North American Stainless

Flat Products Stainless Steel Grade Sheet

2205 (S32205)/ EN 1.4462 (S31803)

Introduction:

SS2205 is a duplex stainless steel with a microstructure, when heat treated properly, of nearly equal proportions of austenite and ferrite. This microstructure ensures that SS2205 is much more resistant to stress corrosion cracking than SS304 or SS316L. The higher chromium, molybdenum and nitrogen contents give SS2205 significantly improved pitting and crevice-corrosion resistance in the presence of chlorides. SS2205 also has better general corrosion resistance than SS316L in most environments. In addition, SS2205 has a 0.2% Proof Stress of about double that of conventional austenitic stainless steels.

SS2205 has a ductile-to-brittle transition temperature of about –50°C. The stainless steel grade can also become embrittled when exposed to temperatures between 300°C and 550°C (475°C embrittlement) and 550°C to 1000°C (sigma [s] and chi [c] phase formation). Thus, application temperatures are generally limited from –50°C to 300°C.

SS2205 is a highly suitable material for service in environments containing chlorides and hydrogen sulfide, 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. SS2205 has thus found widespread use in production tubing and flow lines for the extraction of oil and gas from sour wells, in refineries and in process solutions contaminated with chlorides. SS2205 is also particularly suitable for heat exchangers where chloride-bearing water or brackish water is used as the cooling medium.

Product Range:

Product is available in Cold Rolled, Continuous Mill Plate and Plate Mill Plate form up to 60" wide in various thicknesses.

For inquiry about minimum quantity, specific thickness and tolerances, contact inside sales at NAS.

Certification:

ASTM A240, A480, ASME SA240, SA480, ASTM A923, EN 10028-7

Chemical Composition :

UNS/Euro	ASTM/Euro	Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Nitrogen	Molybdenum
S32205	**2205**	0.03 max	2 max	0.03 max	0.02 max	1 max	22-23	4.5-6.5	0.14-0.2	3-3.5
S31803		0.03 max	2 max	0.03 max	0.02 max	1 max	21-23	4.5-6.5	0.08-0.2	2.5-3.5

Mechanical Properties :

	Tensile Strength min	Yield Strength min	Elongation min	Hardness max
2205	95 ksi	65 ksi	25%	31 HRC
S31803	90 ksi	65 ksi	25%	31 HRC

PROPERTIES AT ELEVATED TEMPERATURE

The properties quoted below are typical of annealed SS2205. 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

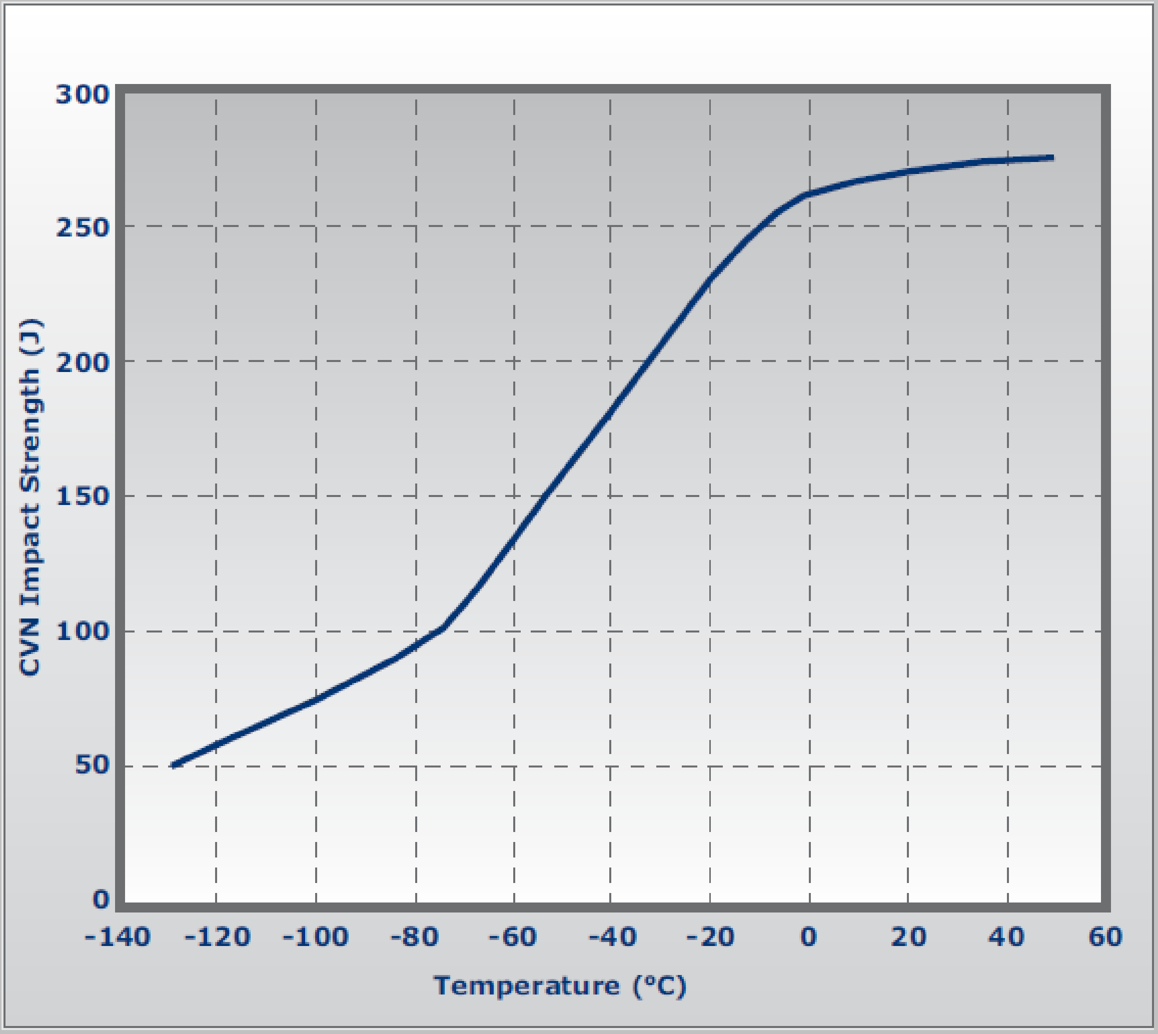
The upper temperature limit for long-term service is 300°C. Exposure of the steel for extended periods between 300°C and 950°C may embrittle the steel and lower the corrosion resistance. At the lower temperature range, the embrittlement is due to
980 precipitation of alpha (475°C embrittlement) and nitrides or carbides. In the high-temperature range chi phase precipitates. 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 is small. In addition, this effect does not necessarily affect the behavior 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 SS2205.

