AK Steel International

ARMCO® NITRONIC® 50

STAINLESS STEEL

Product Data Bulletin

- **Cables**
- **Fasteners**
- **Marine Hardware**
- **Pumps**
- **Valves and Fittings**

Outstanding corrosion resistance gives AK Steel's ARMCO® NITRONIC® 50 Stainless Steel the leading edge for applications where Types 316, 316L, 317 and 317L are only marginal.

The different versions of ARMCO NITRONIC 50 (annealed, High Strength, Super High Strength) provide a wide range of mechanical properties, and high toughness properties compared to Duplex and Super Duplex, without any restriction in terms of working temperatures.

ARMCO NITRONIC 50 is highly effective alloy for the Oil and Gas, offshore, subsea, chemical, fertilizer, nuclear fuel recycling, pulp and paper, textile, food processing and marine industries. Components using the combination of excellent corrosion resistance and high strength include: pumps, valves and fittings, fasteners, cables, chains, marine hardware, boat and valves shafting, heat exchanger parts, and springs.

ARMCO *Representing ARMCO® products since 1924*

AK Steel International

ARMCO® NITRONIC® 50 STAINLESS STEEL

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ARMCO® NITRONIC® 50 STAINLESS STEEL

Product Description

AK Steel's ARMCO NITRONIC 50 Stainless Steel provides a combination of corrosion resistance and strength not found in any other commercial material available in its price range. This austenitic stainless steel has corrosion resistance greater than that provided by Types 316, 316L, 317, and 317L, plus approximately twice the yield strength at room temperature. In addition, AK Steel's ARMCO NITRONIC 50 Stainless Steel has very good mechanical properties at both elevated and subzero temperatures. Unlike many austenitic stainless steels, ARMCO NITRONIC 50 does not become magnetic when cold worked or cooled to sub-zero temperatures. High-Strength (HS) ARMCO NITRONIC 50 Stainless Steel has a yield strength about three to four times that of Type 316 stainless steel.

Composition		(wt %)
Carbon	(C)	0.06 max.
Manganese	(Mn)	4.00 – 6.00
Phosphorus	(P)	0.040 max.
Sulfur	(S)	0.030 max.
Silicon	(Si)	1.00 max.
Chromium	(Cr)	20.50 – 23.50
Nickel	(Ni)	11.50 – 13.50
Molybedenum	(Mo)	1.50 – 3.00
Nitrogen	(N)	0.20 – 0.40
Niobium	(Nb)	0.10 – 0.30
Vanadium	(V)	0.10 – 0.30

HEAT TREATMENT

AK Steel's ARMCO NITRONIC 50 Stainless Steel bars can be supplied in the standard annealed condition and in two other special conditions that are attained by special processing techniques.

ANNEALED CONDITION

AK Steel's ARMCO NITRONIC 50 Stainless Steel is not hardenable by heat treatment. It can be supplied annealed at 1066 – 1121 °C (1950 – 2050 °F). For most applications, the 1066 °C (1950 °F) condition should be selected, as it provides a higher level of mechanical properties along with excellent corrosion resistance. When as-welded material is to be used in strongly corrosive media, the 1121 °C (2050 °F) condition should be specified in order to minimize the possibility of intergranular attack.

HIGH STRENGTH (HS) CONDITION

The superior strength of ARMCO NITRONIC 50 Stainless Steel bars is due to special hot rolling and is size-dependent, approaching that of annealed bars with sizes over 76.2 mm (3 in.) diameter. This process results in mechanical properties that are superior to Annealed material, with $R_{p0.2}$ (0.2% YS) in range 415 – 725 MPa depending on the diameter. Also this condition is non-magnetic and is useful for applications in a wide range of temperatures, from -196 – 650 °C (-320 – 1200 °F), according to Section VIII of the ASME Boiler and Pressure Vessel Code.

SUPER HIGH STRENGTH (SUPER HS) CONDITION

The new ARMCO NITRONIC 50 Super HS Stainless Steel bars are obtained by special hot plastic deformation which provides the product with the highest strength guaranteed for the previous HS condition up to 152.4 mm (6 in.) diameter without being size dependent.

Because their high strength is produced by mill processing, subsequent hot forging, welding or brazing operations cannot be performed both on HS and Super HS material without loss of strength.

By using Electro Slag Remelting (ESR) and Rotary Forging (RF) the enhanced mechanical properties of HS and Super HS can be made available, upon request, to even larger diameters, up to and including 254 mm (10 in.).

Specifications

CORROSION

Outstanding corrosion resistance gives AK Steel's ARMCO NITRONIC 50 Stainless Steel the leading edge for applications where type 316, 316L, 317 and 317L are only marginal.

MECHANICAL PROPERTIES

The different versions of ARMCO NITRONIC 50 Annealed, High Strength, and Super High Strength provide a wide range of mechanical properties and high toughness properties compared to Duplex and Super Duplex without any restriction in terms of working temperatures.

APPLICATIONS

ARMCO NITRONIC 50 is an effective alloy for the petroleum, offshore, subsea, petrochemical, chemical, fertilizer, nuclear fuel recycling, pulp and paper, textile, food processing and marine industries. Components using the combination of excellent corrosion resistance and high strength currently include pumps, valves and fittings, fasteners, cables, chains, marine hardware, boat and valves shafting, heat exchanger parts, and springs. ARMCO NITRONIC 50 is especially suitable for cryogenic application thanks to its excellent impact strength at -196 °C (-320 °F).

SPECIFICATIONS

ARMCO NITRONIC 50 bar, wire, sheet, plate, forgings and forging billets are covered by the following specifications. It is suggested the issuing agency be contacted for the latest revision of the specification.

AK Steel's ARMCO NITRONIC 50 Stainless Steel is listed as Grade XM-19 (UNS S20910) in:

ASTM A314 – Bar and Billet
ASTM A240 – Plate, Sheet and Strip for Fusion Welding Unfired Pressure Vessels
ASTM A412 – Plate, Sheet, and Strip
ASTM A479 – Bars and Shapes for Use in Boilers and Other Pressure Vessels
ASTM A276 – Bars and Shapes
ASTM A580 – Wire
ASTM A182 – Forged or Rolled Pipe Flanges, Forged Fittings and Valves
ASTM A193 – Bolting (Grade B8R)
ASTM A194 – Nuts (Grade 8R)
ASTM A249 – Welded Superheater, Heat-Exchanger and Condenser Tubes
ASTM A269 – Seamless and Welding Tubing for General Service
ASTM A312 – Seamless and Welding Pipe
ASTM A351 and A743 – Castings (Grade CG6MMN)
ASTM A403 – Wrought Piping, Fittings
ASTM A358 – Electric Fusion Welded Pipe
ASTM 5764 – Bars, Forgings, and Extrusions
ASME Boiler and Pressure Vessel Code
NACE MR0175/ISO 15156* – Petroleum and natural gas industries – Materials for use in H2S-containing environments in oil and gas production

**Not all NITRONIC 50 conditions are compliant with NACE MR10175/ISO15156 due to the posed upper limit of hardness of max. 35 HRC.*

Contact your AK Steel International sales representative for additional information.

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.

