NITRONIC® 50
Stainless Steel

(UNS S 20910)

Will Cut To Length!

Stocking Annealed, Hot Rolled & Cold Worked Bars.

Strength and Corrosion Resistant

- Best corrosion resistance of all stainless steels
- Exceptionally low magnetic permeability
- Strength almost double Type 316

HPA

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Product data Bulletin

www.HPAlloy.com

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HPAlloy Nitronic 50 Stainless Steel Product Description

HPAlloys NITRONIC 50 Stainless Steel provides a combination on 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, NITRONIC 50 Stainless Steel has very good mechanical properties at both elevated and sub-zero temperatures. And, unlike many austenitic stainless steels, NITRONIC 50 does not become magnetic when cold worked or cooled to sub-zero temperatures, High Strength (HS) NITRONIC 50 Stainless Steel has a yield strength about three times that of Type 316 stainless steel.

Available Forms

HPAlloys NITRONIC 50 Stainless Steel is available in bar, master alloy pigs, ingots and forging quality billets. Forms available from other manufacturers include castings, extrusions, seamless tubing and plate. NITRONIC 50 Stainless Steel is covered by U.S. Patent3,912,5Q3.

Composition

	%Min	%Max
Carbon	0.030	0.050
Manganese	4.00	5.50
Phosphorus	-	0.040
Sulfur	-	0.015
Silicon	0.20	0.60
Chromium	20.50	22.00
Nickel	11.75	13.00
Molybdenum	2.00	2.50
Copper	-	0.75
Nitrogen	0.24	0.30
Titanium	-	0.020
Aluminum	-	0.020
Boron	0.0008	0.0025
Columbium	0.12	0.20
Tantalum	-	0.10
Tin	-	0.030
Vanadium	0.10	0.30
Tungsten	-	0.15

Other specification coverage is pending. It is suggested that HPAlloys be contacted for information concerning additional coverage.

Annealing Temperature

HPAlloy ITRONIC 50 Stainless Steel can be supplied annealed at 1950 F to 2050 F (1066 C to 1121 C). For most applications, the 1950 F (1066 C) 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 2050 F (1121 C) condition should be specified in order to minimize the possibility of intergranular attack.

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 the American Iron and Steel Institute Metric Practice Guide,1978.

The newton (N) has been adopted by the SI as the metric standard unit of force as discussed in the AISI Metric Practice Guide. The term for force per unit of area (stress) is the newton per square metre (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 metre (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/in2 (psi) = 1 kip/in2 (ksi) = 6.8948 meganewtons/ m^2 (MN/m^2) = 6.8948 megapascals (MPa). Other units are discussed in the Metric Practice Guide.

Mechanical Properties

Table 1

Minimum Properties Acceptable for Material Specification Annealed Bars

Condition	UTS psi(MPa)	0.2% YS psi(MPa)	Elongation % in 2" (50.8 mm)	Reduction of Area %
Annealed 1950F(1066C)to 2050F(1121 C)and	100,000 (690)	55,000 (379)	35	55
water Quenched (up to 144 in^2 [9290cm^2]) Over 144 in^2 (9290 cm^2) to 324 in^2 (2091 cm^2)	95,000 (655)	50,000 (345)	30	45

Table 2

Typical Room Temperature Properties*
1" (25.4 mm) Diameter Bar

Condition	Tensile Properties						Torsional Properties	
	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elong. % in 2" (50.8 mm)	Red. of Area %	Hardness Rockwell	Impact Charpy V-Notch ft-lbs (J)	0.2% Tortional YS ksi (MPa)	Modulus of Rupture ksi (MPa)
Annealed 2050 F (1121 C) plus water quench	120 (827)	60 (414)	50	70	B98	170 (230)	44.5 (307)	114.5 (789)
Annealed 1950 F (1066 C) plus water quench	125 (862)	65 (448)	45	65	C23	130 (176)	55 (379)	120 (827)

*Average of duplicate tests.

Table 3

Typical Short-Time Elevated Temperature Tensile Properties*

Condition	Test Temperature F (C)	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Reduction of Area %
Annealed 1950F(1066C) Bars 3/4 t 01-1/4" (191 to 31.8mm) Diameter	75 (24) 200 (93) 400 (204) 600 (316) 800 (427) 1000 (538) 1200 (649) 1350 (732) 1500 (816)	124 (855) 112 (772) 102 (703) 98 (676) 94 (648) 89 (614) 80 (552) 68 (469) 50 (345)	78 (538) 66 (455) 58(400) 54 (372) 50 (345) 48(331) 44 (303) 42 (290) 32 (221)	40.5 40.5 37.5 37.5 39.5 36.5 36.5 42.5 59.5	67.5 67.5 67 64 63 62.5 63 71.5 85
Annealed 2050 F(1121 C) Bars1" to 1-1/2" (254 to 38,1 mm) Diameter	75(24) 200(93) 400(204) 600(316) 800(427) 1000(538) 1200(649) 1350(732) 1500(816)	117(807) 107(738) 96(662) 92(634) 89(614) 84(579) 74(510) 66(455) 52(359)	60(414) 50(338) 38(262) 35(241) 34(234) 32(221) 31(214) 31(214) 30(207)	45 43.5 43.5 42.5 43.5 41 38 37 41	71 70.5 69.5 67.5 66 66.5 64 61.5 61

Average of triplicate tests from each of three heats

Table 4

Typical Stress-Rupture Strength*

Condition	Test Temperature F (C)	Stress for Failure, ksi (MPal)		
		100 Hours	1000 Hours	10,000 Hours
Annealed 1950F(1066C) Bars 3/4 t 01-1/4" (191 to 31.8mm)	1000(538) 1100(593) 1200(649)	91(627) 72(496) 55(379)	88 (607) 62 (427) 38 (262)	72 (496) 47 (324) 22 (152)

Diameter	1350(732) 1500(816)	21(145) 10(69.0)	12 (82.7) 3.7 (25.5)	6 (41.4) 1.3 (9.0)
Annealed 2050 F(1121 C) Bars1" to 1-1/2" (254 to 38,1 mm) Diameter	1000(538) 1100(593) 1200(649) 1350(732) 1500(816)	65 (448) 50 (345) 29 (2001) 13 (8961)	54 (372) 41 (283) 15 (103) 6.5(44.8)	43 (296) 32.5 (224) 8.5 (58.6) 3.5 (24.1)

Average of triplicate tests from each of three heats

Table 5

Typical Room Temperature Properties*
1" (25.4 mm) Diameter Bar

	Tensile Properties						Torsional Properties	
Condition	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elong. % in 2" (50.8 mm)	Red. of Area %	Hardness Rockwell	Impact Charpy V-Notch ft-lbs (J)	0.2% Tortional YS ksi (MPa)	Modulus of Rupture ksi (MPa)
Annealed 2050 F (1121 C) plus water quench	120 (827)	60 (414)	50	70	B98	170 (230)	44.5 (307)	114.5 (789)
Annealed 1950 F (1066 C) plus water quench	125 (862)	65 (448)	45	65	C23	130 (176)	55 (379)	120 (827)

*Average of duplicate tests.

