

NITRONIC 19D

STAINLESS STEEL

UNS S32001



- Excellent Stress Corrosion Cracking Resistance
- High Strength
- Improved Welding Characteristics

Product Description

AK Steel NITRONIC® 19D is a stainless steel with a mixed ferrite and austenite structure. This alloy provides high yield strength (65 ksi minimum {448 MPa}), good drawing and welding characteristics, excellent chloride stress corrosion cracking resistance, and high cyclic oxidation resistance up to 1800°F (982°C). It also exhibits high ductility (super plasticity) at high temperatures (1800°F {982°C}). Compared to similar duplex stainless alloys such as 2205, NITRONIC 19D Stainless Steel is more economical but less corrosion resistant due to lower alloy content (particularly molybdenum). Inclusion in ASTM A 240 has been granted and the alloy is listed in the A 240-97a publication dated March 1998.

Composition	Typical %	ASTM A 240 %
Carbon	0.02	0.030 max.
Manganese	5.00	4.0 – 6.0
Silicon	0.40	1.00 max.
Chromium	20.00	19.5 – 21.5
Nickel	1.60	1.0 – 3.0
Copper	0.30	1.00 max.
Nitrogen	0.13	0.05 – 0.17
Iron	Balance	Balance

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Data referring to mechanical properties and chemical analyses are the result of tests performed on specimens obtained from specific locations of the products in accordance with prescribed sampling procedures; any warranty thereof is limited to the values obtained at such locations and by such procedures. There is no warranty with respect to values of the materials at other locations.

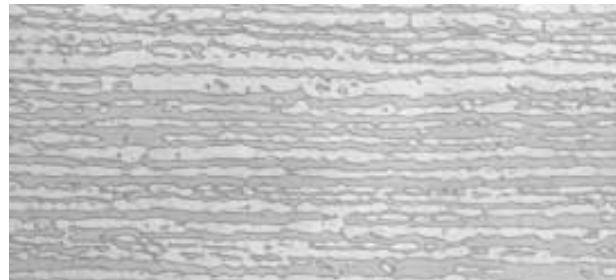
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Microstructure

AK Steel NITRONIC 19D Stainless Steel is alloy balanced to yield a microstructure consisting of 30-60% ferrite (bcc) and 40-70% austenite (fcc) in the wrought form. A typical wrought microstructure is shown in Figure 1. The matrix phase is ferrite (bcc), while the austenite phase (fcc) appears as discrete islands precipitated during solidification and cooling.

Figure 1

Typical longitudinal microstructure of NITRONIC 19D at 500X.



Available Forms

AK Steel NITRONIC 19D Stainless Steel has been produced cold rolled annealed and pickled strip with a 2D finish. Gauges from 0.028" to 0.14" (0.71 to 3.56 mm) have been furnished to customers for trial material.

Other possible surface finishes include 2B, TM (shot blast) matte, Unigrain, polished, bright annealed and Unibrite® (buffed).

Mechanical Properties

Table 1

Typical Room Temperature Mechanical Properties*

Gauge Range	0.028" – 0.084" (0.71 – 2.13 mm)
UTS, ksi (MPa)	100 – 111 (689 – 993)
0.2% YS, ksi (MPa)	69 – 78 (476 – 538)
Elongation, % in 2" (50.8 mm)	31 – 40
Hardness, Rockwell	B93 – B98
Olsen Cup Height	0.330" – 0.450" (8.38 – 11.43 mm)
'n' Value**	0.19

* 2D Finish

** 'n' value is also referred to as the strain-hardening coefficient.

PRODUCT DESCRIPTION

Table 2

Properties Acceptable for Material Specification

Gauge Range	0.028" – 0.084"
Min. UTS, ksi (MPa)	90 (620)
Min. 0.2% YS, ksi (MPa)	65 (448)
Elongation, % in 2" (50.8 mm)	25.0 min.
Hardness, Rockwell	C25 max.

