


2205 Data Book

2205 duplex stainless steel is a cost effective solution to common corrosion problems encountered with 300 series stainless steels. "Duplex" describes a family of stainless steels that are neither fully austenitic or ferritic. The advantage of a duplex structure is that it combines the favorable qualities of a ferritic alloy (stress corrosion cracking resistance and high strength) with those of an austenitic alloy (ease of fabrication and corrosion resistance).

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2205 is a duplex (austenitic-ferritic) stainless steel containing about 40-50% ferrite in the annealed condition. It has been a practical solution to chloride stress corrosion cracking problems experienced with 304/304L or 316/316L stainless. The high chromium, molybdenum, and nitrogen contents provide corrosion resistance superior to 316/316L and 317L stainless in most environments. 2205 is not suggested for operating temperatures over 600°F.

The design strength of 2205 is significantly higher than 316/316L, often permitting lighter wall construction. For this reason, 2205 has become a common material of construction for components of offshore oil platforms and chemical transport tankers. 2205 has good notch impact toughness down to temperatures below -40°F. 2205 is welded with E2209 or ER2209 fillers.

Specifications

UNS: S31803 S32205 **W. Nr./EN:** 1.4462 **ASTM:** A 240, A 276, A 479, A 789, A 790, A 182 (Grade F51), A 923
ASME: SA-240, SA-479, SA-789, SA-790, SA-182 (Grade F51), Pgroup 10H **NACE:** ISO 15156 / MR0175

Chemical Composition, %

	Ni	Cr	Mo	Mn	Si	C	N	S	P	Fe
MIN	4.5	22.0	3.0	–	–	–	0.14	–	–	–
MAX	6.5	23.0	3.5	2.0	1.0	0.03	0.2	0.02	0.03	balance

Features

- High resistance to chloride stress corrosion cracking
- Chloride pitting and crevice corrosion resistance superior to 317L stainless
- Good general corrosion resistance
- High strength
- Good sulfide stress corrosion resistance
- Useful up to 600°F

Applications

- Chemical process vessels, piping, and heat exchangers
- FGD scrubber systems
- Pulp mill digesters, bleach washers, chip presteaming vessels
- Food process equipment
- Oil field piping, heat exchangers
- Offshore oil platforms
- Chemical transport tankers

Physical Properties

Density: 0.278 lb./in^3 **Melting Range:** 2525-2630°F **Poisson's Ratio:** 0.3 **Electrical Resistivity:** 481 Ohm - circ mil/ft

Temperature, °F	70	212	392	572
Coefficient* of Thermal Expansion, in/in°F x 10^{-6}	–	7.5	7.8	8.1
Thermal Conductivity, Btu • ft/ft^2 • hr • °F	8.1	8.7	9.9	10.5
Modulus of Elasticity Dynamic, psi x 10^6	27.6	26.1	25.4	24.9

* 70°F to indicated temperature.

Mechanical Properties

Specification: A240

	2205	316/316L*	317L	904L	Alloy 20	AL-6XN®
Ultimate Tensile Strength, ksi	95	75	75	71	80	95
0.2% Yield Strength, ksi	65	30	30	31	35	45
Hardness MAX, Brinell	293	217	217	183	217	241

*Dual Certified

**Values are minimums unless otherwise stated.

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Stress Values, ksi

Temperature, °F	2205*	316/316L	317L	904L	20	AL-6XN®
200	25.7	20.0	17.0	16.7	20.6	26.2
300	24.8	20.0	15.2	15.1	19.7	23.8
400	23.9	19.3	14.0	13.8	18.9	21.9
500	23.3	18.0	13.1	12.7	18.2	20.5
600	23.1	17.0	12.5	11.9	17.7	19.4

*UNS S31803

Stress Corrosion Cracking

2205 is a cost effective solution for many applications where 300 series stainless steels are susceptible to chloride stress corrosion cracking (SCC). SCC will occur when stainless steels are subjected to tensile stress, while in contact with solutions containing chlorides. Increasing temperatures also increase the susceptibility of stainless steels to SCC.

