

Technical Data

CS316

CS316L

CS316Ti



COLUMBUS
STAINLESS
— [Pty] Ltd —

Technical Data

www.columbusstainless.co.za

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INTRODUCTION

CS316 is a molybdenum bearing austenitic stainless steel with a slightly higher nickel content than CS304. The resultant composition of the CS316 types gives these steels much improved corrosion resistance in many aggressive environments. The molybdenum addition ensures more resistance to pitting and crevice corrosion in chloride containing media, sea water and chemical environments such as sulphuric acid compounds, phosphoric and acetic acids. The lower rate of general corrosion in mildly corrosive environments gives the steel good atmospheric corrosion resistance in polluted marine atmospheres.

CS316 offers higher strength and better creep resistance than CS304. This alloy also possesses excellent mechanical and corrosion resistant properties at sub-zero temperatures. CS316L is a low carbon modification of CS316. The control of the carbon to a maximum of 0.03%, minimises the problem of carbide precipitation during welding and permits the use of the steel in the as-welded condition in a wide variety of corrosive applications.

CS316Ti is a titanium stabilised version of CS316 and is used for its resistance to sensitisation during prolonged exposure to temperatures between 550°C and 800°C.

1.4402 has been specifically designed for use in tank containers and has enhanced mechanical properties to aid in tank container design.

PRODUCT RANGE

The latest revision of the Product Guide should be consulted, as the product range is subject to change without notice. The Product Guide is available from the Technical Customer Services Department or can be found at www.columbusstainless.co.za

SPECIFICATIONS & TOLERANCES

Columbus Stainless (Pty) Ltd supplies CS316 to ASTM A240 (316, 316L and 316Ti), EN 10088-2 and EN 10028-7 (1.4401, 1.4404, 1.4432, 1.4435, 1.4436 & 1.4571) and SANS 50028-7 (1.4402).

Columbus Stainless (Pty) Ltd normally supplies material to the following tolerances:

HOT ROLLED

ASTM A480M

ASME SA480M

EN 10051 and EN 10029 Class B

COLD ROLLED

ASTM A480M

ASME SA480M

EN ISO 9445

Other tolerances may be available on request. Further information is available in the Product Guide, which can be obtained from the Technical Customer Services Department or can be found at www.columbusstainless.co.za

CHEMICAL COMPOSITION

In accordance with ASTM A240 (316, 316L and 316Ti), EN 10088-2 and EN 10028-7 (1.4401, 1.4404, 1.4432, 1.4435, 1.4436 and 1.4571) and SANS 50028-7 (1.4402).

Type	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo	%N	%Ti
316	0.080 max	0.75 max	2.00 max	0.045 max	0.030 max	16.00 18.00	10.00 14.00	2.00 3.00	0.10 max	
316L	0.030 max	0.75 max	2.00 max	0.045 max	0.030 max	16.00 18.00	10.00 14.00	2.00 3.00	0.10 max	
316Ti	0.080 max	0.75 max	2.00 max	0.045 max	0.030 max	16.00 18.00	10.00 14.00	2.00 3.00	0.10 max	5x(C+N) 0.70
1.4401	0.070 max	1.00 max	2.00 max	0.045 max	0.015 max	16.50 18.50	10.00 13.00	2.00 2.50	0.11 max	
1.4402	0.030 max	1.00 max	2.00 max	0.045 max	0.015 max	16.50 18.50	10.00 13.00	2.00 2.50	0.11 max	
1.4404	0.030 max	1.00 max	2.00 max	0.045 max	0.015 max	16.50 18.50	10.00 13.00	2.00 2.50	0.11 max	
1.4432	0.030 max	1.00 max	2.00 max	0.045 max	0.015 max	16.50 18.50	10.50 13.00	2.50 3.00	0.11 max	
1.4435	0.030 max	1.00 max	2.00 max	0.045 max	0.015 max	17.00 19.00	12.50 15.00	2.50 3.00	0.11 max	
1.4436	0.050 max	1.00 max	2.00 max	0.045 max	0.015 max	16.50 18.50	10.50 13.00	2.50 3.00	0.11 max	
1.4571	0.080 max	1.00 max	2.00 max	0.045 max	0.015 max	16.50 18.50	10.50 13.00	2.00 2.50		5xC 0.70

MECHANICAL PROPERTIES

In accordance with ASTM A240 (316, 316L and 316Ti), EN 10028-7 (1.4401, 1.4404, 1.4432, 1.4435, 1.4436 and 1.4571) and SANS 50028-7 (1.4402).