Table 3

Typical Elevated Temperature Properties*

Orientation At Temperature	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Reduction in Area, %
1600°F (871°C)				
L**	12.1 (83.4)	8.4 (57.9)	82.3	65.0
T***	10.1 (69.6)	6.9 (47.6)	88.0	61.6
1800°F (982°C)				
L**	5.5 (37.9)	3.3 (22.8)	113.0	80.0
T***	4.0 (27.6)	2.3 (15.8)	143.0	80.0
2000°F (1093°C)				
L**	2.6 (17.9)	1.3 (9.0)	236.5	84.3
T***	1.9 (13.1)	0.8 (5.5)	179.5	97.0

*7/8" plate

**Longitudinal

***Transverse

Table 4

Effect of Cold Work on Mechanical Properties*

% Cold Work	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell**	n-value
0	98.8 (681)	63.4 (437)	34.5	B91.5	0.17
4.0	104.2 (718)	87.6 (604)	30.1	B97.0	0.16
9.8	113.5 (782)	101.9 (702)	23.6	B99.5	—
15.1	120.7 (812)	113.9 (785)	14.6	C24.0	—
20.7	130.0 (896)	119.9 (827)	12.1	C26.5	—
40.7	154.2 (1063)	141.2 (974)	5.2	C30.0	—
57.8	172.0 (1186)	158.1 (1090)	5.5	C33.0	—

*Lab work-hardened samples average of duplicate tests. All at 0.080 in final gauge.

**Converted

Table 5

Effect of Temperature on Charpy V-Notch Properties (3/16" plate)

Impact Strength (W/A), in-lb./in² (nmm•N/mm²) at Test Temperature

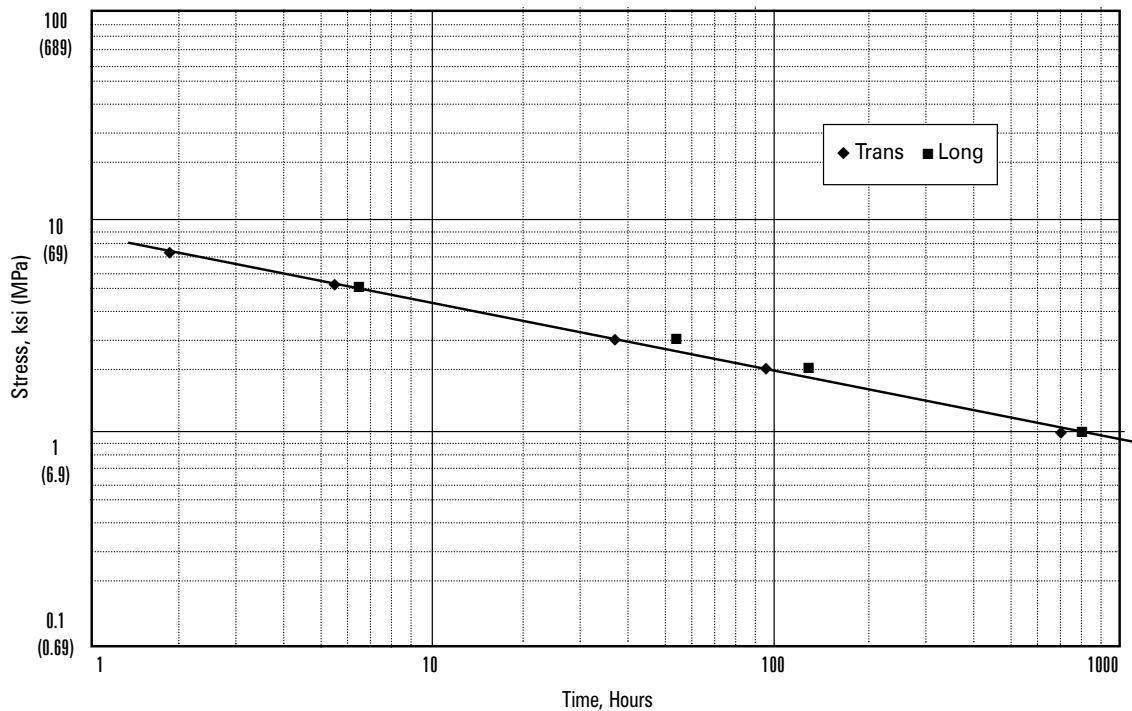
Orientation	73°F (23°C)	0°F (-18°C)	-22°F (-30°C)	-100°F (-73°C)	-150°F (-101°C)
Heat 1					
L*	16,786 (2,938) {4 tests}	10,555 (1,847) {4 tests}	9,703 (1,698) {2 tests}	7,904 (1383) {4 tests}	6,347 (1,111) {2 tests}
T**	4,793 (839) {3 tests}	4,428 (775) {3 tests}	3,962 (693) {3 tests}	3,111 (544) {4 tests}	2,891 (506) {3 tests}
Heat 2					
L*	15,534 (2,719) {3 tests}	9,098(1,592) {3 tests}	8,279 (1,449) {2 tests}	4,903 (858) {4 tests}	1,015 (178) {4 tests}
T**	6,006 (1,051) {3 tests}	5,113 (895) {3 tests}	4,664 (816) {3 tests}	2,225 (389) {4 tests}	859 (150) {3 tests}

