Technical Data

CS2205

COLUMBUS STAINLESS
[Pty] Ltd

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INTRODUCTION

CS2205 is a duplex stainless steel with a microstructure, when heat treated properly, of nearly equal proportions of austenite and ferrite. This microstructure ensures that CS2205 is much more resistant to stress corrosion cracking than CS304 or CS316. The higher chromium, molybdenum and nitrogen contents give CS2205 significantly improved pitting and crevice corrosion resistance in the presence of chlorides. CS2205 also has better general corrosion resistance than CS316 in most environments. In addition, CS2205 has a 0.2% Proof Stress of about double that of conventional austenitic stainless steels.

CS2205 has a ductile to brittle transition temperature of about –50°C. The steel can also become embrittled when exposed to temperatures between 300°C and 550°C (475°C embrittlement) and 550°C and 1 000°C (sigma (σ) and chi (χ) phase formation). Thus, application temperatures are generally limited from –50°C to 300°C.

CS2205 is a highly suitable material for service in environments containing chlorides and hydrogen sulphide such as marine environments and the oil and gas extraction and processing industries. Typical applications also include the chemical industry (processing, transport and storage, e.g. pressure vessels, tanks and piping), the pulp and paper industry (digesters and liquor tanks) and the mining industry. CS2205 has thus found widespread use in production tubing and flowlines for the extraction of oil and gas from sour wells, in refineries and in process solutions contaminated with chlorides. CS2205 is also particularly suitable for heat exchangers where chloride bearing water or brackish water is used as the cooling medium.

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 CS2205 to ASTM A240 (S31803 and S32205) and to EN 10088-2 and EN 10028-7 (1.4462).

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 (S31803 and S32205) and EN 10088-2 and EN 10028-7 (1.4462).

Type	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo	%N
S31803	0.030 max	1.00 max	2.00 max	0.030 max	0.020 max	21.00 23.00	4.50 6.50	2.50 3.50	0.08 0.20
S32205	0.030 max	1.00 max	2.00 max	0.030 max	0.020 max	22.00 23.00	4.50 6.50	3.00 3.50	0.14 0.20
1.4462	0.030 max	1.00 max	2.00 max	0.035 max	0.015 max	21.00 23.00	4.50 6.50	2.50 3.50	0.10 0.22

MECHANICAL PROPERTIES

In accordance with ASTM A240 (S31803 and S32205) and EN 10088-2 and EN 10028-7 (1.4462).

Type	Product Form[1] or Gauge (mm)	0.2% Proof Stress (MPa)	Tensile Strength (MPa)	Elongation (%)	Brinell Hardness	Impact Energy (J) 20°C	-40°C
S31803	All	450 min	620 min	25 min[2]	293 max		
S32205		450 min	655 min	25 min[2]	293 max		
1.4462	C	480	660 950	20 min[3,4]			
	H	460	660 950	25 min[3]		60[5]	40[5]
	P	460	640 840	25 min[3]		60[5]	40[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.

PROPERTIES AT ELEVATED TEMPERATURES

The properties quoted below are typical of annealed CS2205. 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	200	300	400
Tensile Strength (MPa)	630	580	560	550
0.2% Proof Stress (MPa)	365	315	285	275
Young's Modulus	190	180	170	160

MAXIMUM RECOMMENDED SERVICE TEMPERATURE

(In oxidising conditions)