Type	Product Form ¹	0.2% Proof Stress (MPa)	1.0% Proof Stress (MPa)	Tensile Strength (MPa)	Elongation (%)	Brinell Hardness	Impact Energy (J) ⁴
316	All	205 min		515 min	40 min ²	217 max	
316L	All	170 min		485 min	40 min ²	217 max	
316Ti	All	205 min		515 min	40 min ²	217 max	
1.4401 1.4404	C	240 min	270 min	530 680	40 min ^{3,4}		
	H	220 min	260 min	530 680	40 min ³		
	P	220 min	260 min	520 670	45 min ³		60 min ⁵
1.4402	C	290 min	330 min	600 680	50 min ^{3,4}		
	H	290 min	320 min	590 680	48 min ³		
1.4432 1.4435	C	240 min	270 min	550 700	40 min ^{3,4}		
	H	220 min	260 min	550 700	40 min ³		
	P	220 min	260 min	520 670	45 min ³		60 min ⁵
1.4436	C	240 min	270 min	550 700	40 min ^{3,4}		
	H	220 min	260 min	550 700	40 min ³		
	P	220 min	260 min	530 730	40 min ³		60 min ⁵
1.4571	C	240 min	270 min	540 690	40 min ^{3,4}		
	H	220 min	260 min	540 690	40 min ³		
	P	220 min	260 min	520 670	40 min ³		60 min ⁵

1) C = cold rolled strip, H = hot rolled strip ≤ 8mm, P = hot rolled plate > 8mm.

2) Elongation over a gauge length of 50mm.

3) Proportional elongation with the gauge length = $5.65\sqrt{S_0}$

(S_0 = cross-sectional area of the test piece).

4) For gauges < 3mm, elongation gauge length is 50mm.

5) For gauges > 10mm, transverse direction at 20°C.

PROPERTIES AT ELEVATED TEMPERATURES

The properties quoted below are typical of annealed CS316 and CS316Ti only as strength values for CS316L fall rapidly at temperatures above 425°C. These values are given as a guideline only, and should not be used for design purposes.

SHORT TIME ELEVATED TEMPERATURE TENSILE PROPERTIES

Temperature (°C)	100	300	500	600	700	800	900	1 000	1 100
Tensile Strength (MPa)	540	500	480	450	350	205	100	50	25
0.2% Proof Stress (MPa)	235	165	145	140	130	115			
Elongation (% in 50mm)	52	48	47	44	43	42	63	62	76

MAXIMUM RECOMMENDED SERVICE TEMPERATURE

(In oxidising conditions)

Operating Conditions	Temperature (°C)
Continuous	920
Intermittent	870

REPRESENTATIVE CREEP & RUPTURE PROPERTIES

Temperature (°C)	Stress (MPa) to Produce 1% Strain		Stress (MPa) to Produce Rupture	
	10 000 hours	100 000 hours	1 000 hours	10 000 hours
550	225	125	320	270
600	145	80	220	170
650	95	55	160	110
700	65	35	110	70
750	40	20	75	45
800	30	15	55	30
850	20	10	35	20

PROPERTIES AT SUB-ZERO TEMPERATURES

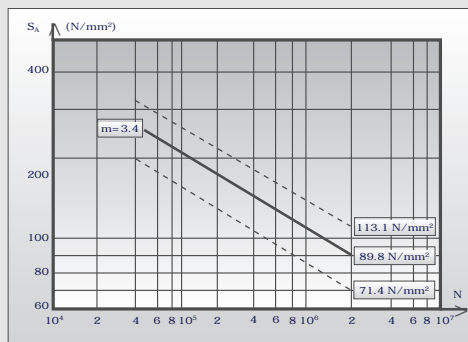
The properties quoted below are typical of annealed CS316 only

