Technical Brochure

Cr-(Mn)-Ni AUSTENITIC STAINLESS STEELS

Unity	AISI	UNS	EN
U-202	-	-	-
U-304	304	S30400	1.4301
U-304H	304H	S30409	1.4301
U-304DQ	304	S30400	1.4301
U-304DDQ			
U-304L-ASTM	304L 304	S30403 S30400	1.4307 1.4301
U-304L-ASME			
U-304LS			
U-304LDDQ			1.4306 1.4307 1.4301
U-304LN	304LN 304N	S30453 S30451	-
U-321	321	S32100	1.4541 1.4878

COLUMBUS STAINLESS [Pty] Ltd

www.columbusstainless.co.za

Introduction

The Cr-(Mn)-Ni austenitics 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 Cr-(Mn)-Ni austenitics enables them to be deep drawn 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.

U-202 is a lower cost alternative to the Cr-Ni austenitic stainless steels, such as U-304. About half the nickel of U-304 is replaced with alloy additions of manganese and nitrogen. Copper is added to compensate for the increased work hardening rate, caused by the nitrogen additions.

U-202 thus has very similar mechanical properties to U-304 and has excellent ductility and formability. It also has excellent low temperature properties and responds similarly to U-304DQ in drawing operations. U-202 has good welding characteristics. Post weld annealing is not normally required. The pitting resistance of U-202 is not as good as the U-304 types and is similar to U-430.

The low carbon grades **(U-304L-ASTM, U-304L-ASME** and **U-304LDDQ)** do not require post weld annealing and find extensive use in heavy gauge components where freedom from carbide precipitation is often required.

The high carbon grades **(U-304, U-304H, U-304DQ** and **U-304DDQ)** have good welding characteristics. There is, however, a risk of carbide precipitation and sensitisation with a possible concomitant loss in intergranular corrosion resistance in corrosive environments in thicker gauges. Post weld annealing is not normally required to restore the excellent performance of these grades in a wide range of corrosive conditions.

U-304H, with a higher carbon content, is normally specified where good mechanical properties at elevated temperatures are required. These grades also have a larger grain sizes (ASTM 7 or coarser) to improve the high temperature creep resistance.

The drawing quality (U-304DQ) and deep drawing quality (U-304DDQ and U-304LDDQ) grades have increased levels of nickel to improve their formability and are thus used in forming operations where the depth of the formed part exceeds the diameter.

U-304LS has a high sulphur level, although still within the U-304L specification. This is to improve the machinability, weldability and forgeability. U-304LS should not be confused with the free-machining grades that have much higher levels of sulphur.

U-304LN has a higher nitrogen content to improve the strength and is also particularly suitable for cryogenic applications.

U-321 is a titanium stabilised version of U-304 and is used in applications exposed to the temperature range 450°C to 850°C where there is a high risk of sensitisation. U-321 has higher elevated temperature properties than U-304. 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 Catalogue should be consulted, as the product range is subject to change without notice.

The Product Catalogue is available from the Technical Department or can be found at www.columbusstainless.co.za

Specifications and tolerances

Columbus Stainless (Pty) Ltd supplies the Cr-(Mn)-Ni austenitics to ASTM A240, ASME SA240, EN 10088-2 and EN 10028-7.

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

HOT ROLLED

ASTM A480M
ISO 9444 - material processed as coil
ISO 18286 - material processed as plate

COLD ROLLED

ASTM A480M
ISO 9445

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

Further information

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Disclaimer

Chemical composition

In accordance with ASTM A240 and EN 10088-2.