Mechanical Properties

TABLE 1 – MINIMUM PROPERTIES ACCEPTABLE FOR MATERIAL SPECIFICATION (BARS)

Condition	Size, mm (in.)	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area, %	Rockwell Hardness Max.	Impact Strength and Lateral Expansion, -196 °C (-321 °F)		Impact Strength -60 °C (-76 °F), J (ft•lbs)	Lateral Expansion -60 °C (-76 °F), mm (in.)
							J (ft•lbs)	mm (in.)		
Annealed	all	690 (100)	415 (60)	35	55	C35	27 (20)	0.381 (0.015)	20 (15)	0.381 (0.015)
HS	0 – 50.8 (0 – 2)	930 (135)	800 (116)	20	50	C35	27 (20)	no minimum guaranteed, but production aims for 0.381 mm min	20 (15)	0.381 (0.015)
HS	> 50.8 – 76.2 (> 2 – 3)	800 (116)	515 (75)	25	50	C35	27 (20)		20 (15)	0.381 (0.015)
HS	> 76.2 – 203.2 (> 3 – 8)	700 (102)	415 (60)	30	50	C35	27 (20)		20 (15)	0.381 (0.015)
SHS	0 – 50.8 (0 – 2)	930 (135)	800 (116)	25	50	C35	27 (20)		20 (15)	0.381 (0.015)
SHS	> 50.8 – 145 (> 2 – 5.7)	900 (131)	725 (105)	25	50	C35	27 (20)		20 (15)	0.381 (0.015)

TABLE 2 – TYPICAL ROOM TEMPERATURE PROPERTIES

Condition	Size, mm (in.)		UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area, %	Rockwell Hardness Max.	Impact Strength and Lateral Expansion, -196 °C (-321 °F)		Impact Strength -60 °C (-76 °F), J (ft•lbs)	Lateral Expansion -60 °C (-76 °F), mm (in.)
								J (ft•lbs)	mm (in.)		
Annealed	25.4 (1)	25.4 (1)	827 (120)	414 (60)	50	70	B98	68 (50)	> 0.381 (0.015)	> 20 (15)	> 0.381 (0.015)
HS	> 50.8 (2)	≤ 101.6 (4)	937 (136)	731 (106)	33	66	C28	68 (50)	> 0.653 (0.026)	> 20 (15)	> 0.381 (0.015)
SHS	> 50.8 (2)	≤ 101.6 (4)	1009 (146)	830 (120)	27	63	C32	50 (37)	> 0.427 (0.017)	> 20 (15)	> 0.381 (0.015)

Mechanical Properties

TABLE 3 – TYPICAL SHORT-TIME ELEVATED TEMPERATURE TENSILE PROPERTIES

Condition	Test Temperature, °C (°F)	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area, %
Annealed 1066 °C (1950 °F) Bars 19.1 – 31.8 mm (0.75 – 1.25 in.) Diameter	24 (75)	855 (124)	538 (78)	41	68
	93 (200)	772 (112)	455 (66)	41	68
	204 (400)	703 (102)	400 (58)	38	67
	316 (600)	676 (98)	372 (54)	38	64
	427 (800)	648 (94)	345 (50)	40	63
	538 (1000)	614 (89)	331 (48)	37	63
	649 (1200)	552 (80)	303 (44)	37	63
	732 (1350)	469 (68)	290 (42)	43	72
	816 (1500)	345 (50)	221 (32)	60	85
Annealed 1121 °C (2050 °F) Bars 25.4 – 38.1 mm (1 – 1.5 in.) Diameter	24 (75)	807 (117)	414 (60)	45	71
	93 (200)	738 (107)	338 (50)	44	71
	204 (400)	662 (96)	262 (38)	44	70
	316 (600)	634 (92)	241 (35)	43	68
	427 (800)	614 (89)	234 (34)	44	66
	538 (1000)	579 (84)	221 (32)	41	67
	649 (1200)	510 (74)	214 (31)	38	64
	732 (1350)	455 (66)	214 (31)	37	62
	816 (1500)	359 (52)	207 (30)	41	61

Average of triplicate tests from each of three heats.

TABLE 4 – TYPICAL STRESS-RUPTURE STRENGTH

Condition	Test Temperature, °C (°F)	Stress for Failure, MPa (ksi)		
		100 Hours	1,000 Hours	10,000 Hours (estimated)
Annealed 1066 °C (1950 °F) Bars 19.1 – 31.8 mm (0.75 – 1.25 in.) Diameter	538 (1000)	627 (91)	607 (88)	496 (72)
	593 (1100)	496 (72)	427 (62)	324 (47)
	649 (1200)	379 (55)	262 (38)	152 (22)
	732 (1350)	145 (11)	82.7 (12)	41.4 (6)
	816 (1500)	69.0 (10)	25.5 (3.7)	9.0 (1.3)
Annealed 1121 °C (2050 °F) Bars 25.4 – 38.1 mm (1 – 1.5 in.) Diameter	538 (1000)	–	–	–
	593 (1100)	488 (65)	372 (54)	296 (43)
	649 (1200)	345 (50)	283 (41)	224 (32.5)
	732 (1350)	200 (29)	103 (15)	58.6 (8.5)
	816 (1500)	89.6 (13)	44.8 (6.5)	241 (3.5)

Average of tests from three heats.

Mechanical Properties

TABLE 5 – TYPICAL CREEP STRENGTH: 25.4 mm (1 in.) DIAMETER BAR

Condition	Test Temperature, °C (°F)	Stress for Min Creep Rate, MPa (ksi)	
		0.0001% per Hour	0.00001% per Hour
Annealed 1121 °C (2050 °F)	593 (1100)	283 (41)	238 (34.5)
	649 (1200)	152 (22)	110 (16)

Test from one heat.

TABLE 6 – TYPICAL MECHANICAL PROPERTIES: COLD DRAWN WIRE

Cold Reduction %	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area, %
15	1138 (165)	986 (143)	23	56
30	1338 (194)	1200 (174)	15	49
45	1489 (216)	1351 (196)	11	45
60	1613 (234)	1489 (216)	9	42
75	1696 (246)	1613 (234)	8	39

Average of duplicate tests.
Starting size 6.35 mm (0.25 in.) dia. rod annealed at 1121 °C (2050 °F).

In common with other ARMCO NITRONIC alloys, ARMCO NITRONIC 50 Stainless Steel, when cold reduced 60% or more in-process anneals, will embrittle very rapidly when exposed at temperatures in the range of 426 – 538 °C (800 – 1000 °F). Therefore, springs made of ARMCO NITRONIC 50 Stainless Steel should not be given the low-temperature stress relief treatment commonly used for austenitic stainless steels.

TABLE 7 – TYPICAL SUB-ZERO MECHANICAL PROPERTIES: 25.4 mm (1 in.) DIAMETER BAR – ANNEALED 1121 °C (2050 °F)

Test Temperature, °C (°F)	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area, %
-73 (-100)	1007 (146)	586 (85)	50	65
-196 (-320)	1558 (226)	883 (128)	41	51

Average of duplicate tests.

Mechanical Properties

TABLE 8 – TYPICAL IMPACT STRENGTH: 25.4 mm (1 in.) DIAMETER BAR

Test Temperature, °C (°F)	Impact – Charpy V. Notch, J (ft•lbs)	
	Annealed at 1121 °C (2050 °F)	Simulated HAZ
24 (75)	230 (170)	230 (170)
-73 (-100)	156 (115)	156 (115)
-196 (-320)	68 (50)	68 (50)

Heat treated at 677 °C (1250 °F) for 1 hour to simulate the heat-affected zone of heavy weldments.
Average of duplicate test.

TABLE 9 – EFFECT OF COLD REDUCTION ON MECHANICAL PROPERTIES OF BARS

Diameter Bar, mm (in.)	Cold Reduction %	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area %	Rockwell Hardness	Charpy Impact, J (ft•lbs) Test Temperature, °C (°F)		
							27 (80)	-40 (-40)	-79 (-110)
19.05 (0.75)	0	804 (116.6)	397 (57.6)	47	71	B91	314 (232)	–	–
19.05 (0.75)	13	982 (142.5) 973 (141.1)	869 (126.0) 844 (122.5)	31 31	67 66	C30	157 (116) 156 (115)	–	–
16.51 (0.65)	28	1086 (157.6) 1076 (156.0)	1058 (153.4) 1036 (150.6)	21 24	64 64	C34	133 (98) 123 (91)	100 (74) 73 (54)	–
19.05 (0.75)	46	1282 (185.9) 1263 (183.1)	1268 (183.8) 1245 (180.6)	18 16	58 58	C36	73 (54) 71 (53)	65 (48) 58 (43)	51 (38) 53 (39)

Mechanical Properties – High Strength Condition

AK Steel's ARMCO NITRONIC 50 Stainless Steel bars also are available in high-strength condition attained by special processing techniques. The superior strength of ARMCO NITRONIC 50 (HS) Stainless Steel produced by hot rolling or rotary forging is size-dependent, approaching that of annealed bars with sizes over 76.2 mm (3 in.) diameter. Because its high strength is produced by mill processing, subsequent hot forging, welding or brazing operations cannot be performed on this material without loss of strength. High-Strength bars produced by rotary forging-special practice may have somewhat reduced resistance to corrosion and sulfide stress cracking.

