ATI Defense

Mission Critical Metallics®

Stainless Steel Chromium-Nickel-Manganese
ATI 201LN™-MIL (UNS Designation S20153)

GENERAL DESCRIPTION

Materials for use at sub-zero temperatures should be ductile, tough and strong at the use temperature. Only a limited number of materials, among them most of the austenitic stainless steels, satisfy all of these requirements. The austenitic stainless steels not only maintain their toughness and ductility, but they also increase in yield and tensile strengths as temperatures decrease. By choosing the right austenitic stainless steel, many cryogenic temperature applications can be satisfied.

The familiar type 300 series austenitic stainless steels have been used satisfactorily for many years as materials of construction for liquid oxygen tanks and accessories as well as liquid hydrogen handling equipment. Other applications include components containing liquid carbon dioxide, acetylene, methane, argon and nitrogen. Hence, service temperatures ranging from -80°F to -320°F are typical based on the boiling points of these liquids.

Type 201 austenitic stainless steel has been available for over 40 years and has gained acceptance in a number of applications. Compared to the 300 series alloys, the lower-nickel 200 series alloys offer an economical way to obtain superior mechanical properties. ATI Defense has created a special composition of type 201 specifically for sub-zero temperature service as welded tanks and vessels. This alloy, designated ATI 201LN™-MIL, also identified by the Unified Numbering System Designation S20153, has replaced the familiar 300 series stainlesses such as type 301 or type 304 in many applications based upon technical equivalency and economic considerations. Consequently, ATI 201LN™-MIL alloy is a natural choice for use at temperatures down to -320°F.

ATI 201LN™-MIL alloy is also suited for many ambient temperature structural applications, such as railroad freight cars, truck trailers, coal handling and other bulk transport equipment where there is a need for a good combination of corrosion resistance, strength, toughness and ease of fabrication.

COMPOSITION

Ferritic alloys such as carbon steels or 400 series stainless steels experience a ductile-to-brittle transition (DBT) as the temperature is reduced. This DBT is a major barrier to the use of most ferritic steels at subambient temperatures. Even some of the austenitic stainless steels can be embrittled at low temperatures. This embrittlement has been attributed to a transformation from austenitic to martensitic structure at low temperature. Most austenitic stainless steels resist transformation to martensite even at very low temperatures and maintain their toughness and ductility. However, the stability of austenite varies with chemical composition. The type 301 stainless steel, which exhibits a relatively high work hardening rate even at room temperature, is an example of relatively unstable austenite. Type 304 has a much lower work hardening rate, indicating a more stable austenite. However, even the relatively unstable type 301 is often satisfactory for low temperature service.

Composition									
Specification	ASTM Range - Weight Percent								
	C*	Mn	P*	S*	Si*	Cr	Ni	N	Cu*
Composition Balanced ATI 201LN™-MIL (UNS S20153)	0.03	6.40/7.50	0.045	0.015	0.75	16.00/17.50	4.00/5.00	0.10/0.25	1.00
Type 201 Alloy to ASME SA-240, ASTM A666, and ASTM A240 (UNS S20100)	0.15	5.50/7.50	0.060	0.030	1.00	16.00/18.00	3.50/5.50	0.25*	--

* means maximum value.

Data are typical and should not be construed as maximum or minimum values for specification or for final design.
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ATI 201LN™-MIL Alloy

ATI Defense ATI 201LN™-MIL alloy has been designed specifically to provide sufficient austenite stability for low temperature service. As part of the composition design, carbon has been restricted to 0.03 percent maximum to minimize sensitization during welding since welding is typically required in the construction of low temperature equipment.

ATI 201LN™-MIL alloy can be used for various pressure vessel, cryogenic, structural, architectural, magnetic and heat resisting applications. ATI 201LN™-MIL (UNS S20153) alloy is a carefully balanced composition of type 201 which satisfies the requirements of ASME Boiler and Pressure Vessel Specification SA-240 and ASTM A 240 (Standard Specification for Heat Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels).

ASME Code Case 2123-3 permits ATI 201LN™-MIL alloy which meets the ASTM A 240-96 requirements to be used for the manufacture of Section VIII, Divisions 1 and 2 welded pressure vessels for low temperature service. The minimum and maximum design temperatures are -320°F (196°C) and 100°F (40°C), respectively. The maximum allowable stress values are 23,800 psi (164 MPa) for Division 1 and the maximum allowable design stress intensity value S^m in tension is 30,000 psi (207 MPa) for Division 2. These limiting stresses (based upon room temperature properties) are employed when designing to cryogenic temperatures even though the strength of austenitic stainless steels increases as temperature decreases below room temperature. The 23,800 psi (164 MPa) maximum allowable stress for ATI 201LN™-MIL alloy is substantially higher than the maximum allowable stress for type 304 alloy, 18,750 psi (129 MPa), allowing the use of thinner sections for ATI 201LN™-MIL alloy, or allowing an additional safety factor with a gage equivalent to that for type 304 alloy.

