Technical Data Sheet

ATI A286™

Iron-Based Superalloy

(UNS S66286)

INTRODUCTION

ATI A286™ alloy (UNS S66286) is an iron-base superalloy useful for applications requiring high strength and corrosion resistance up to 1300°F (704°C) and for lower stress applications at higher temperatures. This heat and corrosion resistant austenitic alloy can be age hardened to a high strength level. The alloy is also used for low temperature applications requiring a ductile, non-magnetic high strength material at temperatures ranging from above room temperature down to at least -320°F (-196°C). The alloy may be used for moderate corrosion applications in aqueous solutions.

ATI A286™ 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.

This alloy is designated Grade or Type 660 in several specifications.

FORMS AND CONDITIONS AVAILABLE

ATI A286™ alloy is available in plate, sheet, strip and long product forms from ATI Allegheny Ludlum. The alloy is available in commonly specified melt variations.

All product forms are available in the solution annealed condition. This is the condition most suitable for fabrication.

SPECIFICATIONS

The following widely published specifications are applicable to ATI A286™ alloy (S66286). In addition, there are restricted analyses for special purpose applications, such as listed in AMS 5858.

AMS 5525	Sheet, strip and plate
AMS 5858	Sheet, strip and plate
AMS 5731	Bar, forgings, tubing and rings
AMS 5732	Bar, forgings, tubing and rings
AMS 5734	Bar, forgings, tubing and rings
AMS 5737	Bar, forgings and tubing
ASTM A453	Bolting
ASTM A638	Forgings, forging stock and bar
ASME SA-638	Forgings, forging stock and bar

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COMPOSITION (TYPICAL)

Element	Weight Percent
Carbon	0.04
Manganese	0.20
Phosphorus	0.015
Sulfur	0.002
Silicon	0.20
Chromium	14.5
Nickel	25.0
Molybdenum	1.25
Titanium	2.10
Vanadium	0.30
Aluminum	0.15
Boron	0.006
Iron	Balance

CORROSION AND OXIDATION RESISTANCE

ATI A286™ alloy content is similar in chromium, nickel, and molybdenum to some of the austenitic stainless steels. Consequently, ATI A286™ alloy possesses a level of aqueous corrosion resistance comparable to that of the austenitic stainless steels. In elevated temperature service, the level of corrosion resistance to atmospheres such as those encountered in jet engine applications is excellent to at least 1300°F (704°C). Oxidation resistance is high for continuous service up to 1500°F (816°C) and intermittent service up to 1800°F (982°C).

Typical corrosion data follow.

Test Environment	Typical Performance		
	Type 304	Type 316	Altemp® A286
5% Neutral Salt Spray	No Rusting 100 Hours	No Rusting 100 Hours	No Rusting 100 Hours
U-Bend Test in 42% Magnesium Chloride	Cracks 8 Hours	Cracks 24 Hours	Cracks 168 Hours
Crevice Corrosion Test in 10% Ferric Chloride (pH 1.5) at 70 F (21 C)	Attacked	Attacked	Attacked

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Test Environment Boiling Solution	Typical Corrosion Rate in mils Per Year (mm/a)		
	ATI 304™	ATI 316™	Altemp® A286*
20% Acetic Acid	<0.1 (<0.01)	<0.1 (<0.01)	<0.1 (<0.01)
45% Formic Acid	48.2 (1.22)	10.9 (0.28)	8.3 (0.21)
10% Oxalic Acid	48.5 (1.23)	40.1 (1.02)	14.4 (0.37)
1% Hydrochloric Acid	107 (2.72)	226 (5.74)	84.1 (2.14)
10% Sulfuric Acid	>500 (>12)	636 (5.74)	29.5 (0.75)
20% Phosphoric Acid	0.2 (<0.01)	0.2 (<0.01)	12.8 (0.33)
10% Sodium Bisulfate	63.6 (1.62)	41.6 (1.06)	7.2 (0.18)

*Tested in the solution treated condition.

