ATI

Technical Data Sheet

ATI 20-25+Nb™

Stainless Steel: Austenitic

(UNS S35140)

GENERAL PROPERTIES

ATI 20-25+Nb™ alloy is an austenitic stainless steel intended primarily for elevated temperature service. This alloy fills a performance gap between conventional heat-resistant stainless steels and nickel-base superalloys, providing high performance with an economical composition. The chromium, nickel, and manganese levels result in superior resistance to high temperature oxidation in air and steam-bearing atmospheres. Additions of nitrogen and molybdenum provide solid-solution-strengthening, resulting in superior room and elevated temperature strength. Control of niobium (columbium) and carbon additions, along with advanced thermo-mechanical processing (TMP) results in the formation of a very fine dispersion of carbides and carbonitride particles with particle size ranging down to the nanoscale. This results in excellent resistance to elevated temperature creep and stress-rupture, while exhibiting austenite phase stability superior to many heat and corrosion-resistant alloys, which allows for retention of mechanical properties after elevated temperature exposures.

ATI 20-25+Nb™ alloy is available in Precision Rolled Strip®, standard strip, sheet and plate product forms in a wide range of sizes and finishes. The properties of this alloy make it a suitable candidate for a variety of applications, including heat exchangers and recuperators, high temperature structural components, vessels, retorts, calciners, piping, tubing and heat-treatment fixtures.

SPECIFICATION COVERAGE

ATI 20-25+Nb™ alloy is included in ASTM A240 for plate, sheet and strip properties.

CHEMICAL COMPOSITION

Element	ASTM A240 Limits (Wt. %)
C	0.10 max
Mn	1.00–3.00
Si	0.75 max
Cr	20.0–22.0
Ni	25.0–27.0
Mo	1.00–2.00
N	0.08-0.20
P	0.045 max
S	0.030 max
Nb	0.25–0.75
Fe	Balance

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PHYSICAL PROPERTIES

Density 7.96 g/cm^3 (0.29 lb/in^3)

Young's Modulus 30 x 10^6 psi (200 GPa)

Coefficient of Linear Thermal Expansion

Test Temperature Range		Linear Thermal Expansion Coefficient of thermal (α)	
(ºC)	(ºF)	10^{-6}/°C	10^{-6}/°F
100	212	14.4	8.0
200	392	15.6	8.7
300	572	16.1	8.9
400	752	16.4	9.1
500	932	16.6	9.2
600	1112	17.0	9.4
700	1292	17.5	9.7
800	1472	17.9	9.9
900	1652	18.2	10.1
1000	1832	18.6	10.3

MECHANICAL PROPERTIES

Room Temperature Mechanical Properties

The mechanical properties of ATI 20-25+Nb alloy at ambient temperatures reflect the fact that the alloy is solid-solution strengthened with nitrogen and molybdenum. The alloy exhibits a tensile yield strength approximately 30% higher than conventional austenitic stainless steels, while maintaining reasonable work hardening rates and formability properties. Complex shapes have been produced by standard sheet metal forming techniques using this alloy.

Nominal Room Temperature Mechanical Properties

	ksi	MPa
Ultimate tensile strength	95	655
Yield Strength (0.5% offset)	45	310
Elongation (2" gauge length)	35%	

Note 1: Room temperature tensile data was generated using samples machined from cold-rolled and annealed sheet material of 0.100" nominal thickness.

Note 2: The strength and ductility of cold-rolled and annealed foil material has been found to be similar.

High Temperature Mechanical Properties

ATI 20-25+Nb alloy also exhibits excellent mechanical properties at elevated temperatures. A significant fraction of the alloy's initially high strength is retained as the test temperature increases, and the inherent microstructural stability of the composition results in minimal reduction of ductility. The figure below shows the relationship of tensile properties with temperature.

