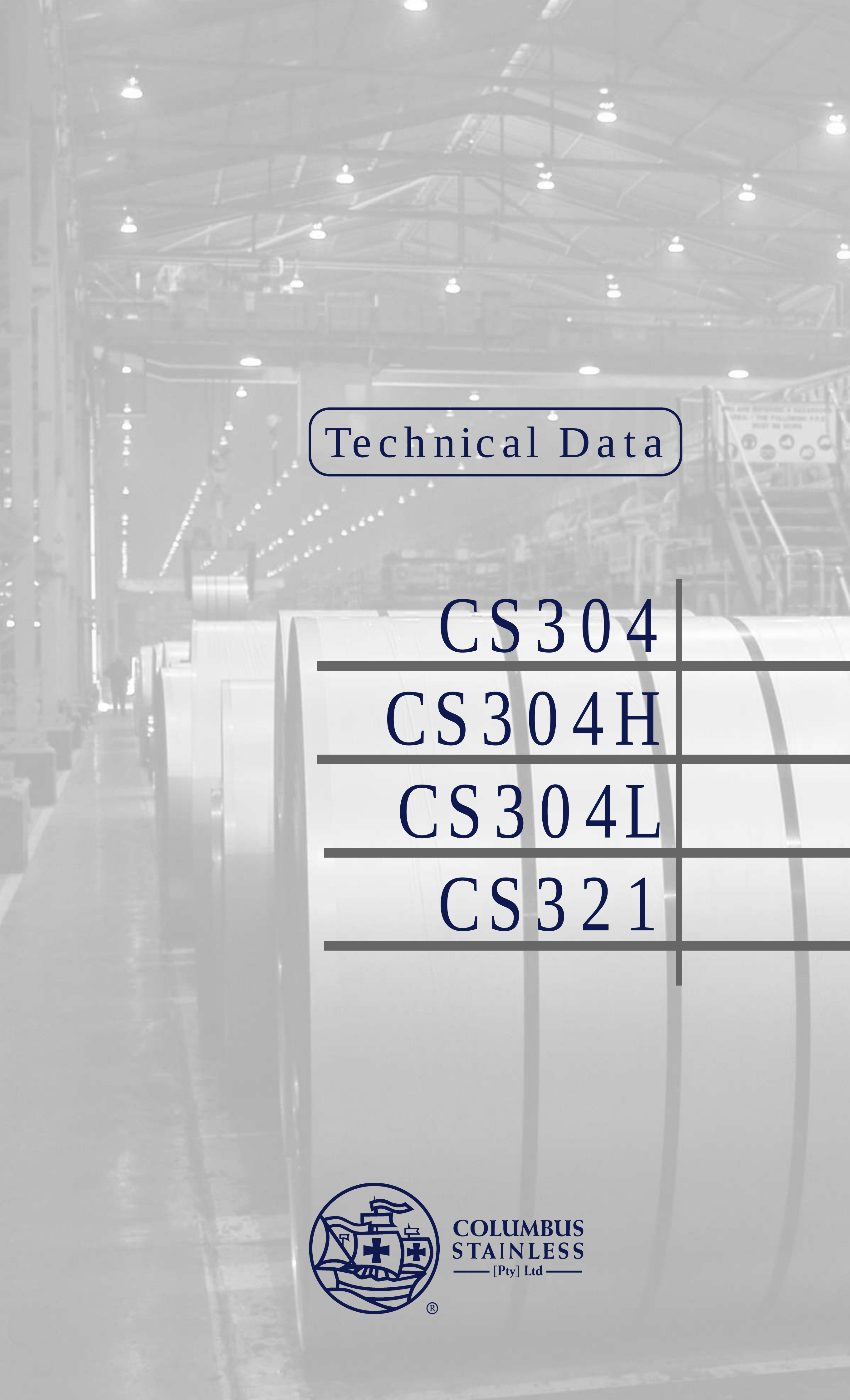

Technical Data

CS304
CS304H
CS304L
CS321

COLUMBUS STAINLESS [Pty] Ltd

Technical Data

www.columbusstainless.co.za

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INTRODUCTION

Types CS304, CS304L and CS304H are the most versatile and widely used of all the stainless steels. Their chemical composition, mechanical properties, weldability and corrosion/oxidation resistance provide the best all-round performance stainless steels at relatively low cost. They have excellent low temperature properties and respond well to hardening by cold working. The carefully controlled chemical composition of the CS304 types enables them to be deep drawn more severely than AISI types 301 and 302, without intermediate annealing. This has made them dominant in the manufacture of drawn stainless steel parts such as sinks and saucepans. They are readily press-braked or roll formed into a variety of shapes for applications in the industrial, architectural and transportation fields.

