P R O D U C T D A T A B U L L E T I N

NITRONIC 30
STAINLESS STEEL

UNS S20400

AK Steel

- Good Wet Abrasion Resistance
- Good Resistance to Aqueous and Atmospheric Corrosion
- High Strength
- Economy
- Improved Stress Corrosion Cracking Resistance

AK Steel NITRONIC® 30 Stainless Steel Sheet, Strip and Plate

Applications Potential

AK Steel NITRONIC 30 Stainless Steel offers significantly higher strength than Type 304 and potential for applications requiring good resistance to aqueous and atmospheric corrosion resistance combined with good toughness and economy.

Specific potential applications include automotive hose clamps, safety belt anchors, truck and bus frames, water supply and control structures, sewage treatment plant structures, bulk solids handling equipment, magnetic ore separator screens, coal buckets and hopper cars.

Stainless steels have served successfully in many structural components in the transportation industry. Bus space frames and bumpers take advantage of the excellent fabricability and high strength and toughness of stainless steel. Tensilized NITRONIC 30 Stainless Steel has been used in rapid transit structurals where the strength-to-weight ratio of up to three times that of carbon steel has improved operating efficiency. Rear frames of refrigerated trucks are easily welded and formed from NITRONIC 30 Stainless Steel, resulting in protective units that can withstand impact blows without cracking. Shipboard container structurals use stainless steel successfully where carbon steel becomes scuffed and rusts wherever the paint is damaged.

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PRODUCT DESCRIPTION

AK Steel NITRONIC 30 is a nitrogen-strengthened stainless steel developed for applications requiring a good level of aqueous corrosion resistance combined with good toughness and economy. AK Steel NITRONIC 30 Stainless Steel provides approximately 50% higher yield strength than Type 304L and, therefore, may allow lighter gauges to further reduce costs. AK Steel NITRONIC 30 Stainless Steel work hardens rapidly while retaining good ductility. Unlike other nitrogen-strengthened stainless steels, AK Steel NITRONIC 30 Stainless Steel is subject to magnetic transformation when cold worked.

Available Forms

AK Steel NITRONIC 30 Stainless Steel is available in sheet, strip and plate in thicknesses from 0.020" to 0.250" (0.5 to 6.4 mm) and up to and including 48" (1219 mm) wide. Inquire for other product forms.

Composition

	%
Carbon	0.03 max.
Manganese	7.0 - 9.0
Phosphorus	0.040 max.
Sulfur	0.030 max.
Silicon	1.00 max.
Chromium	15.0 - 17.0
Nickel	1.5 - 3.0
Nitrogen	0.15 - 0.30
Copper	1.00 max.

Specifications

The following specifications are listed without year of revision indications. Contact ASTM Headquarters for latest revisions.

AK Steel NITRONIC 30 Stainless Steel is listed as Grade UNS S20400 in ASTM A 240 – Plate, Sheet and Strip for Pressure Vessels.

ASTM A 666 – Austenitic Stainless Steel Sheet, Strip, Plate and Flat Bar.

The following ASTM standards are at Main Committee ballot for inclusion of AK Steel NITRONIC 30:

A 249 – Welded Austenitic Steel Boiler, Superheater, Heat Exchanger and Condenser Tubes.

A 312 – Seamless and Welded Austenitic SS Pipes.

A 358 – Electric, Fusion-Welded Austenitic Chromium Nickel Alloy Steel Pipes for High-Temperature Service.

A 409 – Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service.

A 554 – Welded SS Mechanical Tubing.

A 813 – Single- or Double-welded Austenitic Stainless Steel Pipe.

A 814 – Cold-Worked Welded Asutenitic Stainless Steel Pipe.

Metric Practice

The values shown in this bulletin were established in U.S. customary units. The metric equivalents of U.S. customary units shown may be approximate. Conversion to the metric system, known as the International System of Units (SI), has been accomplished in accordance with ASTM E380.

The newton (N) has been adopted by the SI as the metric standard unit of force. The term for force per unit of area (stress) is newton per square meter (N/m^2). Since this can be a large number, the prefix mega is used to indicate 1,000,000 units and the term meganewton per square meter (MN/m^2) is used. The unit (N/m^2) has been designated a pascal (Pa). The relationship between the U.S. and the SI units for stress is: 1000 pounds/in^2 (psi) = 1 kip/in^2 (ksi) = 6.8948 meganewtons/m^2 (MN/m^2) = 6.8948 megapascals (MPa).

Mechanical Properties

As noted in Table 2, NITRONIC 30 Stainless Steel has annealed tensile properties which are well above those of typical austenitic alloys such as Type 304L. Excellent elongation is also maintained. This higher strength affords the opportunity to reduce gauge at equivalent engineering loads.

The high work-hardening rate of NITRONIC 30 Stainless Steel results in a high-strength material with elongation equal or superior to Type 304L with the same cold reduction. Comparative properties are shown in Table 4 and provided graphically in Figure 1. Table 5 presents additional data on the effect of cold reduction at heavy gauge. Such cold reductions would produce a smoother surface and reduce the coefficient of friction for sliding applications such as coal chutes.

Table 1

Properties Acceptable for Material Specification

Condition	ASTM Spec.	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell	Free Bend
Annealed	A 240 A 666	95 (655) min.	48 (331) min.	35 min.	B100 max.	180°-1T
1/4 Hard	A 666	140 (965) min.	100 (689) min.	20 min.	–	≤ .050", 180°-1T > .050" to ≤ .1874", 90°-2T

Table 2

Typical Room-Temperature Sheet and Strip Properties*

Annealing Thickness inches (mm)	Temperature °F (°C)	Direction	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell B
0.124 (3.15)	1950 (1066)	Longitudinal	117.7 (811)	54.0 (372)	52.0	93.5
0.064 (1.62)	2050 (1121)	Longitudinal	100.0 (689)	53.8 (370)	58.5	93.0
		Transverse	103.1 (711)	53.5 (368)	58.0	93.0
0.032 (0.81)	1950 (1066)	Longitudinal	121.9 (840)	55.0 (379)	54.0	94.0
		Longitudinal	119.7 (825)	54.4 (375)	55.0	94.0

* Average of duplicate tests.

Table 3

Typical Annealed Plate Properties*

Thickness inches (mm)	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell B	CVN ft-lbs (J)
3/8 (10)	114 (786)	57 (393)	56	94	–
7/8 (22)	124 (855)	50 (345)	50	92	217 (244)
2 (50.8)	120 (827)	52 (358)	54	–	–

Figure 1

Effect of Cold Reduction on Tensile Properties
of NITRONIC 30

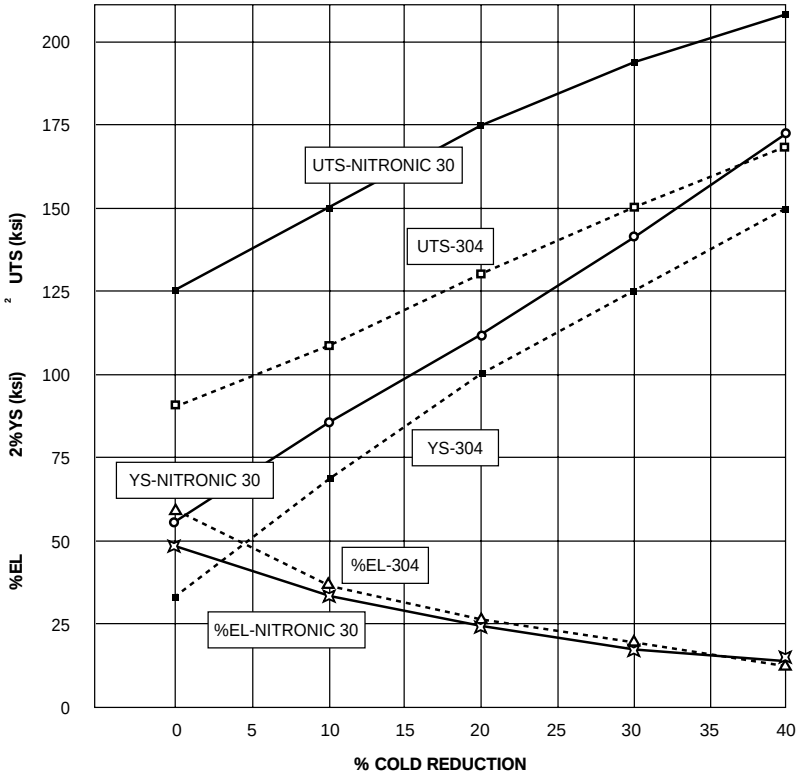


Table 4

Effect of Cold Work on Tensile Properties

(Laboratory data for comparison only – not for specification)

% Cold Work	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell
NITRONIC 30*				
0	125 (862)	57 (393)	49	B95
10	150 (1034)	86 (593)	35	C31
20	173 (1193)	113 (779)	25	C37
30	194 (1338)	142 (979)	18	C43
40	207 (1467)	172 (1186)	15	C45
Type 304				
0	89 (614)	35 (241)	61	B74
10	110 (758)	70 (483)	40	C20.5
20	130 (896)	100 (689)	27	C29.5
30	148 (1020)	125 (862)	20	C35.5
40	167 (1151)	150 (1034)	13	C39

* Average of five thickness ranges – 0.215" – 0.026" (5.5 – 0.7 mm).