TABLE 10 – TORSIONAL PROPERTIES OF HIGH-STRENGTH (HS) BARS (HOT ROLLED UNANNEALED) 31.7 – 50.8 mm (1.25 – 2 in.) DIAMETER, INCLUSIVE

	Prop. Limit, MPa (ksi)	0.2% YS, MPa (ksi)	Modulus of Rupture, MPa (ksi)
Typical	448 (65)	690 (100)	965 (140)
Minimum	345 (50)	483 (70)	827 (120)

Average of duplicate tests. Properties of material over 50.8 mm (2 in.) are somewhat lower. Please inquire.

TABLE 11 – TYPICAL SHORT-TIME ELEVATED TEMPERATURE TENSILE PROPERTIES OF HIGH-STRENGTH (HS) BARS (HOT ROLLED UNANNEALED)

Test Temperature, °C (°F)	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area, %
24 (75)	1034 (150)	869 (126)	29	64
93 (200)	931 (135)	772 (112)	28	65
204 (400)	855 (124)	696 (101)	27	64
316 (600)	807 (117)	641 (93)	28	61
427 (800)	765 (111)	593 (86)	29	61
538 (1000)	710 (103)	552 (80)	27	61
593 (1100)	683 (99)	531 (77)	26	60

Bars 25.4 to 50.8 mm (1 to 2 in.) diameter. Average of triplicate tests from each of three heats.

TABLE 12 – TYPICAL STRESS-RUPTURE STRENGTH OF 25.4 mm (1 in.) DIAMETER HIGH-STRENGTH (HS) BARS (HOT ROLLED UNANNEALED)

Test Temperature, °C (°F)	Stress for Failure, MPa (ksi)		
	100 Hours	1,000 Hours	10,000 Hours (est.)
538 (1000)	676 (98)	655 (95)	538 (78)
593 (1100)	586 (85)	455 (66)	352 (51)

Average of test from two heats. ARMCO NITRONIC 50 High-Strength (HS) bars are not recommended for prolonged use at temperatures above 593 °C (1100 °F).

Mechanical Properties – High Strength Condition

TABLE 13 – TYPICAL LOW TEMPERATURE IMPACT STRENGTH OF HIGH-STRENGTH (HS) BARS (HOT ROLLED UNANNEALED)

Test Temperature, °C (°F)	Charpy V-Notch Impact, J (ft•lbs)		
	25.4 mm (1 in.) dia.	38.1 mm (1.5 in.) dia.	50.8 mm (2 in.) dia.
27 (80)	171 (126)	203 (150)	201 (148)
-60 (-75)	155 (114)	178 (131)	178 (131)
-129 (-200)	65 (48)	84 (62)	83 (61)
-196 (-320)	42 (31)	56 (41)	49 (36)

Average of duplicate test from two heats of each bar size.

TABLE 14 – TYPICAL CRYOGENIC MECHANICAL PROPERTIES OF HIGH-STRENGTH (HS) 50.8 mm (2 in.) BAR

Temperature, °C (°F)	0.2% YS, MPa (ksi)	UTS, MPa (ksi)	Elongation % in $4D_0$	Reduction in Area, %
Room	796 (115.5)	983 (142.5)	40	65
-73 (-100)	942 (136.6)	1171 (169.9)	36	67
-129 (-200)	1051 (152.4)	1308 (189.7)	28	61
-157 (-250)	1151 (166.9)	1382 (200.4)	26	64
-196 (-320)	1330 (192.9)	1664 (241.3)	29	*

**Piece broke from specimen, making accurate determination of final diameter impossible.*

Fatigue Strength

TABLE 15 – ROTATING BEAM FATIGUE TESTS

Condition	Bar Diameter, mm (in.)	Fatigue Strength at 10^8 Reversals of Stress, MPa (ksi)	
		Tested in Air*	Tested in Seawater**
Annealed 1121 °C (2050 °F)	25.4 (1)	290 (42)	152 (22)
Annealed 1066 °C (1950 °F)	25.4 (1)	324 (47)	–
High-Strength (HS) Bars (Hot Rolled Unannealed)	25.4 (1)	469 (68)	124 (18)
	63.5 (2.5)	400 (58)	103 (15)
	102 (4)	303 (44)	103 (15)

**R R Moore specimens tested at room temperature.*

***McAdam specimens tested in ambient temperature seawater (11 – 31 °C) at LaQue Corrosion Laboratory Wrightsville Beach, N.C. Tests from one heat for each size and condition.*

SHEAR STRENGTH

The shear strength of ARMCO NITRONIC 50 Stainless Steel in double shear has been determined following Boeing Aircraft Co. D2-2860, Procedures for Mechanical Testing of Aircraft Structural Fasteners. The results, determined from a typical heat, are as shown.

TABLE 16 – SHEAR STRENGTH

Condition	UTS, MPa (ksi)	Double Shear, MPa (ksi)	Shear/Tensile Ratio, %
Annealed 1066 °C (1950 °F)	869 (126)	598 (86.8)	69
Annealed 1121 °C (2050 °F)	779 (113)	541 (78.5)	69.5

Average of duplicate tests.

ELASTIC PROPERTIES

The elastic properties of annealed ARMCO NITRONIC 50 at room temperature, are as shown.

TABLE 17 – ELASTIC PROPERTIES

Modulus of Elasticity in Tension (E), GPa (Mpsi)	Modulus of Elasticity in Torsion (G), GPa (Mpsi)	Poisson's Ratio
199 (28.9)	74.5 (10.8)	0.312

Average of duplicate tests.

Fatigue Strength

TABLE 18 – ELASTIC PROPERTIES AT ELEVATED TEMPERATURES

Temperature, °C (°F)	Young's Modulus in Tension		Poisson's Ratio
	GPa	Mpsi	
22 (72)	199	28.9	0.312
93 (200)	192	27.8	0.307
149 (300)	186	27.0	0.303
204 (400)	180	26.1	0.299
260 (500)	174	25.3	0.295
315 (600)	170	24.6	0.291
371 (700)	165	24.0	0.288

Tests performed on sheet samples in the longitudinal direction using strain gauges.

NOTCH SENSITIVITY

Tensile test were performed at room temperature using notched specimens with a stress-concentration factor of $k_t = 1.3$. Table 19 shows AK Steel's ARMCO NITRONIC 50 Stainless Steel is not notch sensitive.

TABLE 19 – NOTCH SENSITIVITY

Condition	UTS – Smooth, MPa (ksi)	UTS – Notched, MPa (ksi)
Annealed 1121 °C (2050 °F)	790 (114.5)	1069 (155)
Annealed 1066 °C (1950 °F)	830 (120.5)	–
High-Strength (HS) bars	1041 (151.0)	1355 (196.5)

Average of duplicate tests.

Galling and Wear Resistance

The galling resistance of AK Steel's ARMCO NITRONIC 50 Stainless Steel is similar to Type 316 or slightly better.

Metal-to-metal wear tests demonstrate the superiority of ARMCO NITRONIC 50 over alloy K-500 despite the higher hardness of the latter. Comparative wear data are given in Table 20.