The CS304 types have good welding characteristics. Post weld annealing is not normally required to restore the excellent performance of these grades in a wide range of mildly corrosive conditions. Type CS304L does not require post weld annealing and finds extensive use in heavy gauge components where freedom from carbide precipitation is often required.

Type CS304H, with a higher carbon content, is normally specified where good mechanical properties at elevated temperatures are required. The higher carbon content may lead to sensitisation with a concomitant loss of corrosion resistance in a corrosive environment. Welding procedures should be selected with care.

Type CS321 is a titanium stabilised version of CS304 and is used in applications exposed to the temperature range 450°C to 850°C where there is a high risk of sensitisation. CS321 has higher elevated temperature properties than CS304. Although having good resistance to oxidation and sensitisation, CS321 is unsuitable for use in highly oxidising environments due to possible “knifeline” attack. Typical applications for CS321 would include furnace parts, after burners, expansion bellows, compensators, catalytic converters, etc.

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 CS304/CS321 to ASTM A240 (304, 304H, 304L and 321), EN 10088-2, EN 10028-7 (1.4301, 1.4306, 1.4307 and 1.4541) and EN 10095 (1.4878).

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 (304, 304H, 304L and 321), EN 10088-2, EN 10028-7 (1.4301, 1.4306, 1.4307 and 1.4541) and EN 10095 (1.4878).

Type	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%N	%Ti
304	0.080 max	0.75 max	2.00 max	0.045 max	0.030 max	17.50 19.50	8.00 10.50	0.100 max	
304H	0.040 0.100	0.75 max	2.00 max	0.045 max	0.030 max	18.00 20.00	8.00 10.50		
304L	0.030 max	0.75 max	2.00 max	0.045 max	0.030 max	17.50 19.50	8.00 10.50	0.100 max	
321	0.080 max	0.75 max	2.00 max	0.045 max	0.030 max	17.00 19.00	9.00 12.00	0.10 max	5x(C+N) 0.70
1.4301	0.070 max	1.00 max	2.00 max	0.045 max	0.015 max	17.00 19.50	8.00 10.50	0.11 max	
1.4306	0.030 max	1.00 max	2.00 max	0.045 max	0.015 max	18.00 20.00	10.00 12.00	0.11 max	
1.4307	0.030 max	1.00 max	2.00 max	0.045 max	0.015 max	17.50 19.50	8.00 10.00	0.11 max	
1.4541	0.080 max	1.00 max	2.00 max	0.045 max	0.015 max	17.00 19.00	9.00 12.00		5xC 0.70
1.4878	0.100 max	1.00 max	2.00 max	0.045 max	0.015 max	17.00 19.00	9.00 12.00		5xC 0.80

MECHANICAL PROPERTIES

In accordance with ASTM A240 (304, 304H, 304L and 321), EN 10088-2, EN 10088-7 (1.4301, 1.4306, 1.4307 and 1.4541) and EN 10095 (1.4878).

Type	Product Form[1]	0.2% Proof Stress (MPa)	1.0% Proof Stress (MPa)	Tensile Strength (MPa)	Elongation (%)	Brinell Hardness	Impact Energy (J)
304 304H	All	205 min		515 min	40 min[2]	201 max	
304L	All	170 min		485 min	40 min[2]	201 max	
321	All	205 min		515 min	40 min[2]	217 max	
1.4301	C	230 min	260 min	540 750	45 min[3,4,5]		
	H	210 min	250 min	520 720	45 min[3,5]		60 min[6]
	P	210 min	250 min	520 720	45 min[3]		60 min[6]
1.4306 1.4307	C	220 min	250 min	520 670	45 min[3,4]		
	H	200 min	240 min	520 670	45 min[3]		60 min[6]
	P	200 min	240 min	500 650	45 min[3]		60 min[6]
1.4541	C	220 min	250 min	520 720	40 min[3,4]		
	H	200 min	240 min	520 720	40 min[3]		60 min[6]
	P	200 min	240 min	500 700	40 min[3]		60 min[6]
1.4878	All	190 min	230 min	520 720	40 min[3,4]	215 max	

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 over a gauge length of 50mm.