Effect of Cold Work on Martensite Formation

Unlike the other NITRONIC alloys, AK Steel NITRONIC 30 Stainless Steel will undergo magnetic transformation due to cold reduction. This magnetism is the result of forming deformation martensite with cold work. This martensite increases the strength, work-hardening rate and abrasion resistance of the alloy.

% Cold Work	Ferrite Number*
0	0
12	2
16	4
21	9

* As determined from a Ferritescope by Fisher Technology. The Ferritescope measures the % magnetic phase. Ferrite Number is, therefore, proportional to the amount of martensite present.

Table 5

Typical Tensile Properties 1/4-Hard AK Steel NITRONIC 30 Plate
(Currently restricted to 0.170" (4mm) max.)

Thickness inches (mm)	Direction	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell C	Bend 180°
3/16*	Longitudinal	148.0 (1020)	104.0 (717)	35.5	33.5	–
(4.8)	Transverse	148.6 (1025)	111.4 (768)	31.5	33.5	1T
1/4**	Longitudinal	144.7 (998)	101.8 (702)	35.5	34.0	–
(6.4)	Transverse	146.6 (1011)	110.1 (759)	29.6	34.0	1T

* Duplicates – 1 heat.

** 5 Tests – 2 heats.

Elevated Temperature Tensile Properties

Table 6

Elevated Temperature Tensile
Properties of AK Steel NITRONIC 30 Sheet*

Test Temperature °F (°C)	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell B
75 (24)	122.5 (844)	63.1 (437)	46.8	96.5
200 (93)	100.3 (691)	47.3 (326)	63.3	–
300 (149)	86.8 (599)	41.1 (284)	53.7	–
400 (204)	81.4 (561)	37.6 (259)	44.8	–
500 (260)	79.3 (547)	34.9 (240)	41.3	–
600 (316)	79.3 (547)	33.8 (234)	41.3	–
700 (371)	76.7 (529)	31.4 (217)	44.3	–
800 (427)	73.4 (506)	30.0 (207)	43.7	–
900 (482)	70.3 (485)	28.6 (197)	40.7	–
1000 (538)	66.5 (458)	27.1 (187)	34.1	–

* 0.088" (2.2 mm) and 0.074" (1.9 mm) thicknesses, average of 6 tests from 2 heats.

Table 7

Elevated Temperature Tensile
Properties of AK Steel NITRONIC 30 Plate*

Test Temperature °F (°C)	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell B
75 (24)	123.3 (850)	52.4 (362)	50.0	92.5
200 (93)	91.4 (630)	38.6 (266)	77.8	–
300 (149)	78.2 (539)	32.1 (222)	65.5	–
400 (204)	71.8 (496)	27.6 (190)	48.0	–
500 (260)	70.6 (487)	26.4 (182)	48.6	–
600 (316)	70.7 (488)	25.3 (174)	46.4	–
700 (371)	69.5 (480)	24.4 (168)	49.0	–
800 (427)	66.7 (460)	22.7 (157)	48.3	–
900 (482)	63.7 (439)	22.4 (155)	47.7	–
1000 (538)	60.4 (417)	20.4 (131)	42.9	–

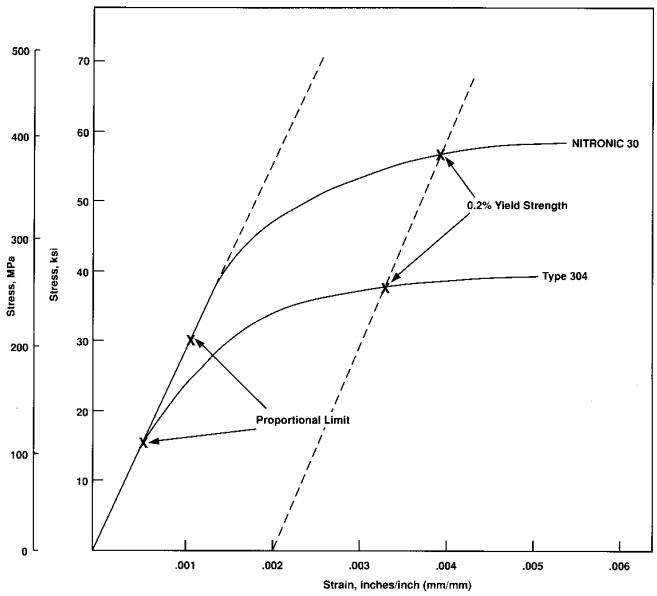
* 7/8" (22.2 mm) and 3/16" (4.8 mm) thicknesses, average of 4 tests from 2 heats.

Cryogenic Impact Properties

Typical Engineering Stress-Strain Curves

Typical engineering stress-strain curves for AK Steel NITRONIC 30 and Type 304 stainless steel (tested in tension in the longitudinal direction) are shown in Figure 2.

Figure 2



ASME Code

The use of NITRONIC 30 Stainless Steel Sheet, Strip and Plate (16 Cr - 2 Ni - 8 Mn - N, UNS S20400) is contained in ASME Code, Section VIII, Division I, Table 1A. The maximum allowable stress in tension is shown in Table 8.

Table 8

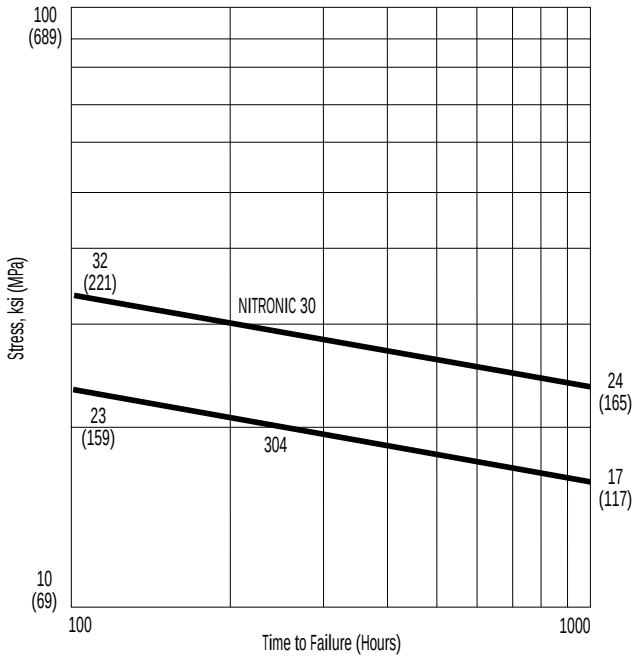
Maximum Allowable Stress Values in Tension

For Metal Temperature Not Exceeding: °F (°C)	Maximum Allowable Stress Values ksi (Mpa)
-20 to 100 (-29 to 38)	23.8 (164)
200 (38)	20.6 (142)
300 (93)	18.0 (124)
400 (149)	16.6 (114)
500 (204)	15.9 (109)
600 (260)	15.7 (108)
700 (343)	15.5 (107)
800 (399)	15.1 (104)
900 (482)	14.3 (99)

Stress Rupture Strength

Figure 3

NITRONIC 30 Stress Rupture At 1200°F (648°C)



Fatigue Strength

AK Steel NITRONIC 30 Stainless Steel offers superior fatigue resistance due to its higher strength relative to other austenitic stainless steels like Type 304. Figures 4 through 7 show the excellent fatigue resistance of NITRONIC 30 Stainless Steel that may benefit users in the transport and vibratory equipment industries.