TYPICAL APPLICATIONS

Liquefied Gas Storage Vessels
Portable Gas Storage Tanks

In summary, the austenitic stainless steels have been proven to be excellent materials for use at sub-zero temperatures to at least -320°F. ATI Defense ATI 201LN™-MIL alloy represents the marriage of high room temperature strength, and excellent mechanical properties at sub-zero temperatures and fabricated corrosion resistance of low carbon type 300 series stainless steels.

DENSITY

0.284 lbs/in^3
7.857 gm/cm^3

MECHANICAL PROPERTIES

The austenitic stainless steels are generally utilized in the annealed condition. The mechanical properties which are of primary importance in fabrication and use, and consequently receive the most attention are the yield strength, tensile strength, elongation, and impact properties. Since toughness and resistance to impact loading are important at low temperatures these properties are given below for a number of heats to demonstrate the excellent impact resistance of ATI Defense ATI 201LN™-MIL alloy.

Impact Loading

It is known that austenitic stainless steels (e.g., type 304), in general, retain their excellent impact properties at low temperatures. ATI 201LN™-MIL alloy, as illustrated on page 4, retains excellent impact properties down to -320°F (-196°C).

ATI 201LN™-MIL Alloy – Room Temperature Data

Data for Tests at +70°F (21°C)

Heat	Direction	0.2% Yield Strength (ksi)	Tensile Strength (ksi)	Elongation (% in 2")	Impact Energy (ft-lbs.)	Lateral Expansion (in.)
M-6	T	46.4	99.3	56.0	208	0.085
M-7	T T	46.6	97.6	59.0	184 162	0.088 0.092
M-8	T T T	49.8	97.1	56.5	154 186 172	0.087 0.084 0.087

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ATI 201LN™-MIL Alloy – Low Temperature Data

Data for Tests at -100°F (-73°C)

Heat	Direction	0.2%Yield Strength (ksi)	Tensile Strength (ksi)	Elongation (% in 2")	Impact Energy (ft-lbs.)	Lateral Expansion (in.)
M-6	T	63.4	179.2	42.5	150	0.084
	T	61.8	176.0	45.0	150	0.081
M-7	T	68.7	177.3	47.0	134	0.080
	T	71.7	176.9	46.0	130	0.072
M-8	T	72.8	179.2	47.5	142	0.070
	T	70.7	177.7	50.0	138	0.078

Data for Tests at -320°F (-196°C)

Heat	Direction	0.2% Yield Strength (ksi)	Tensile Strength (ksi)	Elongation (% in 2")	Impact Energy (ft-lbs.)	Lateral Expansion (in.)
M-1	T	83.2	231.5	27.0	68	0.045
	T				59	0.048
	T				68	0.046
M-2	L	83.9	203.0	25.0	82	0.048
	L				86	0.050
	L				106	0.054
M-6	T	75.6	233.9	31.0	61	0.038
	T	77.8	210.0	23.0	58	0.038
	T				80	0.044
	L	82.5	190.5	22.0	95	0.056
	L	75.2	242.6	37.0	84	0.053
	L				59	0.038
M-7	T	84.8	200.5	22.5	56	0.034
	T	87.6	244.2	36.0	68	0.041
	T				47	0.028
	L	87.6	234.0	27.5	54	0.038
	L	87.4	249.7	34.0	52	0.032
	L				56	0.035

L - Designates impact sample length lies in longitudinal or rolling direction and notch running through thickness.
T - Designates impact sample length lies in transverse or width direction and notch running through thickness.
Impact Energy and Lateral Expansion are determined according to the American Society for Testing and Materials (ASTM) Procedure E-23 (Notched Bar Impact Testing of Metallic Materials).

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ATI 201LN™-MIL Alloy

Yield and Tensile Strengths

The yield and tensile strengths of austenitic stainless steels actually increase as temperature is decreased below zero degrees Fahrenheit. The tensile strength tends to increase more rapidly than does the yield strength. The effects of sub-zero temperatures on the ATI 201LN™-MIL alloy are graphically illustrated on page 5. ATI 201LN™-MIL alloy maintains high elongations and continues to increase in tensile strength as temperature decreases. Austenite stability has been controlled in the ATI 201LN™-MIL alloy.
In addition to the effect of austenite stability, variables associated with welding can also influence low temperature properties.