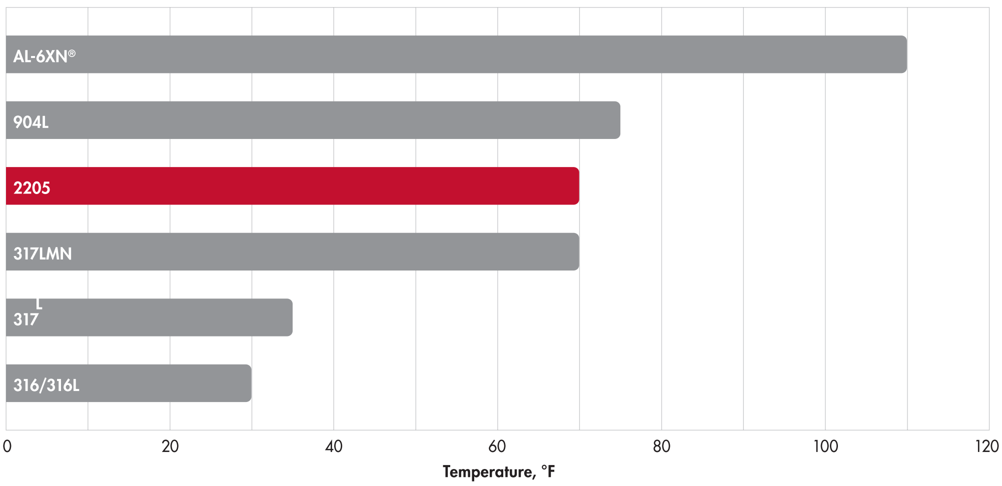
	2205	316/316L	904L	20	317L	317LMN	AL-6XN®
Boiling 42% $MgCl_2$	Failed	Failed	Failed	Failed	Failed	Failed	Passed/ Failed
Wick Test	Passed	Failed	Passed/ Failed	Passed	Failed	–	Passed
Boiling NaCl	Passed	Failed	Passed/ Failed	Passed	Failed	Passed	Passed

Pitting and Crevice Corrosion Resistance

The combination of chromium, molybdenum, and nitrogen impart the good resistance of 2205 to chloride pitting and crevice corrosion. This resistance is extremely important for services such as marine environments, brackish water, bleaching operations, closed loop water systems and some food processing applications. ASTM G 48 Practice B is a common method for evaluating the crevice corrosion resistance of an alloy. Testing is performed in a 10% $FeCl_3 \bullet 6H_2O$ solution. Using this test, the critical crevice temperature (CCCT) of an alloy can be determined. Alloys with higher CCCTs are considered more resistant to crevice attack.

