Stainless Steel

Grade Datasheets

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Stainlessinox
Technical Department

www.stainlessinox.com

STAINLESSINOX

Stainless Steel Datasheets

Austenitic Stainless Steels

301, 301L, 301LN	High strength for roll formed structural components
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

409	Automotive exhaust grade – weld stabilised
430	Resistant to mildly corrosive environments

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

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

STAINLESSINOX

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.

STAINLESSINOX

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

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

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/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)
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.

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

Grade Data Sheet

321 321H 347

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.

STAINLESSINOX

Grade Data Sheet

321 321H 347

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.

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

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/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 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. 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.

STAINLESSINOX

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

STAINLESSINOX

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 S40900	min.	-	-	-	-	-	10.5	-		6x%C	
	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.

STAINLESSINOX

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.

STAINLESSINOX

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/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
			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)		
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.

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

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.

STAINLESSINOX

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. 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+ 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.

STAINLESSINOX

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.

STAINLESSINOX

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.