EFFECT OF SENSITIZATION

Since welding is an important method of fabrication, the potential effect of sensitization on mechanical properties must be considered. Sensitization of annealed austenitic stainless steels normally causes a small loss of toughness at low temperatures. The degree of change is related to the amount of carbide precipitation which occurs. This, in turn, is dependent on the carbon content of the material. In ATI 201LN™-MIL alloy, the carbon content has been reduced to the level of 0.03 percent maximum, minimizing the amount of carbide precipitation, and maintaining low temperature impact properties in welded sections. In addition to the loss of toughness induced by the presence of carbides, the depletion of carbon from solid solution can destabilize austenite. This can lead to martensite formation and further loss of toughness. An additional effect of welding, that of an increased grain size in and adjacent to the welds, can have an effect on sub-zero properties. However the data below on ATI 201LN™-MIL alloy, including data for grain size deliberately grown to ASTM # 1 (a very large grain size), shows that large grain size does not detrimentally affect properties at -320°F (-196°C).

Effect of Grain Size on ATI 201LN™-MIL Alloy (Properties for Heat M-6)

Heat Treatment	ASTM Grain Size	Test Temp °F (°C)	0.2% Yield Strength (ksi)	Tensile Strength ksi (MPa)	Elongation (% in 2")	Impact Energy ft-lbs. (Joules)	Lateral Expansion (in.)
Mill Anneal	6	70 (21)	46.4 (320)	99.3 (685)	51	184-202 (250-274)	0.085-0.088
Mill Anneal	6	-320 (-196)	75.6-77.8 (521-536)	210.0-234.0 (1448-1613)	23-31	58-61 (74-83)	0.038-0.039
Mill Anneal + 100 Min. @ 2050°F	2.5-3	-320 (-196)	81.7 (563)	191.4 (1320)	21	107-108 (145-146)	0.055-0.057
Mill Anneal + 300 Min. @ 2050°F	0.5-1.5	-320 (-196)	71.6 (525)	213.3 (1471)	23.5	124-134 (168-182)	0.057-0.067

Impact Energy and Lateral Expansion data are range of three samples tested.

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RESISTANCE TO CORROSION

ATI Defense ATI 201LN™-MIL alloy is resistant to a wide variety of mild to moderately corrosive media. Generally speaking, ATI 201LN™-MIL alloy has proven entirely adequate for applications where type 301 has been satisfactory and has been successfully substituted for type 304 in a variety of mild environments.

AVAILABLE PRODUCT FORMS

ATI Defense ATI 201LN™-MIL stainless steel is available in plate, sheet, and strip product forms and is listed in ASTM A240.

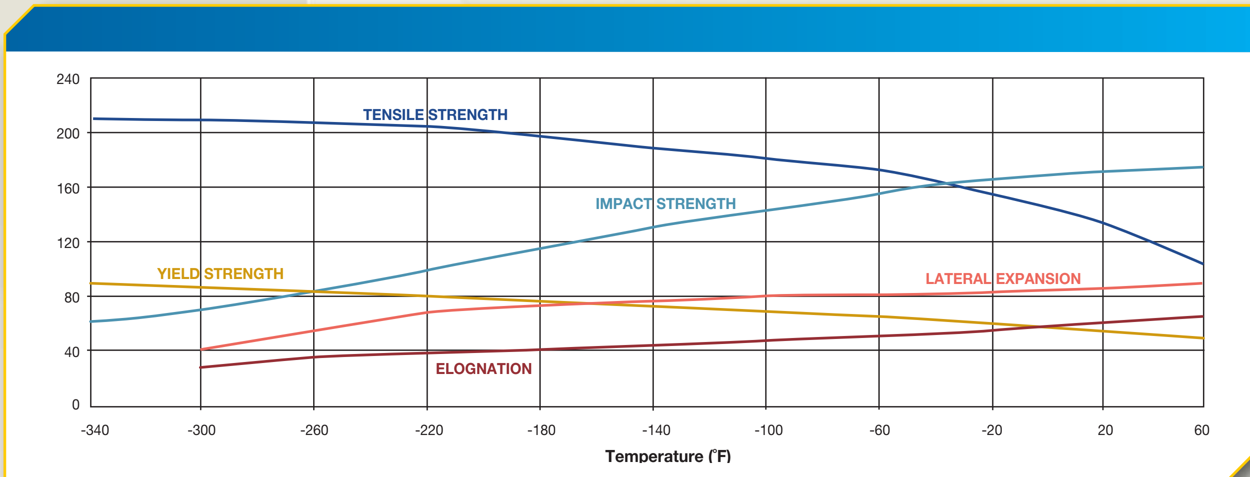

Figure 1 – ATI 201LN™-MIL alloy mechanical properties from room temperature to -320°F

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