For applications requiring superior galling, wear and cavitation resistance coupled with good corrosion resistance, AK Steel's ARMCO NITRONIC 60 Stainless Steel should be considered.

TABLE 20 – WEIGHT LOSS OF COUPLE MG/1000 CYCLES

Alloy (Rockwell Hardness) Versus	Alloy K 500 (C34)	NITRONIC 50 (C28)	Type 316	NITRONIC 50 (B95)
Type 316 (B91)	33.78	10.37	12.51 (B91)	4.29
17-4 PH (C43)	34.08	12.55	18.50 (B91)	5.46
Cobalt Alloy 6B (C48)	18.78	3.26	5.77 (B72)	1.85
Type 431 (C42)	26.40	6.73	5.03 (B72)	3.01
Ti-6Al-4V (C36)	17.19	6.27	6.31 (B72)	4.32
Alloy K-500 (C34)	30.65	34.98	33.78 (B91)	22.87
NITRONIC 50 (C28)	34.98	9.37	10.37 (B72)	4.00
NITRONIC 60 (B95)	22.87	4.00	4.29 (B91)	2.79

Test Conditions: Taber Met-Abrader machine, 12.7 mm (0.5 in.) crossed (90°) cylinders, dry. 71 N load (16 lbs), 105 RPM, room temperature. 120 gm surface finish, 10 000 cycles degreased, duplicates weight loss corrected for density differences.

TABLE 21 – CAVITATION RESISTANCE OF ANNEALED ARMCO NITRONIC 50 STAINLESS STEEL

Alloy	Weight Loss, mg
NITRONIC 50	30
Type 316	100

Data provided by outside laboratory per ASTM G32 Test Method.

Properties

PHYSICAL PROPERTIES

Density, g/cm³ (lbs/in³)	24 °C (75 °F)	7.88 (0.285)
Electrical Resistivity, μΩ•cm	21 °C (70 °F)	82

MAGNETIC PERMEABILITY

AK Steel's ARMCO NITRONIC 50 Stainless Steel does not become magnetic when severely cold worked. This characteristic makes the alloy useful for applications requiring a combination of excellent corrosion resistance and low magnetic permeability.

The magnetic permeability of AK Steel's ARMCO NITRONIC 50 Stainless Steel remains very low at cryogenic temperatures. The magnetic susceptibility data in Table 22 were obtained on mill-annealed sheet samples using the Curie Force Method.

Note that the magnetic susceptibility of AK Steel's ARMCO NITRONIC 50 Stainless Steel exhibits a cusp at approximately -240 °C (-400 °F). This phenomenon is dependent on temperature but not on field strength. Unlike the AISI 300 series stainless steels, most AK Steel's ARMCO NITRONIC Alloys show no supermagnetism.

TABLE 22 – MAGNETIC PERMEABILITY IN NITRONIC 50 WIRE*

Condition	Typical Magnetic Permeability at Field Strength of		
	50 Oer (3978 A/m)	100 Oer (7957 A/m)	200 Oer (15 914 A/m)
Annealed	1.004	1.004	1.004
Cold Drawn 27%	1.004	1.004	1.003
Cold Drawn 56%	1.004	1.004	1.004
Cold Drawn 75%	1.004	1.004	1.004

**Average of duplicate tests.*

TABLE 23 – MAGNETIC SUSCEPTIBILITY IN MILL-ANNEALED NITRONIC 50 SHEET

Temperature, °C (°F)	Magnetic Mass Susceptibility, χ, 10^{-6} cm³/g	Typical Magnetic Permeability, μ
22 (72)	21.5	1.0021
-23 (-9)	22.5	1.0022
-73 (-99)	25.0	1.0025
-123 (-189)	28.5	1.0028
-173 (-279)	35.5	1.0035
-223 (-369)	54.0	1.0053
-240 (-400)	74.0	1.0073
-258 (-432)	61.0	1.0060

Reference: Advances in cryogenic Engineering Materials, Vol. 26 (1980), pp. 37 – 47.
Note that the magnetic susceptibility of ARMCO NITRONIC 50 peaks at approximately -240 °C (-400 °F). This phenomenon is independent of field strength.

Coefficient of Thermal Expansion

TABLE 24 – COEFFICIENT OF THERMAL EXPANSION ANNEALED MATERIAL*

Temperature, °C (°F)	Coefficient of Thermal Expansion	
	µm/m/K	µin./in./°F
21 – 93 (70 – 200)	16.2	9.0
21 – 204 (70 – 400)	16.6	9.2
21 – 316 (70 – 600)	17.3	9.6
21 – 427 (70 – 800)	17.8	9.9
21 – 538 (70 – 1000)	18.4	10.2
21 – 649 (70 – 1200)	18.9	10.5
21 – 760 (70 – 1400)	19.4	10.8
21 – 871 (70 – 1600)	20.0	11.1

Average of duplicate tests.

TABLE 25 – THERMAL CONTRACTION

Temperature, °C (°F)	Contraction Parts Per Million, (ppm)	Mean Expansion Coefficient Between T and 24 °C (75 °F)	
		ppm/°C	ppm/°F
-41 (-41)	948	14.61	8.17
-46 (-51)	1016	14.53	8.06
-51 (-60)	1074	14.34	7.95
-62 (-80)	1237	14.40	7.98
-73 (-100)	1398	14.43	7.99
-87 (-125)	1560	14.07	7.80
-101 (-150)	1723	13.80	7.66
-117 (-178)	1951	13.84	7.71
-129 (-200)	2079	13.60	7.56
-143 (-225)	2231	13.37	7.44
-162 (-260)	2333	12.55	6.96
-196 (-320)	2542	11.56	6.44

TABLE 26 – THERMAL CONDUCTIVITY

Temperature, °C (°F)	Thermal Conductivity*, W/m/K (BTU/hr/ft/in./°F)
21 (70)	–
149 (300)	15.6 (108)
316 (600)	17.9 (124)
482 (900)	20.3 (141)
649 (1200)	23.0 (160)
816 (1500)	25.2 (175)

Average of duplicate tests.

Corrosion Resistance

AK Steel's ARMCO NITRONIC 50 Stainless Steel provides outstanding corrosion resistance – superior to Types 316, 316L, 317 and 317L in many media. For many applications the 1066 °C (1950 °F) annealed condition provides adequate corrosion resistance and a higher strength level. In very corrosive media or where material is to be used in the as-welded condition, the 1121 °C (2050 °F) annealed condition should be specified.

High-Strength (HS) ARMCO NITRONIC 50 bars are useful for applications such as shafting and bolting, but do not quite exhibit the corrosion resistance of the annealed conditions in all environments. The increase in hardness that comes with higher values for ultimate tensile strength slightly decreases the resistance to corrosion.

Typical corrosion rates obtained from laboratory test on ARMCO NITRONIC 50 Stainless Steel in its several conditions are shown in table 27 along with comparable data for Types 316, 316L, 317, and 317L stainless steels.

