for applications such as rail wagons. | | | | | | |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (μm/m/°C) | 0-300°C (μm/m/°C) | 0-500°C (μm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| Atlas CR12Ti | 7700 | 200 | 11.1 | 11.7 | 12.3 | 30 | 40 | 480 | 678 |

## Grade Specification Comparison

| Grade | UNS | Euronorm | | Swedish | Japanese |
|---|---|---|---|---|---|
| | No | No | Name | SS | JIS |
| There are no national or international specifications covering the proprietary grade AtlasCR12Ti. | | | | | |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of AtlasCR12Ti |
|---|---|
| AtlasCR12 (1.4003) | Requirement for a similar grade that is included in national standards and in pressure vessel codes. 1.4003 / AtlasCR12 is not weld stabilised. |
| 304 | Better corrosion resistance and fabrication properties are required. |
| Galvanised steel | A lower cost is required, and the reduced corrosion resistance and fabrication characteristics of galvanised steel are acceptable. |
| Weathering steel | A lower cost is required, and the reduced corrosion resistance and fabrication characteristics of weathering steel are acceptable. |

# Grade Data Sheet

# 409

**Grade 409** is a titanium-stabilised ferritic stainless steel. Although regarded as a general-purpose chromium stainless steel the almost exclusive application for Grade 409 is automotive exhaust systems. Its applications are those where appearance is a secondary consideration to mechanical properties and corrosion resistance, particularly at high temperatures, and where some weldability is required.

The generic grade 409 has now been replaced in some ASTM specifications (notably the flat rolled specification ASTM A240M) by several "sub-grades", designated S40910, S40920 and S40930. These have various degrees of stabilisation with titanium, niobium or both titanium and niobium. Any of these may be certified as S40900 (Grade 409). By contrast only standard Grade 409 is listed in ASTM A268M covering tube.

## Corrosion Resistance

Grade 409 resists atmospheric and exhaust gas corrosion. A light surface rust will form in most atmospheres; this rust retards further corrosion but makes the surface undesirable for decorative applications. The corrosion resistance is about the same as that of AtlasCR12 and the 12% chromium martensitic grades such as 410, and inferior to the 17% chromium grade 430.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Generally 409 is classified as resistant to scaling in intermittent service up to 815°C and up to 675°C in continuous service, but these temperatures are dependent upon the exact service environment.

## Heat Treatment

### Annealing

Heat to 790-900°C and air cool. This grade cannot be hardened by thermal treatment.

## Welding

Readily welded but a pre-heat of 150-260°C is recommended. Grade 409 or Grade 430 electrode or filler rods can be used, but AS 1554.6 pre-qualifies welding of 409 with Grade 309 rods or electrodes. These austenitic fillers result in a more ductile weld.

Post-weld annealing at 760-815°C improves weld ductility.

Post-weld annealing is not required when welding thin sections. Automotive exhaust tubing is typically welded without filler metal (autogenously).

All welding must be carried out with minimum heat input to reduce grain growth effects.

## Typical Applications

Automotive exhaust systems, including catalytic converters and mufflers

# Grade Data Sheet

# 409

## Specified Properties

The properties for Grade 409 are specified for annealed tubing in ASTM A268M. Compositions of other grades are for coil and sheet in ASTM A240M. Similar but not necessarily identical properties are specified for other products in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Ni | N | Ti | Nb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 409 | min. | - | - | - | - | - | 10.5 | - | | 6x%C | |
| S40900 | max. | 0.08 | 1.00 | 1.00 | 0.045 | 0.030 | 11.7 | 0.50 | | 0.75 | |
| S40910 | min. | - | - | - | - | - | 10.5 | - | - | 6x%C | - |
| | max. | 0.03 | 1.00 | 1.00 | 0.040 | 0.020 | 11.7 | 0.50 | 0.030 | 0.50 | 0.17 |
| S40920 | min. | - | - | - | - | - | 10.5 | - | - | 0.15 & 8x(C+N) | - |
| | max. | 0.03 | 1.00 | 1.00 | 0.040 | 0.020 | 11.7 | 0.50 | 0.030 | 0.50 | 0.10 |
| S40930 | min. | - | - | - | - | - | 10.5 | - | - | Ti+Nb=(0.08+8)x(C+N) | |
| | max. | 0.03 | 1.00 | 1.00 | 0.040 | 0.020 | 11.7 | 0.50 | 0.030 | 0.75 | |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max |
| 409 | 380 | 170 | 20 | 95 | 207 |
| These same tensile, yield and elongation limits also apply to the other grades in ASTM A240M. Hardness limits are 88HRB and 179HB maximum for these other grades in flat rolled product. | | | | | |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 409 | 7700 | 208 | 11.0 | 11.7 | 12.4 | 25.8 | 27.5 | 460 | 600 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 409 | S40900 | 1.4512 | X6CrTi12 / X2CrTi12 | - | SUH 409 |
| There no known standardised international alternatives to the ASTM S40910, S40920 and S40930 grades. | | | | | |
| These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted. | | | | | |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 409 |
|---|---|
| AtlasCR12 | Similar corrosion resistance, better weldability and more readily available than 409, particularly in heavy sections. (409 may have better drawability than AtlasCR12.) |
| 304 | Better corrosion resistance and heat resistance but at higher cost. |
| 321 | Higher heat resistance than 409 or 304. |
| Aluminised steel | Lower cost than stainless steel grade 409, but also a lower resistance to exhaust gases. |

# Grade Data Sheet

# 430

**Grade 430** is a ferritic, straight chromium, non-hardenable grade, combining good corrosion resistance and formability characteristics with useful mechanical properties. Its ability to resist nitric acid attack permits its use in specific chemical applications but automotive trim, indoor panelling such as refrigeration cabinets and appliance components are its largest fields of application. This grade is only readily available in sheet and coil (up to 1.2mm thick), most commonly in BA or 2B finishes, or polished to No4. The BA finish sheet has a quite bright, reflective appearance.

**Grade 430F** is the free-machining version of this grade, produced in bar form for high speed machining in automatic screw machines.

## Corrosion Resistance

Grade 430 has good resistance to a wide variety of corrosive media including nitric acid and some organic acids. It attains its maximum corrosion resistance when in the highly polished or buffed condition. Its resistance to pitting and crevice corrosion resistance is a little lower than that of Grade 304. It is not usually recommended for Grade 430 to be subjected to exterior exposure, but it performs well in mild indoor environments. Stress corrosion cracking resistance of Grade 430 is very high, as it is for all ferritic grades.

## Heat Resistance

Grade 430 Resists oxidation in intermittent service up to 870°C and to 815°C in continuous service. This grade may become brittle at room temperature after prolonged heating in the 400-600°C range. This effect can be eliminated by annealing.

## Heat Treatment

### Solution Annealing

Heat to 815-845°C, hold for ½ hour per 25mm of thickness, slow furnace cool to 600°C and then quickly air cool. Slow cooling from 540-400°C will cause embrittlement.

### Sub-Critical anneal

Heat to 760-815°C and then air cool or water quench.

This grade is not hardenable by thermal treatment.

Note that 430 is likely to scale more heavily at elevated temperatures than 304, and the scale produced is more difficult to remove by pickling.

## Welding

If welding is necessary pre-heat at 150-200°C. Embrittlement in the weld metal and heat affected zone can be reduced by a post-weld anneal at 790-815°C, but grain refinement will not occur. Use Grade 430, 308L, 309 or 310 filler rod, depending upon application. AS 1554.6 pre-qualifies welding of Grade 430 with Grade 309 filler rods and electrodes.

## Machining

Grade 430 is easier to machine than the standard austenitic grades such as 304, but there is still a tendency for galling and pick-up on the cutting tool. Bars that have been lightly drawn are easier to machine than those in the annealed condition, but Grade 430 is not usually available in bar. Grade 430F, the free machining version of 430, is very much easier to machine.

## Fabrication

The lower work hardening rate makes bending and forming somewhat easier than for grade 304, but the lower ductility restricts very severe operations. Wherever possible severe bends should be made with the bend axis at right angles to the rolling direction. Severe cold heading of 430 wire is possible.

If very severe cold working is required it may be necessary to carry out a sub-critical intermediate anneal.

## Typical Applications

Linings for dish washers and panels in other domestic appliances. Refrigerator cabinet panels. Automotive trim. Lashing wire. Element supports. Stove trim rings. Fasteners. Chimney liners.

# Grade Data Sheet

# 430

## Specified Properties

These properties for 430 are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M. Properties of Grade 430F are specified for bar in ASTM A582. Similar but not necessarily identical properties are specified for other products in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 430 | min. | - | - | - | - | - | 16.0 | - | - | - |
| | max. | 0.12 | 1.00 | 1.00 | 0.040 | 0.030 | 18.0 | | 0.75 | |
| 430F | min. | - | - | - | - | 0.15 | 16.0 | - | - | - |
| | max. | 0.12 | 1.25 | 1.00 | 0.06 | - | 18.0 | | | |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max |
| 430 | 450 | 205 | 22 | 89 | 183 |
| 430F | 552 typical | 379 typical | 25 typical | - | 262 |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 430 | 7700 | 200 | 10.4 | 11.0 | 11.4 | 23.9 | 26.0 | 460 | 600 |
| 430F | 7700 | 200 | 10.4 | 11.0 | 11.4 | 26.1 | 26.3 | 460 | 600 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 430 | S43000 | 1.4016 | X6Cr17 | 2320 | SUS 430 |
| 430F | S43020 | 1.4105 | X6CrMoS17 | 2383 | SUS 430F |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 430 |
|---|---|
| 430F | Higher machinability than 430 is needed in bar product, and reduced corrosion resistance is acceptable. |
| Durinox F20S | Better pitting resistance, formability and weldability is required in a ferritic stainless steel. |
| 304 | Higher corrosion resistance is needed, together with greatly improved ability to be welded and cold formed. |
| 316 | Much better corrosion resistance is needed, together with greatly improved ability to be welded and cold formed. |
| AtlasCR12 | A lower corrosion resistance is acceptable in a cost-critical application. |

# Grade Data Sheet

# Durinox™ F18S

**Durinox F18S** is a stabilised chromium ferritic stainless steel, combining good corrosion resistance with good formability and weldability. Its corrosion resistance enables it to replace grade 304 in less aggressive applications. Like all ferritic steels it is readily attracted to a magnet.