Table 3

Typical Short-Time Elevated Temperature Tensile Properties*

Condition	Test Temperature F (C)	Stress for min Creep Rate, ksi (MPal)	
		.0001% Hour	.00001% Hour
	1100(593) 1200(649)	41(283) 22(152)	34.5(238) 16(110)

Table 6

Typical Mechanical Properties*
Cold Drawn Wire

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

.Average of duplicate tests.

Starting size 114" (635 mm) dia rod annealed at 2050 F (1121 C). In common with other NITRONIC alloys, NITRONIC 50Stainless Steel, when cold reduced 60% or more without in-process anneals, will embrittle very rapidly when exposed to temperatures in the range of 600to 1000 F (426 to 538 C). Therefore, springs made of 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*

1" (25.4 mm) Diameter Bar -Annealed 2050 F (1121 C)

Test Temp F (Cl	UTS ksi (MPa)	0.2% VS ksi (MPa)	Elongation % in 2" (50.8 mm)	Reduction of Area %
-100 (-73)	146 (1007)	85 (586)	49.5	65
-320(-196)	226(1558)	128(883)	41	51

.Average of duplicate tests

Table 8

Typical Impact Strength
1" (25.4 mm} Diameter Bar -Annealed 2050 F (1121 C)

Test Temp F (C)	Impact -Charpy V-Notch. ft-lbs (JI)	
	Annealed	Simulated HAZ*
75 (24)	170 (230)	170 (230)
-100 (-73)	115(156)	115(156)
-320(-196)	50(156)	50(68)

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

Fatigue Strength

Table 17

Rotating Beam Fatigue Tests

Condition	Bar Size	Fatigue Strength at 10. Reversals of Strel ksi(MPa)	
		Tested in Air*	Tested in Seawater*
Annealed 2050 F (1121 C)	1 n dia (25.4 mm)	42 (290)	
Annealed 1950 F (1066C)	1 n dia (25.4 mm)	47 (324)	
High-Strength (HS) Bars (Hot Rolled Unannealed)	1" dia (25.4 mm)	68 (469)	18 (124)
	2-1/2" dia (63.5 mm)	58(4001)	
	4" dia I (102 mm)	44 (303)	15(103)

R Moore specimens tested at room temperature
McAdam specimens tested .in ambient temperature seawater (11-31 C) at LaQue Corrosion Laboratory, Wrightsville Beach. NC
Tests from one heat for each size and condition

Shear Strength

The shear strength of NITRONIC 50 Stainless Steel in double shear has been determined following Boeing Aircraft Go. 02-2860, Procedures for Mechanical Testing of Aircraft Structural Fasteners. The results, determined from atypical heat, are as shown.

Table 18

Shear Strength

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

Average of duplicate tests.

Elastic Properties

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

Table 19

Elastic Properties

Modulus of Elasticity in Tension (E) psi (MPa)	Modulus of Elasticity in Tension (G) psi (MPa)	Poissons' Ratio
28.9 x 106 (199) x 103	10.8 x 106 (74,500)	0.312

Average of duplicate tests.

Notch Sensitivity

Tensile tests were performed at room temperature using notched specimens

Table 20

Elastic Properties at Elevated Temperatures*

with a stress-concentration factor of Kt = 1.3. The following data at right show HPAlloys NITRONIC 50 Stainless Steel is not notch sensitive.

Temperature F (C)	Youngs' Modulus in Tension		
	psi	(MPa)	Poissons' Ratio
72(22)	28.9 x 10^6	(199x10^3)	0.312
200(93)	27.8 x 10^6	(192x10^3)	0.307
300(149)	27.0 x 10^6	(186x10^3)	0.303
400(204)	26.1 x 10^6	(180x10^3)	0.299
500(260)	25.3 x 10^6	(174x10^3)	0.295
600(315)	24.6 x 10^6	(170x10^3)	0.291
700(371)	24.0 x 10^6	(165x10^3)	0.288

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

Table 21
Notch Sensitivity

Condition	UTS -Smooth. KSI (Mpa)	UTS -Notched. KSI (Mpa)
Annealed 2050 F (1121 C)	1145 (790)	155 (1069)
Annealed 1950 F (1066 C)	1205 1830)	
High-Strength (HS) Bars	151 (1041)	1965 (1354)

Average of duplicate tests

Table 22
Weight Loss of Couple*
mg/1000 cycles

Alloy (Rockwell Hardness) versus	Alloy K-500 (C34)	NITRONIC 50 (C28)	Type 316	NITRONIC 60 (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-6AI-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. 500" 0 crossed (90") cyllnders. dry. 16-lb load. 105 RPM. room temperature. 120 grit surface finish. 10.000 cycles. degreased. duplicates. weight loss corrected for density differences

Physical Properties

Density at 75 F (24 C)
7.88 gm/cmJ
.285 lbs/inJ
Electrical Resistivity at 70 F (21 C) -82 microhm-cm

Table 23
Cavitation Resistance of Annealed NITRONIC 50 Stainless Steel

Alloy	Weight Loss mg*
NITRONIC 50	30
Type 316	100

*Data provided by outside laboratory per ASTM G32 Test Method

Magnetic Permeability

HPAJloysNITRONIC 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 HP.AJoys NITRONIC 50 Stainless Steel remains very low at cryogenic temperatures, but not as low as HPAJloys NITRONIC 33 and NITRONIC 40 Stainless Steels. The magnetic susceptibility data in Table 25

Table 24
Wire*

Condition	Typical Magnetic Permeability at Field Strength of		
	50 Oer. (3978 Alm)	100 Oer (7957 A/m)	200 Oer (15.914 A/m)

were obtained on mill-annealed sheet samples using the Curie Force Method. Note that the magnetic susceptibility of HPAHoys NITRONIC 50 Stainless Steel exhibits a cusp at approximately -400 F (-240 C). This phenomenon, which also occurs with HPAlloys NITRONIC 33 and NITRONIC 40 Stainless Steels, is dependent on temperature but not on field strength. Unlike the AISI 300 series stainless steels, most HPAlloys NITRONIC Alloys show no supermagnetism.