*L –specimen axis parallel to rolling direction with notch through the plate

**T–specimen axis transverse to rolling direction with notch through the plate

Figure 2

NITRONIC 19D Stress Rupture @ 1500°F (816°C) (.079" sheet)



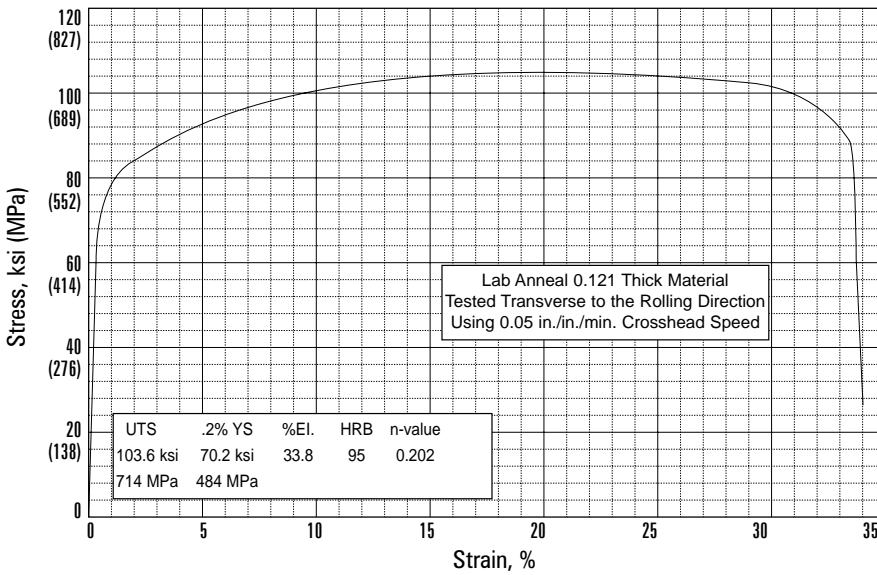


Figure 3
NITRONIC 19D to Failure
in tension test.

Table 6
Low Cycle Fatigue Resistance

Temperature	R-ratio	Frequency, Hz	Strain Range, %	Cycles to Failure
1600°F (871°C)	-1	0.5	1.06	1,447
1600°F (871°C)	-1	0.5	0.80	2,451
1600°F (871°C)	-1	0.5	0.60	4,714
1600°F (871°C)	-1	0.5	0.30	21,652
1600°F (871°C)	-1	0.5	0.16	125,775
1800°F (982°C)	-1	0.5	0.80	1,792
1800°F (982°C)	-1	0.5	0.40	4,245
1800°F (982°C)	-1	0.5	0.20	28,274
1800°F (982°C)	-1	0.5	0.16	37,470