Figure 4

AK Steel NITRONIC 30 Uniaxial Fatigue
.072" Sheet Cold Rolled + Annealed
R = 0.5 Transverse Direction

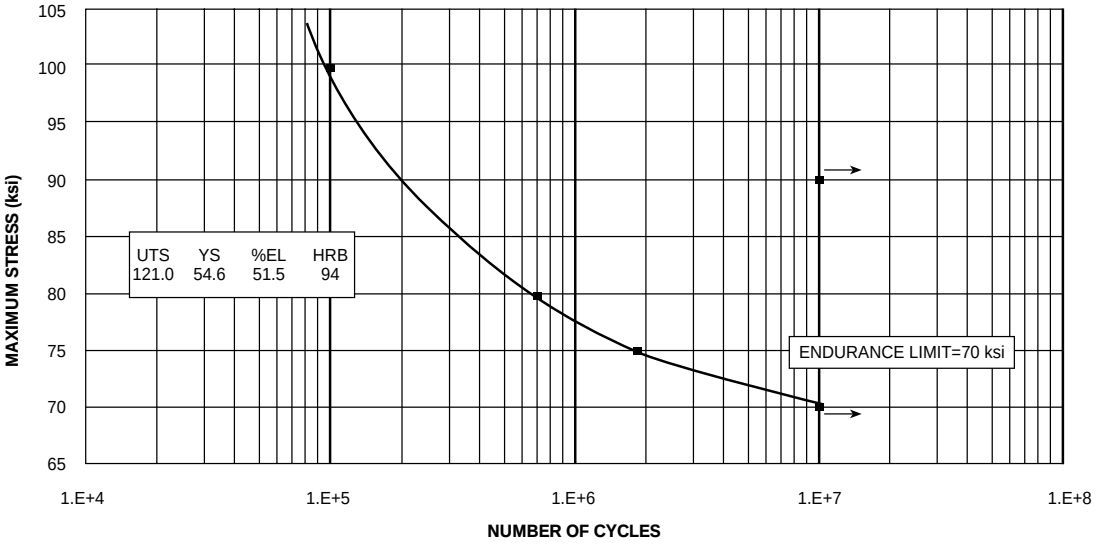


Figure 5

AK Steel NITRONIC 30 Reverse Bend Fatigue
.072" Sheet Cold Rolled + Annealed
R = -1 Transverse Direction

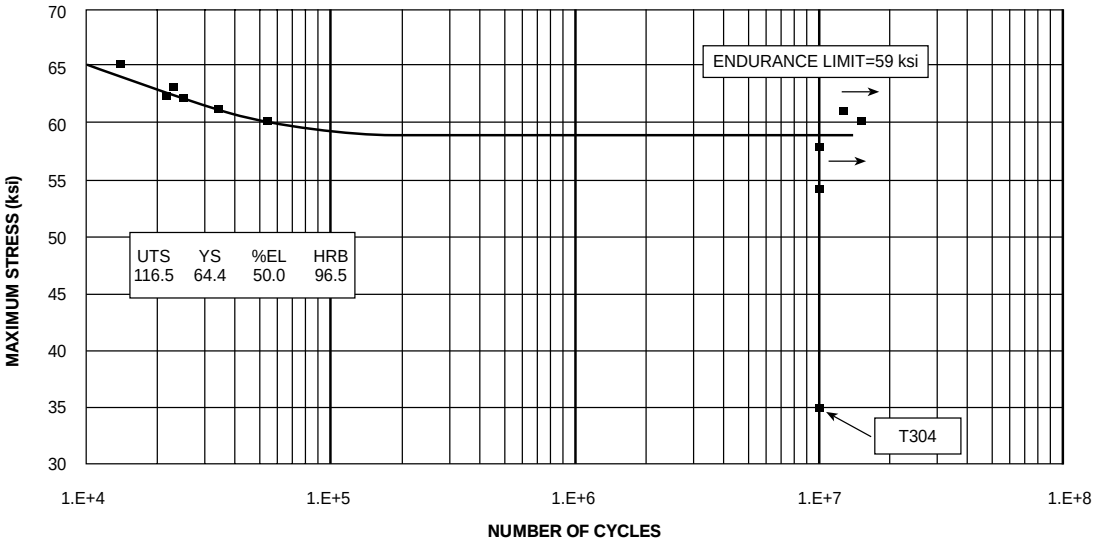


Figure 6

AK Steel NITRONIC 30 Uniaxial Fatigue
3/16" Plate Hot Rolled + Annealed
R = 0.1, 16 to 20 Hz, Transverse Direction

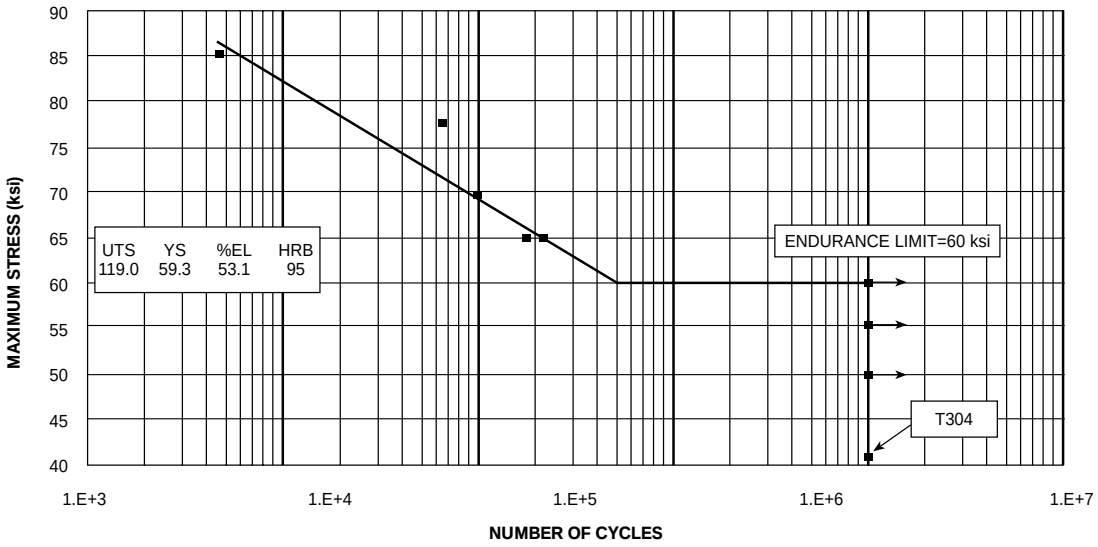
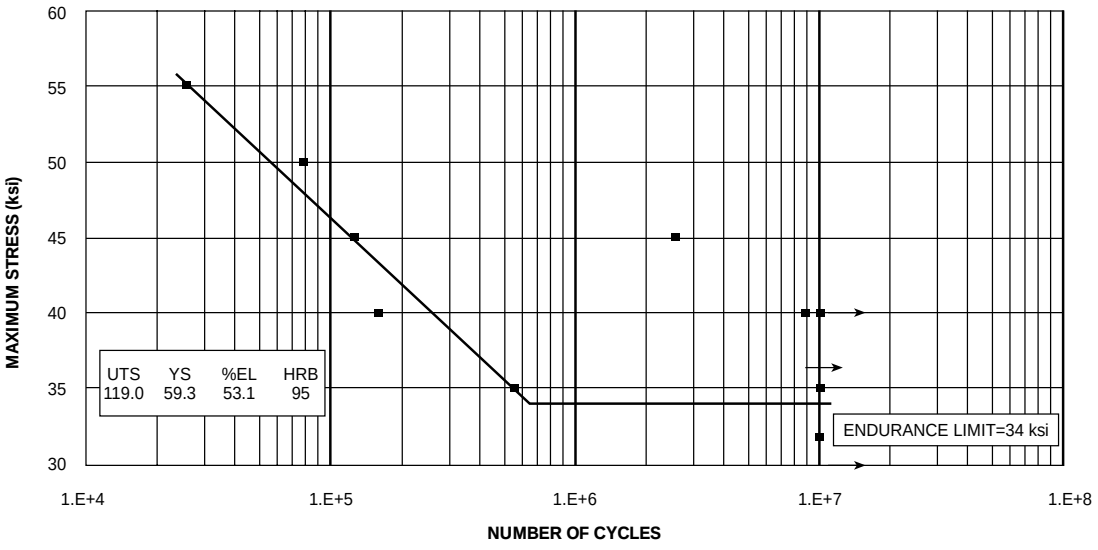


Figure 7

AK Steel NITRONIC 30 Notched Uniaxial Fatigue
3/16" Plate Hot Rolled + Annealed
R = 0.1, 16 Hz, Kt = 3, Transverse Direction



Wear Resistance

The following tables and figures demonstrate the outstanding corrosive wear resistance of AK Steel NITRONIC 30 Stainless Steel under many different sliding conditions. The stainless steels as a class are much more abrasion resistant than abrasion resistant (AR) steels under even mildly corrosive conditions. AK Steel NITRONIC 30 Stainless Steel is more cost effective than Types 409 Ni and 304 which are sometimes used in wet abrasive applications.

