North American Stainless

Flat Product Stainless Steel Grade Sheet

316 (S31600)/EN 1.4401
316L (S31603)/ EN 1.4404

INTRODUCTION

NAS provides 316 and 316L SS, which are molybdenum-bearing austenitic stainless steels. These steels contain a higher percentage of nickel than 304SS. The resultant composition 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 sulfuric 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.

316 SS offers good strength and creep resistance and also possesses excellent mechanical and corrosion-resistant properties at sub-zero temperatures. 316L is a low- carbon modification of 316. The control of the carbon to a maximum of 0.03% minimizes 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.

Additionally, 316/316L is available in pipe and tube chemistry specification.

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, A480/09, A666, ASME SA240, SA480, SA666, ASTM A262, EN 10088-2, EN 10028-7.

Chemical Composition :

UNS/Euro	ASTM/Euro	Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Nitrogen	Molybdenum
S31600	316	0.08 max	2 max	0.045 max	0.03 max	0.75 max	16-18	10-14	0.1 max	2-3
S31603	316L	0.03 max	2 max	0.045 max	0.03 max	0.75 max	16-18	10-14	0.1 max	2-3
X2CrNiMo17-12-2	1.4404	0.03 max	2 max	0.045 max	0.015 max	0.75 max	16.5-18.5	10-13	0.1 max	2-2.5
X5CrNiMo17-12-2	1.4401	0.07 max	2 max	0.045 max	0.015 max	0.75 max	16.5-18.5	10-13	0.1 max	2-2.5

Mechanical Properties :

	Tensile Strength min	Yield Strength min	Elongation min	Hardness max
316	75 ksi	30 ksi	40%	95 HRB
316L	70ksi	25 ksi	40%	95 HRB
1.4404	75ksi	34.81	40%	
1.4401	75ksi	34.81	40%	

Note: Enhanced properties available upon request.

PROPERTIES AT ELEVATED TEMPERATURES

The properties quoted below are typical of annealed 316 only, as strength values for 316L fall rapidly at temperatures above 800°F. 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

	Stress (MPa) to Produce 1% Strain		Stress (MPa) to Produce Rupture	
Temperature (°C)	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

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)

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) use data from low-cycle fatigue tests carried out on machined specimens to produce conservative S-N curves used with stress concentration factors (k1c) or fatigue strength reduction factors (kt). 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.

ANNEALING

Annealing of types 316 and 316L is achieved by heating to above 1900°F and for 60 minutes per inch thickness followed by water or air quenching. The best corrosion resistance is achieved when the final annealing temperature is 1950°F. Controlled atmospheres are recommended in order to avoid excessive oxidation of the surface. Temperatures above 1975°F are not recommended, except when wire is strand annealed in controlled atmosphere.

STRESS RELIEVING

The lower-carbon-grade 316L can be stress relieved at 850°F to1100°F for 60 minutes with little danger of sensitization. A prolonged heat treatment at these temperatures also results in sigma phase formation and change in the ductility of the material.

HOT WORKING

316 can be readily forged, upset and hot headed. Uniform heating of the steel in the range of 2100°F to 2300°F is required. The finishing temperature should not be below 1650°F. Upsetting operations and forgings require a finishing temperature between 1700°F and 1800°F. Forgings should be air cooled. All hot-working operations should be followed by annealing, pickling and passivation to restore the mechanical properties and corrosion resistance.

COLD WORKING

316/316L types, being extremely tough and ductile, can be readily cold worked such as wire drawing, swaging and cold heading etc. without difficulty. Severe cold forming may require intermediate 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. NAS provides 316L grade bars suitable for machining. Contact NAS for details.