5) For stretcher levelled material, the minimum value is 5% lower.

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

PROPERTIES AT ELEVATED TEMPERATURES

The properties quoted below are typical of annealed CS304 and CS321 only as strength values for CS304L 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)								
Property	Type	100	300	500	600	700	800	900	1 000	1 100
Tensile Strength (MPa)	304	510	435	410	360	245	135	75	40	20
	321	525	405	380	335	265	175	100	60	25
0.2% Proof Stress (MPa)	304	220	145	125	110	95	70			
	321	210	165	140	130	115	95			
Elongation (% in 50mm)	304	52	40	36	35	35	37	42	73	96
	321	50	43	37	37	48	68	62	62	87

MAXIMUM RECOMMENDED SERVICE TEMPERATURE
(In oxidising conditions)

Operating Conditions	Temperature (°C)	
Type	304	321
Continuous	830	830
Intermittent	800	800

REPRESENTATIVE CREEP RUPTURE PROPERTIES

	Stress (MPa) to Produce 1% Strain				Stress (MPa) to Produce Rupture			
	10 000 hours		100 000 hours		1 000 hours		10 000 hours	
Temperature (°C)	304	321	304	321	304	321	304	321
550	160		115		315	345	225	255
600	110	125	75	80	200	230	145	160
650	75	85	50	50	130	135	95	105
700	50	50	30	30	85	100	60	65
750	35	30	20	20	60	65	40	40
800	25	20	15	10	35	45	25	25

PROPERTIES AT SUB-ZERO TEMPERATURES

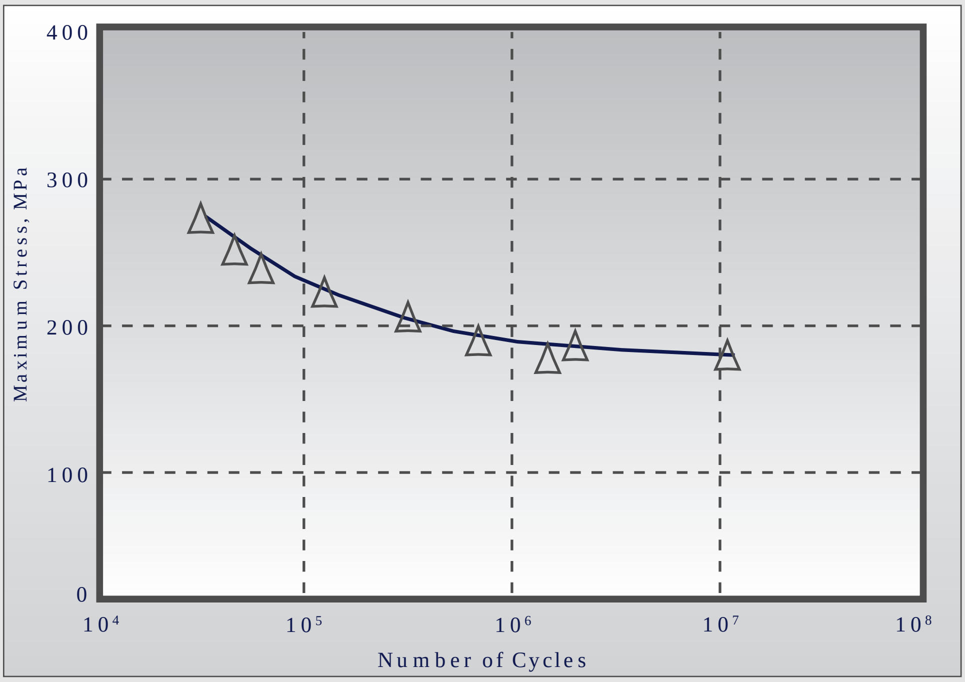
The properties quoted below are typical of annealed CS304 only

Temperature (°C)	20	0	-10	-50	-100	-140	-196
Tensile Strength (MPa)	616	885	976	1101	1281	1368	1609
0.2% Proof Stress (MPa)	255	242	240	236	222	246	231
Elongation (%)	70	64	55	50	42	41	38
Impact Energy (J)	217	204	194	194	168	160	168

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_t). 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 curve below shows a typical S-N curve for CS304 stainless steel (longitudinal).