Table 9

Metal-to-Metal Wear*

Alloy	Hardness Rockwell	Wear, mg/1000 cycles**		
		25 RPM	105 RPM	415 RPM
4340	C52	0.8	0.7	0.5
Stellite 6	C48	1.1	1.0	1.3
Hadfield Mn	B95	1.7	1.2	0.4
AK Steel NITRONIC 30	B93	1.9	3.3	2.2
AK Steel NITRONIC 32	B95	2.4	7.4	3.1
4130 (H + 400°F S.R.)	C47	3.8	9.4	–
Type 304	B85	13.9	12.8	7.6
AK Steel 17-4 PH (H900)	C43	45.3	52.8	12.1
Type 410 (H + 600°F S.R.)†	C40	–	244.0	22.5
4130 (H + 1000°F S.R.)	C32	66.0	258.0	–
Type 410 (Annealed)	B95	–	261.0	116.0

* Self-mated crossed cylinders, 16 lbs (71 N), 10,000 or 40,000 cycles, unlubricated, in air, room temperature, corrected for density differences.

** Relative wear rate for comparison of alloys and not for design purposes.

† H-hardened S.R. stress relieved

Table 10

Metal-to-Metal Weld Wear*

Alloy	Hardness Rockwell	Total Wear (mated to 17-4 PH, Condition H900), 105 RPM mg/100 cycles
AK Steel NITRONIC 30 Weld**	C24	27.58
Type 420 Weld 1150°F (621°C) Temper	C34	68.32

* Self-mated crossed cylinders, 16 lbs (71 N), 10,000 or 40,000 cycles, unlubricated, in air, room temperature, corrected for density differences.

**Weldment in stationary position.

Table 11

Dry Abrasive Wear

Alloy	Hardness Rockwell	Volume of Metal Removed			
		Alloy Wear-Mated to WC mm^3/10,000 cycles		Alloy Wear-Mated to SIC mm^3/10,000 cycles	
		105 RPM	415 RPM	105 RPM	415 RPM
4340	C52	0.1	0.1	0.8	–
Colmonoy 6	C56	1.1	0.8	2.9	2.2
AK Steel NITRONIC 30	B93	1.9	3.3	3.8	11.3
AK Steel NITRONIC 60	B95	2.8	2.3	–	–
AK Steel NITRONIC 32	B95	4.2	4.3	7.1	6.8
Type 304	B85	6.2	13.2	25.2	13.5
Type 431	C42	9.8	1.5	22.6	–
AK Steel 17-4 PH	C42	9.9	5.6	104.2	37.9

* Crossed cylinders, 16 lbs (71 N), 10,000 or 40,000 cycles, unlubricated, in air, room temperature, corrected for density differences.

Table 12
Corrosive Wear
Hub Test*

Alloy	Hardness Rockwell	Wear, mm^3 5% NaCl + 0.5% Acetic Acid	Dry
AK Steel NITRONIC 30	B91	8.15	2.79
AK Steel 17-4 PH	C46	11.95	3.32
AK Steel NITRONIC 33	B94	13.74	3.40
Type 409	B85	28.50	10.56
Hadfield Mn	B93	39.20	2.28
4340	C49	45.47	2.27

* Abrasives: 2.5 liters pea gravel plus slag, 1 liter angular quartz, 400 hours, 1000 in/min tip speed, 0.095" (2.4 mm) sheet thickness, triplicate tests, sheet specimens mounted on hub rotating in and out of slurry.

Figure 8
Corrosive Wear of Alloy and Stainless Steels

Hub Machine, tip speed – 83'/min., 200 hours, R.T.
1500 ml AFS 50/70 sand, 1500 ml slag, 1500 ml pea gravel, pH 8.8-9.2, duplicates, specimens immersed 2.25" in slurry.

Distilled water – 1500 ml

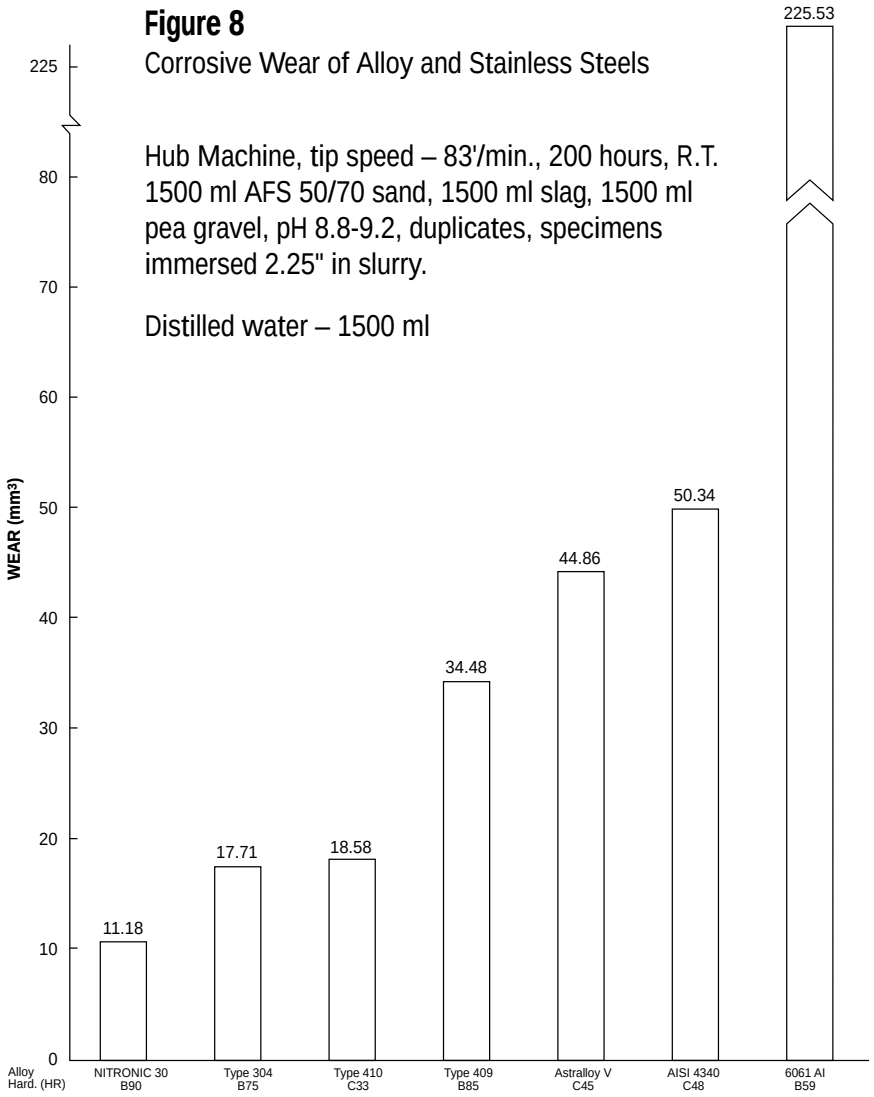


Table 13

Ball Mill Test*

Alloy	Hardness Rockwell	Wear, mm^3
AK Steel NITRONIC 30	B91	4.89
AK Steel NITRONIC 33	B94	6.46
AK Steel 17-4 PH	C46	7.00
Type 304	B75	7.76
Type 409	B85	10.15
Astralloy V	C45	32.14
4340	C49	36.54

* 2 liters 2g/l sulfate + 0.2 g/l chloride ions, pH 9.1-9.6,126 ft/min speed, five 16-hour periods, 0.1l-1/4 + 1/8" plus 0.1l-3/8 + 1/4" pea gravel abrasives, average of duplicate tests.