Durinox F18S is most commonly available in tube, sheet or coil up to about 2mm thick.

## Corrosion Resistance

Durinox F18S has resistance in a variety of mildly corrosive media. It attains its maximum corrosion resistance when in the highly polished or buffed condition.

The resistance of grade F18S to pitting and crevice corrosion in chloride environments is between that of grades 430 and 304. Its PRE value of about 18 is close to that of 304. Chloride stress corrosion cracking (SCC) resistance of Durinox F18S is very high, as it is for all ferritic grades.

The resistance of Durinox F18S to acids is generally lower than that of 304, but performance varies for different acids, and these should be considered on a case by case basis.

## Heat Resistance

Durinox F18S resists oxidation up to 980°C; it is particularly resistant to intermittent service conditions. It may become brittle at room temperature after prolonged heating in the 400 – 500°C range; this effect can be corrected by subsequent annealing. Niobium in F18S results in very high creep strength that makes it a good choice for critical auto exhaust system components.

## Heat Treatment

### Annealing

Heat to 790 - 870°C, hold for only a few minutes and then water quench or quickly air cool. Slow cooling will cause embrittlement and raise the ductile-to-brittle transition temperature, so should be avoided. It is important to not exceed 1000°C.

Durinox F18S is not hardenable by thermal treatment.

## Welding

Welding of Durinox F18S can be readily carried out by all the common electric processes. As F18S has very low carbon and nitrogen contents and is stabilised by additions of titanium and / or niobium it has good resistance to sensitisation and hence intergranular corrosion. Like most ferritic grades it is subject to significant grain growth in the heat affected zones of welds. Heat input should therefore be kept to a minimum, and welding of thicknesses over 2mm become more difficult. Gas shielding of the arc, weld metal and back side of the weld is important to minimise air contact. Use Grade 308L (or 308LSi) filler rod, depending upon application.

## Machining

F18S is easier to machine than the standard austenitic grades such as 304, but the grade is not commonly available as a bar.

## Fabrication

Durinox F18S has a higher yield strength, higher tensile strength and lower work hardening rate compared to 304. Some operations will therefore be easier and some will require a little more force. The lower ductility of F18S restricts some very severe operations. It has quite good deep drawing capability; close to that of 304, but it has limited ability to stretch form. As these two processes are often combined in a single forming operation some changes to settings or tooling compared to the austenitic grades may be needed.

If very severe cold working is required it may be necessary to carry out an intermediate anneal.

## Typical Applications

Chemical process equipment, heat exchanger tubing – particularly in the sugar industry, architectural panels and furniture for indoor environments, trolleys, equipment for food preparation service and display, refrigeration cabinets, exhaust flues, fuel burners.

# Grade Data Sheet

# Durinox™ F18S

## Specified Properties

The composition and mechanical properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M, for grade UNS S43932. Durinox F18S is fully compliant with this specification. Similar but not necessarily identical properties are specified for other products in their respective specifications.

## Chemical Composition (%)

| Grade | C | Mn | Si | P | S | Cr | Mo | Ni | N | Ti+Nb |
|---|---|---|---|---|---|---|---|---|---|---|
| Durinox F18S | - 0.030 | - 1.00 | - 1.00 | - 0.040 | - 0.030 | 17.0 19.0 | - | - 0.50 | - 0.030 | 0.20+4(C+N) 0.75 |

## Mechanical Properties

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | | Cold Bend Transverse direction Bend radius = 1T |
|---|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max | |
| Durinox F18S | 415 | 205 | 22 | 89 | 183 | 180° |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | Thermal Conductivity | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-400°C (µm/m/°C) | at 100°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| Durinox F18S | 7700 | 200 | 11.0 | 11.5 | 25 | 460 | 620 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| Durinox F18S | S43932 | 1.4509 | X2CrTiNb18 | - | - |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of Durinox F18S |
|---|---|
| 304 | Need the increased weldability, especially in heavy sections, or better stretch formability of 304. 304 is also available in sections above the 2 to 3mm upper limit for Durinox F18S, and a much wider range of products generally. |
| 430 | 430 has corrosion resistance that is nearly as high as F18S, so may be appropriate in indoor applications that are not welded. |
| F20S | Durinox F20S could be used if the corrosion resistance of F18S was not quite adequate. F20S is another low cost ferritic steel. |

# Grade Data Sheet

# Durinox™ F20S

**Atlas Durinox F20S** is a stabilised 20% chromium ferritic stainless steel, combining good corrosion resistance with high formability and weldability. This grade contains no nickel and is an economical alternative to grade 304 in many applications. Like all ferritic steels it is readily attracted to a magnet.

Durinox F20S is most commonly available in sheet or coil up to about 2mm thick.

## Corrosion Resistance

Durinox F20S has good resistance in a wide variety of environments. The resistance of Durinox F20S to pitting and crevice corrosion in chloride environments is similar or superior to that of grade 304. Its PRE value of about 20 is above that of 304, confirmed by laboratory and service exposure testing. In outdoor exposure it performs similarly to 304. Chloride stress corrosion cracking (SCC) resistance of Durinox F20S is very high, as for all ferritic grades.

Its resistance to acids is generally slightly lower than that of 304, but performance varies for different acids.

## Heat Resistance

Durinox F20S resists oxidation in intermittent service up to 920°C and to 870°C in continuous service but it may become brittle at room temperature after prolonged heating in the 400 – 500°C range. This effect can be corrected by subsequent annealing.

## Heat Treatment

### Annealing

Heat to approximately 925°C, hold for only a few minutes and then water quench or quickly air cool. Slow cooling from 500-400°C will cause embrittlement. F20S is not hardenable by thermal treatment.

## Welding

Welding of Durinox F20S can be readily carried out by all the common electric processes. As Durinox F20S has very low carbon and nitrogen contents and is stabilised by additions of titanium and / or niobium it has good resistance to sensitisation and hence intergranular corrosion. Like most ferritic grades it is subject to significant grain growth in the heat affected zones of welds. Heat input should therefore be kept to a minimum, and welding of thicknesses over 2mm become more difficult. Welding sections above 3mm is generally not recommended.

Gas shielding of the arc, weld metal and back side of the weld is important to minimise air contact. Shielding gases recommended for TIG (GTAW) are Argon or Argon + Helium. For MIG (GMAW) shielding is by Argon + 2% of Oxygen or Argon + 2% Carbon Dioxide or Argon + 2% $CO_2$ + Helium. Use Grade 308L or 316L (or 316LSi) filler rod.

## Machining

Durinox F20S is easier to machine than the standard austenitic grades such as 304, but the grade is not currently available as a bar.

## Fabrication

Durinox F20S has a higher yield strength, lower tensile strength and lower work hardening rate compared to 304. Some operations will therefore be easier and some will require a little more force. Mechanical and physical properties are very similar to those of common carbon steels, so formability is also very familiar for those fabricators with experience in carbon steel.

The lower ductility of Durinox F20S restricts some very severe operations. Durinox F20S has very good drawing capability; exceeding that of 304, but it has limited ability to stretch form. As these two processes are often combined in a single forming operation some changes to settings or tooling compared to the austenitic grades may be needed. Very severe cold working may not be possible, or may only be possible with an intermediate anneal.

## Typical Applications

General sheet metal fabrication, bench tops, catering equipment, equipment cabinets, flues, process equipment, tank cladding.

# Grade Data Sheet

# Durinox™ F20S

## Specified Properties

Because Durinox F20S is a very new alloy its properties are not as yet included in any national or international specifications. The following composition and mechanical properties are typical, not specification limits.

### Chemical Composition (%)

(typical values)

| Grade | C | Mn | Si | P | S | Cr | N | Ti+Nb |
|---|---|---|---|---|---|---|---|---|
| Durinox F20S | 0.02 | 0.2 | 0.1 | 0.03 | 0.003 | 20 | 0.01 | 0.3 |

Note: Because of on-going product development some minor changes may be made to this composition.

### Mechanical Properties

| Grade | Tensile Strength (MPa) | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness Vickers HV |
|---|---|---|---|---|
| Durinox F20S | 460 | 320 | 30 | 160 |

Note: Because of on-going product development some minor changes may be made to these properties.

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion 0-100°C (µm/m/°C) | Thermal Conductivity at 100°C (W/m.K) | Specific Heat 0-100°C ( J/kg.K) | Electrical Resistivity (nΩ.m) |
|---|---|---|---|---|---|---|
| Durinox | 7750 | 205 | 10.5 | 23 | 440 | 600 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| Durinox | - | - | - | - | - |

Note: no national or international specifications cover this grade as yet.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of Durinox F20S |
|---|---|
| F18S | A lower cost than F20S is required and a slightly lower corrosion resistance can be tolerated. Durinox F18S is less readily available than F20S. |
| 304 | Better ductility is required for severe forming. Better weldability in heavy sections is needed. Product is required in thicknesses above those of F20S. |
| 430 | Lower cost is required, and reduced weldability, formability and corrosion resistance can be tolerated. |
| 444 | Higher corrosion resistance is required, particularly in chloride environments. |

# Grade Data Sheet

# Durinox™ F18MS

**Durinox F18MS** is a stabilised chromium-molybdenum ferritic stainless steel, combining very good corrosion resistance with good formability and weldability. Its excellent corrosion resistance enables it to replace grade 316 in many applications; domestic hot water cylinders are its largest field of application. Like all ferritic steels it is readily attracted to a magnet.