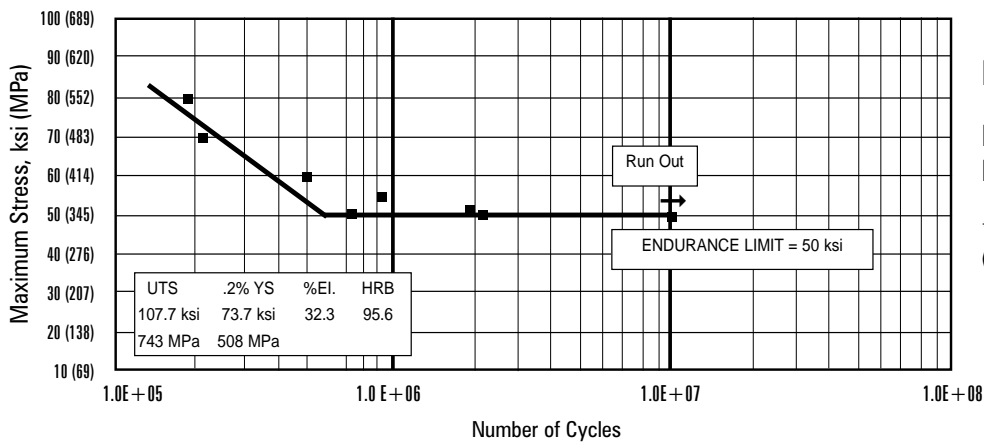


Figure 4
NITRONIC 19D
Reverse Bend Fatigue*

*R = -1, Transverse 0.037"
(0.94 mm) Annealed Sheet

Cyclic Oxidation Resistance

Table 7

Cyclic Oxidation Resistance

1800°F (982°C): 25 minutes heating, 5 minutes cooling. Specimens weighed after 1, 2, 3, 4, 7, 8, 9, 10, 11 and 14 day exposures for a total of 670 cycles.

Alloy	Weight Change, mg/in ²	Rank
AK Steel 18 Cr-Cb	+15.1	1
AK Steel NITRONIC 19D	+26.6	2
Type 310	+ 2.2	3*
2205	-31.0	4

* Ranked 3 due to oxide spalling after day 8.

1600°F (871°C) – 1700°F (926°C): 25 minutes heating, 5 minutes cooling. Total of 958 cycles.

Alloy	Weight Change, mg/in ²
AK Steel NITRONIC 19D	+21.9
Type 309	-210

Chloride Stress Cracking

AK Steel NITRONIC 19D Stainless Steel, like other duplex stainless steels, offers superior chloride stress corrosion cracking resistance relative to fully austenitic stainless steels like Types 304 and 316.

Chloride Stress Cracking Resistance*

Alloy	Hours to Failure
NITRONIC 19D	720 hours with no failure
Type 304	127 hours

*Lab processed 0.056" (1.42 mm) strip at 1950°F (1066°C) anneal, 25% boiling sodium chloride @ pH = 1.5 (adjusted with phosphoric acid). U-bends, 1.25" (31.75 mm) diameter, specimen axis parallel to rolling direction.

Sigma Embrittlement

AK Steel NITRONIC 19D Stainless Steel is highly resistant to embrittlement from sigma phase formation, even with exposure times of 100 hours. After three separate studies, it appears that this alloy is virtually immune to sigma formation with short-time exposure at any elevated temperature, while more highly alloyed alternatives 2205 and 2507 undergo significant embrittlement in just 10 minutes exposure to temperatures from 1400°F (760°C) to 1600°F (871°C).

Table 8

Sigma Embrittlement

Bend tests from 1800°F (982°C) Cyclic Oxidation Results shown in Table 7: 0.060" (1.5 mm) gauge, transverse. Bends were run after day 2, 4, 7, 9 and 14 aiming for 180°.

Shortest time to fail a bend diameter test of 1T (bend diameter = thickness) to 180°

Alloy	Exposure, days	Result
AK Steel NITRONIC 19D	14	OT – No Failures
AK Steel 18 Cr-Cb	4	2T
Type 310	14	1T
2205	2	Failed at 20°

AK Steel NITRONIC 19D Stainless Steel exhibited no sigma formation after 14 days, while 2205 became severely embrittled after just two days due to the large amount of sigma formed.

Formability

Duplex steel is better than the ferritic grades, especially in heavy sections, but not quite as good as the austenitic stainless steels. Limiting Draw Ratio (LDR) is 1.97. Strain Ratio (r-bar): L = 0.86, D = 0.80, T = 1.21 with a weighted average of 0.92, which is similar to austenitic stainless steels. Bend Ductility is OT (flat on self) in both longitudinal and transverse directions. Machining characteristics of this alloy are similar to those of Type 304 stainless steel.