Annealed		1.004	1.004
Cold Drawn 27%		1.004	1.003
Cold Drawn 56%		1.004	1.004
Cold Drawn 75%		1.004	1.004

*Average of duplicate tests

Table 25

Temperature F(C)	Magnetic Mass Susceptibility, χ, 10^{-6} cm^3 g^{-1}	Typical Magnetic Permeability, μ
72(22)	21.5	1.0021
-9(-23)	22.5	1.0022
-99(-73)	25	1.0025
-189(-123)	28.5	1.0028
-279(-173)	35.5	1.0035
-369(-223)	54	1.0053
-400(-240)	74	1.0073
-432(-258)	61	1.0060

Reference: Advances in croyogenicEngineering Materials, Vol. 26 (1980), pp. 37-47.

Coefficient of Thermal Expansion

Table 26

Coefficient of Thermal Expansion Annealed Material*

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

Average of duplicate tests

Table 27

Thermal Contraction

Temperature F (C)	Contraction Parts Per Million ppm	Mean Expansion Coefficient Between T and 75 F(24 C)	
		ppm/˚F	ppm/˚C
-41(-41)	948	8.17	
-51(-46)	1016	8.06	
-60(-51)	1074	7.95	

Corrosion Resistance

HPAlloys NITRONIC 50 Stainless Steel provides outstanding corrosion resistance -superior to Types 316, 316L, 317 and 317L in many media. For many applications the 1950 F (1066 C) 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 2050 F (1121 C) annealed condition should be specified. High-Strength (HS) 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. Typical corrosion rates obtained from laboratory tests on NITRONIC 50 Stainless Steel in its several conditions are shown in Table 29 along with comparable data for Types 316, 316L, 317 and 317L stainless steels.

-80(-62)	1237	7.98	
-100(-73)	1398	7.99	
-125(-87)	1560	7.80	
-150(-101)	1723	7.66	
-178(-117)	1951	7.71	
-200(-129)	2079	7.56	
-225(-143)	2231	7.44	
-260(-162)	2333	6.96	
-320(-196)	2542	6.44	

Thermal Conductivity

Table 28

Temperature F(C)	**Thermal Conductivity BTU/hr/ft^2/in/˚F(W/m•K)**
70 (21)	
300 (149)	108 (15.6)
600 (316)	124 (17.9)
900 (482)	141 (20.3)
1200 (649)	160 (23.0)
1500 (816)	175 (25.2)

*Average of duplicate tests

Table 29

Laboratory Corrosion Test Data

Test Medium	**Corrosion Rates in Inches per Year IIPY) Unless Otherwise Indicated[1]**				
	NITRONIC 50 Bar Annealed 1950 F (1066 C)	**NITRONIC 50 Bar Annealed 2050 F (1121 C)**	**NITRONIC 50 High-Strength (HS) Bar[3]**	**Types 316 & 316L Annealed Bar**	**Types 317 & 317L Annealed Bar**
10% FeCIJ.25 C -plain[2] 10% FeCIJ.25 C -eviced[2]	< .001 g/in^2 < .001 g/in^2	< .001 g/in^2 < .001 g/in^2	< .001 g/in^2 < .001 g/in^2	.011 g/in^2 .186 g/in^2	
1% H_2SO_4, 80 C 2% H_2SO_4, 80 C 5% H_2SO_4, 80 C 10% H_2SO_4, 80 C 20% H_2SO_4, 80 C	< .001 < .001 < .001 - -	< .001 < .001 < .001 0.028 0.133	< .001 < .001 < .001 - -	0.002 0.011 0.060 010 0.48	< .001 < .001 0036 0.049 0155
1% H_2SO_4, Boiling 2% H_2SO_4, Boiling 5% H_2SO_4, Boiling 10% H_2SO_4,Boiling 20% H_2SO_4, Boiling	- - 194 - -	0.027 0.064 0131 0356 1.64	- - 0.296 - -	- 0.12 026 073 2.20	
1%HCI.35C 2% HCI. 35 C	< .001 0.024 0.024	<.001 <.001	0.012 0.021	- 0.12 026 073 2.20	

1% HCl. 80 C 2% HCl. 80 C	- -	<.001 <0.439	0.239 452	- -	
65% HNO3, Boiling	0010	0.007	-	0.012	
70% HJPO4' Boiling	0.203	0.154	-	0.012	
33% Acetic Acid. Boiling	<.001	<.001	<.001	<.001	
20% Formic Acid. Boiling 40% Formic Acid. Boiling	- -	<.001 0.032	- -	0.027 0.034	
10%HNOJ+ 1%HF.35C 10% HNOJ + 1% HF. 80 C	- -	0.007 0.069	- -	0.064 0.442	

l'lImmersion tests performed on 5/8" dia. x 5/8" (159 x 15.9 mm) long machined cylinders. Results are average of five 48- hour periods. Specimens tested at 35 C and 80 C were intentionally activated for third. fourth. and fifth periods Where both active and passive conditions occurred, only active rates are shown.

12JExposure for 50 hours with rubber bands on some specimens to produce crevices

131Corrosionr ates for hot rolled bars. For other mill products, contact Armco.

Table 30

Laboratory Corrosion Test Data*
Cast NITRONIC 50

All tests performed on 5/8" (15.9 mm) diameter x 5/8" (15.9 mm) long machined cylinders Except for the ferric chloride tests, all results are the average of five 48-hour periods Specimens tested at 35 C 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.

Test Medium	NITRONIC 50 As-Cast	NITRONIC 50 Cast + Annealed 2050 F (1121 C)
10% FeCIJ -Uncreviced 50 hrs., Room Temperature		<.001 g/in2
10% FeCIJ -Crevices 50 hrs., Room Temperature		.029 g/in2
5% H2SO4, 80 C	95 MPY	81 MPY
5%H_2SO_4,Boiling	-	418 MPY
1% HCI, 35 C	<1 MPY	<1 MPY
70% H_3PO_4, Boiling	-	83 MPY

Intergranular Attack

The resistance of HPAlloys NITRONJC 50 Stainless Steel to intergranular attack is excellent even when sensitized at 1250 F (675 C) for one hour to simulate the heataffected zone of heavy weldments. Material annealed at 1950 F (1066 C) has very good resistance to intergranular attack for most applications. However, when thick sections of HPAlloys NITRONIC 50 Stainless Steel are used in the as-welded condition in certain strongly corrosive media, the 2050 F (1121 C) condition gives optimum corrosion resistance. This is illustrated by Table 32.

Table 31

Intergranular Corrosion Resistance of Cast NITRONIC 50

Huey Test. JPM		% Ferrite
Annealed *	Sensitized**	
0.0005	0.0006	
0.0004	0.0015	

.2050F(1121 C).112-Hour.Water Quenched

**2050 F (1121 C) .112.Hour .Water Quenched + 1250 F (677 C) -112-Hour -Air Cooled.

Even sensitized cast NITRONIC 50 stainle.s Steel has an acceptable intergranular corrosion rataless than 0.0020 IPM with up to 4% farrita presant.

