Technical Data Sheet

ATI HX™

Nickel-base Superalloy

(UNS N06002)

INTRODUCTION

ATI HX™ alloy (UNS N06002) is an austenitic nickel-base super alloy containing approximately 22 percent chromium for outstanding resistance to oxidation at high temperatures. In addition, the alloy, which is solid solution strengthened, possesses exceptional strength at elevated temperatures. The ATI HX™ alloy has good high temperature and stress rupture properties above 1450°F (788°C) and can be used for applications up to 2200°F (1204°C).

With the high levels of chromium, nickel and molybdenum in the material, ATI HX™ alloy exhibits levels of corrosion resistance similar to high nickel alloys more customarily used in corrosion applications.

The ATI HX™ alloy exhibits good fabricability. The work hardening rate of the alloy is comparable to that of the austenitic stainless steels. Machinability is good in the annealed condition. The alloy can be welded by most of the fusion and resistance welding processes.

ATI HX™ alloy can be produced by AOD refining or vacuum induction melting. Vacuum arc or electroslag remelting procedures may be used to further refine the material.

PRODUCT FORMS

ATI HX™ alloy is available as sheet, strip and plate products from ATI Allegheny Ludlum. The alloy is supplied in the solution treated (annealed) condition.

SPECIFICATIONS

The following specifications are applicable to ATI HX™ nickel superalloy.

Form	AMS	ASTM	ASME
Sheet, Strip and Plate	5536	B435	SB-435
Castings	5390	A567	
Seamless Tube	5587	B622	SB-622
Welded Tube	5588	B626	SB-626
Bar, Forgings and Rings	5754		
Weld Wire	5798		SFA-5.14
Covered Electrodes	5799		SFA-5.11
Fittings		B366	SB-366
Rod		B572	SB-572
Welded Pipe		B619	SB-619
Finned Tubes		B924	

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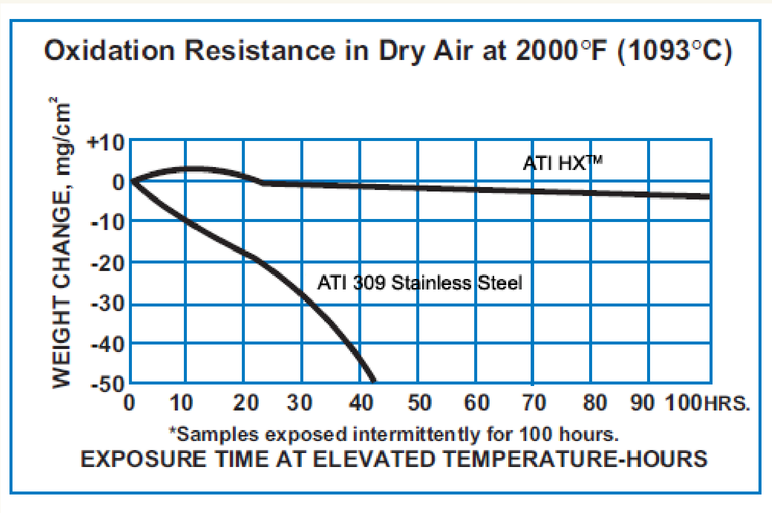
OXIDATION RESISTANCE

ATI HX™ alloy has good resistance to oxidizing, reducing and neutral atmospheres encountered in furnace and jet engine operations up to 2200°F (1204°C). The alloy develops a protective, tenacious oxide film which does not spall off and, therefore, retains oxidation resistance at high temperatures. The figure below compares the weight change of ATI HX™ alloy to that of ATI 309™ stainless resulting from exposure to dry air at 2000°F (1093°C) for 100 hours.



CORROSION RESISTANCE

Carburization and Nitriding Resistance

ATI HX™ alloy resists carburizaton and nitriding, two conditions which may cause failure in high temperature alloys. Tests conducted in carburizing and nitriding atmospheres at elevated temperatures show that ATI HX™ alloy is superior to several other competitive alloys. Table 1 compares the carburization resistance of several alloys after 100 hours exposure in petroleum coke at 1900°F (1038°C). Table 2 compares the nitriding resistance of several alloys after 64 days exposure in an atmosphere of hydrogen, nitrogen, and ammonia at 1100°F (593°C) and 15,000 psi (103MPa).

Table 1--Carburization Resistance at 1900°F (1038°C)

	Maximum Depth of Carburization, Inches (mm)	
Carburizing Material	ATI HX™ Superalloy	ATI 309™ Stainless Steel
50 hrs. in commercial carburizing compound	0.020 (0.51)	0.030 (0.76)
25 hrs. in petroleum coke	0 0	0.025 (0.63)
50 hrs. in petroleum coke	0	0.045 (1.14)
100 hrs. in petroleum coke	0	C.P.

C.P. - Specimen cross-section completely penetrated.