FATIGUE CONSIDERATIONS

The high strength of CS2205 also results in high fatigue strength. SS2205 and SS316L 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 SS2205. In many applications, fatigue interacts with corrosion, giving reduced fatigue strength. In such cases SS2205 offers considerable advantages over mild steel and conventional stainless steels.

IMPACT PROPERTIES

SS2205 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 SS2205 is about –55°C, although the minimum energy requirement of 27J (which is considered to be the lower limit for ductile behavior) is easily met for temperatures as low as –120°C.



Physical Properties:

Density	7 860kg/m³
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	850ηým
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 1020°C and 1100°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

SS2205 can be stress relieved at 525°C to 600°C for 60 minutes per 25mm thickness. Stress relieving SS2205 contributes significantly to improving the resistance to stress corrosion cracking by lowering the residual tensile stresses.

HOT WORKING

SS2205 can be readily forged, upset and hot headed. Uniform heating of the steel in the range of 1150°C to 1250°C is required. Initial hot working should be effected 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 1000°C, rapid cooling (water quenching) can be carried out directly from the working temperature. Otherwise, all hot-working operations should be followed by annealing, pickling and passivating to restore the mechanical properties and corrosion resistance.

COLD WORKING

SS2205 has good formability, but due to the higher proof strength, more power is required for most cold-forming operations than for austenitic stainless steels. Roll forming can be readily applied to SS2205, 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 SS2205 is three times the plate thickness and four times is recommended. Severe bends should be carried out transverse to the rolling direction. SS2205 exhibits greater spring-back than mild steel and this should be compensated for by slight over-bending.

MACHINING

The high strength that makes SS2205 useful in many applications also reduces its machinability. Cutting speeds are approximately 20% slower than those for SS304. 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 minimize the work hardening of the surface layer. A suitable cutting fluid should be used to minimize the risk of built-up edges. The work should be flooded to ensure maximum heat removal.