Stress-Corrosion Cracking Resistance

Table 32

Intergranular Attack Resistance of NITRONIC 50 Bar per ASTM A262

Condition	Practice B Ferric Sulfate	Practice E Copper-Copper Sulfate

In common with most stainless steels, under certain conditions, HP.AJloyNs ITRONIC 50 Stainless Steel may stress-corrosion crack in hot chloride environments. When tested in boiling 42% MgCl2 solution, a very accelerated test, 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 colddrawn conditions. This is illustrated by the comparative data in Table 33 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 NITRONIC 50 Stainless Steel:

Annealed 1950 F (1066 C)	0.00101PM	Passed
Annealed 1950 F (1066 C)	0.0038 IPM	Passed
+ 1250F(677C)-1 hr.-A.C.		
Annealed 2050 F (1121 C)	0.0009 IPM	Passed
Annealed 2050 F (1121 C)	0.00221PM	Passed
+ 1250F(677C)- 1 hr.-A.C.		
High-Strength (Bar Mill)	0.0031 IPM	Passed
High-Strength (PRF)		
Edge	0.0012 IPM	Passed
Intermediate	0.0012 IPM	Passed
Center	0.0011 IPM	Passed

Table 33

Boiling $MgCl_2$

Alloy	Condition	Time to Failure, Hours Under Stress of 75 ksi (517 MPa)	50 ksi (345 MPa)	25 ksi (172 MPa)
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

U-bend-type stress corrosion test specimens of NITRONIC 50 in the following metallurgical conditions have been exposed to marine atmosphere on the 80' lot at Kure Beach. N.C. (1) Mill Annealed 1950 F (1063 C) (2) Mill Annealed & Sensitized 1250 F (675 C) (3) Cold Rolled 44% (160 ksi yield strength) Tests were begun on June 3. 1970. No failure occurred after 15 years exposure.

Sulfide Stress Cracking

Both laboratory tests and field service experience show that HPAloysN ITRONIC 50 Stainless Steel has excellent resistance to sulfide stress cracking in all conditions. NITRONIC 50 Stainless Steel in both the annealed and high-strength (hot-rolled) conditions has been included in the 1988 revision of NACE Standard MR-01-75, "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 an anneal. Table 34 illustrates the resistance of HPAlloys NITRONIC 50 Stainless Steel to cracking in laboratory tests in synthetic sour-well solution (5% NaCl + 1/2% acetic acid, saturated with H2S). Comparable data are included for HPA8oy1s7 -4 PH Stainless Steel, which is considered acceptable by NACE for use in sour-well service in the two heattreated conditions shown.

Table 34

Resistance to Sulfide Stress CrackIng (1)

		Hardness	0.2% YS	Time to Failure, hr., Under Stress. ksi (MPa)

Alloy	Condition	Rockwell	ksi (MPa)	160 (1034)	140 (965)	125 (862)	100 (690)	76 (617)	50 (345)	25 (172)
NITRONIC 50	Annealed 1950 F (1066 C)	C22	67 (448)	-	-	-	>1000	>1000	>1000	-
NITRONIC 50	High-Strength(HS)(3)1" (25.4 mm) dia.	C33	135 (931)	-	204	320	>1000	>1000	-	-
NITRONIC 50	High-Strength(HS)(3)1" (25.4 mm) dia.	C35	146 (1007)	-	358	-	-	-	-	-
NITRONIC 50	High-Strength(HS)(3)1" (25.4 mm) dia.	C36	144 (993)	170 (2)	>1000	>1000	>1000	-	-	-
NITRONIC 50	Cold Drawn 3/8" (9.5 mm) dia.	C41	160 (1103)	>1000	-	-	>1000	-	-	-
17-4 PH	H 1150+ 1150	C32.5	110 (758) est.	-	-	-	-	9.5	16	225
17-4 PH	H 1150-M	C29	85 (586)	-	-	-	-	13.5	29	850

(1) Longitudinal tensile specimens tested according to NACE TM 01-77
(2) Ductile creep failure.
(3) For hot rolled bars only.

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

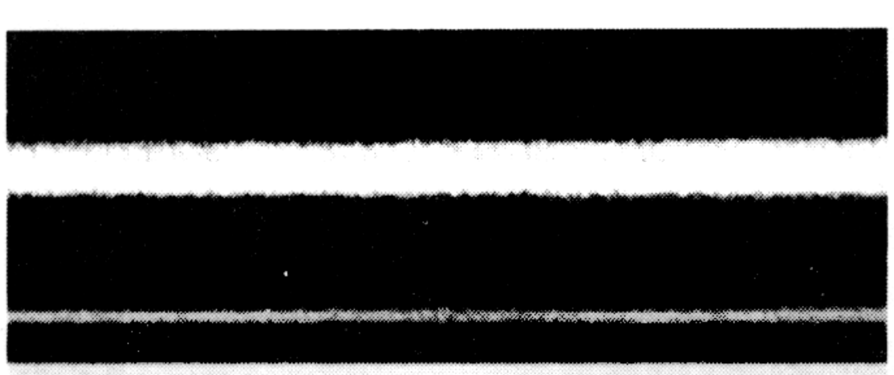
Table 35

Condition	Wire UTS ksi(MPa)	Applied Stress ksi(MPa)	Hrs to Failure
Cold Drawn Wire Wound into a Helical Spring			

Seawater Resistance

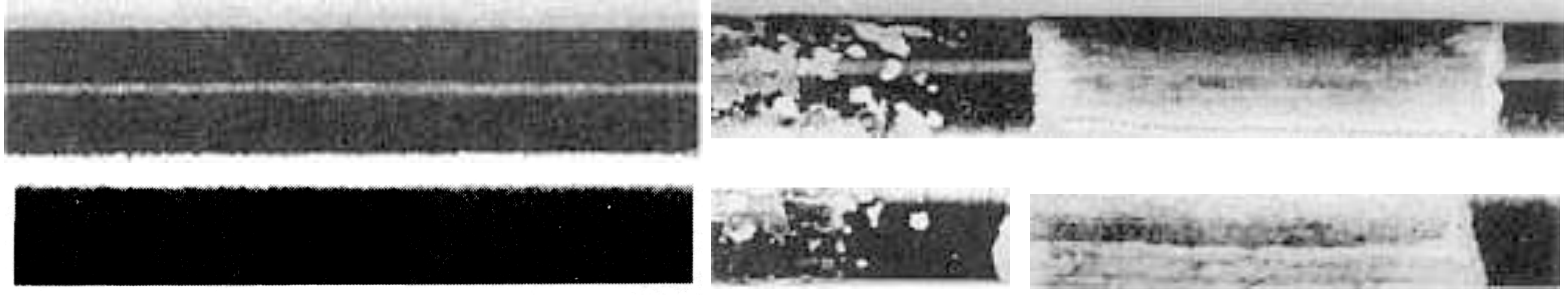
Here is how NITRONIC 50 High-Strength (HS) shafting and Alloy 400 (Ni-Cu) looked after 18 months' exposure in quiet seawater off the coast of North Carolina. The test was conducted without zinc anodes to establish the relative corrosion resistance of NITRONIC