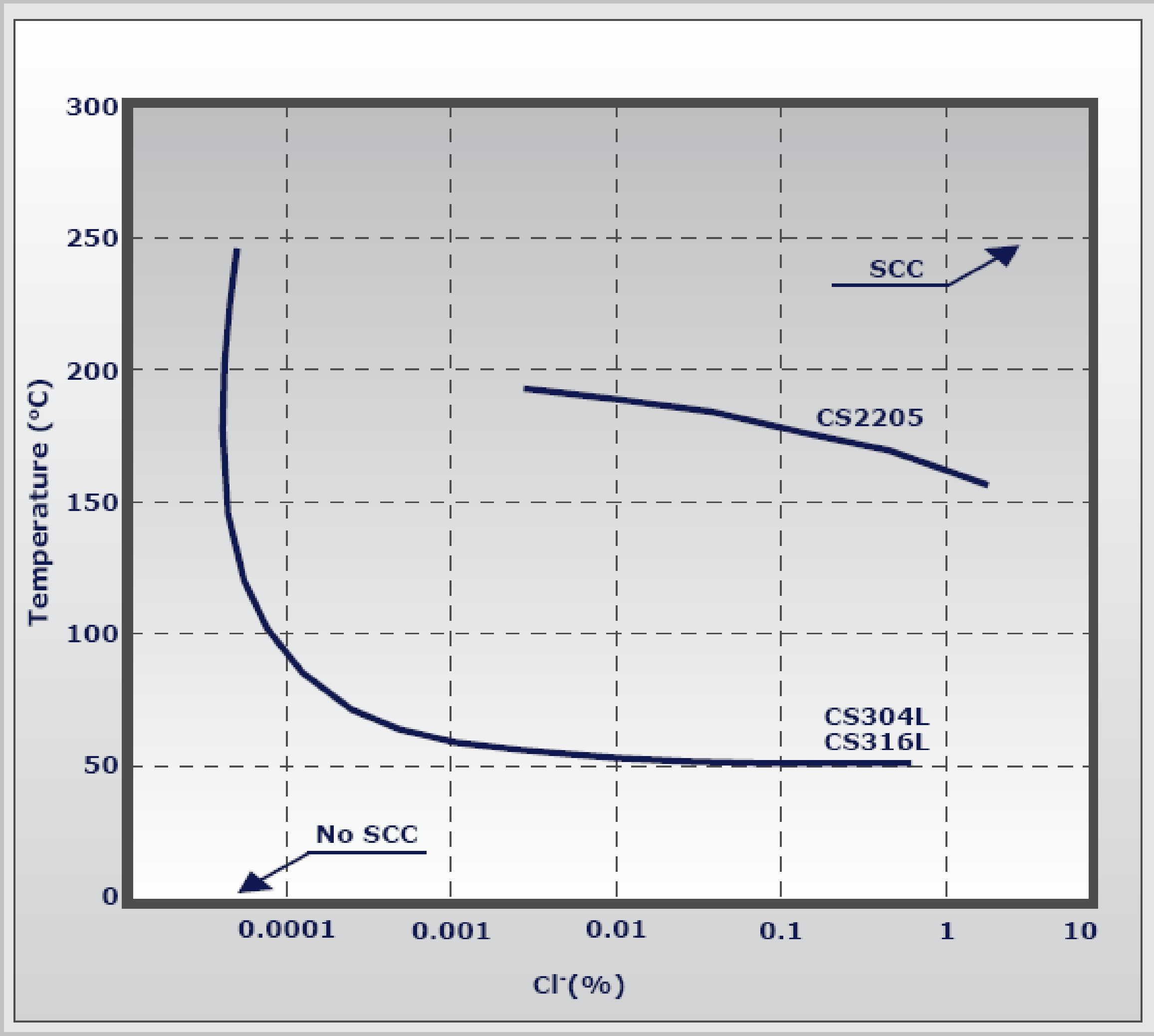
WELDING

316/316L 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, regular 316 should be annealed after welding to dissolve any chromium carbides which may have precipitated. The weld discoloration should be removed by pickling and passivation to restore maximum corrosion resistance.

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 140°F. 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 duplex grade 2205 should be used.