TABLE 27 – LABORATORY CORROSION TEST DATA

Test Medium	Corrosion Rates[1]				
	NITRONIC 50 Bar Annealed 1066 °C (1950 °F), g/mm² (g/in.²)	NITRONIC 50 Bar Annealed 1121 °C (2050 °F), g/mm² (g/in.²)	NITRONIC 50 High-Strength (HS) Bar [3], g/mm² (g/in.²)	Types 316 & 316L Annealed Bar, g/mm² (g/in.²)	Types 317 & 317L Annealed Bar, g/mm² (g/in.²)
10% $FeCl_3$, 25C-Plain[2]	0.6 (< 0.001)	0.6 (< 0.001)	0.6 (< 0.001)	7.1 (0.011)	–
10% $FeCl_3$, 25C-creviced[2]	0.6 (< 0.001)	0.6 (< 0.001)	0.6 (< 0.001)	120 (0.186)	–
	mm/y (MPY[4])	mm/y (MPY[4])	mm/y (MPY[4])	mm/y (MPY[4])	mm/y (MPY[4])
1% H_2SO_4, 80 °C	< 0.03 (< 1)	< 0.03 (< 1)	< 0.03 (< 1)	0.05 (2)	< 0.03 (< 1)
2% H_2SO_4, 80 °C	< 0.03 (< 1)	< 0.03 (< 1)	< 0.03 (< 1)	0.28 (11)	< 0.03 (< 1)
5% H_2SO_4, 80 °C	< 0.03 (< 1)	< 0.03 (< 1)	< 0.03 (< 1)	1.52 (60)	0.91 (36)
10% H_2SO_4, 80 °C	–	0.71 (28)	–	2.54 (100)	1.24 (49)
20% H_2SO_4, 80 °C	–	3.38 (133)	–	12.19 (480)	3.94 (155)
1% H_2SO_4, Boiling	–	0.69 (27)	–	–	0.33 (13)
2% H_2SO_4, Boiling	–	1.63 (64)	–	3.05 (120)	0.69 (27)
5% H_2SO_4, Boiling	4.93 (194)	3.33 (131)	7.52 (296)	6.60 (260)	2.36 (93)
10% H_2SO_4, Boiling	–	9.04 (356)	–	18.54 (730)	11.81 (465)
20% H_2SO_4, Boiling	–	41.66 (1640)	–	55.88 (2200)	33.02 (1300)
1% HCL, 35 °C	< 0.03 (< 1)	< 0.03 (< 1)	< 0.03 (< 1)	0.30 (12)	0.05 (2)
2% HCL, 35 °C	0.61 (24)	< 0.03 (< 1)	0.69 (27)	0.53 (21)	0.58 (23)
1% HCL, 80 °C	–	< 0.03 (< 1)	6.07 (239)	–	3.76 (148)
2% HCL, 80 °C	–	11.15 (439)	11.48 (452)	–	6.68 (263)
65% HNO_3, Boiling	0.25 (10)	0.18 (7)	–	0.30 (12)	0.30 (12)
70% H_3PO_4, Boiling	5.16 (203)	3.91 (154)	–	5.13 (202)	5.11 (201)
33% Acetic Acid, Boiling	< 0.03 (< 1)	< 0.03 (< 1)	< 0.03 (< 1)	< 0.03 (< 1)	< 0.03 (< 1)
20% Formic Acid, Boiling	–	< 0.03 (< 1)	–	0.69 (27)	–
40% Formic Acid, Boiling	–	0.81 (32)	–	0.86 (34)	–
10% HNO_3 + 1% HF, 35 °C	–	0.18 (7)	–	1.63 (64)	–
10% HNO_3 + 1% HF, 80 °C	–	1.75 (69)	–	11.23 (442)	–

[1]Immersion test performed on 15.9 mm (0.625 in.) diameter x 15.9 mm (0.625 in.) long machined cylinders. Results are average of five 48-hour periods. Specimens tested at 35 and 80 °C were intentionally activated for third, fourth, and fifth periods. Where both active and passive conditions occurred, only active rates are shown.

[2]Exposure for 50 hours with rubber bands on some specimens to produce crevices.

[3]Corrosion rates for hot rolled bars. For other mill products, contact AK Steel International.

[4]Mils Per Year (MPY) = 0.001 in. per year.

Corrosion Resistance

TABLE 28 – LABORATORY CORROSION TEST DATE CAST NITRONIC 50

Test Medium	NITRONIC 50 As-Cast, mm/y (MPY)	NITRONIC 50 Cast + Annealed 1121 °C (2050 °F), mm/y (MPY)
10% $FeCl_3$ – Uncreviced 50 hrs, Room Temperature	–	0.6 g/mm² (< 0.001 g/in²)
10% $FeCl_3$ – Crevices 50 hrs, Room Temperature	–	187 g/mm² (0.029 g/in²)
5% H_2SO_4, 80 °C	2.41 (95)	2.06 (81)
5% H_2SO_4 Boiling	–	10.62 (418)
1% HCL, 35 °C	< 0.03 (< 1)	< 0.03 (< 1)
70% H_3PO_4 Boiling	–	2.11 (83)

All test performed on 15.9 mm (0.625 in.) diameter x 15.9 mm (0.625 in.) long machined cylinders. Except for the ferric chloride tests, all results are the average of five 48-hour periods. Specimens tested at 35 and at 80 °C were intentionally activated for the third, fourth, and fifth periods. Where both active and passive periods occurred, only active rates are shown.

INTERGRANULAR ATTACK

The resistance of AK Steel's ARMCO NITRONIC 50 Stainless Steel to intergranular attack is excellent even when sensitized at 675 °C (1250 °F) for one hour to simulate the heat-affected zone (HAZ) of heavy weldments. Material annealed at 1066 °C (1950 °F) has very good resistance to intergranular attack for most applications. However, when thick sections of AK Steel's ARMCO NITRONIC 50 Stainless Steel are used in the as-welded condition in certain strongly corrosive media, the 1121 °C (2050 °F) condition gives optimum corrosion resistance. This is illustrated by table 30.

STRESS-CORROSION CRACKING RESISTANCE

In common with most stainless steels, under certain conditions, AK Steel's ARMCO NITRONIC 50 Stainless Steel may stress-corrosion crack in hot chloride environments. When tested in boiling 42% $MgCl_2$ solution, a very accelerated test, ARMCO NITRONIC 50 Stainless Steel is between Types 304 and 316 stainless steels in resistance to cracking. There is little difference in susceptibility to cracking whether in the annealed, high-strength (HS), or cold-drawn conditions. This is illustrated by the comparative data in Table 31 using the direct-loaded tensile-type test method (described in detail in ASTM STP 425, September 1967). Note that this is a severe test, especially at these temperatures. For marine applications, the following better reflects the resistance of ARMCO NITRONIC 50 Stainless Steel:

U-bend-type stress corrosion test specimens of NITRONIC 50 in the following metallurgical conditions have been exposed to marine atmosphere on a 24.4 m (80 ft) lot, 25 m (82 ft) from waterline.
(1) Mill Annealed 1063 °C (1950 °F).
(2) Mill Annealed & Sensitized 675 °C (1250 °F).
(3) Cold Rolled 44% 1103 MPa (160 ksi yield strength).
No failure after 15 years of exposure.

TABLE 29 – INTERGRANULAR CORROSION RESISTANCE OF CAST ARMCO NITRONIC 50

Huey Test		% Ferrite
Annealed*, mm/y (MPY)	Sensitized#, mm/y (MPY)	
0.15 (6)	0.18 (7.20)	Nil
0.12 (4.8)	0.46 (18.0)	4

**1121 °C (2050 °F) – 30 Minute-Water Quenched*
#1121 °C (2050 °F) – 30 Minute-Water Quenched + 677 °C (1250 °F) – 30 Minute – Air Cooled.
Even sensitized cast ARMCO NITRONIC 50 Stainless Steel has an acceptable intergranular corrosion rate less than 0.61 mm/y (24 MPY) with up to 4% ferrite present.