Temperature (°C)	20	0	-10	-50	-140	-196
Tensile Strength (MPa)	584	680	832	1 105	1 136	1 360
0.2% Proof Stress (MPa)	235	260	336	380	417	444
Elongation (%)	61	70	69	65	61	58
Impact Energy (J)	170	191	186	183	155	166

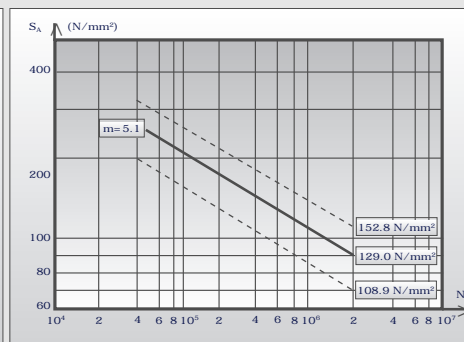
FATIGUE CONSIDERATIONS

When looking into the fatigue of austenitic stainless steels, it is important to note that design and fabrication – not material, are the major contributors to fatigue failure. Design codes (e.g. ASME and BS 5500) use data from low-cycle fatigue tests carried out on machined specimens to produce conservative S-N curves used with stress concentration factors (k_{1c}) or fatigue strength reduction factors (k_f). In essence, the fatigue strength of a welded joint should be used for design purposes, as the inevitable flaws (even only those of cross-sectional change) within a weld will control the overall fatigue performance of the structure.

The curves show results of welded joints under variable loading for austenitic stainless steel CS316Ti following Eurocode 3. When compared with the literature, the fatigue properties of CS316Ti appear to be similar to those of mild steel.



Fatigue strength of stainless steel specimens with longitudinal rib



Fatigue strength of stainless steel specimens with transverse rib

Survival probabilities

- 1 - 2.5%
- 2 - 50%
- 3 - 97.5%

Ref. Eurocode 3

PHYSICAL PROPERTIES

The values given below are for 20°C, unless otherwise specified.

Density	8 000kg/m ³
Modulus of Elasticity in Tension	193GPa
Modulus of Elasticity in Torsion	70GPa
Poisson's Ratio	0.25
Specific Heat Capacity	500J/kgK
Thermal Conductivity: @ 100°C	16.2W/mK
@ 500°C	21.5W/mK
Electrical Resistivity	740η m
Mean Co-efficient of Thermal Expansion: 0 – 100°C	15.9μm/mK
0 – 315°C	16.2μm/mK
0 – 540°C	17.5μm/mK
0 – 700°C	18.5μm/mK
Melting Range	1 390–1 430°C
Relative Permeability	1.02
(Note: this grade is non-magnetic becoming slightly magnetic after cold working)	

THERMAL PROCESSING & FABRICATION

ANNEALING

Annealing of types CS316 and CS316L is achieved by heating to between 1 010°C and 1 120°C for 90 minutes per 25mm thickness followed by water or air quenching. The best corrosion resistance is achieved when the final annealing temperature is above 1 070°C. CS316Ti should not be annealed above 1 066°C. Controlled atmospheres are recommended in order to avoid excessive oxidation of the surface.

STRESS RELIEVING

The lower carbon grade (CS316L) can be stress relieved at 450°C to 600°C for 60 minutes with little danger of sensitisation. A lower stress relieving temperature of 400°C maximum must be used with CS316 with longer soaking times. If, however, stress relieving is to be carried out above 600°C, there is a serious threat of grain boundary sensitisation occurring with a concomitant loss in corrosion resistance. In this instance, a stabilised grade such as 316Ti should be used.

HOT WORKING

CS316 can be readily forged, upset and hot headed. Uniform heating of the steel in the range of 1 150°C to 1 250°C is required. The finishing temperature should not be below 900°C. Upsetting operations and forgings require a finishing temperature between 930 and 980°C. Forgings should be air cooled. All hot working operations should be followed by annealing and pickling and passivation to restore the mechanical properties and corrosion resistance.

COLD WORKING

CS316 types, being extremely tough and ductile, can be readily deep drawn, stamped, headed and upset without difficulty. Since CS316 types work harden, severe cold forming operations should be followed by annealing.