NITRONIC 50

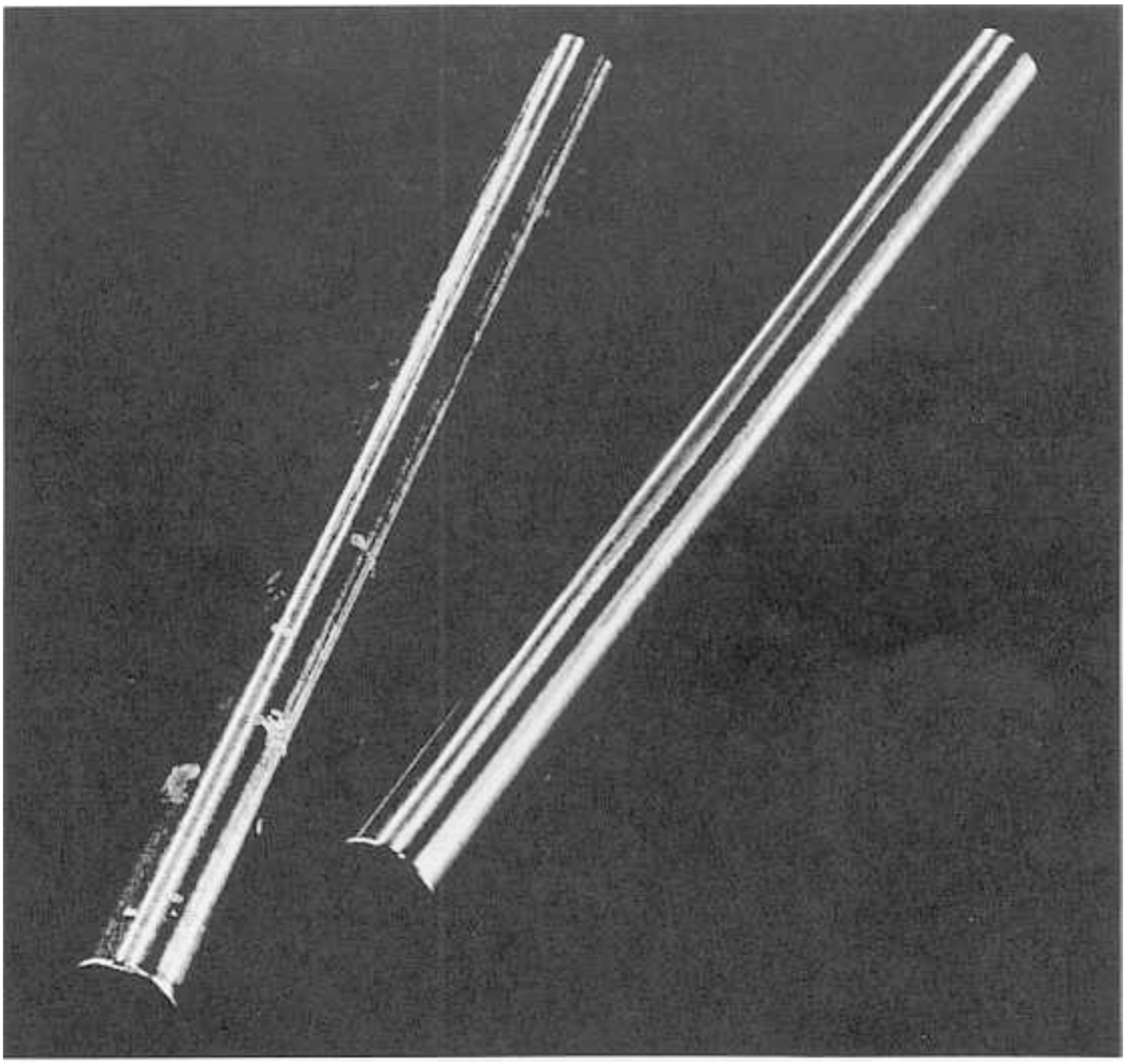


Alloy 400 (Ni-Cu)

50 High-3trength (HS) shafting. Had zinc anodes been us~d or a bronze propeller fitted to these bars, no crevice corrosion should have occurred. The photograph was taken after barnacles and other forms of marine life were cleared from the test bars. Before exposure, all specimens were polished tc 120 grit finish, degreased and passivated. They were then clamped into pepperwood racks and exposed fully immersed in seawater. NITRONIC 50 high-strength (HS) shafting showed no crevice attack under the wooden blocks after the 18 months. One bar of NITRONIC 50 high-strength (HS) shafting remained perfect, while the other showed a few areas of very light crevice attack, < .001 " (0.025 mm) deep under marine attachments. Both samples of.Alloy 400 suffered shallow crevice attack .001 "-.003" (0.025-0.076 mm) deep under the area in contact with the wooden rack, and also under numerous attached barnacles. Type 316 stainless steel tested similarily for nine months suffered random pitting and crevice corrosion under the area in contact with the wooden rack and also under marine attachments, while NITRONIC 50 again remained in perfect condition. These specimens are shown in the photograph.



Wood Block Wood Block



These two bars are immersed in quiet seawater for nine months. Bright shiny bar at right is HP.Ai7JsN, ITRONIC 50 stainless steel, and at left is Type 316 stainless steel showing considerable pitting and crevice corrosion.

Salt Fog - Marine Environment

No change was apparent in NITRONIC 50 Stainless Steel in any condition after exposure to 5% NaCl fog