Operating Conditions	Temperature (°C)
Continuous	980
Intermittent	980

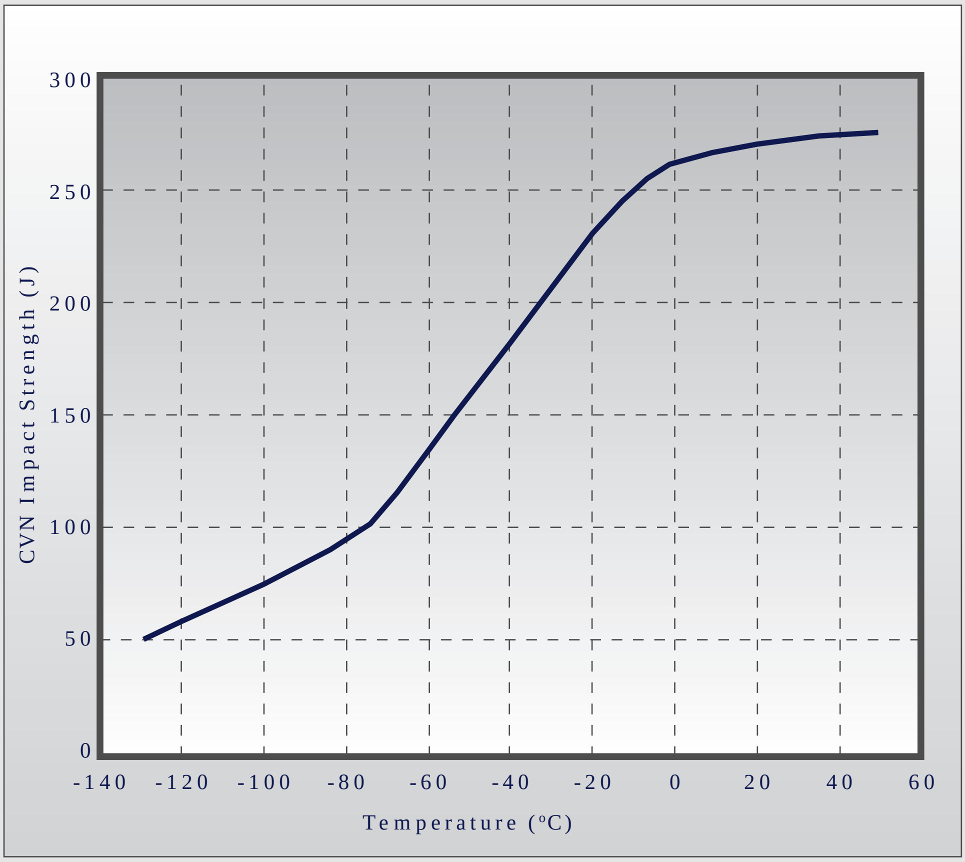
The upper temperature limit for long-term service is 300°C. Exposure of the steel for extended periods between 300°C and 950°C may embrittle the steel and lower the corrosion resistance. At the lower temperature range, the embrittlement is due to the precipitation of α' (475°C embrittlement) and nitrides or carbides. In the high temperature range, χ and σ phases precipitate. However, during normal production and fabrication procedures, the times at these critical temperatures are such that the risk of embrittlement and/or a decrease in corrosion resistance are small. In addition, this effect does not necessarily affect the behaviour of the material at the operating temperature and is less pronounced in thinner gauges. For example, heat exchanger tubes are used at high temperatures without any problems. A full anneal and rapid cooling treatment will restore the toughness and corrosion resistance of CS2205.

FATIGUE CONSIDERATIONS

The high strength of CS2205 also results in a high fatigue strength. CS2205 and CS316L have been tested under reverse bending stresses at room temperature and the fatigue limit is close to the yield strength, i.e. about twice as high for CS2205. In many applications, fatigue interacts with corrosion giving reduced fatigue strength. In such cases, CS2205 offers considerable advantages over mild steel and conventional stainless steels.

IMPACT PROPERTIES

CS2205 possesses good strength both at room and sub-zero temperatures. The ductile to brittle transition temperature (DBTT) curve is shown below. As can be seen, the DBTT of CS2205 is about –55°C, although the minimum energy requirement of 27J (which is considered to be the lower limit for ductile behaviour) is easily met for temperatures as low as –120°C.



PHYSICAL PROPERTIES

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

Density	7 860kg/m^3
Modulus of Elasticity in Tension	200GPa
Specific Heat Capacity	470J/kgK
Thermal Conductivity: @ 100°C	17.0W/mK
@ 500°C	21.0W/mK
Electrical Resistivity	850ηΩm
Mean Co-efficient of Thermal Expansion: 0 – 100°C	13.0µm/mK
0 – 300°C	14.0µm/mK
0 – 400°C	14.5µm/mK
Melting Range	1 410–1 460°C
Relative Permeability	Ferromagnetic

THERMAL PROCESSING & FABRICATION

ANNEALING

Annealing is achieved by heating to between 1 020°C and 1 100°C for 90 minutes per 25mm thickness followed by quenching in an agitated water bath down to room temperature. Controlled atmospheres are recommended in order to avoid excessive oxidation of the surface.