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Table 2--Nitriding Resistance at 1100°F (593°C) and 15,000 psi (103 MPa)[a]

Alloy	Apparent Nitride, Layer, Thickness Inches (mm)	Intergranular Attack	Bend Dectility
ATI HX™	0.0004 (0.01)	No	Not broken at 180°
ATI 310™ stainless steel	0.0033 (0.08)	No	Broke at 120°
ATI 316™ stainless steel	0.0058 (0.15)	No	Broke at 53°
ATI 304™ stainless steel	0.013 (0.33)	No	Broke at 53°
ATI 321™ stainless steel	0.0035 (0.09)	Yes	Broke at 31°
ATI 347™ stainless steel	0.0084 (0.21)	No	Broke at 73°

(a) Exposed 64 days in N_2+H_2+NH_3 mixture.

PHYSICAL PROPERTIES

Typical Values

Density: 0.297 lb/in^3 8.22 g/cm^3

Specific Gravity: 8.22

Melting Range: 2300-2470°F 1260-1355°C

Magnetic Permeability: < 1.002

Specific Heat			
Temperature		Btu/lb-°F	Joules/kg•K
°F	°C		
70	21	0.116	485
600	316	0.119	498
1200	649	0.139	582
1600	871	0.167	700
2000	1093	0.205	860

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Linear Coefficient of Thermal Expansion Tests Conducted on Solution Treated Material			
Temperature Range		Mean Coefficient of Thermal Expansion (units of 10^{-6})	
°F	°C	/°F	/°C
79- 200	25-93	7.70	13.9
79-1000	26-538	8.39	15.1
79-1200	26-649	8.56	15.4
79-1350	26-732	8.76	15.8
79-1500	26-816	8.92	16.1
79-1650	26-899	9.07	16.3
79-1800	26-982	9.20	16.6

Thermal Conductivity			
Temperature		Thermal Conductivity	
°F	°C	Btu-ft/h-ft^2-°F	W/m•K
70	21	5.23	9.1
200	93	6.33	11.0
500	260	8.17	14.1
1100	593	12.0	20.8
1300	704	13.2	22.9
1500	816	14.5	25.0
1700	927	15.7	27.2

Electrical Resistivity		
Temperature		Electrical Resistivity microhm-cm
°F	°C	
70	21	115.8
392	200	120
752	400	123
1112	500	127
1472	800	128
1832	1000	129

Elastic Modulus	
Test Temperature °F °C	Dynamic Modulus of Elasticity 10^6 psi (GPa)
76 (24)	28.49 (196)
212 (100)	28.06 (193)
392 (200)	26.90 (185)
572 (300)	25.95 (179)
752 (400)	24.96 (172)
932 (500)	23.79 (164)
1112 (600)	22.88 (158)
1292 (700)	21.76 (150)
1472 (800)	20.67 (143)
1652 (900)	19.48 (134)
1832 (1000)	18.33 (126)

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MECHANICAL PROPERTIES

Typical Short Time Tensile Properties

Typical short time cryogenic and elevated temperature tensile properties for sheet and plate materials solution treated at 2150 to 2175°F (1177 to 1190°C) and rapidly cooled are shown below:

Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Elongation
°F	°C	psi	MPa	psi	MPa	Percent
-321	-196	-	-	150,200	1035	46
-108	-78	-	-	118,800	819	51
72	22	47,000	324	104,500	720	46
400	204	48,700	336	103,400	713	41
600	316	42,600	294	100,200	691	40
800	427	43,700	301	99,700	687	44
1000	538	41,500	286	94,000	648	45
1200	649	39,500	272	83,000	472	37
1400	760	37,800	261	63,100	435	37
1600	871	25,700	177	36,500	252	51
1800	982	16,000	110	22,500	155	45
2000	1093	8,000	55	13,000	90	40
2200	1204	3,700	26	5,400	37	31

Impact Resistance

The typical impact resistance of ATI HX™ alloy is shown below. The alloy may be embrittled by long times in the 1200 to 1600°F (650 to 870°C) range. This embrittlement accompanies a slight precipitation hardening response.

Impact Properties of ATI HX™ Alloy as Solution Treated			
Test Temperature		Charpy V-Notch Impact Energy	
°F	°C	Foot-lbs	Joules
-321	-196	37	50
-216	-138	44	60
-108	-78	51	69
-20	-29	56	75
70	21	54	73
1500	816	58	79

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Impact Properties of ATI HX™ Nickel Alloy Solution Treated and Subsequently Reheated				
Condition Solution Treated Plus	Test Temperature		Charpy V-Notch Impact Energy	
	°F	°C	Foot-lbs	Joules
1500°F (816°C) 168 Hours	70	21	9	12
1500°F (816°C) 168 Hours	1500	816	29	39
1600°F (871°C) 500 Hours	70	21	9	12
1800°F (982°C) 500 Hours	70	21	20	27
1900°F (1038°C) 50 Hours	70	21	36	49

Creep and Stress Rupture

Typical minimum creep rate data for solution treated material are shown below:

Test Temp		Stress psi (MPa) for minimum creep rate of	
°F	°C	0.0001% per hour	0.00001% per hour
1200	649	16,500 (114)	12,000 (83)
1350	732	11,500 (79)	8,500 (59)
1500	816	6,800 (47)	5,000 (34)
1650	899	3,000 (21)	2,000 (14)

Typical stress rupture data are shown below in Figure form.