Durinox F18MS is most commonly available in sheet or coil up to about 2mm thick.

## Corrosion Resistance

Durinox F18MS has good resistance in a wide variety of corrosive media. It attains its maximum corrosion resistance when in the highly polished or buffed condition.

The resistance of grade F18MS to pitting and crevice corrosion in chloride environments is similar or superior to that of grade 316. Its PRE value of about 25 is at least as high as that of 316. Chloride stress corrosion cracking (SCC) resistance of Durinox F18MS is very high, as it is for all ferritic grades.

The resistance of Durinox F18MS to acids is generally lower than that of 316, but performance varies for different acids, and these should be considered on a case by case basis.

## Heat Resistance

Durinox F18MS resists oxidation in intermittent service up to 920°C and to 870°C in continuous service but it may become brittle at room temperature after prolonged heating in the 400 – 500°C range. This effect can be corrected by subsequent annealing.

## Heat Treatment

### Annealing

Heat to approximately 925°C, hold for only a few minutes and then water quench or quickly air cool. Slow cooling from 500-400°C will cause embrittlement.

Durinox F18MS is not hardenable by thermal treatment.

## Welding

Welding of Durinox F18MS can be readily carried out by all the common electric processes. As F18MS has very low carbon and nitrogen contents and is stabilised by additions of titanium and / or niobium it has good resistance to sensitisation and hence intergranular corrosion. Like most ferritic grades it is subject to significant grain growth in the heat affected zones of welds. Heat input should therefore be kept to a minimum, and welding of thicknesses over 2mm become more difficult. Gas shielding of the arc, weld metal and back side of the weld is important to minimise air contact. Use Grade 316L (or 316LSi) filler rod, depending upon application. AS 1554.6 pre-qualifies welding (listed as Grade 444) with Grade 316L filler rods and electrodes.

## Machining

F18MS is easier to machine than the standard austenitic grades such as 316, but the grade is not commonly available as a bar.

## Fabrication

Durinox F18MS has a higher yield strength, higher tensile strength and lower work hardening rate compared to 316. Some operations will therefore be easier and some will require a little more force. The lower ductility of F18MS restricts some very severe operations. It has quite good deep drawing capability; close to that of 316, but it has limited ability to stretch form. As these two processes are often combined in a single forming operation some changes to settings or tooling compared to the austenitic grades may be needed.

If very severe cold working is required it may be necessary to carry out an intermediate anneal.

## Typical Applications

Hot water cylinders, heat exchanger tubing, chemical process equipment, architectural panels.

# Grade Data Sheet

# Durinox™ F18MS

## Specified Properties

The composition and mechanical properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M, for grade 444 (UNS S44400). Durinox F18MS is fully compliant with this specification. Similar but not necessarily identical properties are specified for other products in their respective specifications.

### Chemical Composition (%)

| Grade | C | Mn | Si | P | S | Cr | Mo | Ni | N | Ti+Nb |
|---|---|---|---|---|---|---|---|---|---|---|
| Durinox F18MS | -<br>0.025 | -<br>1.00 | -<br>1.00 | -<br>0.040 | -<br>0.030 | 17.5<br>19.5 | 1.75<br>2.50 | -<br>1.00 | -<br>0.035 | 0.20+4(C+N)<br>0.80 |

### Mechanical Properties

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | | Cold Bend Transverse direction Bend radius = 1T |
|---|---|---|---|---|---|---|
| | | | | Rockwell B (HR B) max | Brinell (HB) max | |
| Durinox F18MS | 415 | 275 | 20 | 96 | 217 | 180° |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | Thermal Conductivity | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-400°C (µm/m/°C) | at 100°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| Durinox F18MS | 7700 | 200 | 11.0 | 11.5 | 26.8 | 427 | 620 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish | Japanese |
|---|---|---|---|---|---|
| | | No | Name | SS | JIS |
| Durinox F18MS | S44400 | 1.4521 | X2CrMoTi18-2 | 2326 | SUS 444 |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of Durinox F18MS |
|---|---|
| 316 | Need the increased weldability, especially in heavy sections, or better stretch formability of 316. 316 is also available in sections above the 2 to 3mm upper limit for Durinox F18MS, and a wider range of products generally. |
| 2304 | 2304 has better weldability in heavy sections, and higher strength that may alloy down-gauging. |
| F20S | Durinox F20S could be used if the corrosion resistance of F18MS was not needed. Another low cost ferritic steel. |

# Grade Data Sheet

# 2101

**LDX2101®** is a duplex (ferritic/austenitic) stainless steel grade with a useful combination of corrosion resistance and high strength. Because it has almost no molybdenum and a low nickel content the grade is an economical alternative to 304 or 316 in some applications. In 2101 nickel is largely replaced by manganese and molybdenum's corrosion resistance role largely taken over by nitrogen. Yield strength is about double that of the standard austenitic grades 304 and 316.

LDX2101 was developed by Outokumpu as a "lean duplex" grade; it has since been allocated designations UNS S32101 and 1.4162 in the American and European standards systems. It also has ASME pressure vessel endorsement, initially under Code Case 2418.

## Corrosion Resistance

General corrosion resistance between Grades 304 and 316 in most environments. Good resistance to localised corrosion including intergranular, pitting and crevice corrosion; the Pitting Resistance Equivalent (PRE) of 2101 is 26 – slightly higher than that of 316, but actual pitting and crevice corrosion behaviour is generally a between that of 304 and 316.

Grade 2101 is also resistant to chloride stress corrosion cracking (SCC) at temperatures up to over 100°C. It can perform well in environments which cause premature failure of austenitic grades.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Although 2101 has good high temperature oxidation resistance this grade, like other duplex stainless steels, suffers from embrittlement if held at temperatures above 300°C. If embrittled this can only be rectified by a full solution annealing treatment. Duplex stainless steels are almost never used above 300°C.

## Low Temperature Performance

2101 is not generally recommended for use below -50°C because of its ductile-to-brittle-transition, again common to all duplex stainless steels.

## Heat Treatment

### Solution treatment (annealing)

Heat to 1020-1080°C and cool rapidly. This grade cannot be hardened by thermal treatment, but does work harden.

## Welding

Weldable by all standard electric methods. Filler of 2209 rods or electrodes ensures that deposited metal has the correctly balanced duplex structure. Heat input should be kept low (although this is less restrictive than for other duplex grades) and no pre- or post-heat should be used. Unlike other duplex grades welding of 2101 without filler metal may be possible.

The lower co-efficient of thermal expansion of all duplex stainless steels compared with austenitic grades reduces distortion and associated stresses.

## Machining

The high strength that makes 2101 useful in many applications also reduces its machinability, but overall it machines slightly better than 316.

## Fabrication

The high strength of 2101 also makes bending and forming more difficult; these operations will require larger capacity equipment than would be required for austenitic stainless steels. The ductility of 2101 is less than that of an austenitic grade (but is not low when compared to most other structural materials), so severe forming operations, such as cold heading, are not generally possible. If severe cold working is required it is recommended that intermediate annealing be carried out.

## Typical Applications

Chemical processing, transport and storage. All structural and pressure applications requiring high strength and good corrosion resistance at economical cost.

# Grade Data Sheet

# 2101

## Specified Properties

These properties are specified for Grade 2101 (S32101) flat rolled product (plate over 5mm thick) in ASTM A240/A240M. Similar but not necessarily identical properties are specified for other products such as sheet, pipe and bar in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | Cu | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2101 | min. | - | 4.00 | - | - | - | 21.0 | 0.10 | 1.35 | 0.10 | 0.20 |
| | max. | 0.040 | 6.00 | 1.00 | 0.040 | 0.030 | 22.0 | 0.80 | 1.70 | 0.80 | 0.25 |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell C (HR C) | Brinell (HB) |
| 2101 | 650 | 450 | 30 | - | 290 max |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m$^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat 0-100°C ( J/kg.K) | Electrical Resistivity at 20°C (nΩ.m) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (μm/m/°C) | 0-300°C (μm/m/°C) | 0-538°C (μm/m/°C) | at 100°C (W/m.K) | at 300°C (W/m.K) | | |
| 2101 | 7800 | 200 | 13.0 | 14.0 | - | 16 | 18 | 530 | 800 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 2101 | S32101 | 1.4162 | - | - | - |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 2304 |
|---|---|
| 304L | Generally slightly lower pitting and crevice corrosion resistance than 2101 and lower strength, but more easily cold formed and more readily available. 304 is non-magnetic. |
| 316L | Generally slightly higher pitting and crevice corrosion resistance than 2101, more easily cold formed and more readily available, but lower strength. 316 is non-magnetic. |
| 2205 | Higher resistance to corrosion is required, eg resistance to higher temperature chloride solutions. Grade 2205 is often more readily available than 2101. |
| F18MS / 444 | Slightly higher pitting and crevice corrosion resistance than 2101, more easily cold formed and lower cost. F18MS / 444 is only available in thin gauge sheet and coil. |
| 2304 | Slightly higher resistance to corrosion is required, eg resistance to higher temperature chloride solutions. Grade 2304 is generally less readily available than 2101. |

# Grade Data Sheet

# 2304

**2304** is a duplex (ferritic/austenitic) stainless steel grade with a useful combination of corrosion resistance and high strength. Because it has almost no molybdenum the grade is an economical alternative to 316 in some applications.