Corrosion Resistance

TABLE 30 – INTERGRANULAR ATTACK RESISTANCE OF ARMCO NITRONIC 50 BAR PER ASTM A262

Condition	Practice B Ferric Sulfate, mm/y (MPY)	Practice E Copper-Copper Sulfate
Annealed 1066 °C (1950 °F)	0.30 (12.0)	Passed
Annealed 1066 °C (1950 °F) + 677 °C (1250 °F) – 1 hr – A.C.	1.16 (45.6)	Passed
Annealed 1121 °C (2050 °F)	0.27 (10.8)	Passed
Annealed 1121 °C (2050 °F) + 677 °C (1250 °F) – 1 hr – A.C.	0.67 (26.4)	Passed
High-Strength (Bar Mill)	0.94 (37.2)	Passed
High-Strength (Precision Rotary Forging, PRF): Edge Intermediate Center	 0.40 (15.6) 0.37 (14.4) 0.34 (13.2)	 Passed Passed Passed

TABLE 31 – BOILING $MgCl_2$

Alloy	Condition	Time to Failure, Hours Under Stress of		
		517 MPa (75 ksi)	345 MPa (50 ksi)	172 MPa (25 ksi)
Type 304	Annealed	0.2	0.3	0.8
Type 316	Annealed	0.8	2.5	7.0
NITRONIC 50	Annealed	0.4	1.2	5.0
NITRONIC 50	High-Strength	1.2	1.5	6.0
NITRONIC 50	Cold Drawn	1.2	2.6	3.3

Corrosion Resistance

SULFIDE STRESS CRACKING

Both laboratory test and field service experience show that AK Steel's ARMCO NITRONIC 50 Stainless Steel has excellent resistance to sulfide stress cracking in all conditions. ARMCO NITRONIC 50 Stainless Steel in both the annealed and high-strength (hot-rolled) conditions has been included in the NACE MR0175/ISO 15156 and NACE MR0103, "Sulfide Stress Cracking Resistant Material for Oil Field Equipment," at hardness levels up to RC35 maximum. The cold-worked condition to RC35 maximum also is acceptable in valves and chokes for valve shafts, stems and pins, provided this cold working is preceded by annealing.

Table 32 illustrates the resistance of AK Steel's ARMCO NITRONIC 50 Stainless Steel to cracking in laboratory test in synthetic sour-well solution (5% NaCl + 0,5 % acetic acid, saturated with H_2S). Comparable data are included for AK Steel's ARMCO® 17-4 PH® Stainless Steel, which is considered acceptable by NACE for use in sour-well service in the two heat-treated conditions shown.

TABLE 32 – RESISTANCE TO SULFIDE STRESS CRACKING[1]

Alloy	Condition	Rockwell Hardness, C	0.2% YS, MPa (ksi)	Time to Failure, hr, Under Stress, MPa (ksi)						
				1034 (150)	965 (140)	862 (125)	690 (100)	517 (75)	345 (50)	172 (25)
NITRONIC 50	Annealed 1066 °C (1950 °F)	22	488 (67)	–	–	–	> 1000	> 1000	> 1000	–
	High-Strength (HS)[3] 25.4 mm (1 in.) dia.	33	931 (135)	–	204	320	> 1000	> 1000	–	–
	High-Strength (HS)[3] 25.4 mm (1 in.) dia.	35	1007 (146)	–	358	–	–	–	–	–
	High-Strength (HS)[3] 25.4 mm (1 in.) dia.	36	993 (144)	170[2]	> 1000	> 1000	> 1000	–	–	–
	Cold Drawn 9.5 mm (0.375 in.) dia.	41	1103 (160)	> 1000	–	–	> 1000	–	–	–
17-4 PH	H 1150D	32.5	758 (110) est	–	–	–	–	9.5	16	225
	H 1150M	29	586 (85)	–	–	–	–	13.5	29	850

[1]Longitudinal tensile specimens tested according to NACE TM0177.
[2]Ductile creep failure.
[3]For hot rolled bars only.

ARMCO NITRONIC 50 Stainless Steel spring temper wire coiled into a spring was exposed to NACE solution at room temperature under the following conditions:

TABLE 33

Condition	Wire UTS, MPa (ksi)	Applied Stress, MPa (ksi)	Hrs to Failure
Cold Drawn Wire Wound into a Helical Spring	1944 (282)	689 (100)	> 1584 (discontinued)

Corrosion Resistance

SEAWATER RESISTANCE

Figure 1 shows how ARMCO NITRONIC 50 High-Strength shafting and Alloy 400 (Ni-Cu) looked after 18 months exposure in quiet seawater off the coast of North Carolina. The test was conducted without zinc anodes to establish the relative corrosion resistance of ARMCO NITRONIC 50 High-Strength shafting. Had zinc anodes been used or a bronze propeller fitted to these bars, no crevice corrosion should have occurred. The photographs in Figure 1 and Figure 2 were taken after barnacles and other forms of marine life were cleared from the test bars.

Before exposure, all specimens were polished to 120 grit finish, degreased and passivated. They were then clamped into pepper-wood racks and exposed fully immersed in seawater. ARMCO NITRONIC 50 High-Strength shafting showed no crevice attack under the wooden blocks after the 18 months. One bar of ARMCO NITRONIC 50 High-Strength shafting remained perfect, while the other showed a few areas of very light crevice attack, < 0.025 mm (0.001 in.) deep under marine attachments. Both samples of Alloy 400 suffered shallow crevice attack, 0.025 – 0.076 mm (0.001 – 0.003 in.) deep under the area in contact with the wooden rack, and also under numerous attached barnacles. The results, after cleaning, are shown in Figure 1.

Type 316 stainless steel tested similarly for nine months suffered random pitting and crevice corrosion under the area in contact with the wooden rack and also under marine attachments, while ARMCO NITRONIC 50 again remained in perfect condition. These specimen are shown in Figure 2.

FIGURE 1 – COMPARISON BETWEEN ARMCO NITRONIC 50 HS AND ALLOY 400 (Ni-Cu) AFTER 18 MONTHS EXPOSURE IN QUIET SEAWATER

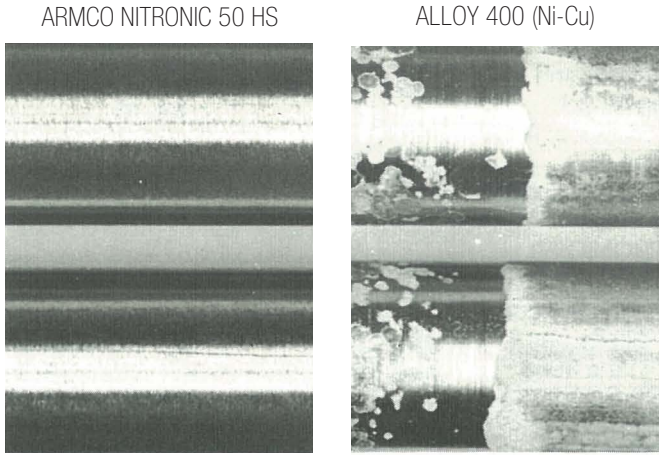
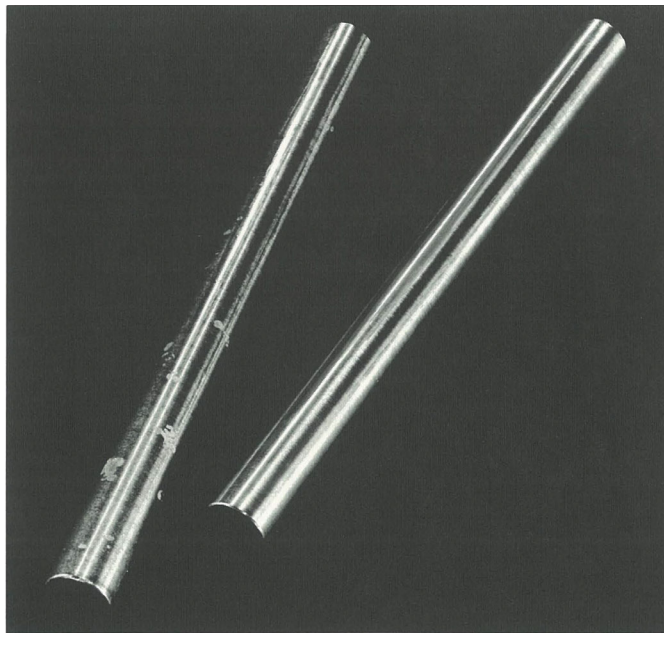


FIGURE 2 – COMPARISON BETWEEN ARMCO NITRONIC 50 HS (RIGHT) AND TYPE 316 STAINLESS STEEL (LEFT) AFTER 9 MONTHS EXPOSURE IN QUIET SEAWATER



These two bars are immersed in quiet seawater for nine months. The bright shiny bar above is AK Steel's ARMCO NITRONIC 50 Stainless Steel and at left is Type 316 stainless steel showing considerable pitting and crevice corrosion.