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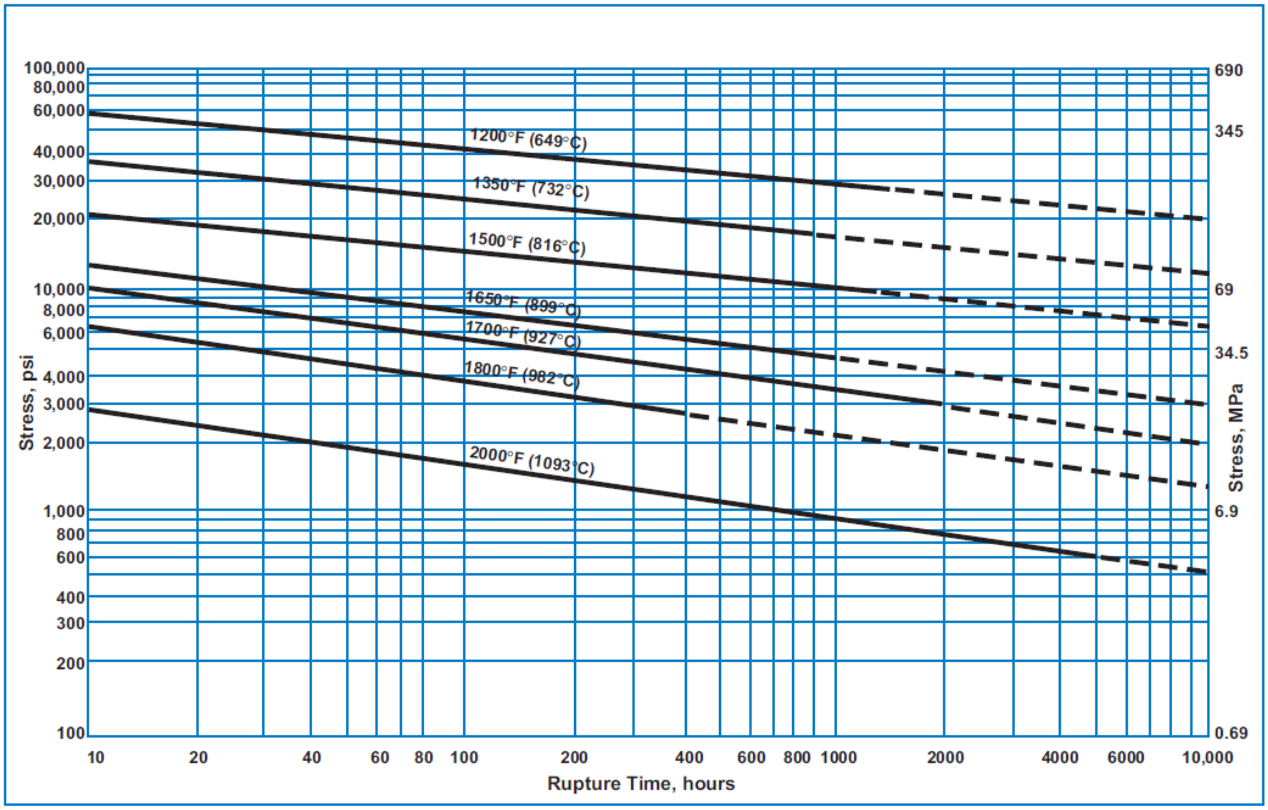

WELDABILITY

ATI HX™ alloy can be welded by most of the conventional processes used for austenitic stainless steels including metallic-arc, gas tungsten-arc (TIG) gas metal-arc (MIG) and resistance methods. The material should be in the solution heat treated condition for welding. Preheating or post-weld treatment is not usually necessary.

The welding surfaces and adjacent areas must be thoroughly descaled and cleaned before welding. The workpiece should be in a relatively flat position due to the fluidity of the alloy. ATI HX™ alloy has a lower thermal conductivity than stainless steel and requires a larger clearance when using a standard groove to insure complete penetration of the weld.

Spot welding requires relatively long welding times and water cooling to develop a full nugget and to avoid coring or segregation. Seam welding requires an intermittent drive operation to facilitate the use of maximum forging pressure to eliminate cracking and minimize distortion. Fusion welds possess high ductility and the recommended procedure is to use TIG welding for sheet up to 1/8 inch (3.2MM) and MIG welding for sheet greater than 1/8 inch (3.2MM).
ATI HX™ alloy can also be brazed using proper procedures and brazing alloys. Large or complex fusion welds are often given a stress relief heat treatment.

HEAT TREATMENT

Solution heat treatment of ATI HX™ alloy is generally conducted between 2100 and 2150°F (1149 and 1177°C) followed by rapid air cool or water quench. The optimum properties of the alloy are developed by this solution heat treatment.

Although a weak age hardening reaction is observed between approximately 1200 and 1800°F (649 and 982°C), the alloy is not generally heat treated to produce age hardening prior to service.

Large or complex fusion welds are stress relieved by heat treatment at 1600°F (871°C) for 1 hour.

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