Unity	C	Si	Mn	P	S	N	Cr	Ni	Others
U-202	0.08	0.75	6.5 8.0	0.045	0.015	0.15	15.0 17.0	3.5 5.0	Cu: 2.0
U-304 U304H	0.07	0.75	2.0	0.045	0.015	0.10	18.0 19.5	8.0 10.5	
U-304DQ	0.07	0.75	2.0	0.045	0.015	0.10	18.0 19.5	8.5 10.5	
U-304DDQ	0.07	0.75	2.0	0.045	0.015	0.10	18.0 19.5	9.0 10.5	
U-304L-ASTM	0.03	0.75	2.0	0.045	0.015	0.10	17.5 19.5	8.0 10.5	
U-304L-ASME	0.03	0.75	2.0	0.045	0.015	0.10	18.0 19.5	8.0 10.5	
U-304LS	0.03	0.75	2.0	0.045	0.005 0.015	0.10	18.0 19.5	8.0 10.5	
U-304LDDQ	0.03	0.75	2.0	0.045	0.015	0.10	18.0 20.0	10.0 10.5	
U-304LN	0.03	0.75	2.0	0.045	0.030	0.10 0.16	18.0 20.0	8.0 12.0	
U-321	0.08	0.75	2.0	0.045	0.015	0.10	17.0 19.0	9.0 12.0	Ti: 5x(C+N) 0.7

- *Compositions are ranges or maximum values.*

Mechanical properties

In accordance with ASTM A240 and EN 10088-2.

Unity	R_m (MPa)	$Rp_{0.2}$ (MPa)	$Rp_{1.0}$ (MPa)	El (%)	Max BHN
U-202	515	205		40	250
U-304 U-304H U-304DQ U-304LDDQ	540 to 750 (CR) 520 to 720 (HR)	230 (CR) 210 (HR)	260 (CR) 250 (HR)	45	201
U-304L-ASTM U-304L-ASME U-304LS U-304LDDQ	520 to 700 (≤8mm) 500 to 700 (>8mm)	220 (CR) 200 (HR)	250 (CR) 240 (HR)	45	201
U-304LN	515	205		40	217
U-321	520 to 700 (≤8mm) 500 to 700 (>8mm)	220 (CR) 200 (HR)	250 (CR) 240 (HR)	40	217

- *Minimum values, unless max or range is indicated.*
- *( ) indicates applicable gauge range.*
- *HR is hot rolled, CR is cold rolled.*
- *The table assumes certification to both ASTM A240, EN 10088-2 and EN 10095, where applicable.*

PROPERTIES AT ELEVATED TEMPERATURES

The properties quoted below are typical of annealed U-304, U-304L and U-321 type steels. These values are given as a guideline only, and should not be used for design purposes.

Short time elevated temperature tensile strength (MPa)

Unity	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1 000°C	1 100°C
U-304 types	530	510	480	450	400	320	230	135	70	40	30
U-304L types	480	460	440	400	350	280	200	120	50	25	15
U-321	525	520	510	470	420	340	260	180	105	60	25

Short time elevated temperature 0.2% proof stress (MPa)

Unity	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C
U-304 types	220	160	145	140	125	110	95	70
U-304L types	200	145	130	125	110	95	85	60
U-321	210	185	165	155	140	130	115	95

Short time elevated temperature elongation (%)

Unity	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1 000°C	1 100°C
U-304 types	52	45	41	38	36	34	35	38	48	66	96
U-304L types	52	45	40	38	36	36	38	43	52	68	90
U-321	52	44	39	38	39	43	48	54	62	73	87

Maximum recommended service temperature

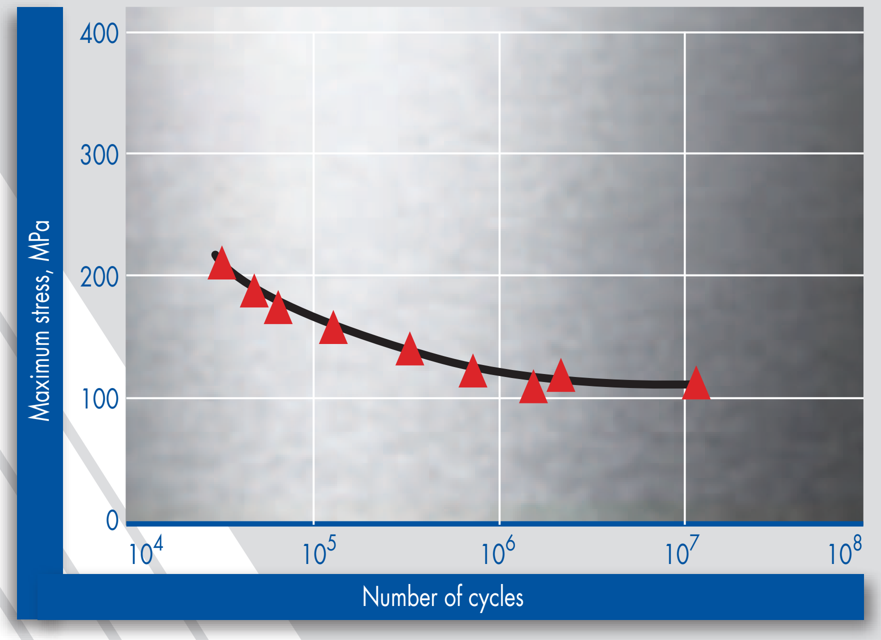
Unity	Continuous (°C)	Intermittent (°C)
U-202	780	750
All U-304/U-304L/U321 types	830	800