MACHINING

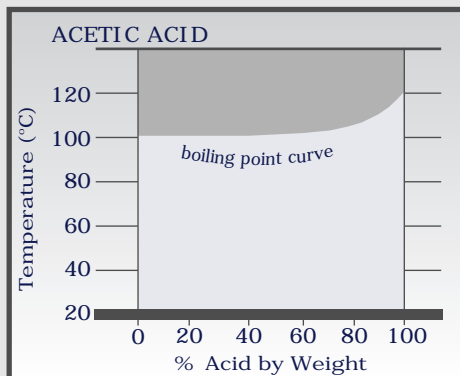
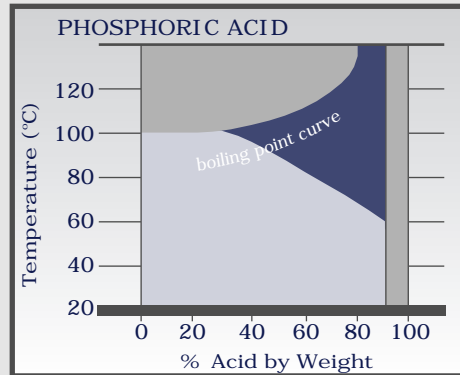
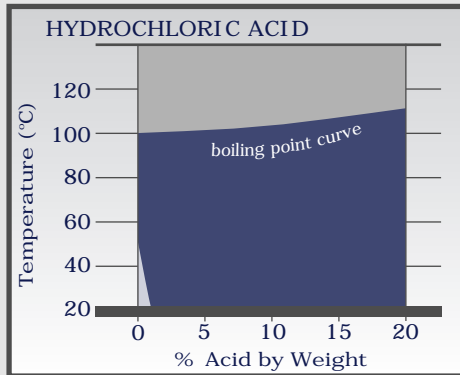
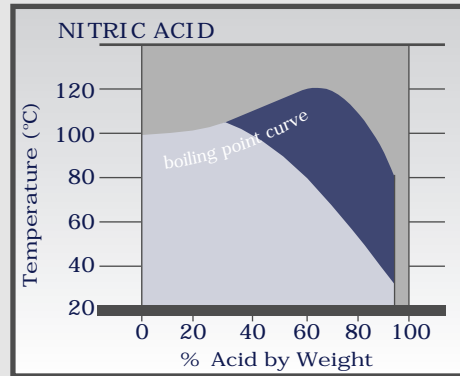
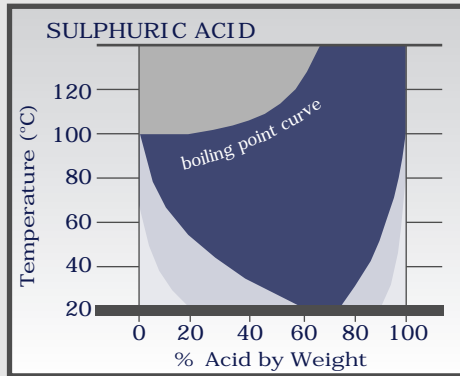
Like all the austenitic steels, this alloy group machines with a rough and stringy swarf. Rigidly supported tools with as heavy a cut as possible should be used to prevent glazing.

WELDING

CS316 types have good welding characteristics and are suited to all standard welding methods. Either matching or slightly over-alloyed filler wires (e.g. ERW 309Mo) should be used. For maximum corrosion resistance, the higher carbon type CS316 should be annealed after welding to dissolve any chromium carbides which may have precipitated. The weld discolouration should be removed by pickling and passivation to restore maximum corrosion resistance.

CORROSION RESISTANCE

CS316 types have superior corrosion resistance to CS304 types. CS316 has good resistance to most complex sulphur compounds such as those found in the pulp and paper industry. CS316 also has good resistance to pitting in phosphoric and acetic acids. CS316 has excellent resistance to corrosion in marine environments under atmospheric conditions.