Pitting Resistance

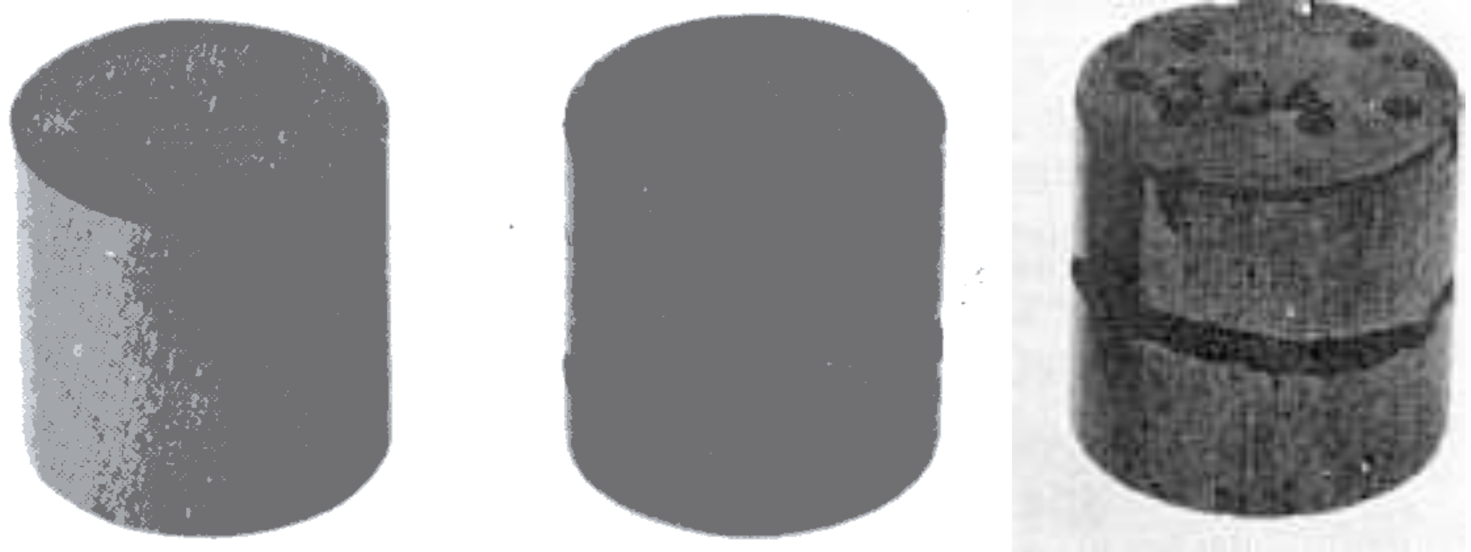
at 35 C for 500 hours, or after exposure to marine atmospheres on the 800-foot (24.4m) lot at Kure Beach, North Carolina, for 7V2 years. Similar exposure to marine atmospheres produces light staining on Type 316 stainless steel.

Food Handling

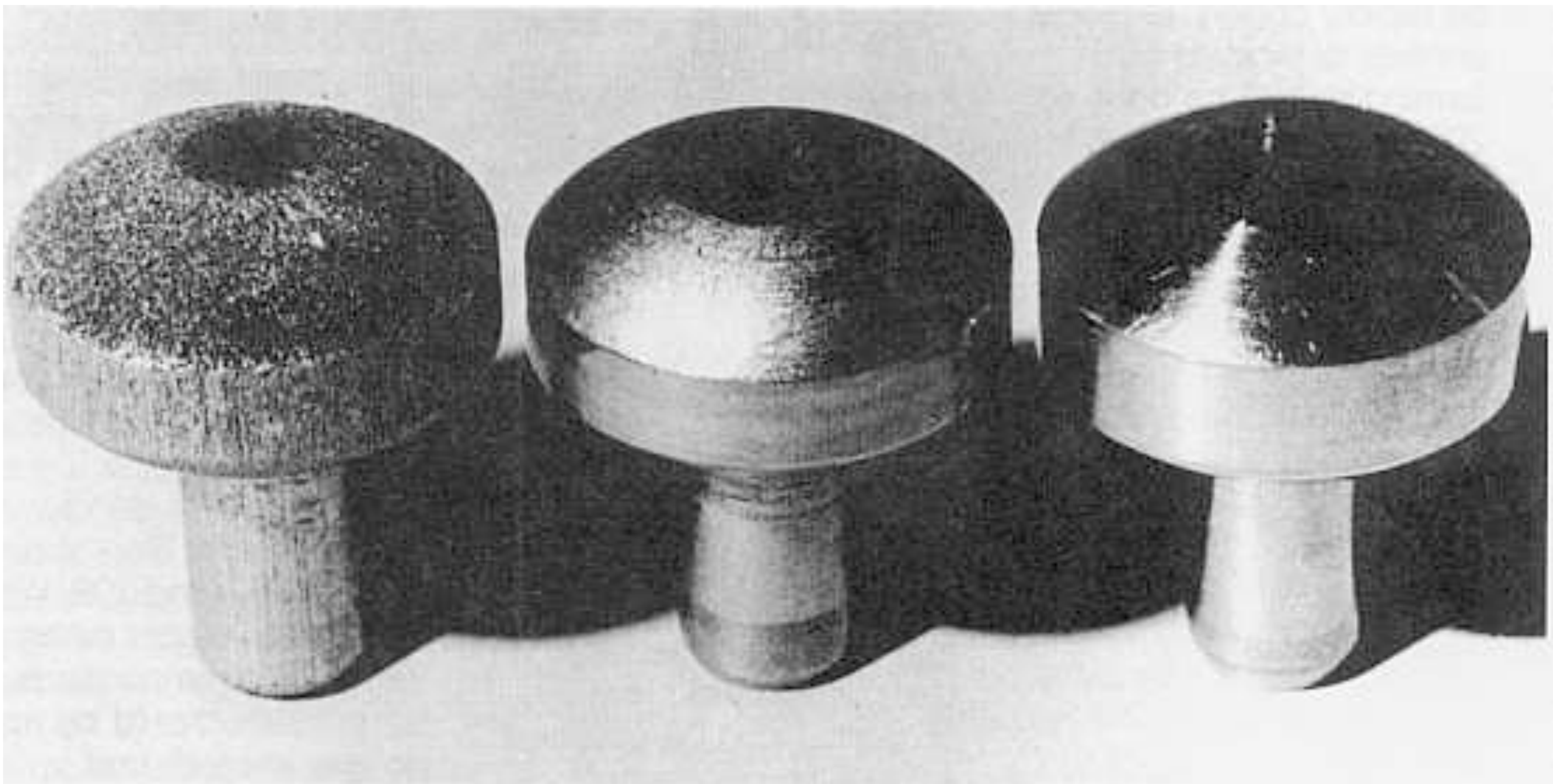
HPAlloys NITRONIC 50 Stainless Steel is considered suitable for food contact use. The National Sanitation Foundation includes HPAlloys NITRONIC 50 Stainless Steel in their .'List of Acceptable Materials for Food Contact Surfaces."

Poly thionic Acid Resistance

Poly thionic acids are of the general formulaH~xO6. 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 NITRONIC 50 stainless, in both the annealed condition and after sensitizing at 1250F (677 C) for 1 hour, showed no trace of cracking after exposure to poly thionic acids for 500 hours at room temperature.



These pieces of bar 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, they are HP.AJk1N,IS IT RON IC 50 Stainless Steel, Type 316 stainless steel and Type 304 stainless steel. OnlyHP.AJkr,'s 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.



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 to 3000 psi. 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 the photograph, 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. HPAlloys NITRONIC 50 Stainless Steel remained unaffected after six weeks' exposure to this aggressive medium. HPAlloysNITRONIC 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

Table 36

Although HPAlloys NITRONIC 50 Stainless Steel is considerably stronger than the conventional 300 series stainless steels, the same fabricating equipment and techniques can be used.