- *In oxidising conditions*

FATIGUE CONSIDERATION

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 adjacent curve shows a typical S-N curve for U-304 stainless steel (longitudinal).



Physical properties

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

		U-202	All U-304 and U-304L types	U-321
Density (kg/m^3)		7 800	7 900	7 800
Modulus of Elasticity in Tension (GPa)		200	193	193
Modulus of Elasticity in Torsion (GPa)			86	86
Specific Heat Capacity (J/kg K)		460	500	500
Thermal conductivity at	100°C (W/mK)	24.2	16.2	16.1
	500°C (W/mK)	30.6	21.5	22.2
Electrical Resistivity (x10^{-9} Ω m)		740	720	720
Mean Coefficient of Thermal Expansion from	0 to 100°C (x10^{-6} K^{-1})	16.2	17.2	16.6
	0 to 300°C (x10^{-6} K^{-1})	17.2	17.8	17.2
	0 to 500°C (x10^{-6} K^{-1})	18.6	18.4	18.6
	0 to 700°C (x10^{-6} K-$^{-1}$)	19.1	18.9	19.0
Melting Range (°C)		1 400	1 400	1 400
		1 450	1 450	1 450
Relative Permeability		1.021	1.021	1.021

- *May become slightly magnetic in the cold worked condition.*

Thermal processing and fabrication

ANNEALING

Annealing of U-202, U-304 and U-304L type steel is achieved by heating to between 1 010°C and 1 120°C for 60 minutes per 25mm thickness (2.5min/mm) followed by water or air quenching. The best corrosion resistance is achieved when the final annealing temperature is above 1 070°C. U-321 should not be annealed above 1 060°C. Controlled atmospheres are recommended in order to avoid excessive oxidation of the surface.

STRESS RELIEVING

The lower carbon grade (U-304L types) can be stress relieved at 450°C to 600°C for 45 minutes per 25mm thickness (1.5min/mm) with little danger of sensitisation. A lower stress relieving temperature of 400°C maximum must be used with U-202 and U-304 types 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, U-321 (titanium stabilised) should be used.

HOT WORKING

The Cr-(Mn)-Ni austenitics 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

The Cr-(Mn)-Ni austenitics are extremely tough and ductile and can thus be readily deep drawn, stamped, headed and upset without difficulty. Since austenitic stainless steels work harden, severe cold forming operations should be followed by annealing.