2304 is not generally suitable for use at temperatures above 300°C as it suffers from precipitation of brittle micro-constituents, nor below -50°C because of its ductile-to-brittle-transition.

## Corrosion Resistance

Good general corrosion resistance; approximately the same as Grade 316 in most environments. Good resistance to localised corrosion including intergranular, pitting and crevice corrosion; the Pitting Resistance Equivalent (PRE) of 2304 is 26 – slightly higher than that of 316 and this is confirmed by actual pitting and crevice corrosion behaviour. It has similar resistance to sea water as grade 316.

Grade 2304 is also resistant to chloride stress corrosion cracking (SCC) at temperatures of up to over 100°C. It will often perform well in environments which cause premature failure of austenitic grades.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Although 2304 has good high temperature oxidation resistance this grade, like other duplex stainless steels, suffers from embrittlement if held at temperatures above 300°C. 2304 resists this high temperature embrittlement better than other duplex grades but the effect will still occur after about 10 hours at elevated temperatures. If embrittled this can only be rectified by a full solution annealing treatment. Duplex stainless steels are almost never used above 300°C.

## Heat Treatment

### Solution treatment (annealing)

Heat to 1020-1100°C and cool rapidly. This grade cannot be hardened by thermal treatment, but does work harden.

## Welding

Weldable by all standard methods, but it should not be welded without filler metal as this may result in excessive ferrite. AS 1554.6 pre-qualifies welding of 2304 with 2209 rods or electrodes to ensure that deposited metal has the correctly balanced duplex structure. Nitrogen added to the shielding gas will also assist in ensuring adequate austenite in the structure. Heat input must be kept low and no pre- or post-heat should be used.

The lower co-efficient of thermal expansion of all duplex stainless steels compared with austenitic grades reduces distortion and associated stresses.

## Machining

The high strength that makes 2304 useful in many applications also reduces its machinability, but not as much as for duplex grade 2205. Machinability of 2304 bars in some operations is not as good as for 316 and in other operations it is in fact better to machine. Poor chip breaking can result in rough finishes after some operations.

## Fabrication

The high strength of 2304 also makes bending and forming more difficult; these operations will require larger capacity equipment than would be required for austenitic stainless steels. The ductility of 2304 is less than that of an austenitic grade (but is not low when compared to most other structural materials), so severe forming operations, such as cold heading, are not generally possible. If severe cold working is required it is recommended that intermediate annealing be carried out.

## Typical Applications

Chemical processing, transport and storage. Oil and gas exploration and processing equipment. Marine and other high chloride environments. Pulp & Paper digesters, liquor tanks and paper machines.

# Grade Data Sheet

# 2304

## Specified Properties

These properties are specified for Grade 2304 (S32304) flat rolled product (plate, sheet and coil) in ASTM A240/A240M. Similar but not necessarily identical properties are specified for other products such as pipe and bar in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | Cu | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2304 | min. | - | - | - | - | - | 21.5 | 0.05 | 3.0 | 0.05 | 0.05 |
| | max. | 0.030 | 2.50 | 1.00 | 0.040 | 0.030 | 24.5 | 0.60 | 5.5 | 0.60 | 0.20 |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell C (HR C) | Brinell (HB) |
| 2304 | 600 | 400 | 25 | 32 max | 290 max |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m$^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-400°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 300°C (W/m.K) | 0-100°C ( J/kg.K) | at 20°C (nΩ.m) |
| 2304 | 7800 | 200 | 13.0 | 14.5 | - | 17 | 19 | 460 | 850 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 2304 | S32304 | 1.4362 | X2CrNiN23-4 | 2327 | - |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 2304 |
|---|---|
| 316L | Approximately the same pitting and crevice corrosion resistance as 2304, more easily cold formed and more readily available. |
| 2205 | Higher resistance to corrosion is required, eg resistance to higher temperature seawater. Grade 2205 is also more readily available than 2304. |
| Durinox F18MS | Approximately the same pitting and crevice corrosion resistance as 2304, more easily cold formed and lower cost. Durinox F18MS is only available in thin gauge sheet and coil. |
| | |

# Grade Data Sheet

# 2205

**2205** is the most widely used duplex (ferritic/austenitic) stainless steel grade. It finds applications due to both excellent corrosion resistance and high strength.

The original S31803 composition has over the years been refined by many steel suppliers, and the resulting restricted composition range was endorsed as UNS S32205 in 1996. S32205 gives better guaranteed corrosion resistance, but much of the S31803 currently produced also complies with S32205. It is recommended that grade 2205 always be clarified as S31803 or S32205, but note that ASTM A240 defines 2205 as S32205.

2205 is not generally suitable for use at temperatures above 300°C as it suffers from precipitation of brittle micro-constituents, nor below -50°C because of its ductile-to-brittle-transition.

## Corrosion Resistance

Excellent general corrosion resistance; superior to Grade 316 in most environments. Excellent resistance to localised corrosion including intergranular, pitting and crevice corrosion; the CPT of 2205 is generally at least 35°C. The grade is also resistant to chloride stress corrosion cracking (SCC) at temperatures of up to about 150°C. Grade 2205 will often perform well in environments which cause premature failure of austenitic grades. It has better resistance to sea water than grade 316. Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Although 2205 has good high temperature oxidation resistance this grade, like other duplex stainless steels, suffers from embrittlement if held for even short times at temperatures above 300°C. If embrittled this can only be rectified by a full solution annealing treatment. Duplex stainless steels are almost never used above 300°C.

## Heat Treatment

### Solution treatment (annealing)

Heat to 1020-1100°C and cool rapidly. This grade cannot be hardened by thermal treatment, but does work harden.

## Welding

Weldable by all standard methods, but should not generally be welded without filler metal as this may result in excessive ferrite. AS 1554.6 pre-qualifies welding of 2205 with 2209 rods or electrodes to ensure that deposited metal has the correctly balanced duplex structure. Nitrogen added to the shielding gas will also assist in ensuring adequate austenite in the structure. Heat input must be kept low and no pre- or post-heat should be used. The lower co-efficient of thermal expansion of all duplex stainless steels compared with austenitic grades reduces distortion and associated stresses.

## Machining

The high strength that makes 2205 useful in many applications also reduces its machinability. Cutting speeds are approximately 20% slower than for grade 304. There is as yet no "Ugima" Improved Machinability version of 2205.

## Fabrication

The high strength of 2205 also makes bending and forming more difficult; these operations will require larger capacity equipment than would be required for austenitic stainless steels. The ductility of 2205 is less than that of an austenitic grade (but is not low when compared to most other structural materials), so severe forming operations, such as cold heading, are not generally possible. If severe cold working is required it is recommended that intermediate annealing be carried out.

## Typical Applications

Chemical processing, transport and storage. Oil and gas exploration and processing equipment. Marine and other high chloride environments. Pulp & Paper digesters, liquor tanks and paper machines.

# Grade Data Sheet

# 2205

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M. Similar but not necessarily identical properties are specified for other products such as pipe and bar in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 2205 (S31803) | min. | - | - | - | - | - | 21.0 | 2.5 | 4.5 | 0.08 |
| | max. | 0.030 | 2.00 | 1.00 | 0.030 | 0.020 | 23.0 | 3.5 | 6.5 | 0.20 |
| 2205 (S32205) | min. | - | - | - | - | - | 22.0 | 3.0 | 4.5 | 0.14 |
| | max. | 0.030 | 2.00 | 1.00 | 0.030 | 0.020 | 23.0 | 3.5 | 6.5 | 0.20 |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell C (HR C) | Brinell (HB) |
| S31803 | 620 | 450 | 25 | 31 max | 293 max |
| S32205 | 655 | 450 | 25 | 31 max | 293 max |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m$^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (μm/m/°C) | 0-315°C (μm/m/°C) | 0-538°C (μm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 2205 | 7800 | 200 | 13.7 | 14.7 | - | 19.0 | - | 450 | 850 |
| Physical properties of S31803 and S32205 are identical. | | | | | | | | | |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 2205 | S31803 / S32205 | 1.4462 | X2CrNiMoN22-5-3 | 2377 | SUS 329J3L |
| These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.<br>ASTM grade S31803 is a closer equivalent to most other specifications than is S32205. | | | | | |

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 2205 |
|---|---|
| 904L | Better formability is needed, with similar corrosion resistance and lower strength. |
| UR52N+<br>2507 | Higher resistance to corrosion is required, eg resistance to higher temperature seawater. These super duplex grades also have higher strength than 2205. |
| 6%Mo | Higher corrosion resistance is required, but with lower strength and better formability. |
| 316L | The high corrosion resistance and strength of 2205 are not needed … 316L is more available and may be lower cost. |

# Grade Data Sheet

# 2507

**2507** is one of a group of "super duplex" grades, combining high strength with exceptional corrosion resistance.

2507 is very highly resistant to general corrosion and to pitting and crevice corrosion in high chloride, hot environments. Its duplex structure also results in excellent resistance to stress corrosion cracking.

Like other duplex (ferritic/austenitic) grades the super duplex grades are not suitable for high or low temperature service. 2507 is not recommended for temperatures below -50°C or above +300°C, because of reduced toughness outside this range.

The high strength favours applications in pressure vessels and for marine and other shafts

## Corrosion Resistance

2507 has excellent general corrosion resistance, superior to virtually all other stainless steels. It has high resistance to intergranular corrosion and very high resistance to stress corrosion cracking in both chloride and sulphide environments.

A PRE of least 40 indicates that the material has good pitting and crevice corrosion resistance to warm sea water and other high chloride environments; it is rated as more resistant than grade 904L and approximating that of the 6% Molybdenum "super austenitic" grades.