STRESS RELIEVING

CS2205 can be stress relieved at 525°C to 600°C for 60 minutes per 25mm thickness. Stress relieving CS2205 contributes significantly to improving the resistance to Stress Corrosion Cracking by lowering the residual tensile stresses.

HOT WORKING

CS2205 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. Initial hot working should be affected without large reductions or change of shape (especially if upsetting or staving up). Once the material starts to flow, progressively more deformation can be accomplished.

The finishing temperature should not be below 950°C. If the temperature after forging is still above 1 000°C, rapid cooling (water quenching) can be carried out directly from the working temperature. Otherwise, all hot working operations should be followed by annealing and pickling and passivating to restore the mechanical properties and corrosion resistance.

COLD WORKING

CS2205 has good formability, but due to the higher proof strength, more power is required for most cold forming operations than austenitic stainless steels. Roll forming can be readily applied to CS2205, but loadings will be about 60% higher than for mild steel and slower speeds should be used. Severe deep draws may require an intermediate anneal. Cold bending reduces the maximum gauge capacity of the machine by about half, compared with austenitic stainless steels. The minimum inner bend radius for CS2205 is three times the plate thickness and four times is recommended. Severe bends should be carried out transverse to the rolling direction. CS2205 exhibits greater spring back than mild steel and this should be compensated for by slight over bending.

MACHINING

The high strength that makes CS2205 useful in many applications also reduces its machinability. Cutting speeds are approximately 20% slower than those for CS304. Machine tools should be ground to close tolerances to avoid the risk of excessive work hardening in the outer layer of the stock. Larger tools should be used to give stability and efficient heat dissipation. Tools with large rake angles, sharp edges and smooth surfaces reduce the work hardening and the risk of built up edges. Relatively large feed rates and cutting depths minimise the work hardening of the surface layer. A suitable cutting fluid should be used to minimise the risk of built up edges. The work should be flooded to ensure maximum heat removal.

WELDING

CS2205 has good weldability in most applications, provided that the recommended procedures are adopted. CS2205 is suited to most standard welding methods (MMA/SMAW, MIG/GMAW, TIG/GTAW, FCAW, SAW and PAW). If CS2205 is autogenously welded, the fabrication must be solution annealed to restore the desirable duplex microstructure and hence the toughness. Only welding consumables specifically specified for CS2205 should be used to ensure that the deposited metal has the correctly balanced duplex microstructure. Nitrogen, added to the shielding gas, will also assist in ensuring adequate austenite in the microstructure.

The heat input should be minimised and in any case, kept below 2kJ/mm in order to keep the Heat Affected Zone (HAZ) narrow. The interpass temperatures should not exceed 150°C.

The lower coefficient of thermal expansion of CS2205, compared to austenitic stainless steels, reduces distortion and the associated stresses.

Preheating, although not essential, is beneficial on thicker gauge sections. Typical preheat temperatures are between 100°C and 250°C. Post-weld heat treatment is not normally required, but solution annealing will restore the toughness and confer the optimum stress corrosion cracking resistance to the fabrication.

CORROSION RESISTANCE

CS2205 has excellent general corrosion resistance and generally speaking, this is better than CS316 or 317 in most environments.

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.