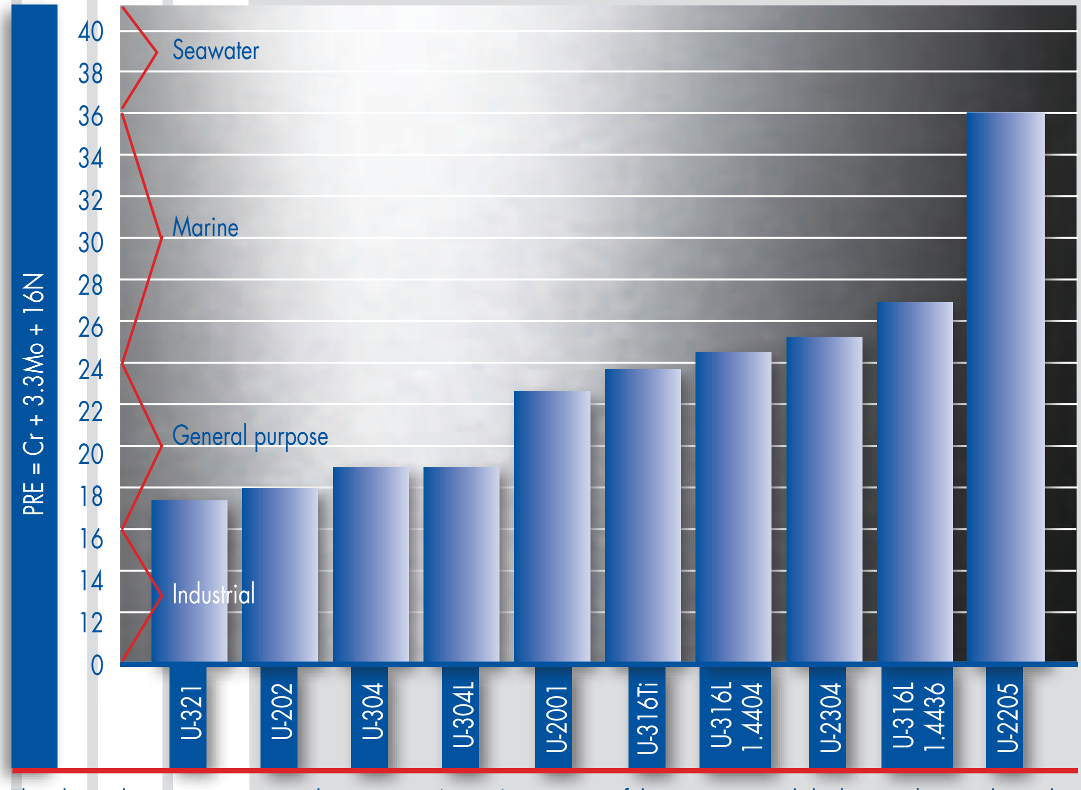
MACHINING

Like all the austenitic stainless 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

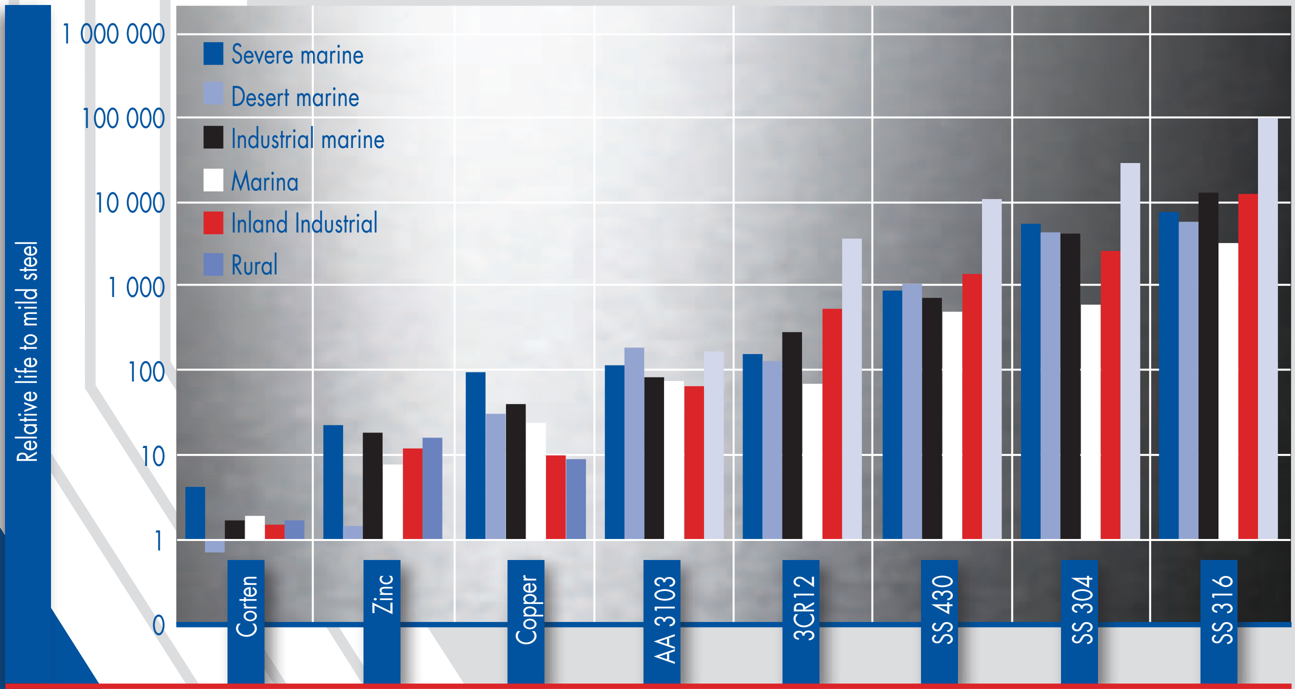
The Cr-(Mn)-Ni austenitics have good welding characteristics and are suited to all standard welding methods. Either matching or slightly over-alloyed filler wires should be used, such as 308L. When welding U-202, nitrogen containing shielding gases are recommended. For maximum corrosion resistance, the higher carbon type U-304 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