2507 is the grade of choice for severe high temperature marine environments and for chemical and petrochemical processing, even including some solutions of strong acids.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Although super duplex grades have good high temperature oxidation resistance, like other duplex stainless steels they suffer from embrittlement if held for even short times at temperatures above 300°C. If grade 2507 becomes embrittled this can only be rectified by a full solution annealing treatment.

## Heat Treatment

### Solution Treatment (Annealing)

Heat to 1040 - 1120°C and cool rapidly in air or by water quenching.
Duplex and super duplex grades cannot be hardened by thermal treatment.

## Welding

2507 is weldable by standard methods, without pre-heat. Consumables over-alloyed with nitrogen and nickel are generally recommended such as those with ISO designation "25 9 4 L N". TIG (GTAW), MIG (GMAW) and all positional manual (MMAW) electrodes are available. Heat input should be within the range 0.5 – 1.5kJ/mm. Post weld annealing is essential following autogenous welding, but not otherwise. Nickel-based consumables (eg Alloy C22) can also be used to give higher corrosion resisting welds. As for other duplex stainless steels the coefficient of thermal expansion of 2507 is lower than for austenitic grades, reducing distortion and residual stresses.

## Fabrication

2507 is a high strength steel, so high forming forces will be required and high spring-back should be anticipated. The ductility of the grade is quite adequate for most operations, but heavy deformation, such as cold forging, is not possible. If more than about 20% cold work is carried out an intermediate solution anneal is required. Hot forging can be carried out in the temperature range 1200 – 1025°C. Like other duplex grades 2507 has low hot strength, so may need support during heat treatment or forging. Hot forging should be followed by solution treatment.

## Typical Applications

Oil and gas exploration, processing and support systems, pollution control including flue gas desulphurisation, marine and other high chloride environments, desalination plants, chemical processing, transport and storage, pulp and paper processing.

# Grade Data Sheet

# 2507

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240M and for pipe in ASTM A790M, as UNS S32750. Similar but not necessarily identical properties are specified for other products in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | Cu | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2507 | min. | - | - | - | - | - | 24.0 | 3.0 | 6.0 | - | 0.24 |
| | max. | 0.030 | 1.20 | 0.80 | 0.035 | 0.020 | 26.0 | 5.0 | 8.0 | 0.50 | 0.32 |

### Mechanical Property Specification

| Grade | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell B (HR C) max | Brinell (HB) max |
| 2507 | 795 | 550 | 15 | 32 | 310 |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | Thermal Conductivity | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-400°C (µm/m/°C) | at 20°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 2507 | 7800 | 200 | 13.0 | 14.5 | 14.2 | 460 | 850 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 2507 | S32750 | 1.4410 | X2CrNiMoN25-7-4 | 2328 | - |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 2507 |
|---|---|
| 2205 | The lower cost and better availability of 2205 are required, and a lower corrosion resistance and strength can be accepted. |
| 6% Mo | Higher ductility of this austenitic grade is needed, and the much lower strength is acceptable. Corrosion resistance is similar in many environments, but needs to be considered case by case. |
| Ni Alloys | A corrosion resistance even higher than 2507 is required, and a higher cost is acceptable. |

# Grade Data Sheet

# 2507Cu

**Grade UR2507Cu** is a registered trade name of the ArcelorMittal group. The grade was previously designated UR52N+.

2507Cu is specified as UNS S32520 for plate (in ASTM A240M) and pipe (in ASTM A790M) but retains the older designation UNS S32550 for bar (in ASTM A276M). The specified compositions and mechanical properties of these alternatives are slightly different.

2507Cu is one of a group of "super duplex" grades, combining high strength with exceptional corrosion resistance.

## Corrosion Resistance

2507Cu has excellent general corrosion resistance, superior to virtually all other stainless steels. It has high resistance to intergranular corrosion. Because of its high strength it performs well in abrasion/corrosion conditions.

A PRE guaranteed to be at least 40 indicates that the material has good pitting and crevice corrosion resistance to warm sea water and other high chloride environments; it is rated as more resistant than grade 904L and approaching that of the 6% Molybdenum "super austenitic" grades. The crevice corrosion resistance of 2507Cu can be in excess of that of the 6% Mo grades in some cases. Copper adds resistance to sulphuric and other reducing acids, particularly in the very aggressive "mid concentration" range.

Because of its duplex structure 2507Cu has excellent resistance to stress corrosion cracking, resistant to all concentrations of chlorides up to over 200°C, and also resists SCC in sulphide (sour gas) environments.

2507Cu is a grade of choice for severe hot sea water environments and for chemical and petrochemical processing, including strong acids.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Although super duplex grades have good high temperature oxidation resistance they suffer from embrittlement if held for even short times at temperatures above +270°C. If embrittled this can only be rectified by a full solution annealing treatment.

## Low Temperature Performance

2507Cu is not generally recommended for use below -50°C because of its ductile-to-brittle-transition, again common to all duplex stainless steels.

## Heat Treatment

### Solution Treatment (Annealing)

Annealing - heat to 1080 - 1120°C and cool rapidly.
Duplex and super duplex grades cannot be hardened by thermal treatment.

## Welding

Weldable by standard methods, without pre-heat. Consumables over-alloyed with nitrogen and nickel are generally recommended. TIG (GTAW), MIG (GMAW) and all positional manual (MMAW) electrodes are available. Nickel-based consumables (eg Alloy C22) give higher corrosion resisting welds. As for other duplex stainless steels the coefficient of thermal expansion is lower than for austenitic grades, reducing distortion and residual stresses. Post weld annealing increases the corrosion resistance of welds.

## Fabrication

2507Cu is a high strength steel, so high forces will be required for cold forming. The ductility of the grade is quite adequate for most operations, but heavy deformation, such as cold forging, is not possible. If more than about 20% cold work is required an intermediate solution anneal is required.

## Typical Applications

Oil and gas exploration, processing and support systems, pollution control including flue gas desulphurisation, marine and other high chloride environments, chemical processing, transport and storage, pulp and paper processing.

# Grade Data Sheet

# 2507Cu

## Specified Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240M as Grade S32520, for pipe in ASTM A790M (also as Grade S32520) and for bar in specification ASTM A276, as Grade S32550, Condition A. Similar but not necessarily identical properties are specified for other products in their respective specifications.

### Composition Specification (%)

| Grade & Spec. | | C | Mn | Si | P | S | Cr | Mo | Ni | Cu | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S32520 ASTM A240M | min. | - | - | - | - | - | 24.0 | 3.0 | 5.5 | 0.5 | 0.20 |
| | max | 0.030 | 1.50 | 0.80 | 0.035 | 0.020 | 26.0 | 4.0 | 8.0 | 2.0 | 0.35 |
| S32520 ASTM A790M | min. | - | - | - | - | - | 24.0 | 3.0 | 5.5 | 0.5 | 0.20 |
| | max | 0.030 | 1.5 | 0.80 | 0.035 | 0.020 | 26.0 | 5.0 | 8.0 | 3.0 | 0.35 |
| S32550 ASTM A276M | min. | - | - | - | - | - | 24.0 | 2.9 | 4.5 | 1.5 | 0.10 |
| | max | 0.040 | 1.50 | 1.0 | 0.040 | 0.030 | 27.0 | 3.9 | 6.5 | 2.5 | 0.25 |

### Mechanical Property Specification

| Grade & Specification | Tensile Strength (MPa) min | Yield Strength 0.2% Proof (MPa) min | Elongation (% in 50mm) min | Hardness | |
|---|---|---|---|---|---|
| | | | | Rockwell C (HR C) max | Brinell (HB) max |
| S32520 – A240M & A790M | 770 | 550 | 25 | - | 310 |
| S32550 – A276 Cond A | 750 | 550 | 25 | - | 290 |

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m$^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat 20°C ( J/kg.K) | Electrical Resistivity (nΩ.m) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 20-200°C (µm/m/°C) | 20-300°C (µm/m/°C) | 20-500°C (µm/m/°C) | at 20°C (W/m.K) | at 200°C (W/m.K) | | |
| 2507Cu | 7850 | 200 | 13.5 | 14.0 | 14.5 | 17 | 19 | 450 | 850 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 2507Cu | S32520 S32550 | 1.4507 | X2CrNiMoCuN25-6-3 | - | - |

European 1.4507 is closer to S32520 than S32550, but is not exactly the same as either.
These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 2507Cu |
|---|---|
| 2205 | The lower cost and better availability of 2205 are required, and a lower corrosion resistance and strength can be accepted. |
| 6% Mo | Higher ductility of this austenitic grade is needed, and the much lower strength is acceptable. Corrosion resistance is similar in many environments, but needs to be considered case by case. |
| Nickel Alloys | A corrosion resistance even higher than 2507Cu is required, and a higher cost structure is acceptable. |

# Grade Data Sheet

# 410

**Grade 410** is the basic martensitic stainless steel; like most non-stainless steels it can be hardened by a "quench-and-temper" heat treatment. It contains a minimum of 11.5 per cent chromium, just sufficient to give corrosion resistance properties. It achieves maximum corrosion resistance when it has been hardened and tempered and then polished. Grade 410 is a general purpose grade often supplied in the hardened, but still machinable condition, for applications where high strength and moderate heat and corrosion resistance are required.

Martensitic stainless steels are optimised for high hardness, and other properties are to some degree compromised. Fabrication must be by methods that allow for poor weldability and usually the need for a final heat treatment. Corrosion resistance of the martensitic grades is lower than that of the common austenitic grades, and their useful operating temperature range is limited by their loss of ductility at sub-zero temperatures and loss of strength by over-tempering at elevated temperatures.