CCCT

Critical Crevice Corrosion Temperature 10% $FeCl_3 \bullet 6H_2O$



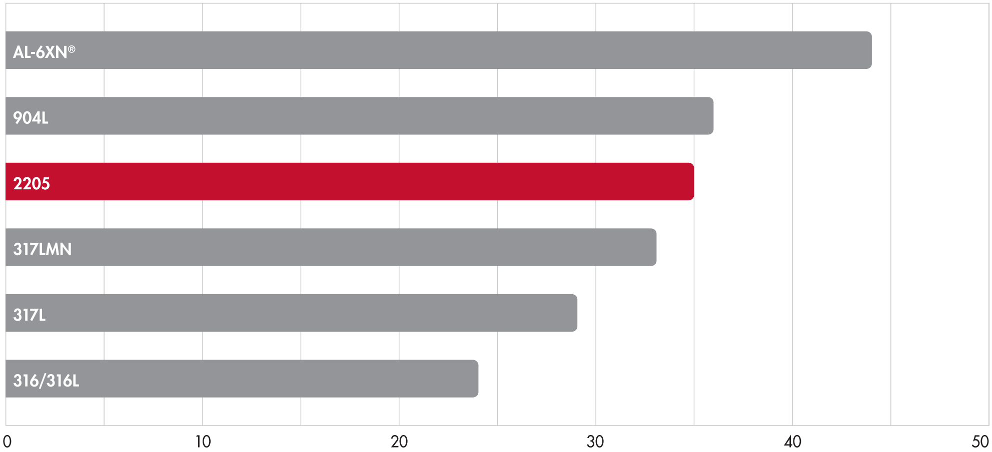
PRE$_N$

Pitting Resistance Equivalent

PRE$_N$ = Cr + 3.3Mo + 16N

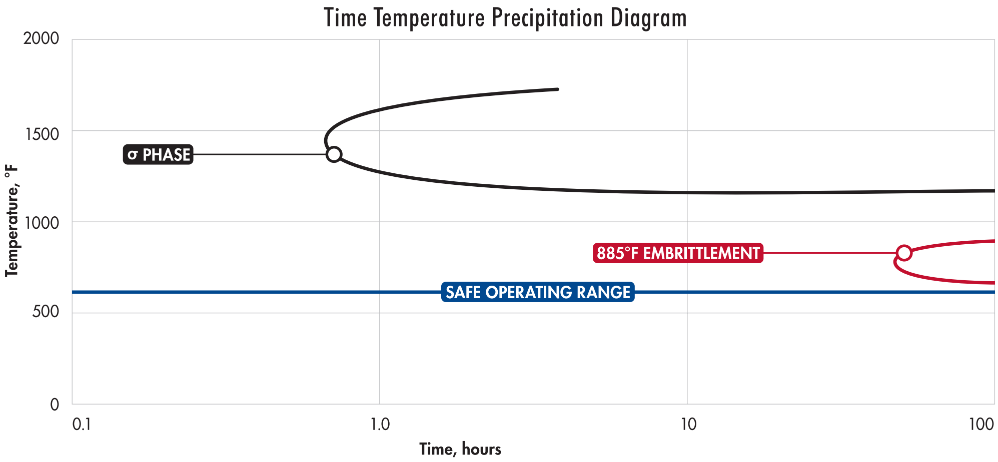
Pitting resistance relates heavily to the Cr, Mo and N content of a stainless steel. A numerical relationship has been developed for comparing the pitting resistance of stainlesses based on these three elements. This method is known as the Pitting Resistance Equivalent, PRE$_N$. The following figure compares the PRE$_N$ of 2205 to other common corrosion resistant alloys.

The high chromium, molybdenum and nitrogen contents of 2205 provide corrosion resistance superior to common stainlesses, such as 316/316L and 317L in most environments.



Structural Stability

Usage of 2205 should be limited to temperatures below 600°F. Extended elevated temperature exposure can embrittle 2205 stainless. The figure below shows the temperatures and lengths of time required for secondary phases to precipitate in 2205 stainless.



Sigma Phase

Sigma phase will precipitate upon exposure to temperatures within the 1300-1800°F range. Precipitation occurs most rapidly at 1485°F. The presence of sigma phase will cause both a loss in room temperature ductility and a reduction in corrosion resistance. 2205 mill products are evaluated in accordance with ASTM A 923 and are free of harmful levels of intermetallic phases.

The welding of 2205 does subject the heat affected zone (HAZ) of the joint to the sigma formation temperature range. The high nitrogen content of 2205 slows the precipitation of intermetallic phases so that welding can be performed without the formation of harmful levels of sigma phase formation.

Exposure to temperatures in the 650-980°F range causes the precipitation of alpha prime in the ferritic portion of the material. This phenomenon is also referred to as 885°F embrittlement. During welding the time at temperature is typically not long enough to cause embrittlement. 885°F embrittlement limits the use of 2205 to temperatures below 600°F.

Hot Forming
Fabrication

Heat 2205 uniformly to 2050-2100°F. Do not forge at temperatures below 1740°F. Reheat as often as necessary. Hammer forging is preferred. Dies should have generous radii. Cool forgings in air and anneal, followed by water quench. Hot tearing or surface checking are possible if the initial forging temperature is too high. As with other high chromium alloys, 2205 can be sensitive to coarse grinding marks on the forging billet. In order to dissolve undesirable precipitates occurring from the hot forming operations, and to restore the austenite-ferrite balance, the finished forging should be heat treated at 1950°F minimum for 10 minutes, or 30 minutes per inch of thickness, water quenched. Rapid heat-up rate is desired to avoid developing second phases. This alloy has very low strength at the annealing temperature, so the workpiece should be well supported in the furnace. It is important to cool to below 700°F as quickly as possible. If the cooling rate is too slow, it will lead to decreased corrosion resistance and lowered impact strength.

Cold Forming
Fabrication

2205 stainless can be readily formed and cold worked using techniques and designs similar to the basic austenitic stainless steel grades. However, due to higher strength and slightly lower ductility, bend radii must be more generous than those used for austenitic materials. A bend radius greater than 2T is encouraged. Power requirements for forming operations will be greater due to the higher yield strength of 2205 stainless as compared to standard austenitic stainless.

2205 stainless plate can normally be press brake bent over a radius equal to twice the plate thickness. As with other stainless and nickel alloys, bending over a sharp male die may cause the material to crack. Annealing may be required after 15% cold deformation.

Heat Treatment
Fabrication

Solution annealing is performed in the range 1870-2010°F. Fixture the workpiece to minimize distortion, as this alloy has low strength at the annealing temperature. The aim point for 2205 stainless is 1950°F for at least 10 minutes, or 30 minutes per inch of thickness, followed by a mandatory water quench. Furnace or air cooling of 2205 stainless is definitely not recommended, and would result in unacceptable mechanical and corrosion properties.