PHYSICAL PROPERTIES

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

		CS304	CS321
Density		7 900kg/m³	7 800kg/m³
Modulus of Elasticity in Tension		193GPa	193GPa
Modulus of Elasticity in Torsion		86GPa	86GPa
Poisson's Ratio		0.26	0.24
Specific Heat Capacity		500J/kgK	500J/kgK
Thermal Conductivity:	@ 100°C	16.2W/mK	16.1W/mK
	@ 500°C	21.5W/mK	22.2W/mK
Electrical Resistivity		720ηΩm	720ηΩm
Mean Co-efficient of Thermal Expansion:	0 – 100°C	17.2µm/mK	16.6µm/mK
	0 – 315°C	17.8µm/mK	17.2µm/mK
	0 – 540°C	18.4µm/mK	18.6µm/mK
	0 – 700°C	18.9µm/mK	19.0µm/mK
Melting Range		1 400–1 450°C	1 400–1 450°C
Relative Permeability		1.02	1.02
(Note: this grade is non-magnetic becoming slightly magnetic after cold working)			

THERMAL PROCESSING & FABRICATION

ANNEALING

Annealing of types CS304 and CS304L 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. CS321 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 (CS304L) 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 CS304 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 CS321 should be used.

HOT WORKING

CS304 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°C 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

CS304 types, being extremely tough and ductile, can be readily deep drawn, stamped, headed and upset without difficulty. Since CS304 types work harden, severe cold forming operations should be followed by annealing.

MACHINING

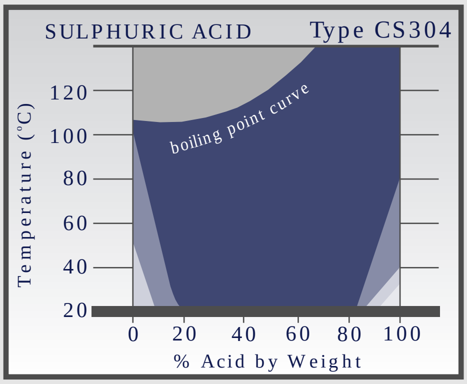
Like all the austenitic steels, this alloy group machines with a rough and stringy swarf. Rigidly supported tools with as heavy a cut as possible should be used to prevent glazing.

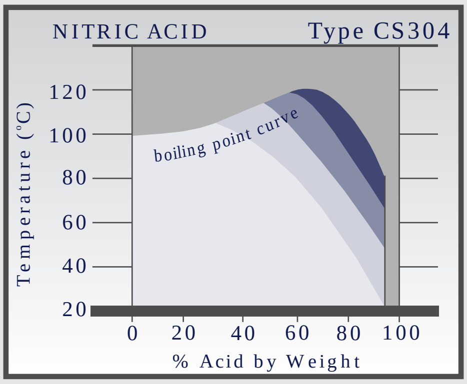
WELDING

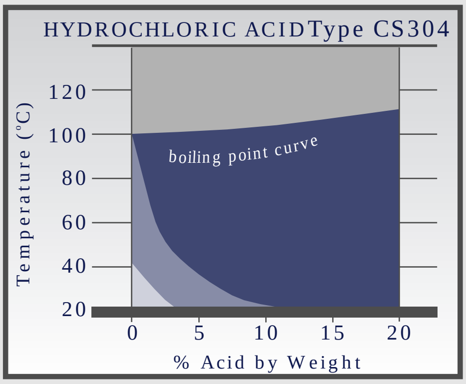
CS304 types have good welding characteristics and are suited to all standard welding methods. Either matching or slightly over-alloyed filler wires should be used. For maximum corrosion resistance, the higher carbon type CS304 should be annealed after welding to dissolve any chromium carbides which may have precipitated. The weld discolouration should be removed by pickling and passivation to restore maximum corrosion resistance.