Forging

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

Annealing

Like other austenitic stainless steels, NITRONIC 50 must be rapidly cooled. In-process anneals to facilitate cold forming should be done at 2050 F (1066 C). Please note Page 3.

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 ksi(MPa)	2% YS ksi(MPa)	Elong. %
AWS 308L	0.04 max	1.0 / 2.5	19.5 / 22.0	9.0 / 11.0	-		85(586)	55(379)	45
AWS 309	0.15 max	1.0 / 2.5	22.0 / 25.0	12.0 / 14.0	-		90(621)	55(379)	40
AWS 312	0.15 max	1.0 / 2.5	28.0 / 32.0	8.0 / 10.5	-		110(758)	80(552)	30
Armco NITRONIC 50W (AWS E 209)	0.05 max	4.0 / 7.0	20.5 / 24.0	9.5 / 12.0	Mo 1.5 / 3.0	N 1.0 / 3.0	110(758)	85(586)	20
INCONEL 182	0.10 max	5.0 / 9.5	13.0 / 17.0	Bal.	Fe 6.0 / 10.0	Cb 1.0 / 2.5	85(586)	55(379)	40

Welding

In addition to the improved mechanical properties and corrosion resistance, HPAlloys 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. HPAlloyNs ITRONIC 50 Stainless 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 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 HPABoys NITAONIC 50W (AWS E/EA 209), 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 corrosion differences. Nominal compositions and representative mechanical properties are shown for the more common electrode filler rods in Table 36. 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 HP.AJloys NITAONIC 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 (NITAONIC 50W, AWS E/EA 209) for HPAloys NITAONIC 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 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 HPAlloys NITRONIC 50 Stainless Steel. Mechanical property values similar to those of the base metal have been obtained in the aswelded condition. The corrosion resistance of GTA welded joints has been evaluated using the standard Huey test (ASTM A 262, Practice C) for detecting intergranular attack in stainless steels. Laboratory test experience shows that welds made using the NITRONIC 50W Stainless Steel filler metal exhibit the same resistance to intergranular attack as the base metal.

Table 37

Typical Mechanical Properties
HPAlloys NITRONIC 50 Stainless Plate Weld Joints

Weld Process	Weld Filler	UTS ksi (MPa)	0.2% VS ksi (MPa)	Elong, % in2"	Red. in Area. %	Failure Location
Shielded Metal Arc (SMA)	NITAONIC 50W	113 (779)	76 (524)	20	36	Weld Metal
Gas Metal Arc (GMA) Spray	NITRONIC 50W	112 (772)	77 (531)	21	30	Weld Metal

Heavy Section Weld Joint Properties

The mechanical properties of welds in 1-1/4" (32.1 mm) 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 wit!I 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 beads and adequate shielding are normal factors in good stainless steel welding practice.

Resistance Welding

Although no direct resistance welding experience has been obtained with HPAlloys NITRONIC SO Stainless Steel, the similarity of the alloy to HPAlloys NITRONIC 40 Stainless Steel suggests a good response to resistance spot welding and cross-wire welding techniques. The welding schedules outlined in the fabricating bulletin, "Welding HPAlloys Stainless Steels: ' can be used as a guide to produce sound, high-strength joints in both annealed and cold-reduced sheet. Average shear strength data for spot welded joints in HPAlloys NITRONIC 40 Stainless Steel appear in the Product Data Bulletin, "HPAlloysNITRONIC 40 Stainless Steel Sheet and Strip." HPAloys NITRONIC SO Stainless Steel is expected to perform in a similar manner. For more specific suggestions and for NITRONIC SOW filler metal sources, contact Baltimore Specialty Steels Corporation.

Machinability

HPAlloysN ITRONIC 50 Stainless Steel has machining Characteristics similar to other austenitic stainless steels. It is suggested that coated carbides be considered when machining all NITRONIC alloys, since higher cutting rates may be realized. 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 21% of the cutting rate for B1112. This means NITRONIC 50 Stainless Steel can be machined at approximately 1/2 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 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. The alloy provides a good surface finish.

Table 38

Machinability*

AISI B 1112	Type 304	Armco NITRONIC 50
100%		

'1"0 (25.4 mm)-annealed-R_B 95
Five-hour form tool life using high-speed tools
Data based on duplicate tests

Table 39

Recommended Machining Rates for NITRONIC 50

Machining Operation	Cutting Rates. SFM
Automatic Screw Machine	40-65
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
Automatic Screw Machine (Swiss Type) Cast Alloy or Carbide Tools	
Single Point Turning	
Carbide Tools	
Roughing	90-140
Finishing	120-190
High Cobalt or Cast Alloy Tools	
Roughing	50-65
Finishing	50-75
High-Speed Steel Tools	
Roughing	30-45
Finishing	50-60
Milling (When using end mills, use two-fluted type and shorten it 25%)	
Reaming Smooth Finish	15-40
Work Sizing	40-60
High-speed steel reamers Greatly increased rates obtainable with carbide tooling	
Threading and Tapping	10-25
Drilling	
High-speed Drills	30-50

Castings

HPAlloys NITRONIC 50 Stainless Steel may be readily cost by all conventional techniques. Castings should be annealed at 2050F (1121 C) for 1 /2-hour and water quenched in order to attain a high level of corrosion resistance, Cast NITRONIC 50 Stainless Steel is listed as Grade CG6MMN in ASTM A 351/351M and A 743.

Table 40

Typical Room Temperature and Short.Time Elevated Temperature Properties of Cast NITRONIC 50 Stainless Steel (CG6MMN) Annealed*

Text Temperature F (C)	UTS ksi (MPa)	0.2% VS ksi (MPa)	Elongation % in 2" (50.8 mm)	Reduction %
75 (24)	93 (641)	50 (345)	48	46
200 (93)	84 (579)	39 (269)	47	57
400 (204)	74 (510)	30 (207)	50	54
600 (316)	67 (462)	27 (186)	49	48
800 (427)	65 (448)	27 (186)	47	55
1000 (538)	60 (414)	25 (172)	46	51
1200 (649)	54 (372)	24 (166)	43	55