Welding Consumables
Fabrication

UNS	Form	Process	AWS	Cr	Ni	Mo	Mn	Si	N
S39209	Bare Wire	GMAW	A5.9, ER2209	22.5	8.5	3.1	1.6	0.4	0.14
S39209	Bare Wire	GTAW	A5.9, ER2209	22.5	8.5	3.1	1.6	0.4	0.14
S39209	Bare Wire	SAW	A5.9, ER2209	22.5	8.5	3.1	1.6	0.4	0.14
W39209	Covered Electrode	SMAW	A5.4, E2209	22.5	9.5	3.1	0.9	–	0.14
W39239	Gas-Shielded Flux Core Wire	FCAW	A5.22, E2209-T0-1, E2209-T1-1	22.5	9.0	3.0	1.3	–	0.10

GMAW
Gas Metal Arc Welding

2205 plate is GMAW welded using either the spray arc or pulsed-arc transfer mode. Short circuiting arc transfer is used for welding thin sheets and for out-of-position welding. Pulsing arc transfer provides some of the benefits of spray arc at a lower average heat input, which permits the method to be used on sheet gauges and in all positions. Heat inputs should be maintained around 20-45 kJ/inch. The upper end of the range is not critical. Shielding gas is normally 100% welding grade argon having a nominal purity of 99.996% and a dew point of -77°F. 2% nitrogen may be added. Helium may be added if desired to flatten the bead contour. Argon-25% helium is desirable to get good edge fusion when welding very heavy plate with small diameter wire. A newer gas mixture with desirable characteristics is 95%Ar 3%He 2%N_2. Do not add oxygen or hydrogen. Oxygen or hydrogen contamination lowers impact toughness in duplex stainless weldments.

Wire Diameter, in	Direct Current, Reverse Polarity	Voltage Range
0.035	170 - 200	24 - 28
0.045	180 - 260	27 - 31
0.062	230 - 350	26 - 32

Spry-Arc transfer ,100% Argon shielding at 24-36 SCFH

GTAW
Gas Tungsten Arc Welding

With GTAW, use straight stringer beads. Limit dilution of the weld bead by 2205 base metal. This is particularly important in tack welding and during the root pass. If there is any problem with tack welds or roots cracking it is probably due to insufficient weld filler, or too low a heat input. Both conditions promote high ferrite contents and reduced ductility in the bead. For light gages, 3/16" and thinner, heat input should be 20-50 kJ/inch to ensure sufficient austenite in weld bead.

Electrode Diameter, in (2% Thoriated Tungsten)	Direct Current Straight Polarity, Amperes (Electrode Negative)	Voltage	Shielding Gas*, Argon / Argon + 2% Nitrogen / Argon-Helium Mix
0.040	25 - 80	10 - 14	25
0.062	50 - 145	12 - 16	25
0.094	135 - 235	12 - 16	25

* Do not use hydrogen in the shielding gas. This may hydrogen embrittle the weld. Helium may be added to get deeper penetration and faster speeds in automatic welding.

SAW
Submerged Arc Welding

When sub-arc welding 2205 stainless, use a highly basic flux, such as Avesta Flux 805. DO NOT USE ACID FLUXES meant for 18-8 stainless. Heat inputs in the range 45-55 kJ/inch are preferred.

Wire Diameter, in	DCPR, Amperes	Voltage
3/32	250 - 450	28 - 32
1/8	300 - 500	29 - 34
5/32	400 - 600	30 - 35

SMAW
Shielded Metal Arc Welding

Wire Diameter, in	Current, Amperes	Voltage
3/32	60 - 80	22 - 28
1/8	80 - 110	22 - 28
5/32	100 - 160	22 - 28
3/16	130 - 180	22 - 28

FCAW
Flux Core Arc Welding

Shielding gases used are either 75% argon, 25% carbon dioxide or 100% carbon dioxide. Argon-CO_2 offers the best weldability in the horizontal position while 100% CO_2 is preferred for vertical welding. Use stringer beads with very little weave. Weaving will tend to trap slag at the edges of the bead. Allow the metal to cool down below 300°F between passes.

	Wire Diameter, in	75% Ar + 25% CO_2, Horizontal Position	100% CO_2, Vertical Position
Amperes, DCRP (Electrode Positive)	0.045	150-250	60-110
Volts	0.045	22-38	20-24

Dissimilar Metal Welding

Each dissimilar combination has to be assessed on its own merit but some general recommendations can be made for a number of commonly encountered combinations.

	Carbon/Low Alloy Steel	Austenitic Stainless Steel	Duplex Stainless	AL-6XN, 20, 625, C-276, C22, INCONEL® 686
2205	316L, 309LMo, 309L*	316L, 309LMo, 2209, R2209	2209, R2209, 2507	C-276, C22, 686-CPT

*The use of 2209 duplex stainless weld metal on carbon steel may result in a weld with a hard, brittle martensitic zone of about Rockwell C35.

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