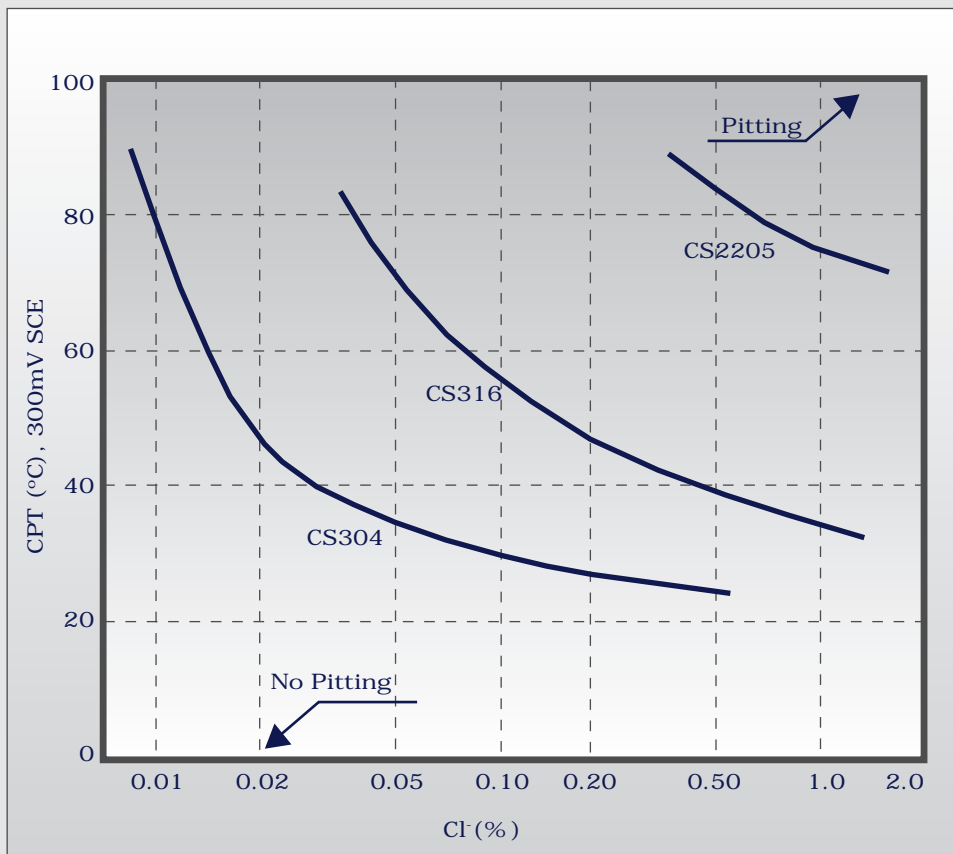


KEY

	mils per year	mm per year
	< 4	< 0.1
	4-40	0.1-1
	> 40	> 1

PITTING CORROSION

Pitting resistance is important, mainly in applications involving contact with chloride solutions, particularly in the presence of oxidising media. These conditions may be conducive to localised penetration of the passive surface film on the steel and a single deep pit may well be more damaging than a much greater number of relatively shallow pits. The addition of molybdenum to the steel ensures that CS316 has good resistance to localised corrosion such as pitting and crevice corrosion. The diagram below shows the critical temperature for initiation of pitting (CPT) at different chloride contents for CS304, CS316 and CS2205 types.



Critical pitting temperatures (CPT) for CS304, CS316 and CS2205 at varying concentrations of sodium chloride (potentiostatic determination at + 300 mV SCE). pH = 6.0.

OXIDATION

CS316 types have good oxidation resistance in intermittent service up to 870°C and in continuous service to 920°C. Continuous use of type CS316 in the 450° to 850°C temperature range is not recommended due to carbide precipitation but CS316 often performs well in temperatures fluctuating above and below this range. One should use the “L” variant in these applications.

ATMOSPHERIC CORROSION

The atmospheric corrosion resistance of austenitic stainless steel is unequalled by virtually all other uncoated engineering materials. Stainless steel develops maximum resistance to staining and pitting with the addition of molybdenum. For this reason, it is common practice to use the CS316 molybdenum bearing grade in areas where the atmosphere is highly polluted with chlorides, sulphur compounds and solids, either singly or in combination. However, in urban and rural areas CS304 generally performs satisfactorily.