Figure 9

Corrosive Wear of Alloy and Stainless Steels

Ball Mill – Synthetic Nickel Mine Water

Speed – 126'/min., R.T., pH 9.1-9.6 2000 ml of 2 g/l sulfate + 0.2 g/l chloride ion 100 ml – 1/4" + 1/8" and 100 ml – 3/8" + 1/4" pea gravel

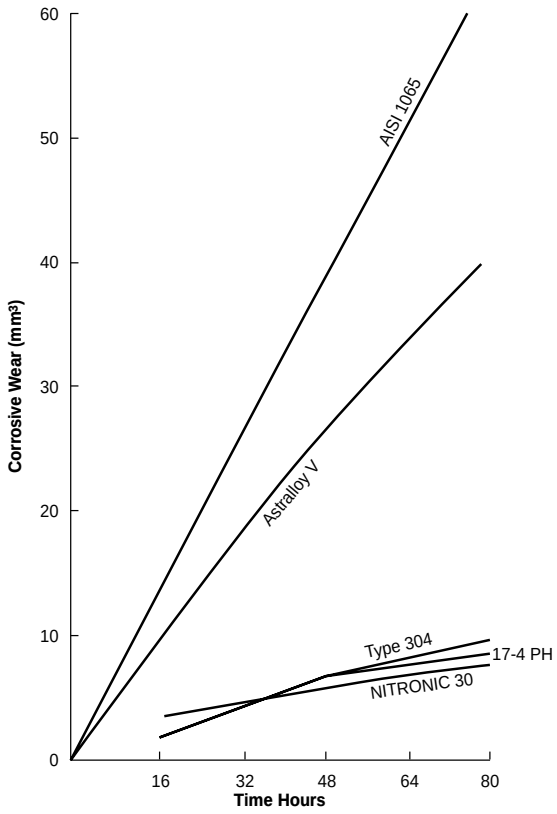


Table 14

Corrosive Wear of Alloy and Stainless Steels in a Coal Mine Effluent*

		Cumulative Volume Loss, mm^3		
Alloy	Hardness Rockwell	Period 1	Period 2	Period 3
Astralloy V	C45	3.50	11.45	20.17
AISI 4340	C48	4.25	12.76	21.75
Type 409	B85	3.80	5.46	8.99
AK Steel 17-4 PH	C44	1.51	4.55	7.39
AK Steel NITRONIC 30	B90	1.31	4.27	7.13
Type 304	B75	1.58	4.98	8.30
Type 316	B73	2.08	7.39	12.56

* Test Conditions: Laboratory ball mill, 0.64 m/s, room temperature, Five 16-hour periods, pH 6.7, 2 liters of coal mine effluent, 0.2 liters pea gravel – 6.4 mm + 3.2 mm, duplicate sheet specimens.

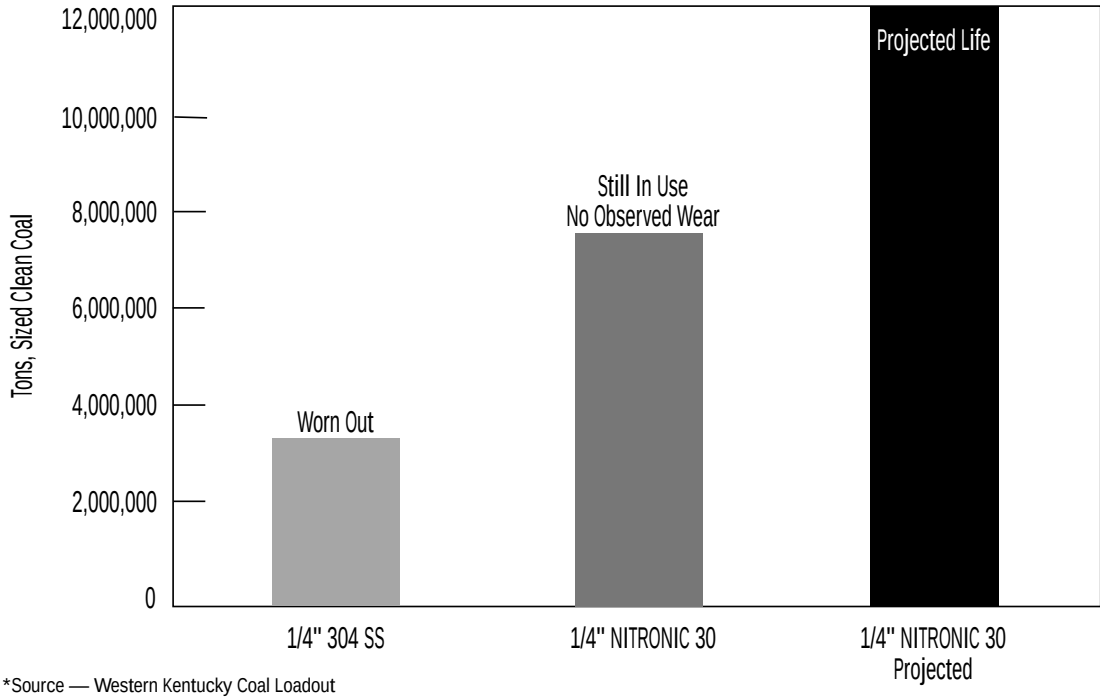
Table 15
Corrosive Wear of Steel, Stainless Steels and Cast Irons in a Coal Preparation Plant

Alloy	Hardness Rockwell	Metal Loss mils/year	Metal Loss µm/year
NITRONIC 30 (Annealed)	B94	0.3	8
NITRONIC 30 (Tensilized)	C33	0.3	8
Type 304	B90	0.4	10
Type 316	B85	0.4	10
Type 410 (Annealed)	B81	0.5	13
Type 301	C36	0.6	15
F45009 (Ni Hard* #1)	C55	1.6	41
F45003 (Ni Hard* #4)	C42	13.1	333
F45001 (White Cast)	C58	51.5	1308
AISI 1044	B84	68.4	1737

* Trademark of The International Nickel Co.

Figure 10 shows projections based on visual inspections of a directional barge loading chute liner. No visual wear to the NITRONIC 30 stainless steel liner was observed after 7.6 million tons, resulting in a projected life increase of 300 percent. This increased life in comparison to Type 304 stainless steel means three downtime changeouts can be eliminated.

Figure 10
Directional Barge Loading Chute Liner
Sized Clean Coal



*Source — Western Kentucky Coal Loadout

Table 16

AK Steel NITRONIC 30 Stainless Steel
The Rust Resistant AR Steel

Category	AR500	409 Ni* Stainless Steel	Type 304 Stainless Steel	NITRONIC 30 Stainless Steel
Formability	Very Poor	Good	Excellent	Excellent
Weldability	Very Poor	Good	Excellent	Excellent
Impact Resistance	Poor	Fair	Excellent	Excellent
Corrosive Wear (CW)	4.50	3.10	1.60	1.00
Alloy Cost Factor (ACF)	1.00	1.16	1.49	1.42
Life Cycle Cost Factor (CW x ACF)	4.50	3.60	2.40	1.40

Typical Applications: buckets, ore separator screens, hopper cars, chutes, distributors

* Cost/performance similar to 3CR12

Corrosion Resistance

AK Steel NITRONIC 30 Stainless Steel exhibits good corrosion resistance to a variety of media. Pitting resistance, as measured by tests in 10% $FeCl_3$ solution, is better than Type 304. In sulfuric acid and hydrochloric acid, AK Steel NITRONIC 30 Stainless Steel is much better than Types 409 and 410, and approaches Type 304 in more dilute solutions. However, caution should be used with reducing acids. Activated Nitronic 30 may not repassivate when exposed to HCl or H_2SO_4 and significant corrosion may occur. Typical laboratory test data obtained on these alloys are shown in Table 17. Atmospheric corrosion resistance is shown in Figure 12.