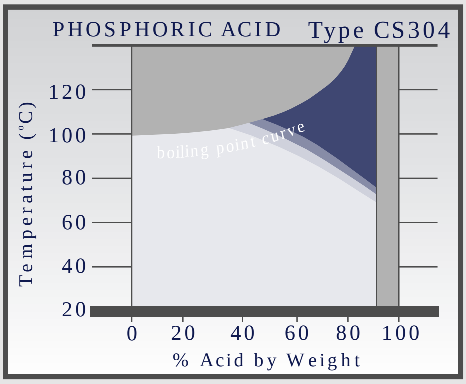
CORROSION RESISTANCE

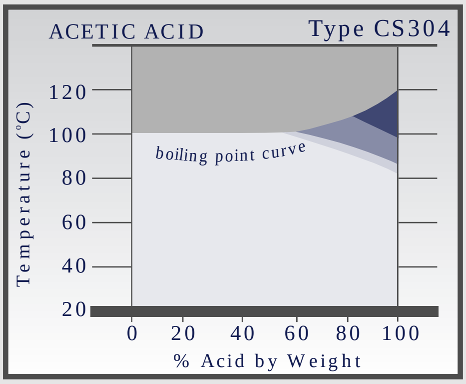
CS304 and CS321 have excellent corrosion resistance in a wide variety of corrosive media, including foodstuffs, sterilising solutions, most organic chemicals and dyes and a wide variety of inorganic chemicals. Iso-corrosion diagrams for CS304 in sulphuric, nitric, hydrochloric, phosphoric and acetic acids are shown below. Iso-corrosion diagrams for CS321 appear overleaf.







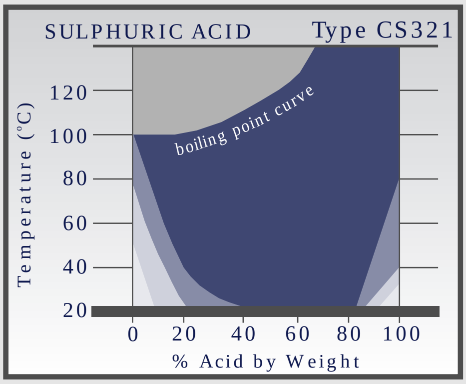


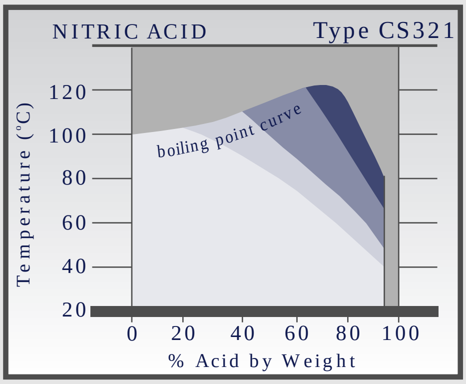


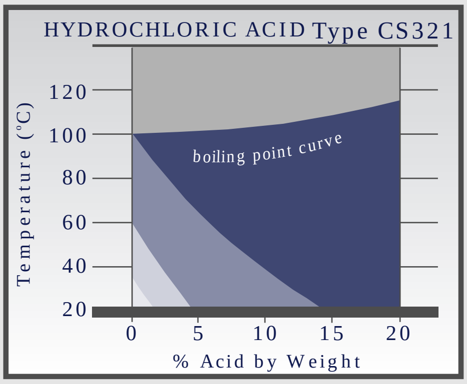
KEY

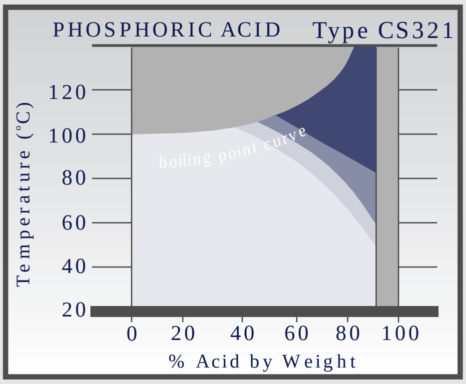
	mils per year	mm per year
	<1	<.03
	1-5	.03-.13
	5-30	.13-.75
	>30	>.75