Corrosion Resistance

SALT FOG – MARINE ENVIRONMENT

No change was apparent in ARMCO NITRONIC 50 Stainless Steel in any condition after exposure to 5% NaCl fog at 35 °C for 500 hours, or after exposure to marine atmospheres on 24.4 m (80 ft) lot, 25 m (82 ft) from waterline for over 7 years. Similar exposure to marine atmospheres produces light staining on Type 316 stainless steel.

FOOD HANDLING

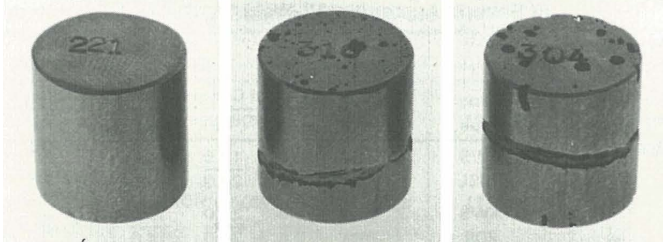
AK Steel's ARMCO NITRONIC 50 Stainless Steel is considered suitable for food contact use. The National Sanitation Foundation includes AK Steel's ARMCO NITRONIC 50 Stainless Steel in their "List of Acceptable Materials for Food Contact Surfaces." The grade has received approval for use in food applications in the European Union after passing stringent Italian standards for requirements for food contact stainless steel.

POLYTHIONIC ACID RESISTANCE

Polythionic acids are of the general formula $H_2S_xO_6$ where x is usually 3, 4, or 5. These acids can form readily in petroleum refinery units, particularly desulfurizers, during shutdown.

Stressed U-bend specimens of ARMCO NITRONIC 50 stainless, in both the annealed condition and after sensitizing at 677 °C (1250 °F) for 1 hour, showed no trace of cracking after exposure to polythionic acids for 500 hours at room temperature.

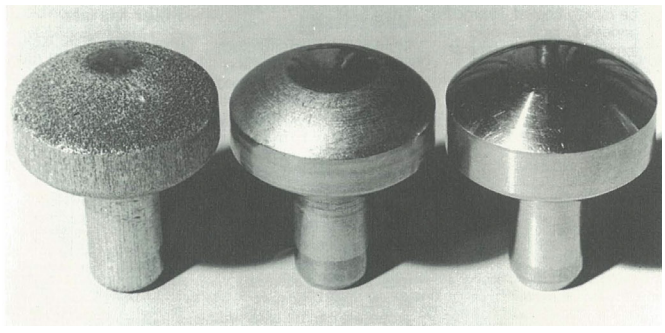
FIGURE 3 – PITTING CORROSION COMPARISON BETWEEN ARMCO NITRONIC 50 (LEFT), TYPE 316 STAINLESS STEEL (MID) AND TYPE 304 STAINLESS STEEL (RIGHT) AFTER 50 HOURS EXPOSURE TO 10% FERRIC CHLORIDE, AT ROOM TEMPERATURE.



PITTING RESISTANCE

These pieces of bars were all exposed to 10% ferric chloride solution for 50 hours at room temperature. A rubber band was placed around each to promote crevice corrosion which sometimes occurs in areas where the surface is shielded from oxygen. From left to right, in Figure 3, they are AK Steel's ARMCO NITRONIC 50 Stainless Steel, Type 316 stainless steel and Type 304 stainless steel. Only AK Steel's ARMCO NITRONIC 50 stainless is still bright and shiny. The Type 316 and Type 304 stainless steels are badly pitted and show severe crevice corrosion in the area where the rubber bands were placed.

FIGURE 4 – COMPARISON OF RESISTANCE TO AMMONIUM CARBAMATE ATTACK, GRADES AS SHOWN



Type 304 Type 316 NITRONIC 50

UREA PRODUCTION

Ammonium carbamate – an intermediate produced during the manufacture of urea – is extremely corrosive to process equipment. Pump parts in the process are subjected to a combination of severe corrosive attack, high temperatures and cyclical operating pressures ranging up 21 MPa (3 ksi). Some parts made of Type 316L stainless steel have shown surface attack in just a few months.

A manufacturer of special valves tested three stainless steels in ammonium carbamate. As shown in Figure 4, Type 304 stainless steel became severely etched in two weeks and Type 316 stainless steel showed some corrosive attack in all exposed areas after six weeks. AK Steel's ARMCO NITRONIC 50 Stainless Steel remained unaffected after six weeks' exposure to this aggressive medium.

AK Steel's ARMCO NITRONIC 50 Stainless Steel is presently being specified for the blocks, plungers and related parts of reciprocating pumps when service requires handling ammonium carbamate or other corrosive materials.

Fabrication

Although AK Steel's ARMCO NITRONIC 50 Stainless Steel is considerably stronger than the conventional 300 series stainless steels, the same fabrication equipment and techniques can be used.

FORGING

ARMCO NITRONIC 50 Stainless Steel is readily forged like Type 316 stainless steel, except that it requires more power and the temperature is 1177 – 1232 °C (2150 – 2250 °F).

ANNEALING

Like other austenitic stainless steels, ARMCO NITRONIC 50 must be rapidly cooled. In-process anneals to facilitate cold forming should be done at 1066 °C (2050 °F). Please note the remarks on annealing on page 1.

TABLE 34 – NOMINAL COMPOSITION AND TYPICAL MECHANICAL PROPERTIES OF SEVERAL AUSTENITIC ALL-WELD-METAL DEPOSITS

Alloy Type	Nominal Composition Weight %						Typical Mechanical Properties		
	C	Mn	Cr	Ni	Others		UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$
AWS 308L	0.04 Max	1.0 – 2.5	19.5 – 22.0	9.0 – 11.0	–		586 (85)	379 (55)	45
AWS 309	0.15 Max	1.0 – 2.5	22.0 – 25.0	12.0 – 14.0	–		621 (90)	379 (55)	40
AWS 312	0.15 Max	1.0 – 2.5	28.0 – 32.0	8.0 – 10.5	–		758 (110)	552 (80)	30
NITRONIC 50W (AWS E209)	0.05 Max	4.0 – 7.0	20.5 – 24.0	9.5 – 12.0	Mo 1.5 – 3.0	N 0.10 – 30	758 (110)	586 (85)	20
INCONEL 182	0.10 Max	5.0 – 9.5	13.0 – 17.0	Balance	Fe 6.0 – 10.0	Cb 1.0 – 2.5	586 (85)	379 (55)	40

Welding

In addition to the improved mechanical properties and corrosion resistance, AK Steel's ARMCO NITRONIC 50 Stainless Steel can be welded successfully by using any of the conventional welding processes that are normally employed with the austenitic stainless steels.

AK Steel's ARMCO NITRONIC 50 Stainless Steel is readily arc welded in all forms. As with most austenitic stainless steels, good weld joint properties can be obtained without the necessity of preheat or post-weld annealing. Good shielding of the molten weld puddle is important to prevent any absorption of nitrogen from the atmosphere that could result in porosity.

Autogenous, high-power density joining processes such as electron beam (EB) and laser welding should be used with caution due to the low Ferrite Number (FN)* potential of the base metal (FN approximately 2). Field reports also indicate the possibility of severe outgassing during EB welding in a vacuum atmosphere. Under vacuum conditions, this outgassing is to be expected for liquid weld metal containing a high nitrogen level.