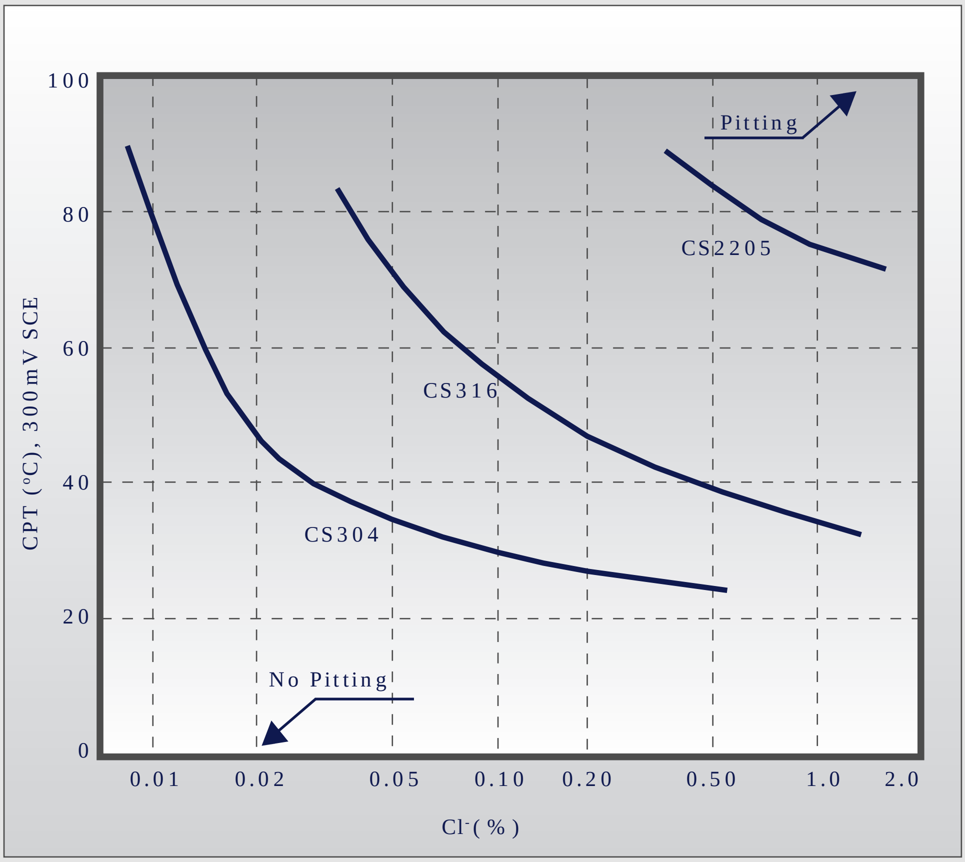
Pitting (and crevice corrosion) resistance of stainless steels is primarily determined by the chromium, molybdenum and nitrogen contents. An empirical equation has been developed to compare the resistance of different steels to pitting. This defines the Pitting Resistance Equivalent (PRE) as:

PRE = Cr + 3.3Mo + 16N

The PRE's for CS304, CS316, CS2101 and CS2205 are given below:

Alloy	%Cr	%Mo	%N	PRE
CS304	18.20	0.05	0.0500	19.2
CS316	17.00	2.10	0.0500	24.7
CS2101	21.50	0.40	0.2250	26.4
CS2205	22.50	3.30	0.1700	36.1

This illustrates the expected superior resistance of CS2205 to pitting or crevice corrosion. The diagram overleaf shows the experimentally measured critical temperature for initiation of pitting (CPT) at different chloride contents for CS304, CS316 and CS2205. This agrees well with the empirical PRE's above and with practical experience. Thus, CS2205 can be used at considerably higher temperatures and chloride contents than CS304 or CS316 without pitting occurring. CS2205 is therefore far more serviceable in chloride bearing environments than standard austenitic stainless steels.



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

CS2205 has good oxidation resistance, both in intermittent and continuous service, up to 980°C. However, continuous use of 2205 between 300°C and 950°C may embrittle the steel and lower the corrosion resistance. At the lower temperature range, the embrittlement is due to the precipitation of α' (475°C embrittlement) and nitrides or carbides. In the high temperature range, χ and σ phases precipitate. However, during normal production and fabrication procedures, the times at these critical temperatures are such that the risk of embrittlement and/or a decrease in corrosion resistance are small. In addition, this effect does not necessarily affect the behaviour of the material at the operating temperature and is less pronounced in thinner gauges. For example, heat exchanger tubes are used at high temperatures without any problems. A full anneal and rapid cooling treatment will restore the toughness and corrosion resistance of CS2205.

ATMOSPHERIC CORROSION

The atmospheric corrosion resistance of duplex stainless steels is unequalled by virtually all other uncoated engineering materials. However, CS316 is normally sufficient in areas where the atmosphere is highly polluted with chlorides, sulphur compounds and solids, either singly or in combination. In urban and rural areas, CS304 generally performs satisfactorily.