Grade 410 is usually a bar steel, most commonly only available in Australia when imported for a particular application.

## Corrosion Resistance

410 resists dry atmosphere, fresh water, mild alkalies and acids, food, steam and hot gases. It must be hardened for maximum heat and corrosion resistance. Performance is best with a smooth surface finish. This grade has less corrosion resistance than the austenitic grades and also less than 17% chromium ferritic alloys such as Grade 430.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Good resistance to scaling up to approximately 650°C, but generally not recommended for use in temperatures between 400 and 580°C, because of the reduction in mechanical properties.

## Heat Treatment

### Full Annealing

815-900°C, slow furnace cool to 600°C and then air cool.

### Process Annealing

650-760°C and air cool.

### Hardening

Heat to 925-1010°C, followed by quenching in oil or air. Oil quenching is necessary for heavy sections. Temper, generally within the range 200-400°C, to obtain a variety of hardness values and mechanical properties as indicated in the accompanying table.

The tempering range 400-580°C should generally be avoided.

## Welding

Readily welded by all standard methods, but a pre-heat of 150-260°C and post-weld annealing treatment is required to reduce the possibility of cracking. Use Grade 410 welding rod if post hardening and tempering is involved. If parts are to be used in the "as welded" condition, a ductile joint can be achieved by using Grade 309 filler rods.

AS 1554.6 pre-qualifies welding of 410 with Grade 309 rods or electrodes.

## Machining

In the annealed or highly tempered conditions Grade 410 is relatively easily machined, but if hardened to above 30HRC machining becomes more difficult. Free machining Grade 416 (refer to the Atlas Steels Datasheet) is a very readily machined alternative, but with lower corrosion resistance and mechanical properties.

## Typical Applications

Bolts, nuts, screws, bushings. Pump and valve parts and shafts. Steam and gas turbine parts. Petroleum fractionating towers. Mine ladder rungs.

# Grade Data Sheet

# 410

## Specified Properties

These properties are specified for bar product in ASTM A276. Similar but not necessarily identical properties are specified for other products such as plate, wire and forgings in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 410 | min. | 0.08 | - | - | - | - | 11.5 | - | - | - |
| | max. | 0.15 | 1.00 | 1.00 | 0.040 | 0.030 | 13.5 | | | |

### Mechanical Properties - typical and specified values

| Tempering Temperature (°C) | Tensile Strength (MPa) | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness Brinell (HB) | Impact Charpy V (J) |
|---|---|---|---|---|---|
| Annealed * | 480 min | 275 min | 16 min | - | - |
| 204 | 1310 | 1000 | 16 | 388 | 30 |
| 316 | 1240 | 960 | 14 | 325 | 36 |
| 427 | 1405 | 950 | 16 | 401 | # |
| 538 | 985 | 730 | 16 | 321 | # |
| 593 | 870 | 675 | 20 | 255 | 39 |
| 650 | 755 | 575 | 23 | 225 | 80 |

* Annealed properties are specified for Condition A of ASTM A276, for cold finished bar.

# Due to associated low impact resistance this steel should not be tempered in the range 425-600°C

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | at 20°C (nΩ.m) |
| 410 | 7700 | 200 | 9.9 | 11.4 | 11.6 | 24.9 | 28.7 | 460 | 570 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 410 | S41000 | 1.4006 | X12Cr13 | 2302 | SUS410 |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 410 |
|---|---|
| 416 | High machinability is required, and the lower corrosion resistance of 416 is acceptable. |
| AtlasCR12 | A non-hardenable alternative with much better availability in flat products. Similar corrosion resistance to 410. |
| 420 | A higher hardened strength or hardness than can be obtained from 410 is needed. |
| 440C | A higher hardened strength or hardness than can be obtained even from 420 is needed. |

# Grade Data Sheet

# 416

**Grade 416** has the highest machinability of any stainless steel, at about 85% of that of a free-machining carbon steel. As for most other free-machining steels the improvement in machinability is achieved by addition of sulphur which forms manganese sulphide inclusions; this sulphur addition also lowers the corrosion resistance, weldability and formability to below that of its non-free machining equivalent Grade 410.

Grade 416 is sometimes used in the unhardened or hardened and highly tempered condition because of its low cost and ready machinability.

Martensitic stainless steels are optimised for high hardness, and other properties are to some degree compromised. Fabrication must be by methods that allow for poor weldability and usually also allow for a final harden and temper heat treatment. Corrosion resistance is lower than the common austenitic grades, and their useful operating temperature range is limited by their loss of ductility at sub-zero temperatures and loss of strength by over-tempering at elevated temperatures.

## Corrosion Resistance

Grade 416 has useful resistance to dry atmospheres, fresh water and mild alkalies and acids, but less resistant than the equivalent non-free-machining grades. Less corrosion resistant than the austenitic grades and also less than 17% chromium ferritic alloys such as Grade 430. High sulphur content free machining grades such as 416 are totally unsuitable for marine or other chloride exposure.

Maximum corrosion resistance is achieved in the hardened condition, with a smooth surface finish.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Fair resistance to scaling in intermittent service up to 760°C and up to 675°C in continuous service. Not recommended for use in temperatures above the relevant tempering temperature, if maintenance of mechanical properties is important.

## Heat Treatment

### Full Annealing

Heat to 815-900°C for ½ hour per 25mm of thickness. Cool at 30°C per hour maximum to 600°C and air cool.

### Sub-Critical Annealing

Heat to 650-760°C and air cool.

### Hardening

Hardened by heating to 925-1010°C, quenching in oil, and tempering to suit the mechanical requirements. See accompanying table.

Note: The tempering range 400-580°C should be avoided, due to poor ductility.

## Welding

Grade 416 has poor weldability. If welding is necessary ... use Grade 410 low hydrogen electrodes. Pre-heat to 200-300°C. Follow immediately with annealing or re-hardening, or a stress relief at 650-675°C.

A better option if the weld is not required to be hard is to use a Grade 309 austenitic stainless steel filler rod.

## Machining

Grade 416 offers exceptionally good machinability, the highest of any of the commonly available stainless steels. Best machinability is in the sub-critical annealed condition.

## Typical Applications

Valve parts, pump shafts, automatic screw machined parts, motor shafts and washing machine components. Bolts, nuts, studs and gears.

# Grade Data Sheet

# 416

## Specified Properties

These properties are specified for bar product in ASTM A582/A582M. Similar but not necessarily identical properties are specified for other products such as wire and forgings in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 416 | min. | - | - | - | - | 0.15 | 12.0 | - | - | - |
| | max. | 0.15 | 1.25 | 1.00 | 0.06 | - | 14.0 | | | |

### Mechanical Properties - typical and specified values

| Tempering Temperature (°C) | Tensile Strength (MPa) | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness Brinell (HB) | Impact Izod (J) |
|---|---|---|---|---|---|
| Annealed * | 517 | 276 | 30 | 262 max * | - |
| Condition T ** | - | - | - | 248-302 ** | - |
| 300 | 1350 | 1050 | 10 | 410 | 50 |
| 400 | 1390 | 1090 | 12 | 420 | 43 |
| 500 | 1400 | 1100 | 17 | 420 | 15 # |
| 600 | 870 | 720 | 20 | 280 | 45 |
| 700 | 710 | 500 | 22 | 210 | 65 |

* Annealed Condition A of ASTM A582M - Brinell Hardness is specified maximum, other properties are typical only, and will depend upon exact composition and heat treatment details.

** Hardened and tempered Condition T of ASTM A582M – specified hardness range.

# Due to associated low impact resistance this steel should not be tempered in the range 400-580°C

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 416 | 7700 | 200 | 9.9 | 11.0 | 11.6 | 24.9 | 28.7 | 460 | 570 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 416 | S41600 | 1.4005 | X12CrS13 | 2380 | SUS416 |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 416 |
|---|---|
| 410 | The high machinability of 416 can be sacrificed to gain better corrosion resistance and formability. |
| 303 | A slight drop in machinability to gain better availability. Grade 303 is non-hardenable. |
| 182 | A free-machining ferritic grade with better "soft magnetic" performance for solenoid shafts. Grade 182 is non-hardenable. |

# Grade Data Sheet

# 420

**Grade 420** stainless steel is a higher carbon version of 410; like most carbon and low alloy steels it can be hardened by heat treatment. It contains a minimum of 12 per cent chromium, just sufficient to give corrosion resistant properties. 420 has good ductility in the annealed condition but is capable of being hardened up to Rockwell Hardness 50HRC, the highest hardness of the 12 per cent chromium grades. Its best corrosion resistance is achieved when hardened and surface ground or polished.

Related grades to 420 are high carbon high hardness martensitic stainless steels such as the 440 series (see the Atlas Datasheet on this series of grades) and also variations to 420 containing molybdenum (for increased corrosion resistance and mechanical properties), sulphur (for increased machinability) or vanadium (for higher hardness). A slightly higher carbon version of 420 is the non-standard grade 420C.

Martensitic stainless steels are optimised for high hardness, and other properties are to some degree compromised. Fabrication must allow for poor weldability and usually also include a final harden and temper heat treatment. Corrosion resistance is lower than the common austenitic grades, and their useful operating temperature range is limited by their loss of ductility at sub-zero temperatures and loss of strength by over-tempering at elevated temperatures.

## Corrosion Resistance

Grade 420 in the hardened condition has good resistance to the atmosphere, foods, fresh water and mild alkalies or acids. Corrosion resistance is lower in the annealed condition. Less corrosion resistant than the austenitic grades and also less than 17% chromium ferritic alloys such as Grade 430; 420 also has slightly lower resistance than grade 410. Performance is best with a smooth surface finish.