PHYSICAL PROPERTIES

Typical Values		
Density		
Solution Treated	0.286 lb./in^3	7.92 g/cm^3
Solution Treated and Aged	0.287 lb./in^3	7.94 g/cm^3
Specific Gravity		
Specific Treated	7.92	
Solution Treated and Aged	7.94	
Melting Range	2500-2600°F	1370-1430°C
Magnetic Permeability		
Solution Treated	1.010	
Solution Treated and Aged	1.007	
Specific Heat	0.10 Btu/lb-°F	420 Joules/kg-°K

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Linear Coefficient of Thermal Expansion Tests Conducted on Solution Treated and Aged Material			
Temperature Range		Linear Coefficient of Thermal Expansion (units of 10^{-6})	
°F	°C	/°F	/°C
70-200	21-93	9.17	16.5
70-400	21-204	9.35	16.8
70-600	21-316	9.47	17.0
70-800	21-427	9.64	17.4
70-1000	21-538	9.78	17.6
70-1200	21-649	9.88	17.8
70-1400	21-760	10.32	18.6

Thermal Conductivity

Temperature		Thermal Conductivity	
°F	°C	Btu-ft/ft²-h-°F	W/m•K
302	150	8.7	15.1
572	300	10.3	17.8
932	500	12.6	21.8
1112	600	13.8	23.9

Electrical Resistivity

Temperature		Electrical Resistivity microhm-cm
°F	°C	
77	25	91.0
1004	540	115.6
1202	650	118.8
1346	730	120.1
1499	815	122.4

Elastic Modulus, Modulus of Rigidity and Poisson's Ratio

Temperature		Modulus of Elasticity* (Modulus of Ridigity)		Poisson's Ratio
°F	°C	10^6 psi	GPa	(μ)
-320	-196	29.6 (11.6)	204 (80)	0.280
-100	-73	29.4 (11.4)	203 (79)	0.290
75	24	29.1 (11.2)	201 (77)	0.300
1000	538	23.5 (8.8)	162 (61)	0.330
1100	593	22.9 (8.6)	158 (59)	0.335
1200	649	22.2 (8.3)	153 (57)	0.340
1300	704	21.6 (8.0)	149 (55)	0.345
1400	760	20.6 (7.6)	142 (53)	0.350
1500	816	19.8 (7.3)	137 (50)	0.355
1600	871	18.9 (7.0)	130 (48)	0.360

*Dynamic

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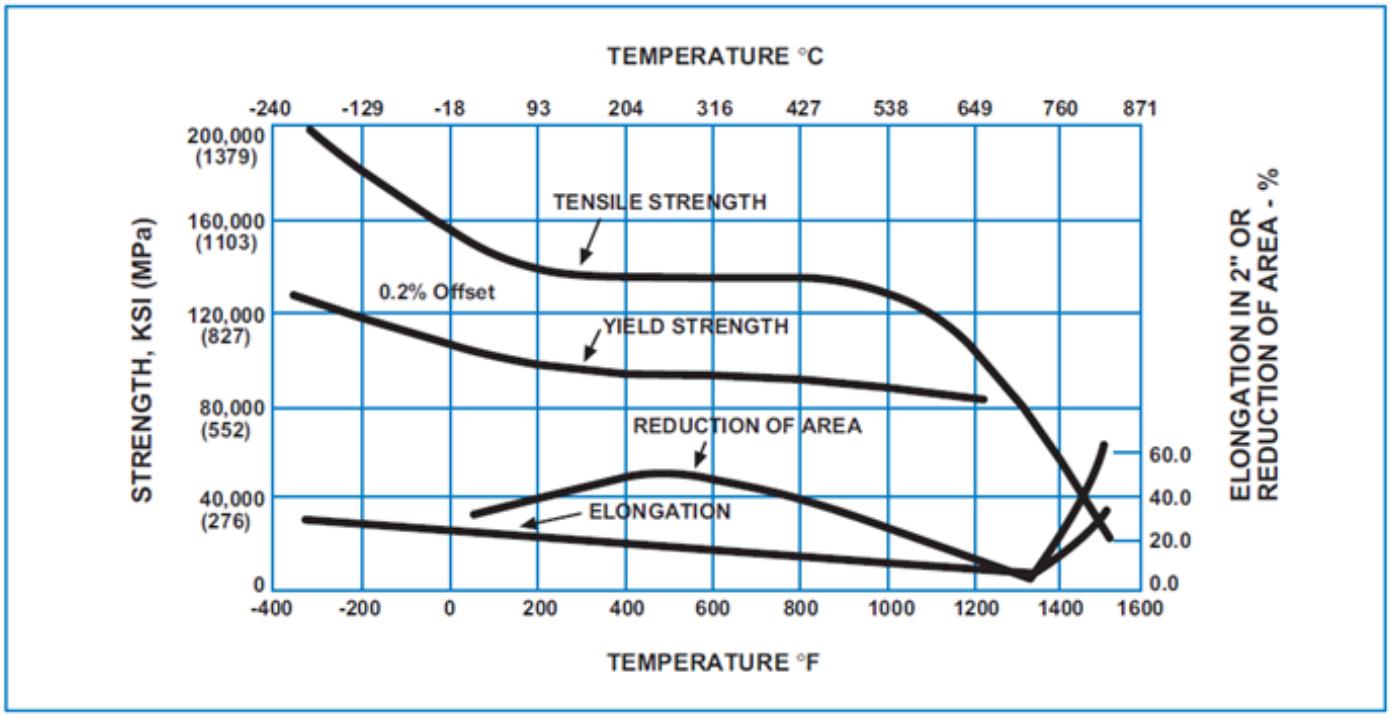
MECHANICAL PROPERTIES