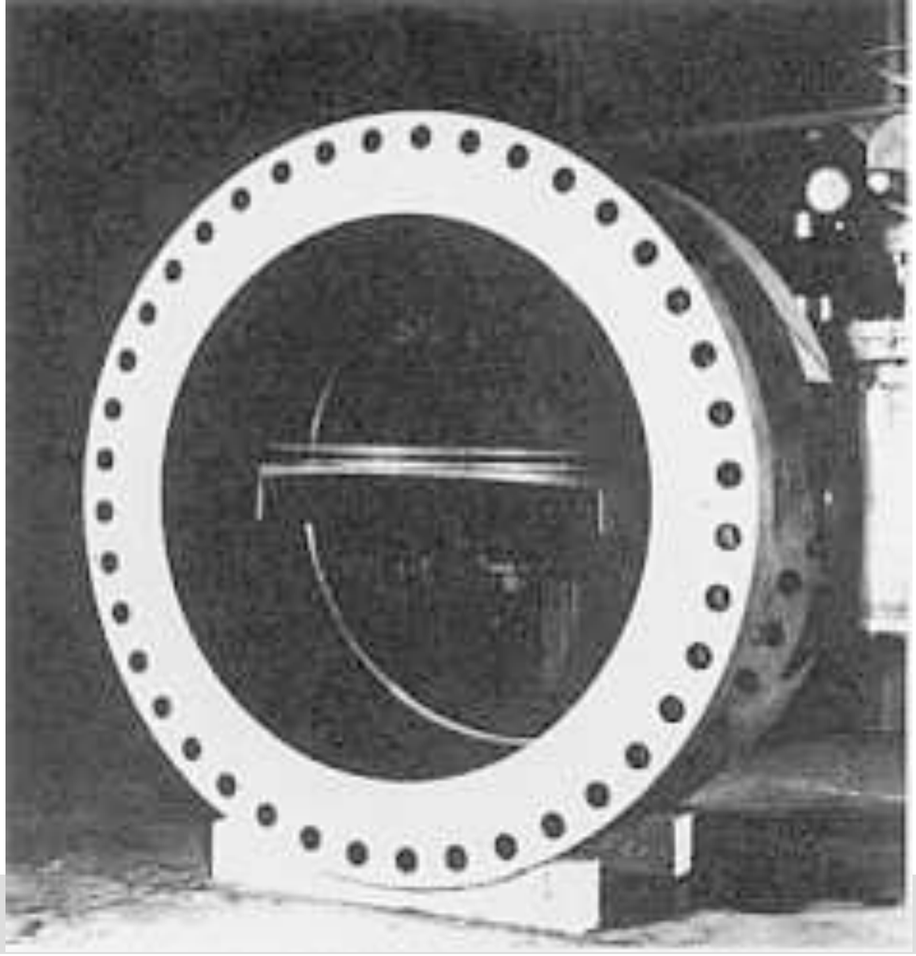
Average of three heats. two tests per heat.

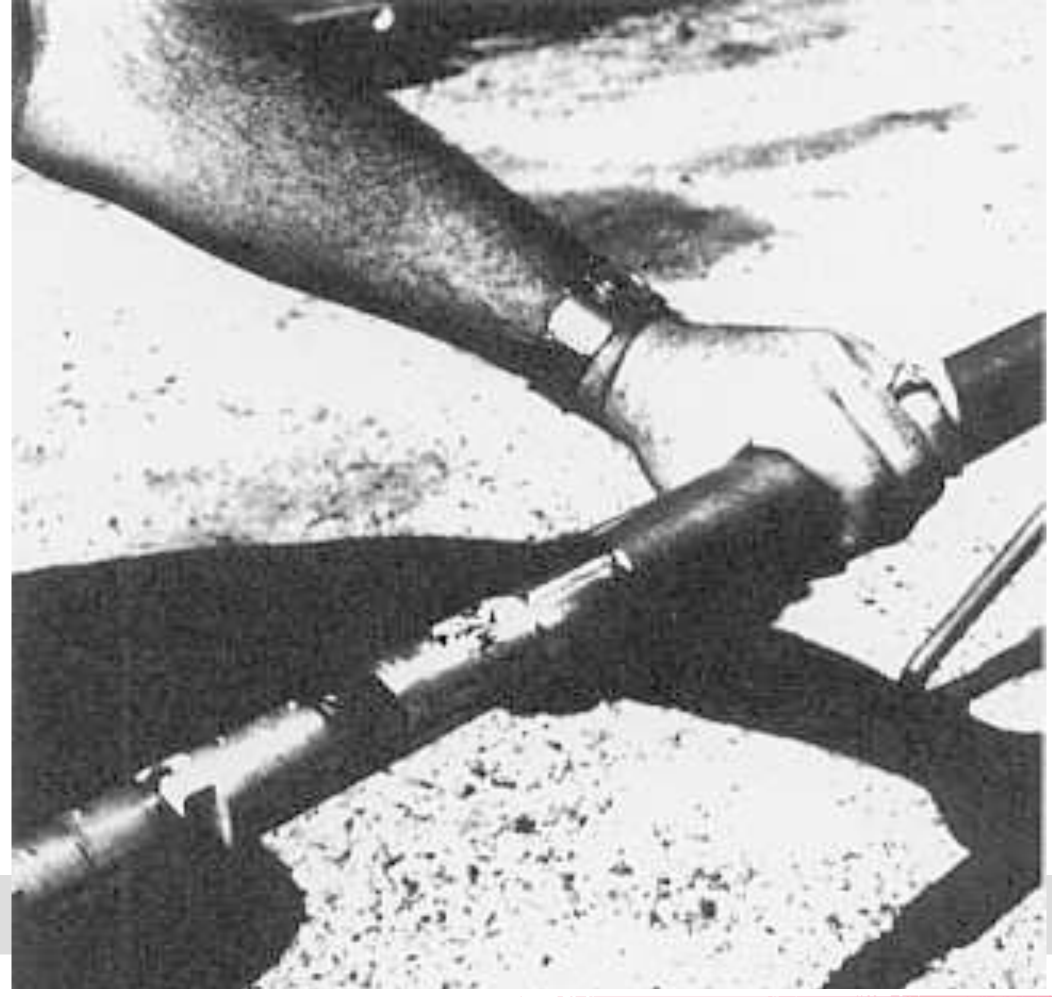
Surface

A manufacturer of valves for gas wells tested NITRONIC 50 Stainless Steel against the material previously used. HPAlloys NITRONIC 50 Stainless Steel Shafts delivered the needed extra corrosion resistance without sacrificing strength. Seal rings for some high-performance industrial butterfly valves operating at 350 psi must have high hardness plus superior corrosion resistance to meet the demands of a variety of chemical media. One valve manufacturer found NITRONIC 50 Stainless Steel met the needs better than Type 316 stainless, and adopted the material as the standard for this precision part. Mounted in the bodies of the company's 30-, 36-, and 48 inch valves, the NITRONIC 50 Stainless Steel rings give the body seat a positive seal with excellent finish and high resistance to cavitation and crevice corrosion. The material also provides high resistance to mechanical damage.

Oilfield Equipment

NITRONIC 50 shows better resistance than T ypes 316 and 316L to pitting and crevice corrosion by sour oil and gas fluids, plus much higher strength. It is included in NACE MR-OI-75 in both the annealed and high-strength bar conditions.





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