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 these grades in areas where the atmosphere is highly polluted with chlorides, sulfur compounds and solids, either singly or in combination.

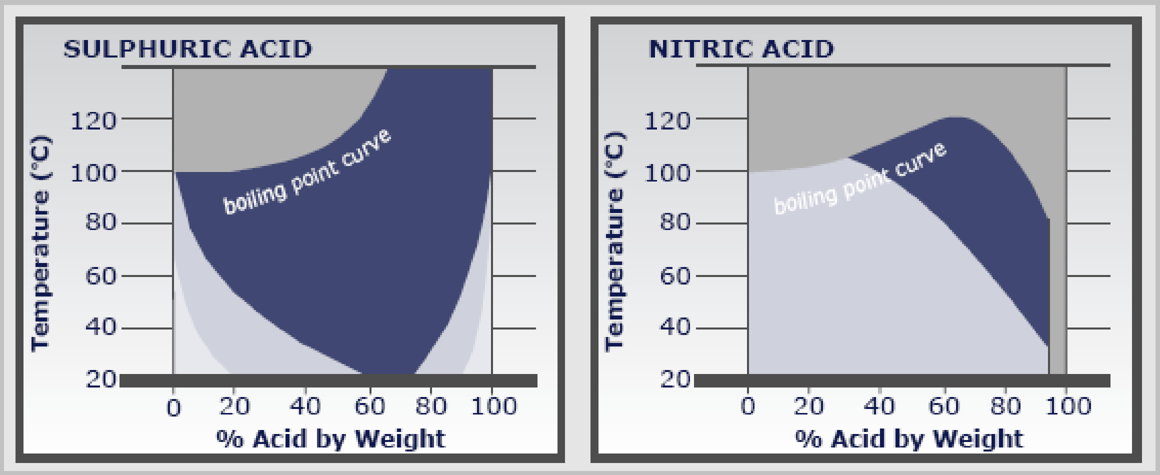
INTERGRANULAR CORROSION

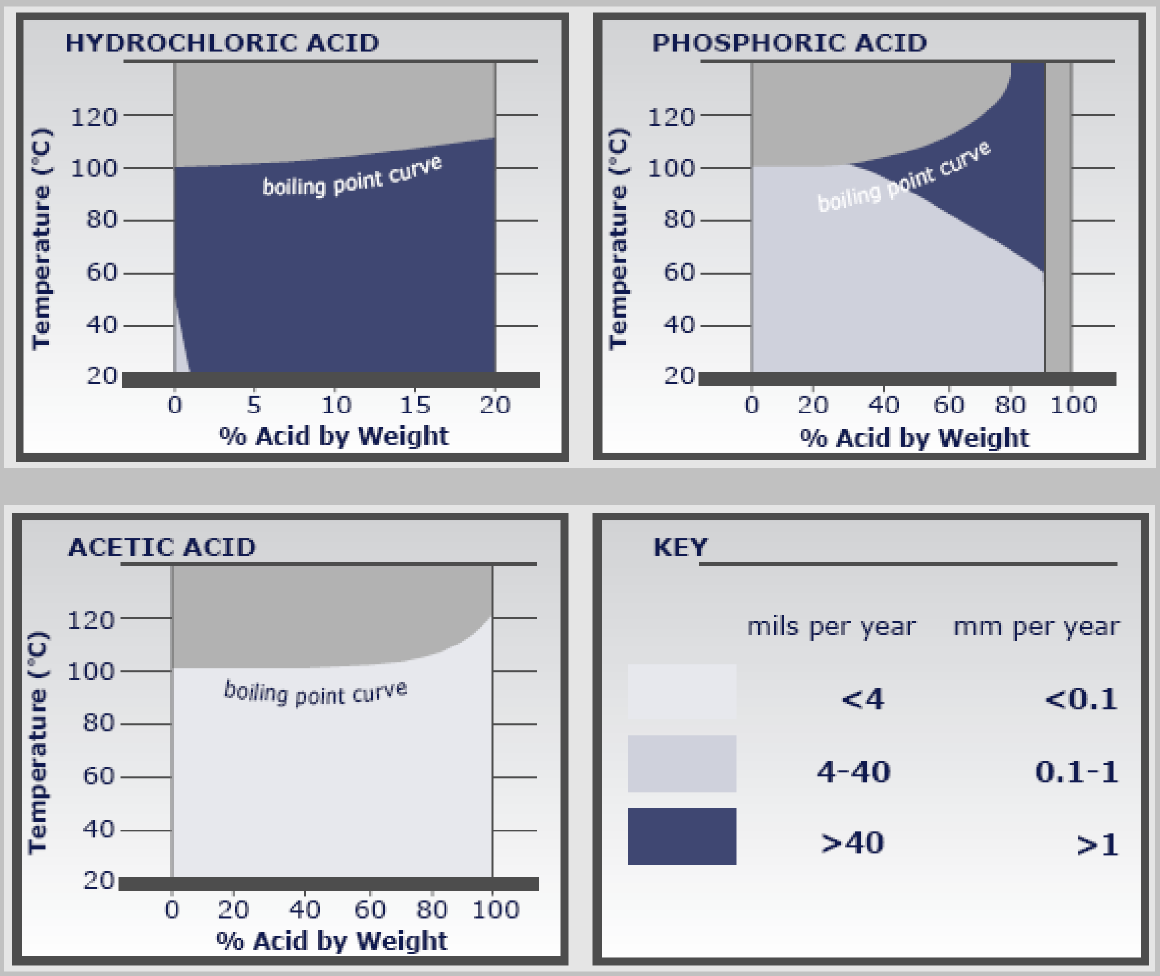
Sensitization may occur when the heat-affected zones of welds in some austenitic stainless steels are cooled through the sensitizing temperature range of between 850° and 1550°F. At these temperatures, a compositional change may occur at the grain boundaries. If a sensitized material is then subjected 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. This form of attack is often termed "weld decay".