Typical Short Time Tensile Properties as a Function of Temperature

ATI A286™ alloy is formed most easily in the solution annealed condition. Typical room temperature tensile properties of material solution treated at 1800°F (982°C) are shown below.

Yield Strength	Ultimate Tensile Strength	Elongation
40,000 psi	90,000 psi	40%
(275 MPa)	(620 MPa)	

The strength of ATI A286™ alloy is substantially increased by aging the solution treated material at approximately 1325°F (718°C). The short time tensile properties of ATI A286™ alloy in the age hardened condition are high from cryogenic temperatures to approximately the 1325°F (718°C) aging temperature. In the following chart, material tested was solution treated at 1800°F (982°C) and aged at 1325°F (718°C) for 16 hours.



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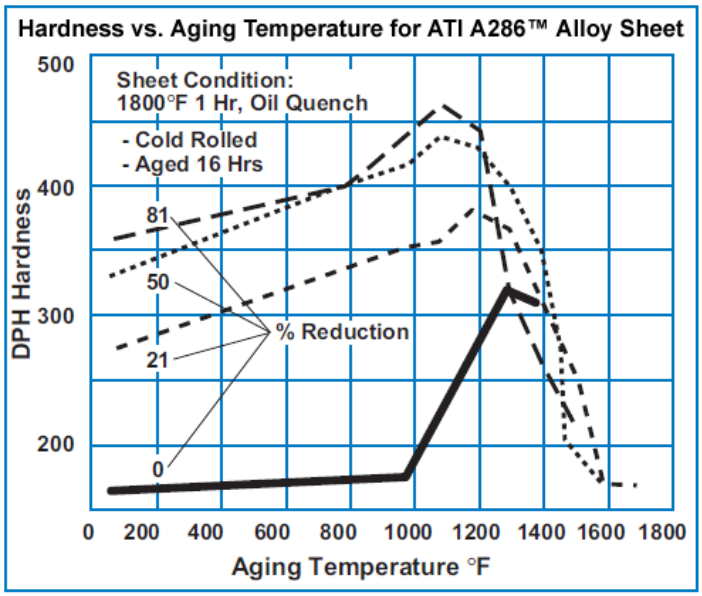
The aging reaction in ATI A286™ alloy may be conducted on either solution treated or solution treated and subsequently cold worked material. In the latter case, the aging reaction results in a further increase in strength and hardness in comparison to solution treatment and direct age. This tendency is balanced by the tendency of higher aging temperatures to relieve some of the effects of the cold working operations.

Impact properties determined on full size Charpy V-Notch impact specimens over the -320 to 1450°F (-196 to 788°C) temperature range show high impact energy retained in ATI A286™ alloy in the aged condition. Samples tested were solution treated at 1800°F (982°C) and aged at 1325°F (718°C) for 16 hours.



Testing Temperature		Charpy V-Notch Impact Energy	
°F	°C	Ft-lbs	Joules
-320	-196	57	77
-100	-73	68	92
80	27	64	87
410	210	60	81
810	432	52	70
1010	543	46	62
1113	600	44	60
1250	677	41	56
1450	788	52	71