Table 17

Immersion Tests in Various Media

	Corrosion Rates in IPY (unless otherwise indicated[1])			
Test Medium	NITRONIC 30	Type 304	Type 409	Type 410
10% $FeCl_3$ @ 25°C plain[2]	.227 gm/in^2	.424 gm/in^2	.772 gm/in^2	–
10% $FeCl_3$ @ 25°C Creviced[3]	.192 gm/in^2	.358 gm/in^2	.636 gm/in^2	–
65% HNO_3 @ Boiling	.043	.010	.671	.266
50% H_3PO_4 @ Boiling	.008	.008	.48	12.1 @ 80°C
5% Formic @ 80°C	< .001	< .001	.056[4]	.334 @ 35°C
1% H_2SO_4 @ 80°C	< .001-.360	< .001-.063	Dissolved	1.0 @ 1/2% H_2SO_4 @ 35°C
1% HCl @ 35°C	< .001-.012	< .001	.535	2.11
2% HCl @ 35°C	.100	< .001-.014	–	–
33% Acetic @ Boiling	Nil	Nil	–	–

(1) Immersion tests of 1"x2" sheet coupons in lab-annealed (1950°F – 5 min – AC) condition for NITRONIC 30 Stainless Steel, and mill-annealed for the other alloys. Results are the average of duplicate specimens exposed for five 48-hour periods. Those specimens tested at 35°C and at 80°C were intentionally activated for the third, fourth and fifth periods. Where both active and passive conditions occurred, the averages of both are shown.

(2) Exposed for 48 hours uncreviced.

(3) Exposed for 48 hours with rubber bands to produce crevices.

(4) Average of three 48-hour periods, not activated.

Intergranular Attack

Intergranular attack tests were performed following the procedures of ASTM A 262 on duplicate annealed sheet specimens of AK Steel NITRONIC 30 and Type 304 stainless steels. Before testing, some of these specimens were heat treated at 1250°F (675°C) for one hour and air cooled to exaggerate the conditions that might be found in the heat-affected zones of heavy weldments. Results are shown in Table 18.

Stress-Corrosion Cracking

As shown by Table 19, the threshold stress for cracking of NITRONIC 30 Stainless Steel in boiling 42% $MgCl_2$ solution is about 25 ksi (172 MPa), compared with about 10 ksi (69 MPa) for Types 304 and 304L. This suggests that NITRONIC 30 Stainless Steel is more resistant than these alloys to cracking in hot $MgCl_2$ solutions at lower stress levels. At higher stress levels (about 25 ksi {172 MPa} and above) the $MgCl_2$ stress-corrosion cracking resistance of NITRONIC 30 Stainless Steel appears similar to Types 304 and 304L.

The weldments in Figure 11 are more realistic of the expected improvement of NITRONIC 30 Stainless Steel over Type 304 regarding stress-corrosion cracking in hot $MgCl_2$. Type 308L weld metal (SMAW) was deposited in a 2-inch (50.8 mm) diameter circle to induce residual tensile stresses in the center of the weld. Six Type 304 weldments cracked at 73 to 103 hours. One NITRONIC 30 Stainless Steel test was stopped after 511 hours, but no cracks were found. Two other NITRONIC 30 Stainless Steel weldments were stopped at 1015 hours with no cracking.

Table 18

Intergranular Corrosion Resistance of AK Steel NITRONIC 30

Alloy	Practice C Treatment	Practice E Boiling 65% HNO_3 (Huey Test)	Copper-Accelerated Copper Sulfate
AK Steel NITRONIC 30	Annealed 1250°F (675°C) 1 hr.	0.0034 IPM 0.0052 IPM	Passed Passed
Type 304	Annealed 1250°F (675°C) 1 hr.	0.0010 IPM 0.0620 IPM	Passed Failed Badly

Note that although the nitric acid attack rate for NITRONIC 30 in the annealed condition is higher than that for Type 304, it did not increase greatly with the 1250°F (675°C) heat treatment. This indicates that there would be little tendency for preferential attack of weldments in service. NITRONIC 30 Stainless Steel is currently limited to a maximum 0.03% carbon content.

Table 19

Resistance to Hot $MgCl_2$ Stress-Corrosion Cracking

Alloy	Time to Failure, Hr, Under Stress of: 75 ksi (517 MPa)	50 ksi (345 MPa)	25 ksi (172 MPa)
AK Steel NITRONIC 30	–	0.3	890
Types 304 and 304L	0.2	0.6	2.5
Types 316 and 316L	0.8	2.5	7.0

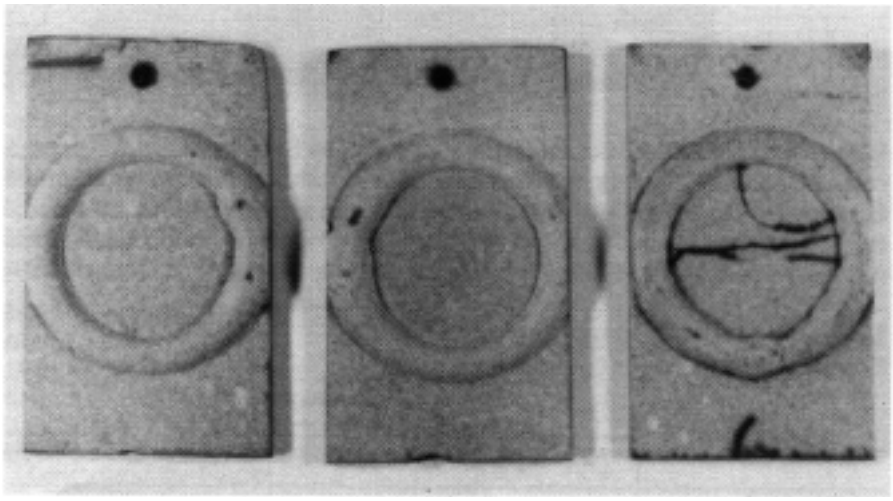
* All materials were in the annealed condition, direct tension loaded and tested in boiling 42% $MgCl_2$ solution.

Sulfide Stress Cracking

Laboratory tests show that AK Steel NITRONIC 30 Stainless Steel has excellent resistance to sulfide stress cracking. When stressed to 100% of its yield strength and exposed to the solution described in NACE TM-01-77 at room temperature (5% NaCl + 1/2% acetic acid, saturated with H_2S), NITRONIC 30 Stainless did not fail in over 720 hours.

Figure 11

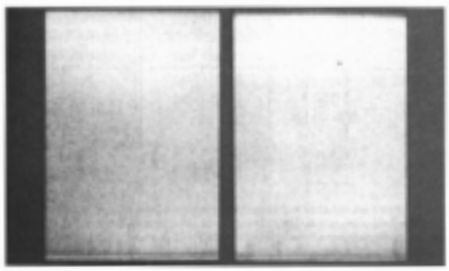
42% Boiling $MgCl_2$
Tested Per ASTM G-58



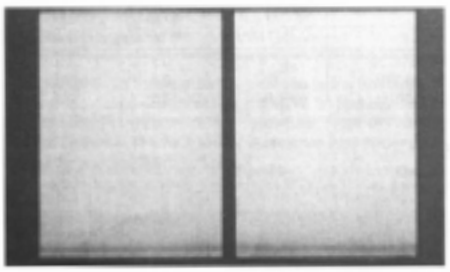
AK Steel NITRONIC 30	AK Steel NITRONIC 30	Type 304
511 Hours	1015 Hours	103 Hours
No Cracks	No Cracks	Cracks

Kesternich Test (simulates severe industrial atmosphere corrosion)

Figure 12



AK Steel NITRONIC 30
10 Cycles – 16 Hours Exposed and 8 Hours Dry



Type 304
10 Cycles – 16 Hours Exposed and 8 Hours Dry

Both AK Steel NITRONIC 30 and Type 304 Stainless Steels exhibited acceptable corrosion protection to the following environment with no discernible color differences: Specimen size: 0.125" x 4" x 6" (3 mm x 102 mm x 152 mm); mill annealed; 60 grit finish; autogenous weld bead down center and ground flush; duplicates; 2 liters distilled water 2 liters SO_2; 104°F (40°C); 10 cycles (1 cycle – 16 hours exposure + 8 hours drying).