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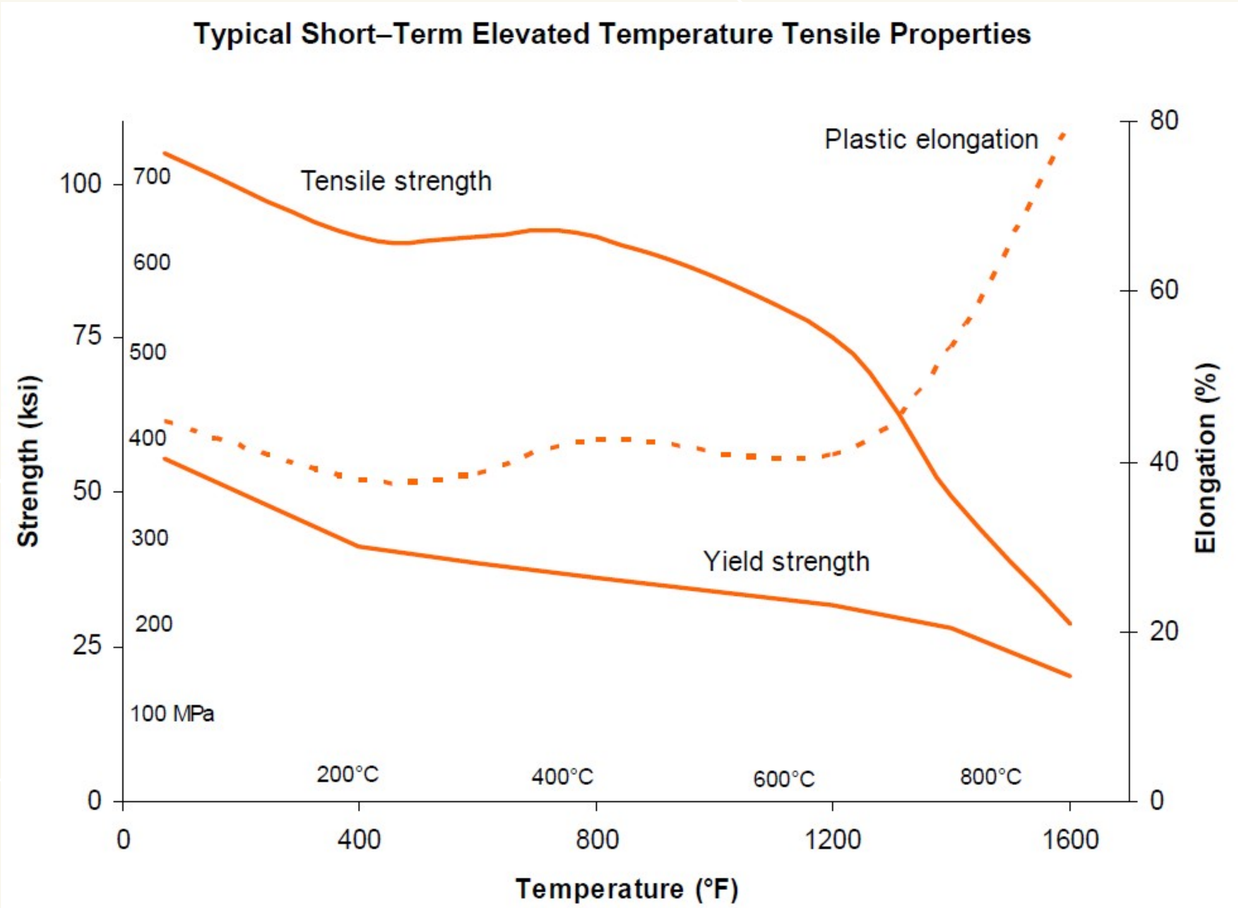

CREEP AND STRESS-RUPTURE RESISTANCE

ATI 20-25+Nb alloy is compositionally balanced and carefully processed to produce excellent resistance to creep at elevated temperatures. Solid-solution strengthening, microstructural stability, and the formation of a fine dispersion of secondary niobium (columbium) carbonitride particles in sizes down to the nano-scale results in creep resistance rivaling some of the nickel-base superalloys, with a nominal 100F° (56C°) improvement in rupture life capability over standard austenitic stainless steels such as UNS S34700 while retaining high levels of ductility at failure (typically greater than 20% irreversible creep strain). In addition, the creep resistance of this alloy has been shown to be relatively insensitive to the thickness of the test material, which is not always the case with many heat-resistant alloys which lose creep strength at light gauge due to the necessity of a fine grain size in thin sections. The carbide strengthening mechanism active in ATI 20-25+Nb alloy provides strengthening which is not dependent on grain size.

A representative creep parameter (Larson-Miller) plot for 0.005" thick strip (0.13 mm) is shown below.