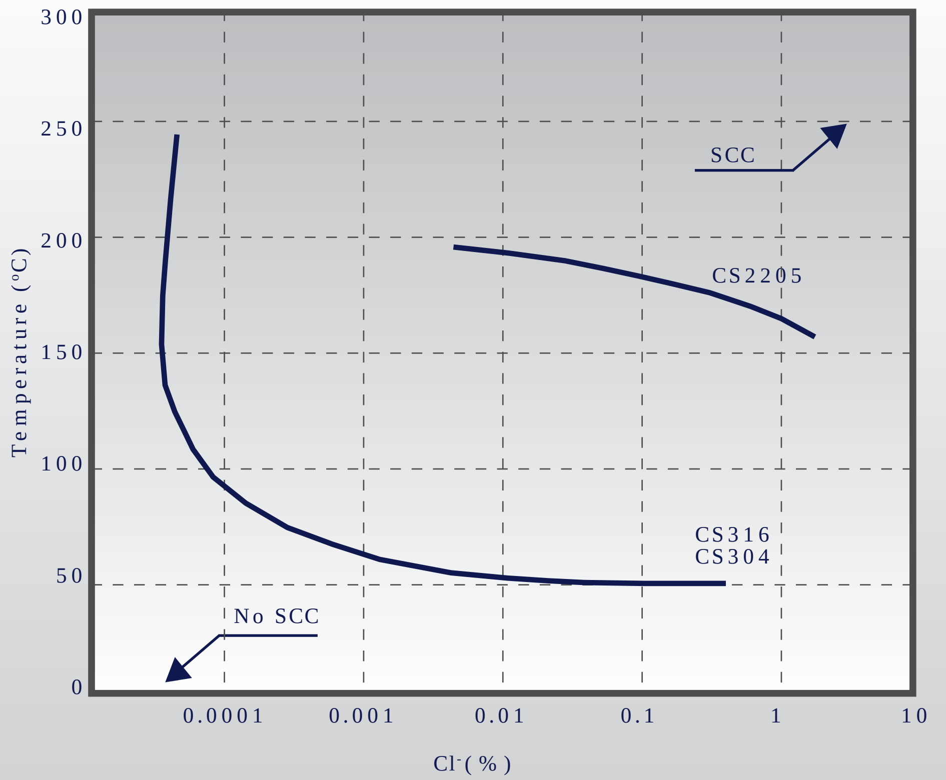
INTERGRANULAR CORROSION

Sensitisation may occur when the Heat Affected Zones of welds in some stainless steels are cooled through the sensitising temperature range of between 450°C and 850°C. At this temperature, a compositional change (carbide precipitation) 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. The low carbon content of CS2205 ensures that, together with the appropriate welding conditions, precipitation of carbides (and hence sensitisation) in the Heat Affected Zone (HAZ) does not take place. Welded joints in CS2205 easily pass intergranular corrosion testing according to ASTM A262 Practice E (boiling copper sulphate/sulphuric acid test).

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 stress corrosion cracking occurring in service is therefore difficult. Where there is a likelihood of stress corrosion cracking occurring, a beneficial increase in life can be easily obtained by a reduction in operating stress and/or temperature.

2205 is far less prone to this type of corrosion than the conventional austenitic stainless steels. The diagram overleaf indicates the chloride-temperature range within which CS2205, CS316 and CS304 can be used with negligible risk of stress corrosion cracking.



Resistance to Stress Corrosion Cracking (Laboratory results).

EROSION CORROSION

Conventional austenitic stainless steels are attacked by erosion corrosion if exposed to flowing media containing highly abrasive solid particles, e.g. sand, or to media with very high flow velocities. Owing to its combination of high initial hardness, work hardenability and corrosion resistance, CS2205 displays very good resistance under such erosion corrosion conditions.

CORROSION FATIGUE

CS2205 possesses higher strength and better corrosion resistance than ordinary austenitic stainless steels. CS2205, therefore, also possess better fatigue strength under corrosive conditions than such steels. For example, in rotary bending fatigue tests in a 3% NaCl solution (6 000rpm, 40°C, pH 7), CS2205 required 430MPa stress in the unnotched condition to bring about rupture after $2x10^7$ cycles, while 316N failed at only 260MPa. The corresponding notched figures were 230MPa and 140MPa for CS2205 and 316N respectively.

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