316 SS has reasonable resistance to carbide precipitation. However, 316L grade should be specified for welded structures unless the higher-carbon types are required for their increased strength.

CORROSION RESISTANCE

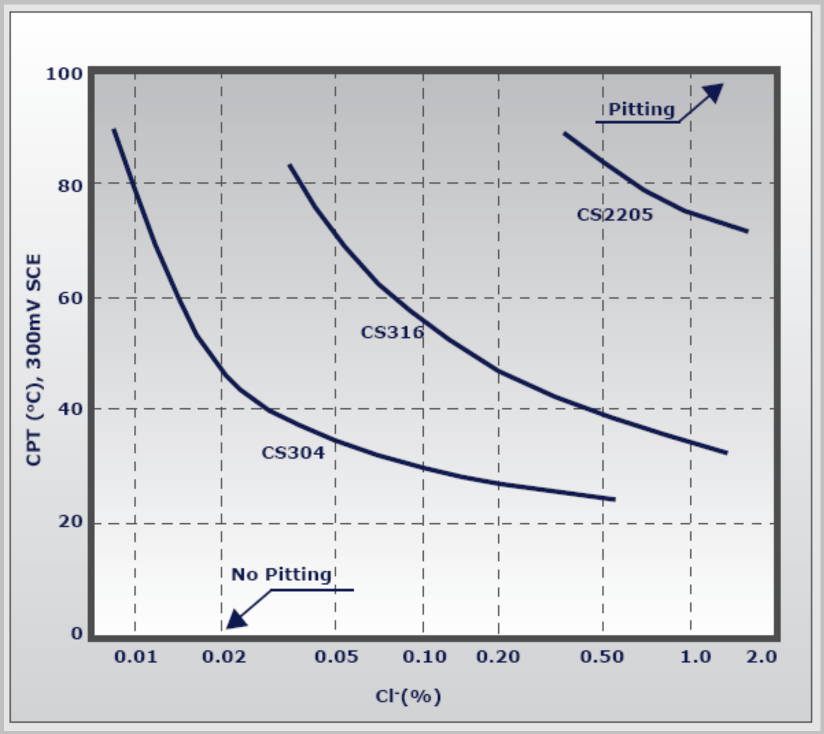
SS316 types have superior corrosion resistance to SS304 types. SS316 has good resistance to most complex sulfur compounds such as those found in the pulp and paper industry. CS316 also has good resistance to pitting in phosphoric and acetic acids. SS316 has excellent resistance to corrosion in marine environments under atmospheric conditions.