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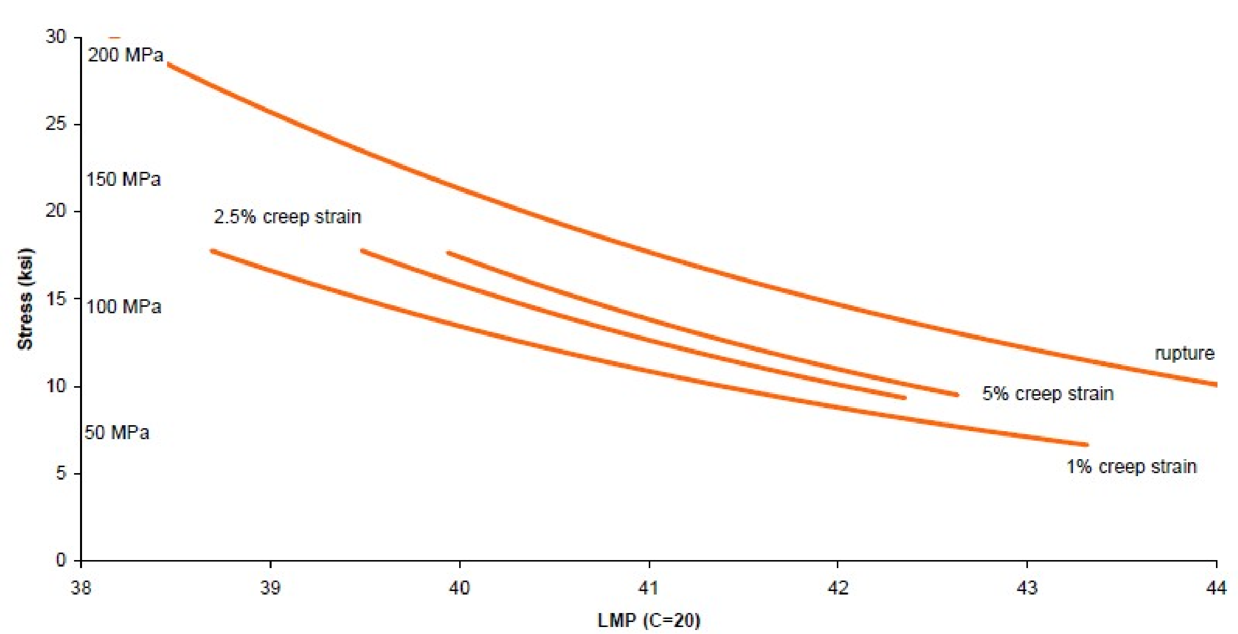
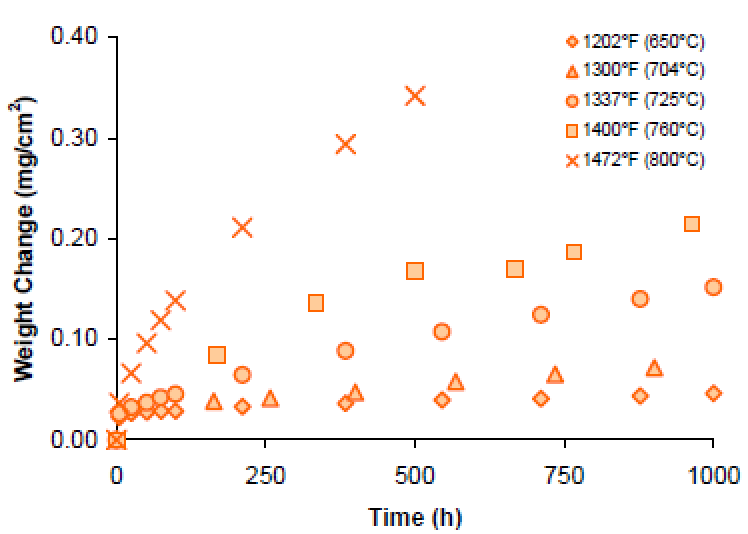
Creep Parameter Plot for Light Gauge Strip



RESISTANCE TO HIGH TEMPERATURE DEGRADATION

Elevated temperature oxidation can lead to surface damage by scaling, loss of section thickness, and general degradation of material properties. The progress of oxidation generally is measured in terms of weight gain (due to oxygen uptake) or as metal recession/section loss (measured using metallographic methods on a post-exposure specimen or component). ATI 20–25+Nb alloy is resistant to oxidation in air, which is a commonly encountered exposure environment. This can be seen in the chart below, which shows moderate weight gains with increasing time at temperature.