This grade is commonly used for cutlery - particularly blades of table knives and for some carving knives and similar. The corrosion resistance is sufficient to resist food and normal washing methods, but prolonged contact with unwashed food residues can result in pitting. Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Not recommended for use in temperatures above the relevant tempering temperature, because of reduction in mechanical properties. The scaling temperature is approximately 650°C.

## Heat Treatment

### Annealing

Full anneal - 840-900°C, slow furnace cool to 600°C and then air cool.
Process Anneal - 735-785°C and air cool.

### Hardening

Heat to 980-1035°C, followed by quenching in oil or air. Oil quenching is necessary for heavy sections. Temper at 150-370°C to obtain a wide variety of hardness values and mechanical properties as indicated in the accompanying table.

The tempering range 425-600°C should be avoided.

## Welding

Pre-heat to 150-320°C and post-heat at 610-760°C. Grade 420 coated welding rods are recommended for high strength joints, where a post-weld hardening and tempering heat treatment is to be carried out.

If parts are to be used in the "as welded" condition, a ductile joint can be achieved by using Grade 309 filler rod. AS 1554.6 pre-qualifies welding of 420 with Grade 309 rods or electrodes.

## Machining

In the annealed condition this grade is relatively easily machined, but if hardened to above 30HRC machining becomes more difficult. Free machining grade 416 (refer Atlas Datasheet) is a very readily machined alternative.

## Typical Applications

Cutlery, knife blades, surgical instruments. Needle valves. Shear blades.

# Grade Data Sheet

# 420

## Specified Properties

These properties are specified for bar product in ASTM A276. Bar is the most commonly available form of grade 420. Similar but not necessarily identical properties are specified for other products such as plate and forgings in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 420 | min. | 0.15 | - | - | - | - | 12.00 | - | - | - |
| | max. | - | 1.00 | 1.00 | 0.040 | 0.030 | 14.00 | | | |

### Mechanical Properties - typical values

| Tempering Temperature (°C) | Tensile Strength (MPa) | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness Brinell (HB) | Impact Charpy V (J) |
|---|---|---|---|---|---|
| Annealed * | 655 | 345 | 25 | 255 max * | - |
| 204 | 1600 | 1360 | 12 | 444 | 20 |
| 316 | 1580 | 1365 | 14 | 444 | 19 |
| 427 | 1620 | 1420 | 10 | 461 | # |
| 538 | 1305 | 1095 | 15 | 375 | # |
| 593 | 1035 | 810 | 18 | 302 | 22 |
| 650 | 895 | 680 | 20 | 262 | 42 |

* Annealed tensile properties are typical for Condition A; annealed hardness is the specified maximum for cold finished Condition A bar, given in ASTM A276-06.

# Due to associated low impact resistance this steel should not be tempered in the range 425-600°C

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (μm/m/°C) | 0-315°C (μm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 420 | 7700 | 200 | 10.3 | 10.8 | 24.9 | - | 460 | 550 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 420 | S42000 | 1.4021 | X20Cr13 | 2303 | SUS 420J1 |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 420 |
|---|---|
| 410 | Only a lower hardened strength is needed. |
| 416 | High machinability is required, and the lower hardened strength and lower corrosion resistance of 416 is acceptable. |
| 440C | A higher hardened strength or hardness than can be obtained from 420 is needed. |
| "specials" | Variations of 420 are available to special order. These offer higher hardness, corrosion resistance and machinability for particular applications. |

# Grade Data Sheet

# 431

This heat treatable martensitic, nickel-bearing grade has the best corrosion resistance properties of all the martensitic grades. It has excellent tensile and torque strength, and good toughness, making it ideally suited to shafting and bolt applications. It can be hardened to approximately 40HRC. Because of its high yield strength, this grade is not readily cold worked and is therefore not recommended for use in operations such as cold heading, bending, deep drawing or spinning.

Martensitic stainless steels are optimised for high hardness, and other properties are to some degree compromised. Fabrication must be by methods that allow for poor weldability and usually also allow for a final harden and temper heat treatment. Corrosion resistance is generally lower than the common austenitic grades, and their useful operating temperature range is limited by their loss of ductility at sub-zero temperatures and loss of strength by over-tempering at elevated temperatures.

## Corrosion Resistance

Grade 431 has excellent resistance to a wide variety of corrosive media. Reasonable resistance to salt water in cold southern waters but is unlikely to be successful in warmer tropical waters. Overall the corrosion resistance of 431 is approximately the same as or slightly below that of Grade 304.

Performance is best with a smooth surface finish, in the hardened and tempered condition.

Consult Atlas Technical Services for specific environmental recommendations.

## Heat Resistance

Resists scaling in intermittent service to 925°C and in continuous service to 870°C, but is generally not recommended for use in temperatures above the relevant tempering temperature, because of reduction in mechanical properties.

## Heat Treatment

### Annealing

Full anneal - not practical for this grade - it hardens even when cooled slowly.
Process Anneal - heat to 620-660°C and air cool.

### Hardening

Hardened by heating to 980-1065°C, holding for about 1/2 hour then quenching in air or oil. Pre-heating at 760-790°C may be useful for complex parts or those already hardened. Temper to suit mechanical requirements, at temperatures as indicated in the accompanying table.

The tempering range 425-600°C should be avoided due to reduced impact toughness, although the effect is less marked than in most other martensitic grades.

## Welding

Welding is difficult due to the risk of cracking. A pre-heat of 200-300°C is recommended prior to welding. Grade 410 filler rod can be used, but Grades 308L, 309 or 310 will provide more ductile welds, so long as matching properties are not required. Post-weld heat treat at 650°C.

## Machining

In the annealed condition this grade is relatively easily machined, but if hardened to above 30HRC machining becomes more difficult. A Ugima Improved Machinability version of Grade 431 offers a significant improvement in achievable machining speeds and tool life.

## Typical Applications

Nuts and bolts. Propeller shafting. Pump shafts. Beater bars. Marine hardware.

# Grade Data Sheet

# 431

## Specified Properties

These properties are specified for bar product in ASTM A276. Similar but not necessarily identical properties are specified for other products such as plate and forgings in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 431 | min. | - | - | - | - | - | 15.00 | - | 1.25 | - |
| | max. | 0.20 | 1.00 | 1.00 | 0.040 | 0.030 | 17.00 | | 2.50 | |

### Mechanical Properties

(All values are typical except as noted)

| Tempering Temperature (°C) | Tensile Strength (MPa) | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness Brinell (HB) | Impact Izod (J) |
|---|---|---|---|---|---|
| Annealed * | 862 | 655 | 20 | 285 max * | - |
| Condition T ** | 850 - 1000 | 635 min. | 11 min. | 248 - 302 | |
| 300 | 1320 | 1020 | 20 | 380 | 75 |
| 400 | 1310 | 1010 | 22 | 395 | 80 |
| 500 | 1350 | 1030 | 20 | 395 | 55 # |
| 600 | 1030 | 800 | 20 | 310 | 45 # |
| 700 | 920 | 700 | 20 | 290 | 70 |

* Annealed tensile properties are typical for Condition A of ASTM A276; annealed hardness listed is the specified maximum. Grade 431 is only rarely stocked in annealed Condition A.

** Grade 431 is frequently stocked and supplied in "Condition T" to AS 1444 or BS 970, with specified tensile strength of 850 - 1000MPa. Yield and elongation are typically in conformance with the limits listed above. ASTM A276 only lists a Condition A version of Grade 431.

# Due to associated low impact resistance this steel should not be tempered in the range 425-600°C

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 431 | 7700 | 200 | 10.2 | 12.1 | - | 20.2 | - | 460 | 720 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 431 | S43100 | 1.4057 | X17CrNi16-2 | 2321 | SUS 431 |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 431 |
|---|---|
| 410 | Only a lower hardened strength is needed. |
| 416 | High machinability is required, and the lower hardened strength and lower corrosion resistance of 416 is acceptable. |
| 440C | A higher hardened strength or hardness than can be obtained from 431 is needed. |

# Grade Data Sheet

# 440C

**Grade 440C** is capable of attaining, after heat treatment, the highest strength, hardness (Rockwell C 60) and wear resistance of all the stainless alloys. Its very high carbon content of 1.0% is responsible for these characteristics, which make 440C particularly suited to such applications as ball bearings and valve parts.

Grades **440A** and **440B** are identical except for slightly lower carbon contents (0.60 - 0.75% and 0.75 - 0.95% respectively); these have lower attainable hardnesses but slightly higher corrosion resistances. Although all three versions of this grade are standard, in practice 440C is more available than the A or B variants; none of these are regularly stocked in Australia however.

A free-machining variant **440F** (UNS S44020) also exists, with the same high carbon content as 440C. Again this grade is not readily available in Australia.

Martensitic stainless steels are optimised for high hardness, and other properties are to some degree compromised. Fabrication must be by methods that allow for poor weldability and also allow for a final harden and temper heat treatment. Corrosion resistance is generally lower than the common austenitic grades, and their useful operating temperature range is limited by their loss of ductility at sub-zero temperatures and loss of strength by over-tempering at elevated temperatures.

## Corrosion Resistance

Good resistance to the atmosphere, fresh water, foods, alkalies and mild acids. Best resistance in the hardened and tempered and passivated condition. A smooth polished surface also assists.

The corrosion resistance of Grade 440C is close to that of grade 304 in many environments.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

Not recommended for use in temperatures above the relevant tempering temperature, because of reduction in mechanical properties by over-tempering.

## Heat Treatment

### Annealing

Full anneal - 840-870°C, slow furnace cool to about 600°C and then air cool.
Sub-critical Annealing - 735-760°C and slow furnace cool.