PITTING CORROSION

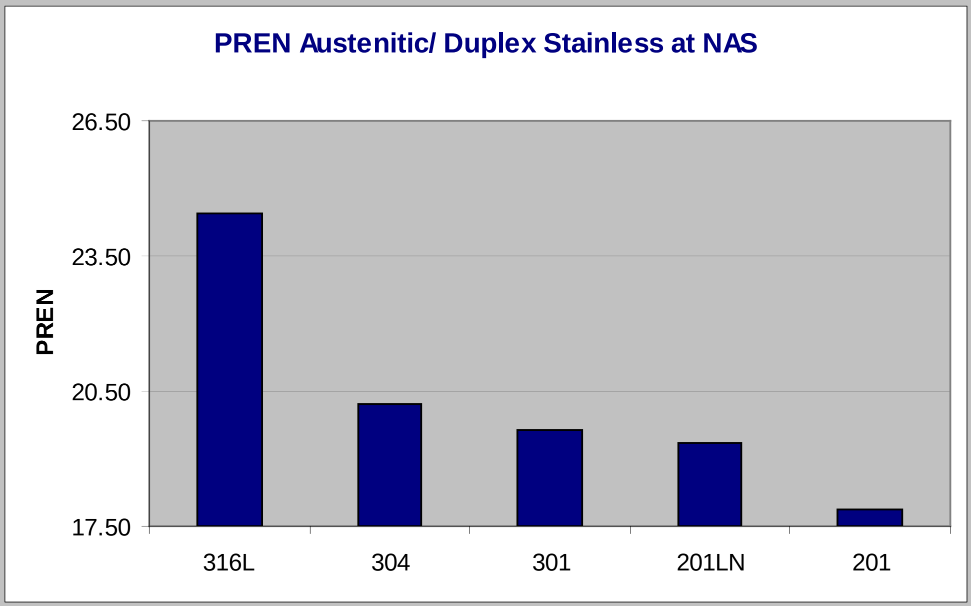
Pitting resistance is important, mainly in applications involving contact with chloride solutions, particularly in the presence of oxidizing media. These conditions may be conducive to localized penetration of the passive surface film on the steel, and a single deep pit may well be more damaging than a much greater number of relatively shallow pits. The addition of molybdenum to the steel ensures that 316 has good resistance to localized corrosion such as pitting and crevice corrosion. The diagram below shows the critical temperature for initiation of pitting (CPT) at different chloride contents for 304, 316 and 2205 types.



Critical pitting temperatures (CPT) for 304, 316 and 2205 at varying concentrations of sodium chloride (potentio-static determination at + 300 mV SCE). pH=6.0.

Pitting- resistance equivalent numbers (PREN) are a theoretical way of comparing the pitting corrosion resistance of various types of stainless steels, based on their chemical compositions. The PREN (or PRE) numbers are useful for ranking and comparing the different grades, but cannot be used to predict whether a particular grade will be suitable for a given application, where pitting corrosion may be a hazard.

Typical PREN on NAS grades and comparison are shown below.



OXIDATION

316/316L has good oxidation resistance in intermittent service up to 1600°F and in continuous service to 1700°F. Continuous use of type 316 in the 850° F to 1550°F temperature range is not recommended due to possibility of carbide precipitation but performs well in temperatures fluctuating above and below this range. One should use the 316L in these applications.

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

DISCLAIMER