Short–Term Oxidation Test Results In Ambient Air



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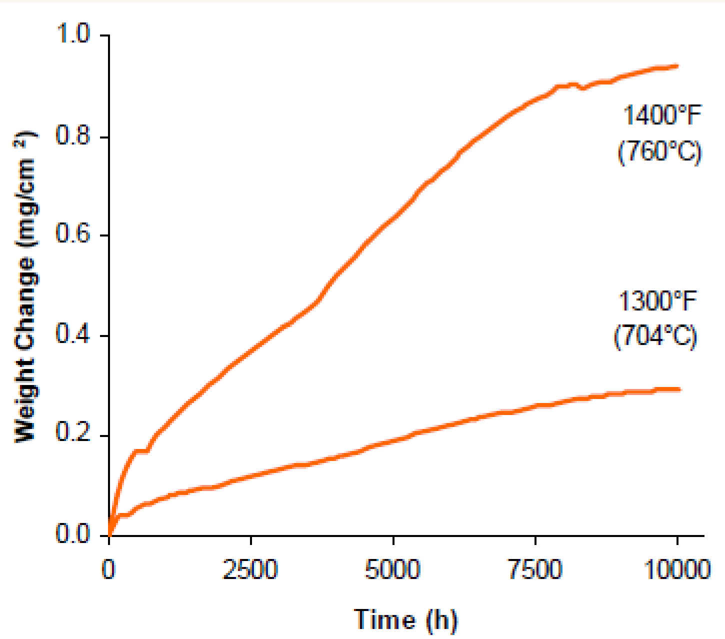
Many applications require the use of thin metal foils at elevated temperatures in air. Thin foils are inherently less resistant to oxidation than sheet-gauge samples, as they can be quickly depleted in critical alloying elements, e.g. chromium. Once this occurs, the rate of oxidation can accelerate rapidly, consuming the foil substrate. The oxidation behavior of thin foil samples during extended duration exposures is therefore regarded as a good measure of the oxidation resistance of an alloy. Testing on 0.004 inch thick (0.1 mm) foils have been carried out past 10,000 hours in air with no tendency towards accelerated oxidation.

Long–Term Oxidation Test Results For Ambient Air Exposures Of Foil at 0.004 Inches (0.1 mm) Thick



Water vapor (steam) is present in many environments, notably the products of fossil fuel combustion and the waste streams of advanced energy generation devices such as high temperature fuel cells. Mixtures of air and steam are more aggressive than either of the individual components and have been noted to result in accelerated oxidation attack on lower alloyed stainless steels. The water vapor reacts with excess oxygen and the chromium-based surface oxide, causing it to vaporize. This can lead to early failure by accelerated oxidation through evaporative chromium loss. Laboratory and field testing has shown that the presence of high levels of water vapor has minimal effect on ATI 20-25+Nb alloy due to the addition of a controlled amount of manganese to the alloy composition. This modifies the nature of the oxide from a chromium oxide (Cr_2O_3) to a manganese chromite-type spinel ($MnCr_2O_4$), which evaporates at a much slower rate.

The process of degradation at elevated temperatures is often complex. Oxygen, sulfur, carbon and nitrogen can all interact with surfaces and cause corrosion. General data can often be used only in estimating the relative oxidation and corrosion resistance of different alloys. ATI can supply extensive data and published literature references for ATI 20-25+Nb alloy pertaining to specific applications on request.

Environmental attack is not the only significant form of elevated temperature degradation. Many heat and corrosion-resistant stainless steels and alloys exhibit microstructural instability, manifested by the formation of second phase particles such as sigma (σ), which are detrimental to mechanical properties, corrosion resistance, and creep strength. The composition and microstructure of ATI 20-25+Nb alloy has been formulated to be resistant to second phase formation, resulting in minimal loss of ductility and creep strength during elevated temperature exposures, even under conditions of applied stress. This is evident from electron microscopy studies of long-term creep samples, which show no evidence of phases other than beneficial carbides which increase creep resistance.

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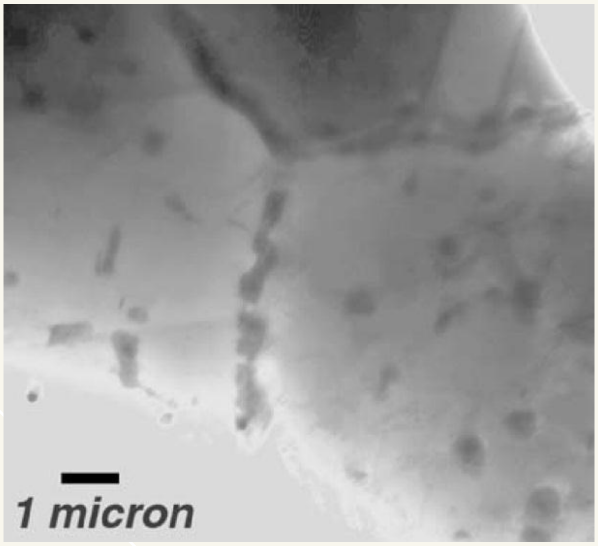
Microstructure (TEM) of a creep sample after 13,760 hours at 1350°F (5.1% creep strain)