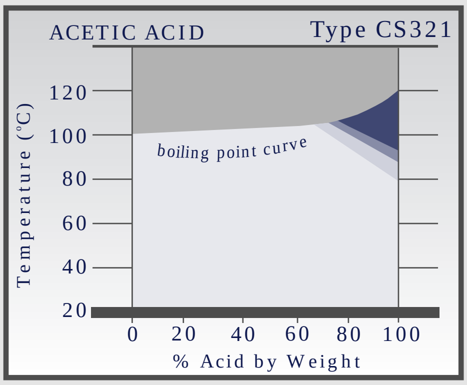
In service, acid corrosion may be either inhibited or accelerated by the presence of other chemicals or contaminants. The reaction of a material to all the possible service variables cannot be fully assessed in the laboratory. Consequently, tests have been carried out in pure acid solutions and are intended only to provide a guide to general uniform corrosion in these media. In-situ testing will provide more reliable data for material selection.









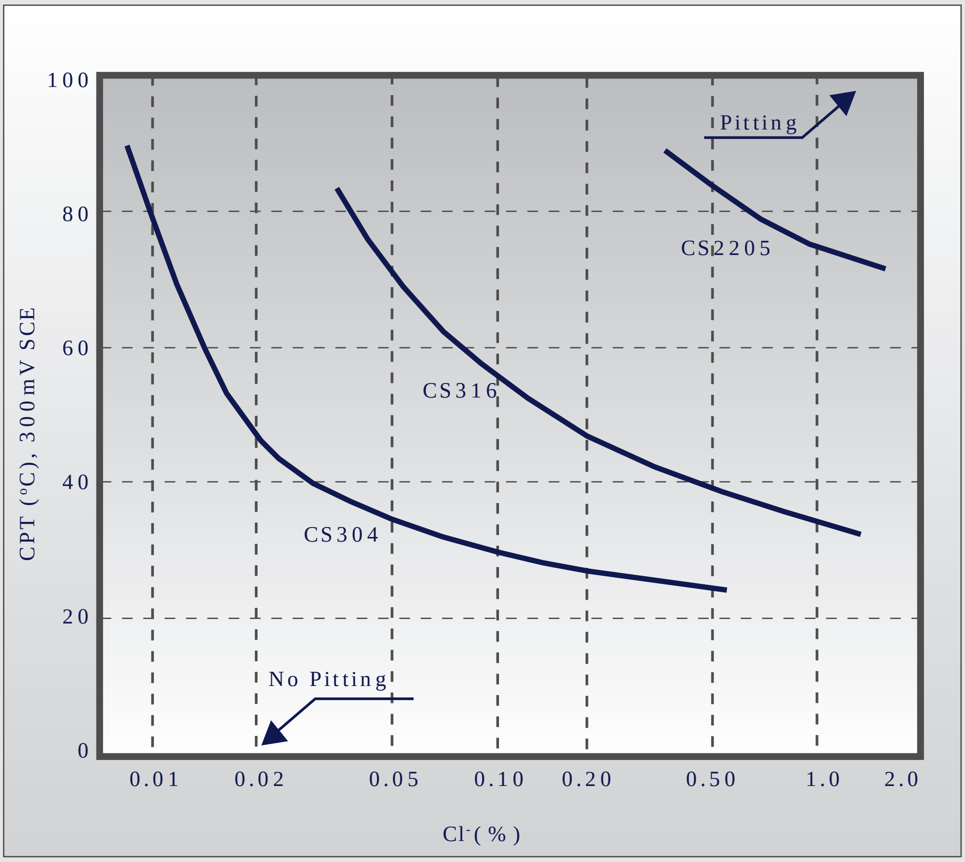


KEY

	mils per year	mm per year
	<1	<.03
	1-5	.03-.13
	5-30	.13-.75
	>30	>.75

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. Where pitting corrosion is anticipated, steels containing molybdenum (such as CS316) should be considered. 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 + 300mV SCE). pH = 6.0.