Welding

Welding of NITRONIC 19D should follow basically the same guidelines as the other duplex stainless steels, like 2205. However, it so effectively resists sigma phase formation that the upper limit on heat input for arc welding (0.5 – 2.5 kJ/mm) is not critical. High heat input during arc welding slows the cooling rate, allowing more time for the required transformation to a duplex structure in the weld metal and heat-affected zone (most literature suggests a minimum of 30% austenite). In GTA welding, an addition of 2–5% nitrogen to the argon shielding gas and the use of nitrogen backing gas will also assist in this transformation in the weld metal. When filler metal is required, one balanced more toward an austenitic structure is preferred

for this reason. A suitable metal cored filler is under development at ESAB and trial quantities are available. A post-weld anneal of about 1900°F (1037°C) will also improve the phase balance, if neither of the preceding suggestions are feasible or adequate. AWS A5.4/5.9 Classifications ER/E2209 would also be good weld filler selections for this grade.

Like other duplex stainless steels, laser welding is an option that must be considered carefully as the high solidification and cooling rates will yield a primarily ferritic weldment structure. Post-weld annealing would be very beneficial for such welds. The conventional processes of GMAW and SMAW are both very feasible and, again, high heat inputs are suggested.

Table 9

As-Welded Autogenous GTA Mechanical Properties*

	UTS ksi (MPa)	YS ksi(MPa)	Elongation % in 2" (50.8 mm)	Elongation % in 0.5" (12.7 mm)	Base Hardness Rockwell B**	Weld Hardness Rockwell B***
Weld ⁺	100.2 (690.9)	69.4 (478.5)	20	33.9	94	94
Weld dup. ⁺	99.5 (686.0)	70.2 (484.0)	16	31.8	—	—
Base metal ⁺⁺	103.0 (710.2)	69.3 (477.8)	32	—	96	—

*0.060" (1.5 mm) thickness.

**6 Replicates

***3 Replicates

+ Tensiles oriented with weld across the reduced section.

++ Duplicate transverse production values.

Note: 1) Elongations in 0.5" (12.7 mm) are more appropriate for welds.

Fractures were in the weld metal.

2) Hardness results in "Weld" row are from separate coupon.

Physical Properties

Density – 0.279 lb/in³ (7.72 g/cm³)

Table 10

Thermal Expansion*

Temperature °F	Relative Expansion %	Coefficient Expansion $\Delta L/L/^\circ F \times 10^{-6}$	Temperature °C	Relative Expansion %	Coefficient Expansion $\Delta L/L/^\circ C \times 10^{-6}$
175	0.076	7.04	75	0.069	12.58
275	0.151	7.30	125	0.138	13.08
375	0.229	7.46	175	0.207	13.36
475	0.309	7.59	225	0.279	13.58
575	0.392	7.72	275	0.352	13.79
675	0.475	7.83	325	0.427	13.99
775	0.561	7.93	375	0.503	14.16
875	0.647	8.02	425	0.580	14.32
975	0.734	8.08	475	0.658	14.46
1075	0.824	8.18	525	0.735	14.56
1175	0.917	8.29	575	0.817	14.72
1212.7	0.957	8.36	625	0.900	14.88
—	—	—	655.9	0.957	15.04

*Average of triplicate tests on two specimens, heating curves.

Applications Potential

One manufacturer selected NITRONIC 19D Stainless Steel as a corrosion-resistant, high-pressure alternative for undersea umbilical tubing. The material was chosen for its combination of strength, corrosion resistance and ease of forming and welding. The result was a cost-effective alternative to higher-cost alloys.

AK Steel 19D Stainless Steel is also being used for production of annealed tubing for oilfield applications. Automotive exhaust tubing applications are currently being evaluated.

Metric Conversion

Data in this publication are presented in U. S. customary units. Approximate metric equivalents may be obtained by performing the following calculations:

Length (inches to millimeters) — Multiply by 25.4

Strength (ksi to megapascals or meganewtons per square meter) — Multiply by 6.8948

Temperature (Fahrenheit to Celsius) —
(°Fahrenheit - 32) - Multiply by 0.5556

Density (pounds per cubic inch to kilograms per cubic meter) — Multiply by 27,670



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