The above diagram summarises the corrosion (pitting) resistance of the austenitic and duplex stainless steels produced at Columbus Stainless. This would indicate that the corrosion resistance of the Cr-(Mn)-Ni austenitic types are all similar and suitable for general purpose applications.

ATMOSPHERIC CORROSION

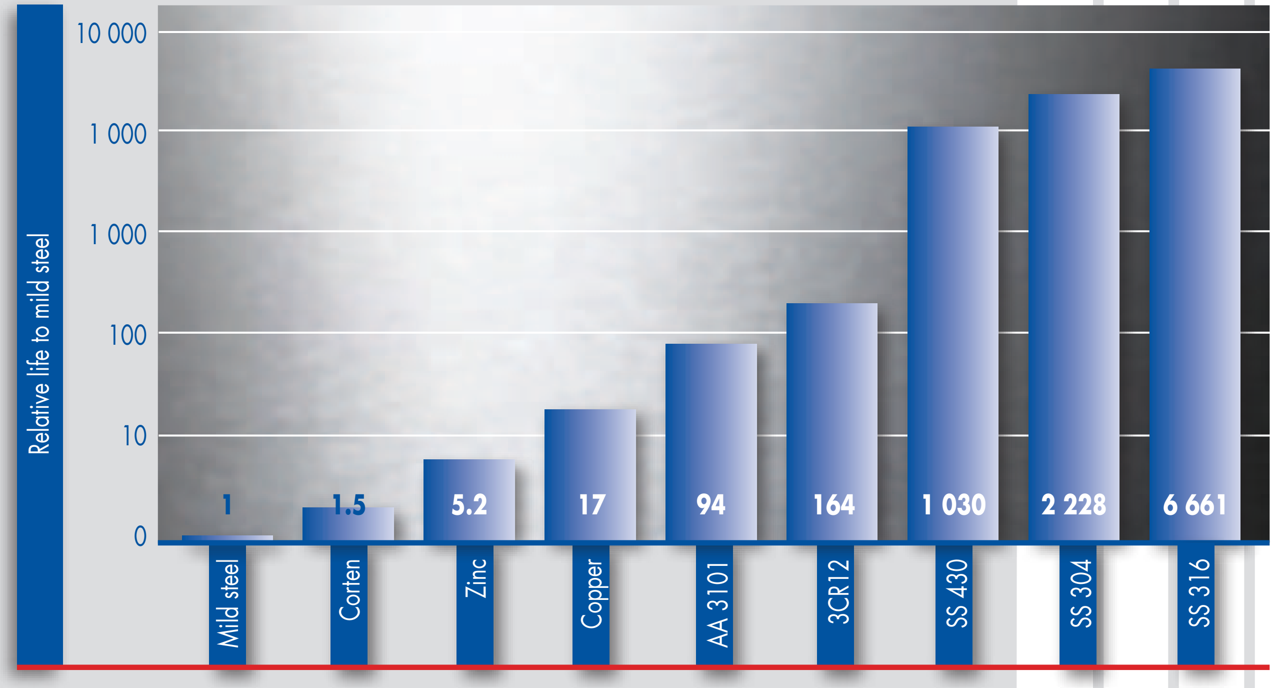


The atmospheric corrosion resistance of austenitic stainless steel is unequalled by virtually all other uncoated engineering materials. From the report 'Atmospheric Corrosion Testing in Southern Africa - Results of a Twenty Year Exposure Programme' by BG Callaghan, Division of Materials Science and Technology, CSIR, the adjacent graphs can be constructed. This shows the relative life of eight metals compared to mild steel in six different atmospheric environments.