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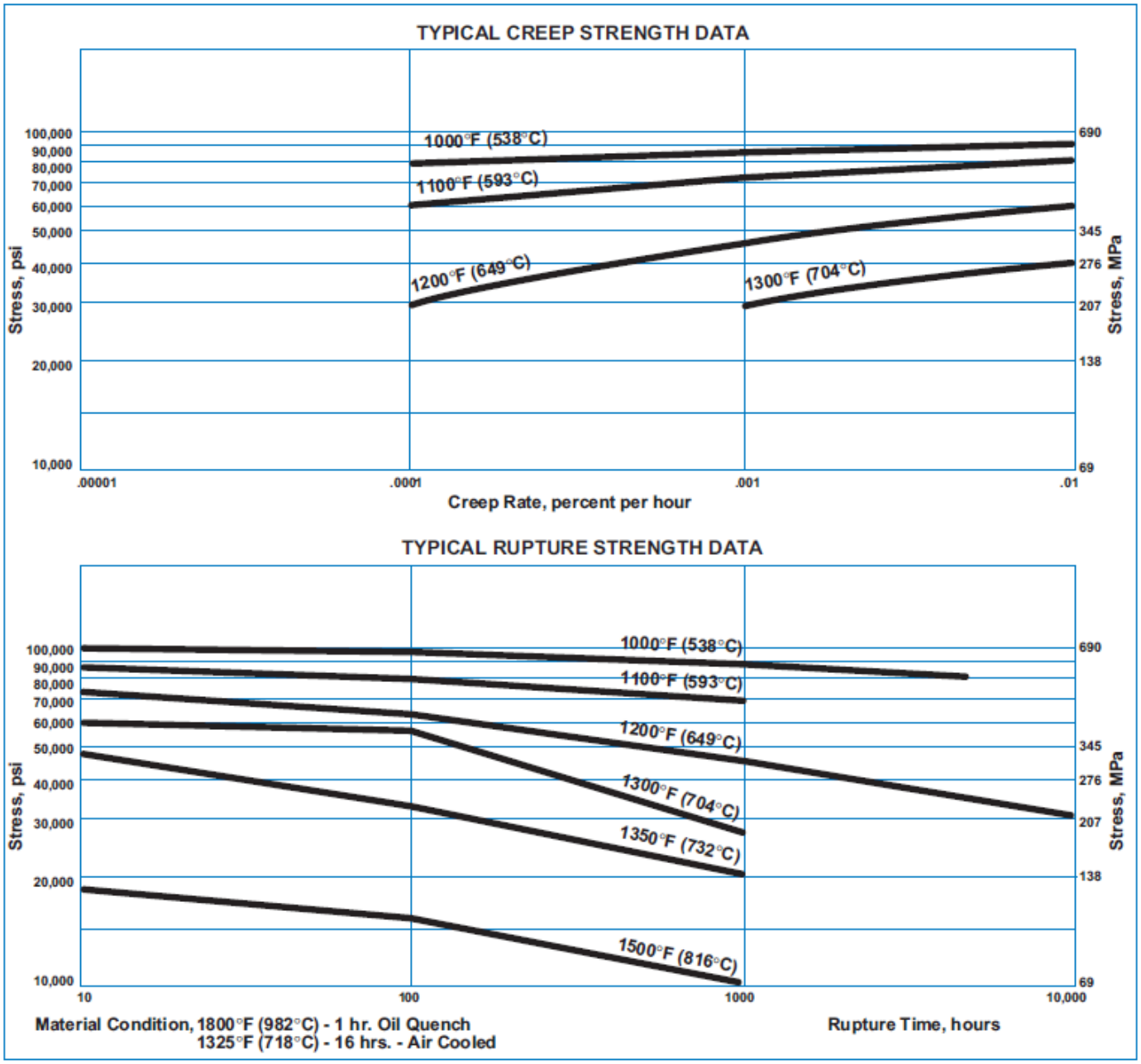
CREEP AND STRESS RUPTURE PROPERTIES

ATI A286™ alloy is designed for elevated temperature strength. At elevated temperatures, creep and stress rupture properties, rather than short time tensile properties, are the limiting design criteria for elevated temperature service. Typical creep and stress rupture strengths of material aged at 1325°F (718°C) are shown below.



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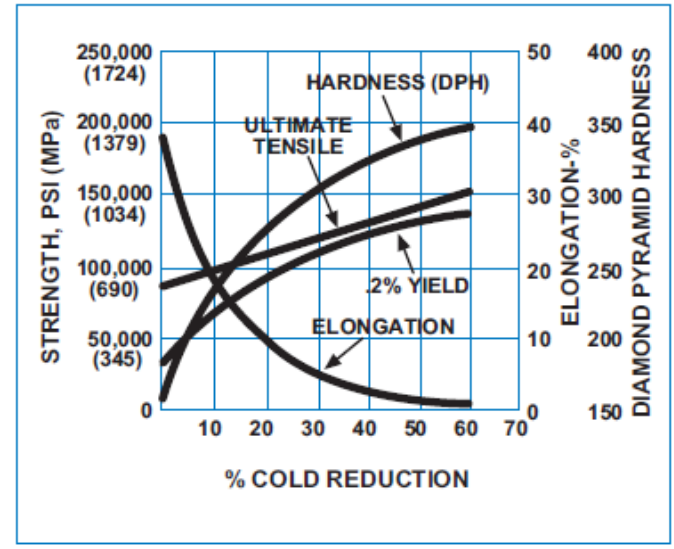
FORMABILITY