Table 20

Salt Spray Test*

	Corrosion Rates			
Test Medium	AK Steel NITRONIC 30	Type 304	Type 409	Type 410
5% salt fog @35°C	OK after 500 hours	OK after 500 hours	Rusting in 24 hours	Rusting in 24 hours

* Per ASTM B 117 Salt Spray

Figure 13
Cyclic Oxidation at 1000°F (538°C)

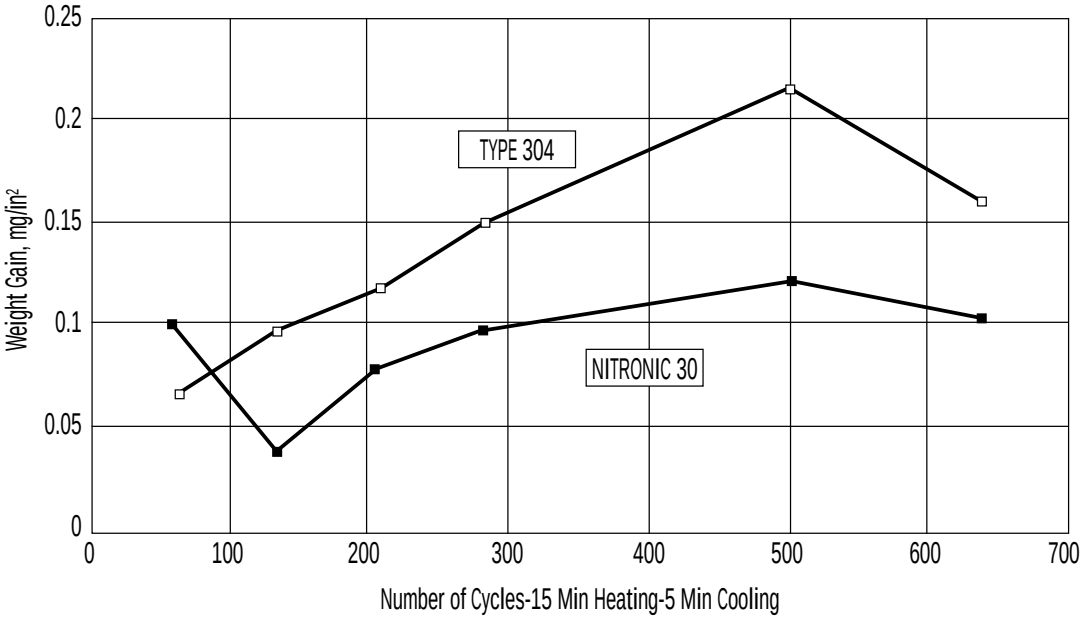
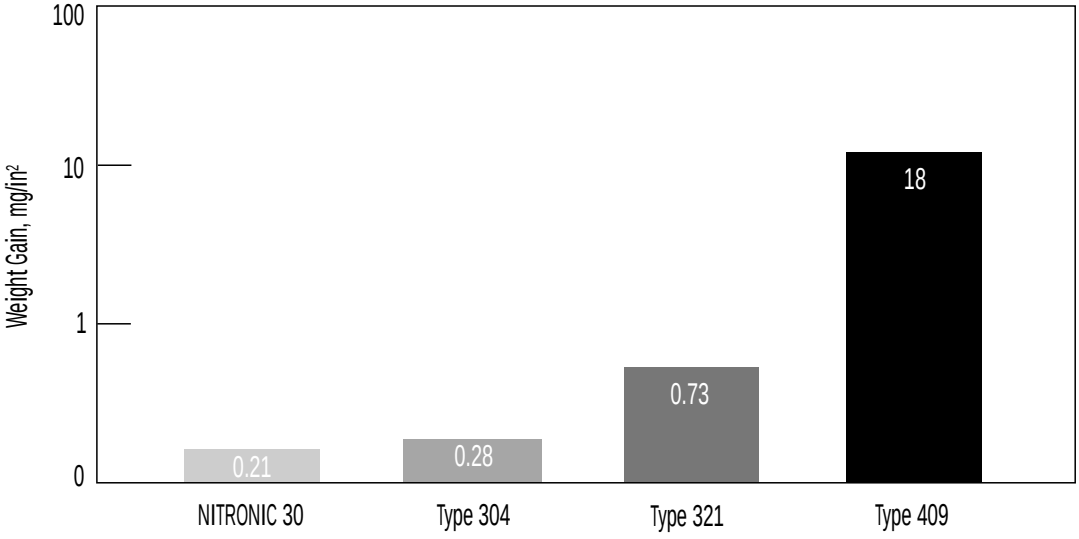


Figure 14
Cyclic Oxidation at 1250°F (677°C) 1000 Cycles of 15 Minutes Heating + 5 Minutes Cooling



Weldability

The austenitic class of stainless steels is generally considered to be weldable by the common fusion and resistance techniques. Special consideration is required to avoid weld "hot cracking" by assuring formation of ferrite in the weld deposit. This particular alloy is generally considered to have similar weldability to the most common alloy of this stainless class, Type 304L. A major difference is that the alloy requires slower arc welding speed to obtain penetration. When a weld filler is needed, AWS E/ER 308L, 309L and 209 are most often specified. Type 304L is well known in reference literature and more information can be obtained in the following ways:

1. ANSI/AWS A5.9, A5.22, and A5.4 (filler metals, minimum UTS and elongation).
2. "Welding of Stainless Steels and Other Joining Methods," SSINA, (800:982-0355).
3. "Welding Stainless Steels," FDB #SF-71.
4. ANSI/AWS B2.1.009-90 (GTAW 300's @ 0.50" - 0.14").
5. ANSI/AWS B2.1-8-024-94 (GTAW 300's @ 1/8" - 1-1/2").
6. ANSI/AWS B2.1.013-91 (SMAW 300's @ 0.050" - 0.14").
7. ANSI/AWS B2.1-8-023-94 (SMAW 300's @ 1/8" - 1-1/2").
8. ANSI/AWS B2.1.005-90 (GMAW 300's @ 0.050" - 0.14").

Table 21

Mechanical Properties of Unwelded AK Steel NITRONIC 30 Compared to Various AWS Austenitic Stainless Steel All-Weld Metal Deposits

Type	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)
AWS E209 (NITRONIC 35W)	110 (758)	85 (586)	20
AWS E308L	85 (586)	55 (379)	45
AWS E312	110 (758)	80 (550)	30
AK Steel NITRONIC 30 (0.08" sheet-annealed)	115 (793)	50 (345)	55

Table 22

Weld Bend Test Results*

Bend Direction	Bend Diameter
Weld Face	OT
Weld Root	OT

* NITRONIC 30 hot-rolled and pickled sheet (0.112") (2.8 mm) has been autogenous gas tungsten arc welded to make bend tests. Bend tests on this material (HR Condition) were successfully flattened (0 bend diameter) when either the weld face or weld root was in tension, illustrating the excellent formability of as-welded NITRONIC 30 Stainless Steel.

Table 23

Typical Mechanical Properties of AK Steel NITRONIC 30 in Autogenous Gas Tungsten Arc Welding*

Area Tested	Thickness inches (mm)	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell B
As-Welded (Stressed Transverse to Weld Direction)	0.060 (1.52)	119.1 (821)	57.6 (397)	50.7	87
Unwelded (Annealed)	0.060 (1.52)	113.0 (779)	46.1 (318)	55.7	87
Unwelded (As Hot Rolled)	0.112 (2.8)	120.4 (829)	48.9 (337)	60.0	89.5

* GTA Welded vs. Unwelded Annealed 2050°F (1121°C) Mechanical properties from duplicate tests.

Table 24

Tensile Properties of AK Steel NITRONIC 30 GTAW Welded Pipe

(1-1/4" (31.8 mm) OD, 0.135" (3.4 mm) wall thickness)

	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell C
Base Metal*	161.8 (1116)	106.7 (736)	40.1	34.0
As-Welded**	174.1 (1201)	116.7 (805)	37.8	–

* Taken from pipe side wall away from weld.