ATMOSPHERIC CORROSION (CONTINUED)

These graphs can be summarised to give an average relative life of the different metals in atmospheric conditions.

In appearance, all the metals showed discolouration at the more severe sites after 20 years. None of the metals were washed during the exposure programme and this clearly emphasises the importance of keeping stainless steel clean and that stainless steel is a LOW maintenance (not NO maintenance) option in atmospheric corrosion applications.

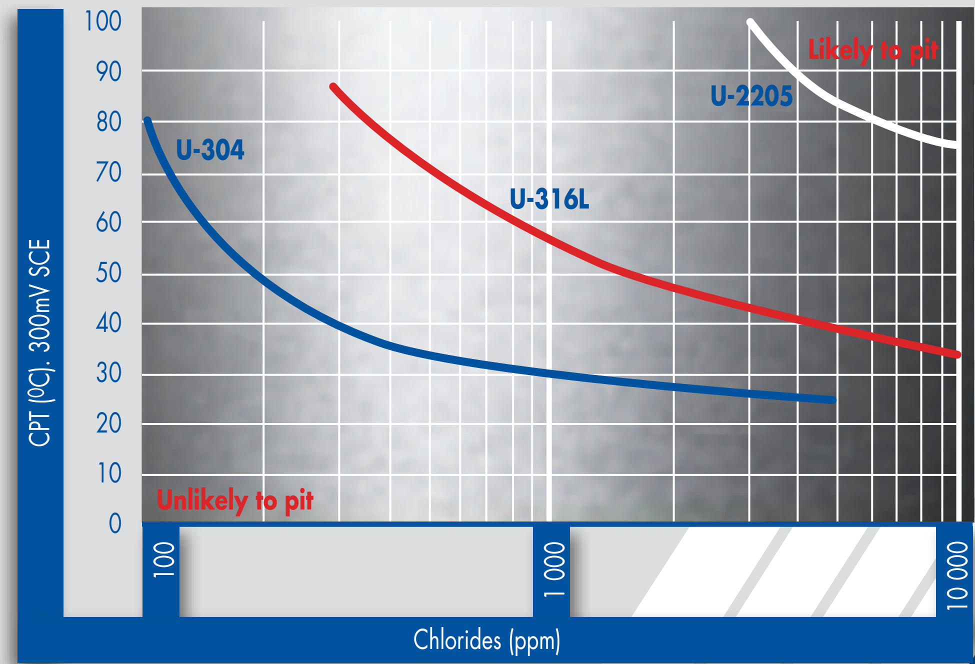


GENERAL CORROSION

The Cr-(Mn)-Ni austenitics have good general 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. In most corrosive solutions U-202 would have a general corrosion resistance approaching that of the Cr-Ni austenitics.

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 the Cr-Ni-Mo austenitics) should be considered. The adjacent diagram shows the critical temperature for initiation of pitting (CPT) at different chloride contents for U-304, U-316 and U-2205 types (potentiostatic determination at + 300mV SCE, pH = 6.0).



OXIDATION RESISTANCE

Cr-(Mn)-Ni austenitics types have good oxidation resistance. Continuous use of the U-304 types in the 450°C to 850°C temperature range is not recommended due to carbide precipitation but U-304 often performs well in temperatures fluctuating above and below this range. One should use the low carbon 'L' variant in these applications.

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, Practice E.
b) for non titanium stabilised grades only, boiling nitric acid test as specified in ASTM A262, Practice C.

In the more severe nitric acid test, some weldments in plates of U-304 may exhibit slight intergranular corrosion. For service in the as-welded condition in severe chemical environments, U-304L would be recommended in preference to U-304.

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.