ATI A286™ alloy is most easily formed in the solution treated condition. ATI A286™ alloy is capable of being formed like the standard austenitic stainless steels. The material is somewhat stronger than conventional austenitic stainless steels and consequently requires higher loads to cause the material to deform. During cold working, solution treated ATI A286™ alloy sheet has a work hardening rate about the same as that of Type 310 stainless steel. The work hardening of solution treated ATI A286™ sheet is summarized below.



Intermediate anneals at 1800°F (982°C) can be employed to soften the material if the cold deformation is extensive.

WELDING AND BRAZING

Welding of the ATI A286™ alloy is conducted preferably in the solution treated condition. This alloy is susceptible to hot cracking, particularly in the aged condition. Similarly, heavy sections are more difficult to weld because of the tendency to hot cracking. A restricted analysis of ATI A286™ alloy, which is specifically designed for welding, is listed in AMS 5858. Cracking sensitivity can be minimized by keeping welding conditions closely controlled, avoiding restraints, keeping the weld zone to a minimum and by the use of the analysis designed specifically for welding.

Fusion welding is performed by the gas tungsten arc (GTAW), gas metal arc (GMAW), and shielded metal arc (SMAW) methods. Austenitic welding wire and coated electrodes of various compositions, preferably nickel base, can be used. ATI A286™ wire and electrodes are available for the high weld strength which can be developed by aging after welding. The inert gas methods must be used to prevent loss of titanium which is important in the development of high strength on aging.

Resistance seam and spot welds can be made using high current and high electrode pressures. ATI A286™ alloy may be joined to other austenitic, ferritic or martensitic alloys. Usually, the inert gas welding methods are used.

ATI A286™ alloy can be brazed successfully in a pure, dry hydrogen atmosphere, or in a vacuum. Nickel plating before brazing is helpful in promoting wetting. The ductility of the alloy at the room temperature and at 1200°F (649°C) is impaired by the 1200°F (1149°C) brazing cycle. Improvements in ductility of the alloy are accomplished by solution heat treating at 1650°F (899°C) or 1800°F (982°C) after the brazing cycle. After the solution heat treatment, ductility appears to be only slightly less than that of unbrazed material.

HEAT TREATMENT

ATI A286™ alloy is an age hardening heat resisting alloy which attains optimum strength properties by solution heat treatment followed by aging heat treatment. ATI A286™ alloy may be solution treated at either 1650°F (899°C) or 1800°F (982°C)

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depending upon properties desired. The 1650°F (899°C) solution treatment results in a finer grain size and superior room and elevated temperature short time tensile properties. The 1800°F (982°C) solution treatment develops a slightly coarser grain size with superior creep and stress rupture properties.

Large sections, such as plate, are generally oil quenched from the solution heat treatment. Thin sections, such as sheet or strip, may be air cooled from the solution heat treatment.

An aging treatment of 1325°F (718°C) for 16 hours followed by air cooling is conducted after either solution heat treatment. The aging treatment develops the high strength of ATI A286™ alloy. For an even higher aged strength, solution treated material may be cold worked prior to the aging treatment. As the figure on page 6 shows, cold working should be followed by an aging cycle at a temperature lower than 1325°F (718°C) if maximum strength is to be produced.

DESCALING AND PICKLING

During heat treatment, ATI A286™ alloy forms a tight oxide film which is most effectively loosened by treatment in reducing, oxidizing or electrolytic fused salt baths. This treatment should be followed immediately by pickling in warm separate solutions of sulfuric and nitric-hydrofluoric acids.

MACHINING

The same techniques and equipment are used for machining ATI A286™ iron-base superalloy as for the 18-8 stainless steels. Since it is gummy in the soft, solution-treated condition, ATI A286™ steel is generally machined after it has been partially or fully aged, or overaged. Material cold worked after solution treating also exhibits good machining characteristics.

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