WELDING

SS2205 has good weldability in most applications, provided that the recommended procedures are adopted. SS2205 is suited to most standard welding methods (MMA/SMAW, MIG/GMAW, TIG/GTAW, FCAW, SAW and PAW). If SS2205 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 SS2205 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 minimized and, in any case, kept below 2 kJ/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 SS2205, 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

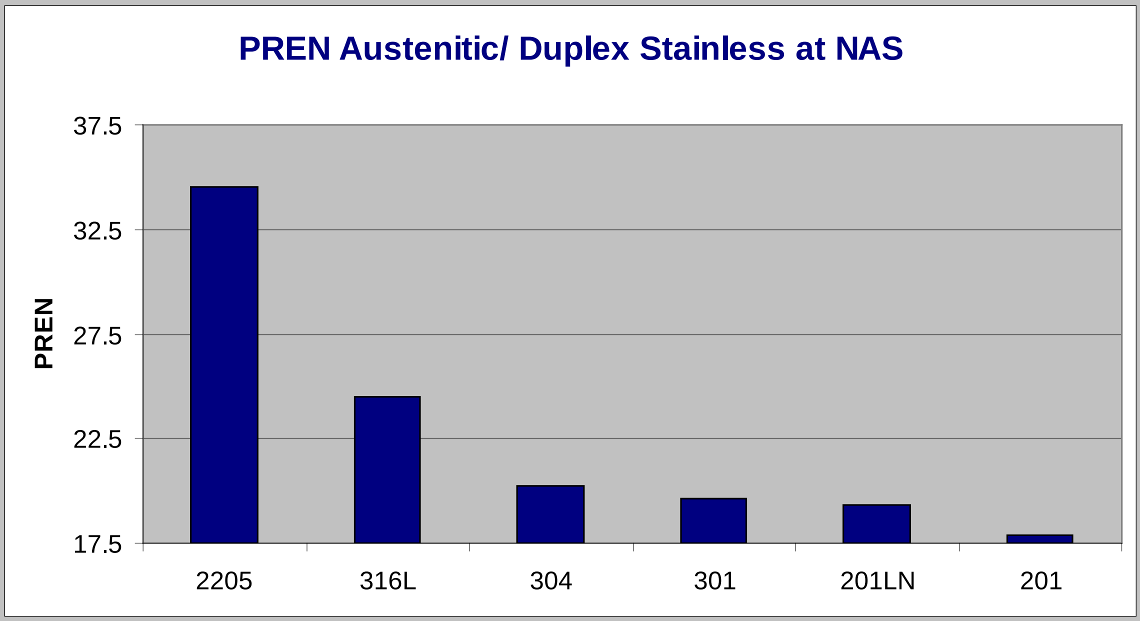
SS2205 has excellent general corrosion resistance and, generally speaking, this is better than SS316 or 317 in most environments.

PITTING CORROSION

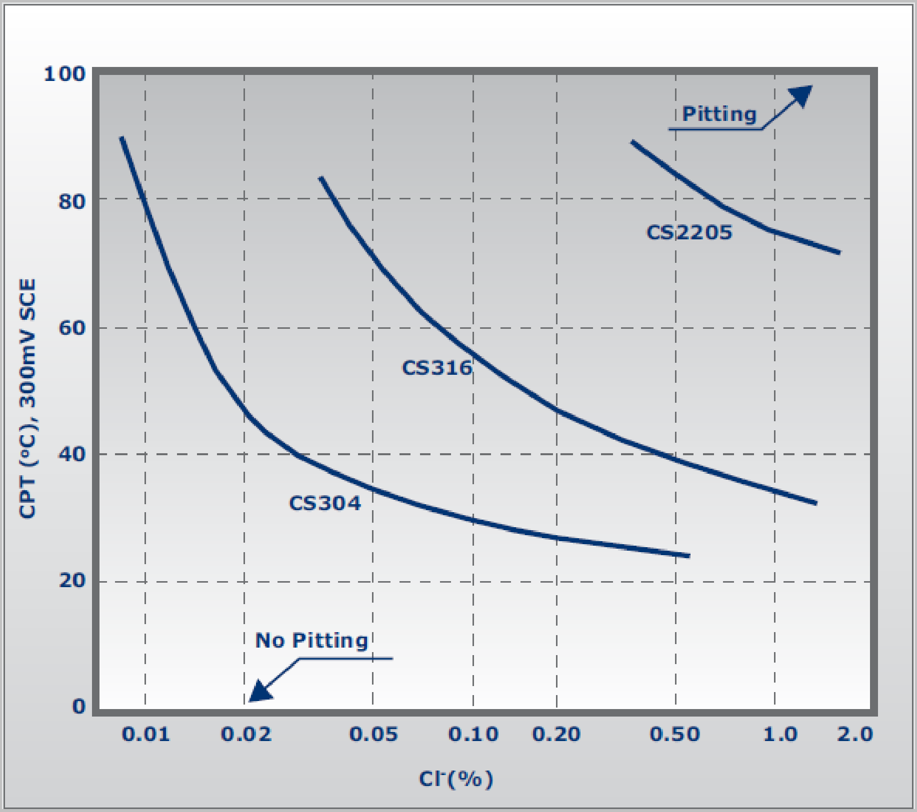
Pitting resistance is important, mainly in applications involving contact with chloride solutions, particularly in the presence of oxidizing media. These conditions may be conducive to localized penetration of the passive surface film on the steel; and a single deep pit may well be more damaging than 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:

$PRE = Cr + 3.3Mo + 16N$



This illustrates the expected superior resistance of SS2205 to pitting or crevice corrosion. The diagram overleaf shows the experimentally measured critical temperature for initiation of pitting (CPT) at different chloride contents for SS304, SS316 and SS2205. This agrees well with the empirical PRE's above and with practical experience. Thus, SS2205 can be used at considerably higher temperatures and chloride contents than SS304 or SS316 without pitting occurring. SS2205 is therefore far more serviceable in chloride-bearing environments than standard austenitic stainless steels.



Critical pitting temperatures (CPT) for SS304, SS316 and SS2205 at varying concentrations of sodium chloride (potentiostatic determination at + 300 mV SCE).
pH =6

OXIDATION

SS2205 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 a' (475°C embrittlement) and nitrides or carbides. In the high temperature range, chi and si 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 is small. In addition, this effect does not necessarily affect the behavior 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 SS2205.

ATMOSPHERIC CORROSION

The atmospheric corrosion resistance of duplex stainless steels is unequalled by virtually all other uncoated engineering materials. However, SS316 is normally sufficient in areas where the atmosphere is highly polluted with chlorides, sulfur compounds and solids, either singly or in combination. In urban and rural areas, SS304 generally performs satisfactorily.

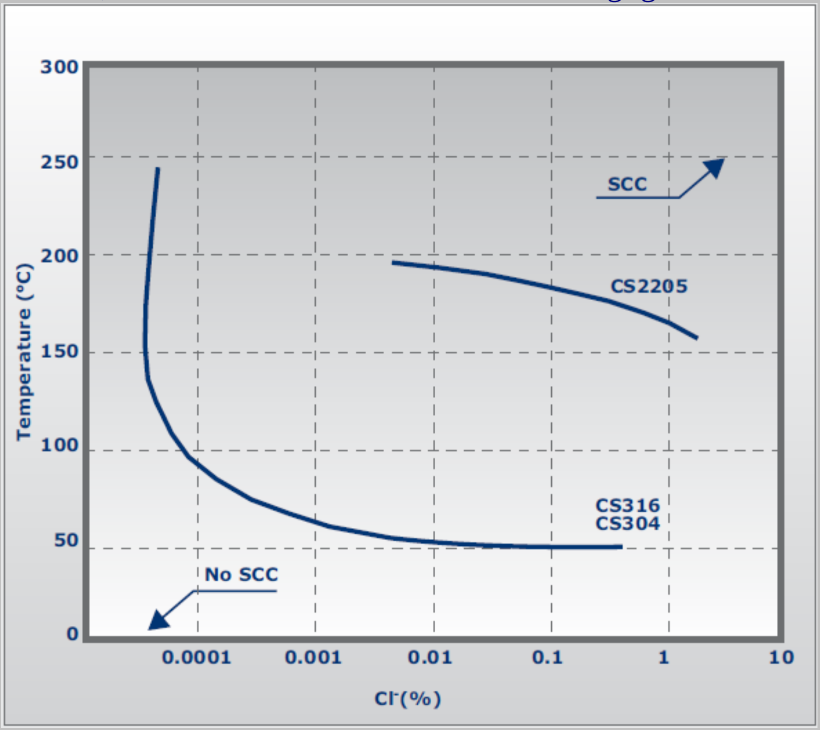
INTERGRANULAR CORROSION

Sensitization may occur when the heat-affected zones of welds in some stainless steels are cooled through the sensitizing temperature range of between 450°C and 850°C. At these temperatures, a compositional change (carbide precipitation) may occur at the grain boundaries. If a sensitized 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 SS2205 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 SS2205 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 SS2205, SS316 and SS304 can be used with negligible risk of stress corrosion cracking.



Resistance to Stress Corrosion Cracking

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

SS2205 possesses higher strength and better corrosion resistance than ordinary austenitic stainless steels. SS2205, 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), SS2205 required 430MPa stress in the unnotched condition to bring about rupture after 2x107 cycles, while 316N failed at only 260MPa. The corresponding notched figures were 230MPa and 140MPa for SS2205 and 316N respectively.

Technical Service: For further information, email qualitycontrol@northamericanstainless.com
For new product development requirements, contact sales@northamericanstainless.com.

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