INTERGRANULAR CORROSION

Sensitisation may occur when the Heat Affected Zones of welds in some austenitic stainless steels are cooled through the sensitising temperature range of between 450°C and 850°C. At this temperature, a compositional change may occur at the grain boundaries. If a sensitised material is then subjected to a corrosive environment, intergranular attack may be experienced. This corrosion takes place preferentially in the heat affected zone away from and parallel to the weld. Susceptibility to this form of attack, often termed “weld decay”, may be assessed by the following standard tests:

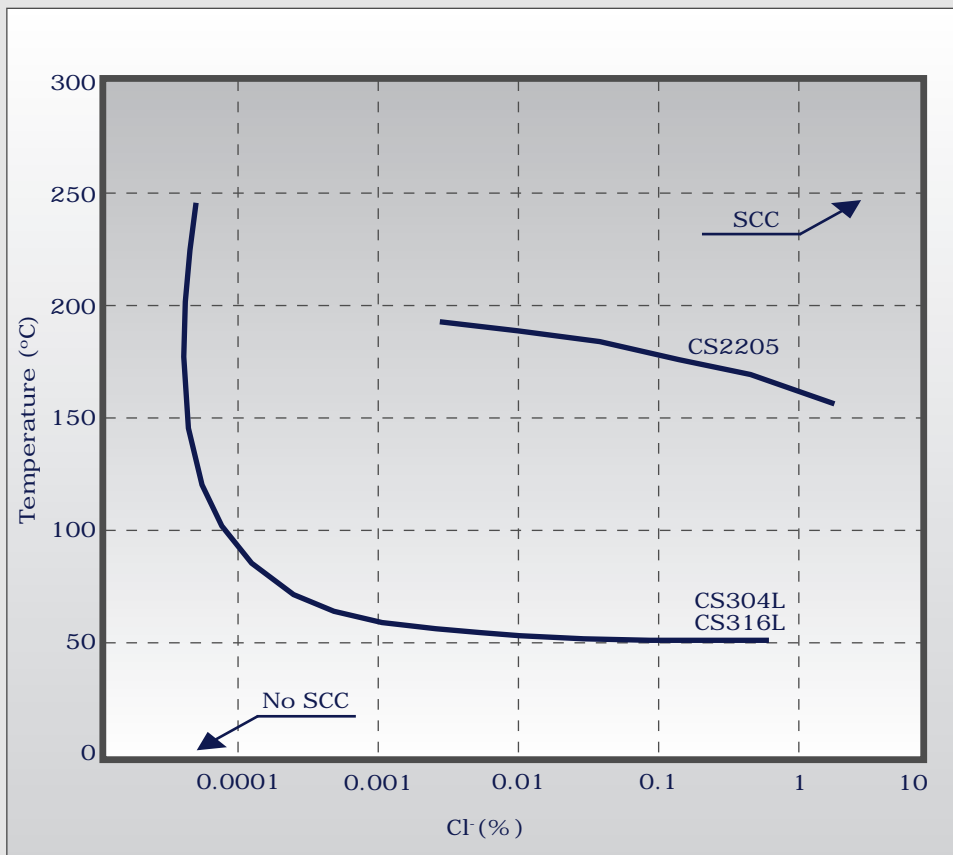
- a) boiling copper sulphate/sulphuric acid test as specified in ASTM A262-98, Practice E.
- b) for non titanium stabilised grades only, boiling nitric acid test as specified in ASTM A262-98, Practice C.

CS316 has reasonable resistance to carbide precipitation. The low carbon “L” grades should in any case be specified for welded structures unless the higher carbon types are required for their increased strength at elevated temperatures. In this case, CS316Ti should be specified.

STRESS CORROSION CRACKING

Stress corrosion cracking (SCC) can occur in austenitic stainless steels when they are stressed in tension in chloride environments at temperatures in excess of about 60°C. The stress may be applied, as in a pressure system or it may be residual arising from cold working operations or welding. Additionally, the chloride ion concentration need not be very high initially, if locations exist in which concentrations of salt can accumulate. Assessment of these parameters and accurate prediction of the probability of SCC occurring in service is therefore difficult.

Where there is a likelihood of SCC occurring, a beneficial increase in life can be easily obtained by a reduction in operating stress and temperature. Alternatively, specially designed alloys, such as CS2205, a duplex stainless steel, will have to be used where SCC is likely to occur.



Resistance to Stress Corrosion Cracking (Laboratory results) for CS304L, CS316L and CS2205.

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