### Hardening

Heat to 1010-1065°C, followed by quenching in warm oil or air. Oil quenching is necessary for heavy sections. Immediately temper at 150-370°C to obtain the hardness values and mechanical properties as indicated in the accompanying table.

Best corrosion resistance is when tempered below 425°C. Tempering in the range 425-565°C is to be avoided because of reduced impact resistance and corrosion resistance. Tempering in the range 600-675°C results in lower hardness – the product becomes machinable.

Maximum achievable hardnesses are approximately HRC56 for Grade 440A, HRC58 for 440B and HRC60 for 440C.

## Welding

Welding is seldom carried out because of the grades' high hardenability. If welding is necessary pre-heat at 250°C and follow welding with a full anneal. Grade 420 filler will give a high hardness weld (although not as high as the 440C), but 309 or 310 will produce soft welds with higher ductility.

## Machining

In the annealed condition this grade is relatively easily machined; approximately the same as for high speed steel. Chips are tough and stringy so chip breakers are important. If these grades are hardened machining becomes more difficult and probably impossible.

## Typical Applications

Rolling element bearings, valve seats, high quality knife blades, surgical instruments and chisels.

# Grade Data Sheet

# 440C

## Specified Properties

These properties are specified for bar product in ASTM A276. Similar but not necessarily identical properties are specified for other products such as wire and forgings in their respective specifications. These grades are not normally available in flat rolled or fluids products.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Mo | Ni | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 440A | min. | 0.65 | - | - | - | - | 16.00 | - | - | - |
| | max. | 0.75 | 1.00 | 1.00 | 0.040 | 0.030 | 18.00 | 0.75 | | |
| 440B | min. | 0.75 | - | - | - | - | 16.00 | - | - | - |
| | max. | 0.95 | 1.00 | 1.00 | 0.040 | 0.030 | 18.00 | 0.75 | | |
| 440C | min. | 0.95 | - | - | - | - | 16.00 | - | - | - |
| | max. | 1.20 | 1.00 | 1.00 | 0.040 | 0.030 | 18.00 | 0.75 | | |

### Mechanical Properties - 440C - typical and specified values

| Tempering Temperature (°C) | Tensile Strength (MPa) | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness Rockwell (HR C) | Impact Charpy V (J) |
|---|---|---|---|---|---|
| Annealed * | 758 | 448 | 14 | 269HB max # | - |
| 204 | 2030 | 1900 | 4 | 59 | 9 |
| 260 | 1960 | 1830 | 4 | 57 | 9 |
| 316 | 1860 | 1740 | 4 | 56 | 9 |
| 371 | 1790 | 1660 | 4 | 56 | 9 |

* Annealed properties are typical for Grade 440C ASTM A276 annealed condition.

\# Brinell Hardness is ASTM A276 specified maximum for annealed 440A, B and C, hot finished.

## Physical Properties

(typical values in the annealed condition)

| Grade | Density ($kg/m^3$) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-200°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 440A/B/C | 7650 | 200 | 10.1 | 10.3 | 24.2 | - | 460 | 600 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 440A | S44002 | - | - | | SUS 440A |
| 440B | S44003 | 1.4112 | X90CrMoV18 | | SUS 440B |
| 440C | S44004 | 1.4125 | X105CrMo17 | - | SUS 440C |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 440C |
|---|---|
| 440A/B | Slightly softer and more corrosion resistant grade needed |
| 440F | High machinability required, with same hardness and hardenability as 440C |
| 420 | Lower strength and hardness needed than any of the 440 grades |
| 416 | Higher machinability required, and the much lower hardness and strength is still adequate |

# Grade Data Sheet

# 630 (17-4PH)

**Grade 630** martensitic precipitation hardening stainless steel has a combination of high hardness and strength after suitable heat treatment. It also has similar corrosion and heat resistance to Grade 304. The terms "Type 630" and "17-4PH" refer to the same grade.

The great benefit of this grade (and of other precipitation hardening grades of stainless steel) is that they are generally supplied in the solution treated condition, in which they are just machinable, and then can be age hardened to achieve quite high strengths. This aging treatment is so low in temperature that there is no significant distortion. These grades are therefore well suited to production of long shafts, which require no re-straightening after heat treatment.

## Corrosion Resistance

Good resistance to a wide range of corrosive environments; approaching that of Grade 304 stainless steel. Like 304, this grade is subject to pitting and crevice corrosion in warm chloride environments. Grade 630 has been used for boat shafting for fresh water, and in sea water with the addition of cathodic protection.

Highly resistant to stress corrosion cracking if aged at 550°C or higher. Higher aging temperatures give better SCC resistance. Grade 630 is resistant to sulphide stress cracking (SSC) if highly aged; NACE MR0175 permits the use of 630 but only in a double age hardened condition (refer to MR0175 and ASTM A564M).

In solution treated Condition A the grade has lower resistance to stress corrosion cracking, and lower ductility compared to aged conditions. It should not generally be used in the solution treated condition, even if the hardness is considered satisfactory.

Consult Atlas Technical Assistance for specific environmental recommendations.

## Heat Resistance

This grade has good oxidation resistance, but to avoid reduction of its mechanical properties and hardness it should not be used above its age hardening temperature. Prolonger exposure in the range 370-480°C should be avoided if ambient temperature toughness is critical.

## Heat Treatment

### Solution treatment (Condition A)

Heat at 1040°C for ½ hour and cool to 30°C maximum in air. Oil quenching may be used for small non-intricate sections.

### Hardening (Aging)

After solution treatment a single low temperature "age hardening" treatment is employed to achieve required properties, as below. This treatment results in no distortion and only superficial discolouration. A slight decrease in size (shrinkage) takes place during the hardening; this is approximately 0.05% for Condition H900 and 0.10% for H1150.

Typical mechanical properties achieved after solution treating and then age hardening at the indicated temperatures are as in the table in the following page. The Condition is designated by the age hardening temperature in °F (Condition A is solution treated, ie not aged).

## Welding

Grade 630 can be successfully welded by all standard methods. Preheating is not necessary. Properties comparable to those of the parent metal may be achieved in the weld metal by post-weld heat treatment. As for other high strength steels precaution should be taken in design and welding procedures to avoid concentration of weldment stresses.

## Machining

This steel is usually supplied in the solution treated condition, in which it can be machined. Machinability is similar to Grade 304.

## Typical Applications

Gears, bolts and valve components. Plastic moulding dies. High strength pump shafts and boat propeller shafts. Engine components. In general applications where some level of corrosion resistance is needed in conjunction with high strength or hardness.

# Grade Data Sheet

# 630 (17-4PH)

## Specified Properties

These properties are specified for bar products in ASTM A564/A564M; round bar is the most commonly available product form for this grade. Similar but not necessarily identical properties are specified for other products such as plate and forgings in their respective specifications.

### Composition Specification (%)

| Grade | | C | Mn | Si | P | S | Cr | Ni | Cu | Nb+Ta |
|---|---|---|---|---|---|---|---|---|---|---|
| 630 | min. | - | - | - | - | - | 15.0 | 3.0 | 3.0 | 0.15 |
| | max | 0.07 | 1.00 | 1.00 | 0.040 | 0.030 | 17.5 | 5.0 | 5.0 | 0.45 |

### Mechanical Property Specification

| Condition | Hardening | | Tensile Strength (MPa) | Yield Strength 0.2% Proof (MPa) | Elongation (% in 50mm) | Hardness | |
|---|---|---|---|---|---|---|---|
| | Temp (°C) | Time (h) | | | | Rockwell C (HR C) | Brinell (HB) |
| A | - | - | 1105 typ. | 1000 typ. | 15 typ. | 38 max | 363 max |
| H900 | 480 | 1 | 1310 | 1170 | 10 | 40 | 388 |
| H925 | 495 | 4 | 1170 | 1070 | 10 | 38 | 375 |
| H1025 | 550 | 4 | 1070 | 1000 | 12 | 35 | 331 |
| H1075 | 580 | 4 | 1000 | 860 | 13 | 32 | 311 |
| H1100 | 595 | 4 | 965 | 795 | 14 | 31 | 302 |
| H1150 | 620 | 4 | 930 | 725 | 16 | 28 | 277 |

Single property values are minima except as noted as typical or maximum.

Values from ASTM A564M; these values apply only to certain size ranges. The specification should be consulted for the complete details of these properties and of heat treatment procedures.

Solution treatment is at 1040°C followed by cooling as required.

Specialist double-aging treatments H1150M and H1150D are also possible – refer to ASTM A564M.

## Physical Properties

(typical values in the annealed condition)

| Grade | Density (kg/m³) | Elastic Modulus (GPa) | Mean Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat | Electrical Resistivity |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0-100°C (µm/m/°C) | 0-315°C (µm/m/°C) | 0-538°C (µm/m/°C) | at 100°C (W/m.K) | at 500°C (W/m.K) | 0-100°C ( J/kg.K) | (nΩ.m) |
| 630 | 7750 | 196 | 10.8 | 11.6 | - | 18.4 | 22.7 | 460 | 800 |

## Grade Specification Comparison

| Grade | UNS No | Euronorm | | Swedish SS | Japanese JIS |
|---|---|---|---|---|---|
| | | No | Name | | |
| 630 | S17400 | 1.4542 | X5CrNiCuNb16-4 | - | SUS 630 |

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

## Possible Alternative Grades

| Grade | Why it might be chosen instead of 630 (17-4PH) |
|---|---|
| 431 | 431 has higher toughness than 630. Better availability in some sizes. |
| 416 | Free machining martensitic stainless steel - better machinability. Lower cost but lower corrosion resistance. |
| 316 | Higher corrosion resistance of 316 is needed, but with much lower strength than 630. |
| 2205 | Much better corrosion resistance than 630, with a lower strength (but not as low as 316). |