OXIDATION

CS304 types have good oxidation resistance in intermittent service up to 800°C and in continuous service to 830°C. Continuous use of type 304 in the 450°C to 850°C temperature range is not recommended due to carbide precipitation but CS304 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:

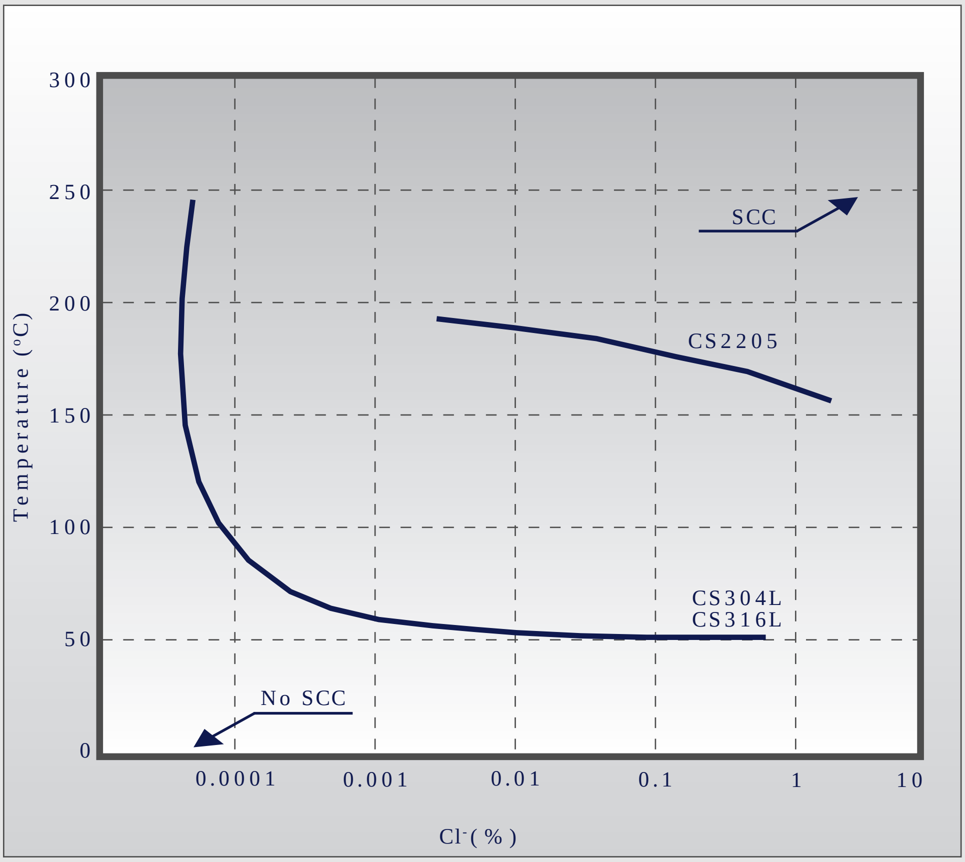
a) boiling copper sulphate/sulphuric acid test as specified in ASTM A262-98, Practice E.
b) for non titanium stabilised grades only, boiling nitric acid test as specified in ASTM A262-98, Practice C.

In the more severe nitric acid test, some weldments in plates of CS304 may exhibit slight intergranular corrosion. For service in the as-welded condition in severe chemical environments, CS304L would be recommended in preference to CS304.

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 duplex stainless steels, will have to be used where SCC cracking is likely to occur.



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

FOR FURTHER INFORMATION PLEASE CONTACT:

Technical Customer Services

Columbus Stainless (Pty) Ltd

PO Box 133

Middelburg 1050

South Africa

Tel: +27 (13) 247 3343

Fax: +27 (13) 247 2289

E-mail: technical-help@columbus.co.za

Commercial

Columbus Stainless (Pty) Ltd

PO Box 133

Middelburg 1050

South Africa

Tel: +27 (13) 247 2020

Fax: +27 (13) 247 2771

E-mail: commercial-help@columbus.co.za

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