FILLER METALS

Filler metal, when added to the joint, should be AK Steel's ARMCO NITRONIC 50W (AWS E/ER209), a matching filler metal composition that provides comparable strength and corrosion resistance to the base metal. However, sound weld joints may also be obtained using the conventional austenitic stainless steel fillers such as Types 308L and 309. When using these more common filler metal compositions, allowances should be made for the strength and differences in corrosion resistance.

Nominal compositions and representative mechanical properties are shown for the more common electrode filler rods in Table 34. The weld metal alloys are listed generally in the order of (a) increasing alloy content, (b) increasing strength level, (c) increasing corrosion resistance and (d) increasing cost.

These data show that the highest strength levels with good tensile ductility and alloy elements that impart good corrosion resistance are provided by the AK Steel's ARMCO NITRONIC 50W Electrode. In some specific applications where the high strength levels or superior corrosion resistance in the weld deposits are not required, other filler metals can be used to advantage because of reduced costs and/or ready availability.

The matching weld filler (ARMCO NITRONIC 50W, AWS E/ER209) for AK Steel's ARMCO NITRONIC 50 Stainless Steel is similar to many of the regular austenitic stainless steel filler metals in that a small percentage of the magnetic ferrite phase has been introduced to assure sound weld deposits. The small quantity of the second phase usually produces a magnetic permeability value of approximately 1.2 μ in shielded metal-arc weld deposits. This corresponds to a ferrite number (FN) of approximately 6.

Highly overalloyed Ni base fillers are suggested for applications requiring high resistance to pitting media or very low as deposited magnetic permeability.

GTA WELD JOINTS

Gas tungsten arc weld joints have been fused successfully in several flat-rolled thicknesses of AK Steel's ARMCO NITRONIC 50 Stainless Steel. Mechanical property values similar to those of the base metal have been obtained in the as-welded condition.

The corrosion resistance of GTA welded joints has been evaluated using the standard Huey test (ASTM A262, Practice C) for detecting intergranular attack in stainless steels. Laboratory test experience shows that welds made using the ARMCO NITRONIC 50W Stainless Steel filler metal exhibit the same resistance to intergranular attack as the base metal.

**For FN values of up to 8, the ferrite number approximates the percentage of δ-ferrite in the steel.*

Welding

TABLE 35 – TYPICAL MECHANICAL PROPERTIES NITRONIC 50 STAINLESS STEEL WELD JOINTS

Weld Process	Weld Filler	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Red. in Area, %	Failure Location
Shielded Metal Arc (SMA)	NITRONIC 50W	779 (113)	524 (76)	20	36	Weld Metal
Gas Metal Arc (GMA) Spray	NITRONIC 50W	772 (112)	531 (77)	21	30	Weld Metal

HEAVY SECTION WELD JOINT PROPERTIES

The mechanical properties of welds in 32.1 mm (1.25 in.) thick plate have been determined using two weld processes that are normally employed in heavy section welding, namely, (a) shielded metal arc (SMA) or stick electrode welding and (b) gas metal arc (GMA) or MIG welding with the spray mode. Typical test values that can be expected from tensile samples cut transverse to the weld centerline are shown in Table 37.

Heat input is important in obtaining the most satisfactory weld joint. Narrow stringer beads rather that a wide "weave" technique should be used for highest weld ductility. Good shielding of the molten puddle is important to eliminate additional nitrogen from the atmosphere that could cause porosity. Both stringer breads and adequate shielding are normal factors in good stainless steel welding practice.

RESISTANCE WELDING

Although no direct resistance welding experience has been obtained with AK Steel's ARMCO NITRONIC 50 Stainless Steel, the similarity of the alloy to AK Steel's ARMCO NITRONIC 40 Stainless Steel suggests a good response to resistance spot welding and cross-wire welding techniques. Average shear strength data for spot welding joints in AK Steel's ARMCO NITRONIC 40 Stainless Steel appear in the Product Data Bulletin, "AK Steel's ARMCO NITRONIC 40 Stainless Steel Sheet and Strip." AK Steel's ARMCO NITRONIC 50 Stainless Steel is expected to perform in a similar manner.

For more specific suggestions and for ARMCO NITRONIC 50W filler metal sources, contact your AK Steel International Representative.

Machinability

AK Steel's ARMCO NITRONIC 50 Stainless Steel has machining characteristics similar to other austenitic stainless steels. It is suggested that coated carbides be considered when machining all ARMCO NITRONIC alloys, since higher cutting rates may be realized. ARMCO NITRONIC 50 Stainless Steel is more susceptible to cold work hardening than Types 304 and 316 stainless steels. Also, the alloy has higher strength. Machining tests show the alloy to machine at approximately 20% of the cutting rate for AISI B1112 Structural Steel. This means ARMCO NITRONIC 50 Stainless Steel can be machined at approximately half the cutting rate (SFM) used for Type 304 or 316 stainless steels, based on using high-speed tool steels. For that reason, as stated above, coated carbides are recommended for best results.

Because of the high strength of ARMCO NITRONIC 50 Stainless Steel, more rigid tool and work holders than used for Types 304 and 316 stainless steels should be used. Care should be taken not to allow tools to slide over the alloy. Positive cutting action should be initiated as soon as possible in order to limit cold working/work hardening. The alloy provides a good surface finish.

TABLE 36 – MACHINABILITY

AISI B1112	Type 304	ARMCO NITRONIC 50
100%	45%	21%

25.4 mm (1 in.) – annealed – R_B 95.
Five-hour form tool life using high-speed tools.
Data based on duplicate test.

TABLE 37 – RECOMMENDED MACHINING RATES FOR ARMCO NITRONIC 50

Machining Operation	Cutting Rates, SFM	Cutting Rates, m/min
Automatic Screw Machine	45 – 65	14 – 20
Heavy duty Single or Multiple Spindle and Turret Lathe. High Speed Tools Rates may be increased 15-30% with High-Cobalt or Cast Alloys	40 – 65	12 – 20
Automatic Screw Machine (Swiss Type) Cast Alloy or Carbide Tools	40 – 65	12 – 20
Single Point Turning Carbide Tools Roughing Finishing	 197 – 328 263 – 394	 60 – 100 80 – 120
High Cobalt or Cast Alloy Tools Roughing Finishing	 50 – 65 50 – 75	 15 – 20 15 – 23
High-Speed Steel Tools Roughing Finishing	 30 – 45 50 – 60	 9 – 14 15 – 18
Milling (When using end mills, use two-fluted type and shorten it 25%)	20 – 40	6 – 12
Reaming Smooth Finish Work Sizing	 15 – 40 40 – 60	 5 – 12 12 – 18
High-speed steel reamers. Greatly increased rates obtainable with carbide tooling. Threading and Tapping	10 – 25	3 – 8
Drilling High-Speed Drills	 30 – 50	 9 – 15

SFM = Surface Foot per Minute

Casting

AK Steel's ARMCO NITRONIC 50 Stainless Steel may be readily cast by all conventional techniques. Casting should be annealed at 1121 °C (2050 °F) for 30 minutes and water quenched in order to attain a high level of corrosion resistance. Cast ARMCO NITRONIC 50 Stainless Steel is listed as Grade CG6MMN in ASTM A351/351M and A743.

TABLE 38 – TYPICAL ROOM TEMPERATURE AND SHORT-TIME ELEVATED TEMPERATURE PROPERTIES OF CAST ARMCO NITRONIC 50 STAINLESS STEEL (CG6MMN) ANNEALED

Test Temperature, °C (°F)	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction, %
24 (75)	641 (93)	345 (50)	48	46
93 (200)	579 (84)	269 (39)	47	57
204 (400)	510 (74)	207 (30)	50	54
316 (600)	462 (67)	186 (27)	49	48
427 (800)	448 (65)	186 (27)	47	55
538 (1000)	414 (60)	172 (25)	46	51
649 (1200)	372 (54)	166 (24)	43	55

Average of three heats, two tests per heat. Data supplied by Wisconsin Centrifugal, Inc.

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