FABRICATION

Joining
The austenitic stainless steels are considered readily weldable and can be joined using all of the common processes. This is generally true of ATI 20-25+Nb alloy. When filler metal is required, matching composition or higher alloy weld metal is generally specified. One common choice for this grade is specified as AWS ERNiCrMo-3 (commonly known as alloy 625 filler metal).

The austenitic alloys exhibit a relatively high coefficient of thermal expansion, low thermal conductivity, and form low levels of ferrite in the solidifying weld metal. These factors can lead to hot cracking. The problem can be more severe for restrained and/or wide joints, or for autogenous weld practices where the heat input is highly localized, e.g. laser welding.This alloy has successfully been vacuum-brazed. The composition restricts the levels of titanium and aluminum, which can hinder bonding through the formation of thin oxide films. The moderate nitrogen addition to this alloy may present some difficulty in brazing, which can be addressed with proper operating techniques and the choice of appropriate braze filler material.

Forming
Mild carbon steel is generally treated as the standard for performance in most metal forming operations. With respect to carbon steel, the austenitic stainless steels exhibit a significant difference — they are tougher and tend to work harden rapidly. While this does not alter the general methods used for cutting, machining, forming, etc. it does affect the specifics of those methods.

The austenitic stainless steels are readily cold formable by standard methods such as bending, stretch forming, roll forming, hammer forming, flaring/flanging, spinning, drawing and hydroforming. They work harden readily, which is manifested by steadily increasing amounts of force needed to continue deformation. This results in the need to use stronger forming machines and eventually limits the amount of deformation possible without cracking.

A relatively narrow range of temperatures can be used for effective hot working of this alloy due to numerous environmental and metallurgical factors. Forging should start in the temperature range 1800-2200ºF (980-1200ºC) and finish no cooler than 1600ºF (870ºC). Following forging, the workpiece should be cooled rapidly to a black heat.

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Cutting

Cutting and machining the austenitic stainless steels is readily accomplished using standard techniques typically employed for common mild steel, with some modifications. Their cutting behavior can be quite different — they are tougher and tend to harden rapidly during working. The chips produced are stringy and tough and retain considerable ductility. Tooling should be kept sharp and be rigidly held. Deeper cuts and slower speeds are generally used to cut below work hardened zones. Due to the low thermal conductivity and high coefficient of thermal expansion inherent to the austenitic stainless steels, heat removal and dimensional tolerances must be considered during cutting and machining operations.

Annealing

The primary reasons for annealing are to produce a recrystallized microstructure with a uniform grain size and for dissolving detrimental precipitates. To ensure complete annealing, pieces should be held in the range 2000º-2150ºF (1093°-1179°C) for approximately 30 minutes (time at temperature) per inch of section thickness. This is a general recommendation only—specific cases may require further investigation. When properly annealed, this alloy is austenitic at room temperature, with finely dispersed niobium carbides.

Oxide scale formation is inevitable during air annealing of this alloy. The annealing scale generally must be removed prior to further processing or service. There are two typical methods for removing scale—mechanical and chemical. A combination of surface blasting prior to chemical scale removal is generally effective at removing all but the most tightly adherent scale. Silica sand or glass beads are a good choice for the blasting media. Iron or steel shot can also be used, but will lead to embedded free iron in the surface which may then result in surface rusting or discoloration unless the surface is subsequently pickled. Alternatively, the alloy can be annealed in an inert atmosphere, which results in a bright surface.

Chemical removal of scale is generally performed with mixed nitric–hydrofluoric acids. The proper bath makeup and process temperature combination depends on the situation. A typical pickling bath used consists of 5-25% HNO3 (65% initial strength) and 0.5-3% HF (60% initial strength) in aqueous solution. Higher concentrations of hydrofluoric acid leads to more aggressive scale removal. Bath temperatures generally range from ambient to about 140ºF (60°C). Higher temperatures result in faster descaling, but may attack grain boundaries aggressively, resulting in surface grooving. Acid pickling must be followed with a thorough water wash to remove all traces of pickling acids. Drying should then be used to avoid spotting and staining.

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