** Weld parallel to specimen length; cut from pipe side wall. 1 heat – duplicate tests.

Table 25

Typical Tensile Properties of GMAW Weldments
Cold-Rolled Unannealed AK Steel NITRONIC 30 and Type 304 Sheet

Condition	Gauge in (mm)	% Cold Work	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell C	YSW/YSB*
AK Steel NITRONIC 30							
Base Metal	0.110 (2.8)	16.0	155.8 (1095)	99.4 (685)	29.3	35.5	–
Weld Metal	0.110 (2.8)	16.0	136.1 (939)	85.0 (586)	14.6	35.5	0.86
Base Metal	0.135 (3.4)	16.0	158.3 (1091)	101.2 (697)	28.4	35.0	–
Weld Metal	0.135 (3.4)	16.0	141.7 (970)	94.7 (654)	14.5	35.0	0.94
Base Metal	0.110 (2.8)	21.0	168.5 (1162)	112.2 (773)	25.7	38.0	–
Weld Metal	0.110 (2.8)	21.0	140.9 (972)	90.0 (621)	7.9	38.0	0.80
Base Metal	0.135 (3.4)	21.0	165.7 (1143)	115.1 (794)	25.9	37.0	–
Weld Metal	0.135 (3.4)	21.0	141.1 (973)	94.4 (686)	8.6	37.0	0.86
Type 304**							
Base Metal	0.031 (0.8)	–	130.3 (898)	110.4 (761)	30.6	–	–
Weld Metal	0.031 (0.8)	–	106.2 (732)	66.8 (461)	5.4	–	0.61
Base Metal	0.042 (1.1)	–	131.7 (909)	108.5 (748)	34.9	–	–
Weld Metal	0.042 (1.1)	–	107.7 (744)	71.9 (496)	4.5	–	0.66

* Ratio of welded YS to unwelded YS. GMAW – Type 312 wire, 0.045" diameter, spray arc mode.

** GTAW – no filler. AISI Industry Data

As noted in Table 25, AK Steel NITRONIC 30 Stainless Steel retains higher strength and ductility when welded in the cold-worked (1/4-hard) condition compared to Type 304. This is described by the higher welded to unwelded yield strength ratio in the last column.

Table 26

Impact Strength (W/A) in-lbs/in^2 (mm • N/mm^2)

	Thickness inches (mm)	Test Temperature, °F °(C)		
		RT	32 (0)	-150 (-101)
Weld Metal*	0.112 (2.8)	10,510 (1839)	9,610 (1682)	7,450 (1304)
Base Metal	0.112 (2.8)	7,640 (1337)	7,340 (1284)	6,180 (1082)

* Notch in weld.

Figure 15

Impact Toughness

Effect of Temperature on the Impact Toughness of AK Steel NITRONIC 30, Type 304 and Type 409*

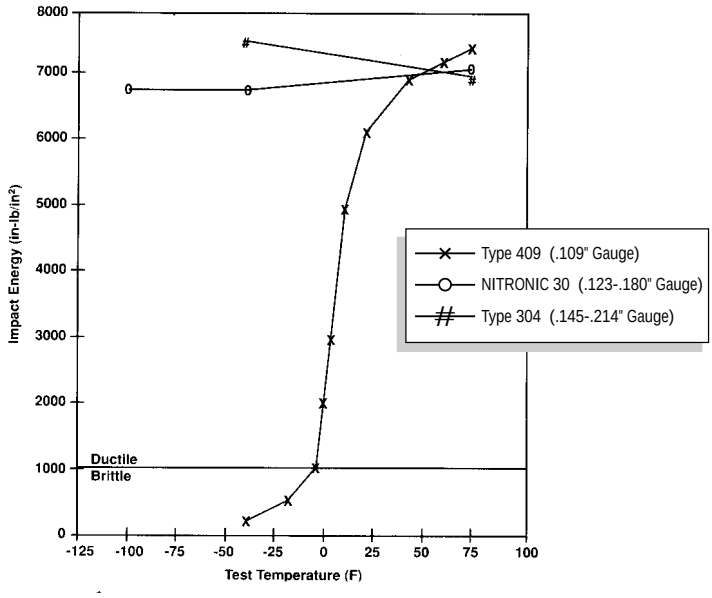


Table 27

Cryogenic Impact Strength of Annealed Sheet and Plate*

Thickness in (mm)	Direction	Number of Tests	Test Temperature °F (°C)	Impact Energy, W/A in-lbs/in² (mm•N/mm²)	Lateral Expansion mils (mm)
0.130 (3)	Longitudinal	2	-100 (-73)	9,340 (1,633)	18.5 (0.73)
0.130 (3)	Transverse	2	-100 (-73)	7,257 (1,269)	15.2 (0.60)
0.130 (3)	Longitudinal	2	-320 (-196)	5,557 (972)	9.6 (0.38)
0.130 (3)	Transverse	2	-320 (-196)	3,606 (631)	7.5 (0.29)
0.1875 (5)	Transverse	23	-320 (-196)	4,626 (809)	21.7 (0.86)
0.50 (13)	Transverse	5	-320 (-196)	5,597 (979)	27.8 (1.10)
Weld Metal w/notch in HAZ**					
0.5 (13)	Transverse	5	-320 (-196)	4,068 (711)	18.5 (0.73)

* ASTM A 353 and A 20

** With 308L Filler Metal

Table 28

Cryogenic Impact Strength of Annealed AK Steel NITRONIC 30 Stainless Steel Plate

Thickness inches (mm)	Test Temperature °F (°C)	Direction	Impact Strength Charpy V-Notch ft-lbs (J)	Lateral Expansion mils (mm)
7/8 (22)	-100 (-73)	Transverse	125* (167)	69 (1.8)
	-150 (-101)		77 (103)	47 (1.2)
	-320 (-195)		25 (33)	14 (0.4)

* Average of 4 tests.

Formability

Table 29
Formability

Alloy	Olsen Cup Height, inches (mm)	3" Stretch Cup	LDR*
AK Steel NITRONIC 30 Base Metal	0.480 (12.2)	1.40	2.04
AK Steel NITRONIC 30 Weld Face in Tension	0.483 (12.3)	–	–
AK Steel NITRONIC 30 Weld Root in Tension	0.498 (12.6)	–	–
Type 301 Base Metal	0.480 (12.2)	–	2.06
Type 304L Base Metal	–	1.14	2.04

* Limiting Draw Ratio

Table 30
Effect of Strength Level on Formability
ASTM E 643 Biaxial Stretch (Cup Height)

0.2% YS ksi (MPa)	Type 304L inches (mm)	AK Steel NITRONIC 30 inches (mm)
40 (276)	0.43 (11)	– –
50 (345)	0.39 (10)	0.52 (13)
60 (414)	0.36 (9)	0.46 (12)
70 (483)	0.34 (9)	0.40 (10)
80 (552)	0.32 (8)	0.37 (9)
90 (621)	0.31 (8)	0.34 (9)
100 (689)	0.30 (8)	0.33 (8)

Physical Properties

Density at 70°F (21°C)
7.862 g/cm^3
0.284 lbs/in^3

Modulus of Elasticity at 70°F (21°C)
28.0 x 10^6 psi
0.193 x 10^6 MPa

Table 31
Magnetic Permeability
(Annealed)

Field Strength Oersteds	Permeability
100	1.011
200	1.011
500	1.014
1000	1.015

Table 32

Thermal Expansion*

Temperature °F	Relative Expansion %	Coefficient of Expansion ΔL/L/°F x 10^{-6}	Temperature °C	Relative Expansion %	Coefficient of Expansion ΔL/L/°C x 10^{-6}
79 – 200	0.123	9.35	26 – 50	0.048	16.13
79 – 300	0.223	9.60	26 – 100	0.135	16.90
79 – 400	0.326	9.81	26 – 150	0.225	17.29
79 – 500	0.432	10.01	26 – 200	0.317	17.64
79 – 600	0.541	10.18	26 – 250	0.413	17.95
79 – 700	0.654	10.35	26 – 300	0.511	18.24
79 – 800	0.768	10.50	26 – 350	0.611	18.51
79 – 900	0.884	10.63	26 – 400	0.713	18.77
79 – 1000	1.002	10.75	26 – 450	0.817	19.00
79 – 1100	1.123	10.88	26 – 500	0.922	19.20
79 – 1200	1.245	11.00	26 – 550	1.029	19.41
79 – 1300	1.368	11.11	26 – 600	1.137	19.61
79 – 1400	1.492	11.21	26 – 650	1.248	19.80
79 – 1500	1.619	11.31	26 – 700	1.358	19.98
79 – 1600	1.749	11.42	26 – 750	1.470	20.14
			26 – 800	1.583	20.31
			26 – 850	1.700	20.48

* Average of duplicate tests. Full heating curves available upon request.

AK Steel

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