Technical Data Sheet

ATI 2102®

Lean Duplex Stainless Steel

(UNS S82011)

GENERAL CHARACTERISTICS

ATI 2102® (UNS S82011) alloy is a proprietary* lean duplex stainless steel (LDSS) in which the composition is controlled to create a material with the structure and properties of more highly alloyed duplex grades at a lower and more stable cost. ATI 2102® LDSS has better corrosion resistance than Type 304L in most applications and performs as well as Type 316L in many environments, while at the same time having the higher strength characteristic of duplex stainless steels.

ATI 2102® products are well suited for applications requiring high strength and good resistance to general corrosion. Possible end uses are for tubing, storage tanks, top side and subsea oil and gas applications, heat exchangers for the chemical process industry, and structural and cosmetic applications in architecture.

Chemical Composition of ATI 2102® LDSS (ASTM A240 Limits for S82011)

Element	Weight Percent
Carbon	0.030 max
Manganese	2.0 - 3.0
Phosphorus	0.040 max
Sulfur	0.020 max
Silicon	1.00 max
Chromium	20.50 - 23.50
Nickel	1.00 - 2.00
Molybdenum	0.10 - 1.00
Copper	0.50 max
Nitrogen	0.15 - 0.27
Iron	Balance

When heat-treated properly, the composition of ATI 2102® LDSS (nominally 21.5% chromium, 1.5% nickel, 2.8% manganese, and 0.22% nitrogen) produces a microstructure that consists of a nearly equal mixture of the austenitic and ferritic phases. The microstructure and composition of ATI 2102 alloy provide stress-corrosion cracking resistance that is superior to that of Types 304 or 316, and a yield strength that is more than double that of conventional austenitic stainless steels.

The microstructure and phase balance of ATI 2102® LDSS have been designed to facilitate the production of pipe and tube products, as well as sheet, strip, and plate. With reduced levels of Cr and Mo, the ATI 2102® alloy is less susceptible than ATI 2205™ material to the formation of detrimental intermetallic phases such as sigma. ATI 2102® alloy should be considered for use in environments where resistance to general corrosion and chloride stress corrosion cracking are important.

SPECIFICATION COVERAGE

ATI 2102® (UNS S82011) alloy is currently included in ASTM standards A240 and A480 (plate, sheet, and strip), ASTM A789, (welded tube) and A790 (welded pipe). ATI 2102® alloy is also covered by ASME Code Case 2735 for Section VIII, Division 1 use.

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Technical Data Sheet

PHYSICAL PROPERTIES

Density	0.279 lb/in³ (7.75 g/cm³)
Elastic Modulus	29 x 10^6 psi (200 GPa)
Poisson's Ratio	0.31
Magnetic Permeability	Ferromagnetic

Thermal Expansion (mean coefficient over range)

Temperature Range			
°F	°C	in/in/°F x 10^{-6}	mm/mm/°C x 10^{-6}
-166 to 68	-110 to 20	6.4	11.5
-40 to 68	-40 to 20	6.6	12.0
68 to 212	20 to 100	7.1	12.7
68 to 392	20 to 200	7.3	13.2
68 to 572	20 to 300	7.5	13.6
68 to 752	20 to 400	7.7	13.9

Thermal Conductivity

Temperature			
°F	°C	Btu-in/ft² * hr-°F	W/m * K
0	-18	107	15.4
32	0	109	15.7
73	23	112	16.1
212	100	120	17.4
347	175	128	18.4
482	250	135	19.5
617	325	144	20.7
752	400	151	21.7

ROOM TEMPERATURE MECHANICAL PROPERTIES

ASTM A240 specification limits for annealed ATI 2102® sheet, strip, and plate material are shown in the table below. Because of microstructural refinement that occurs during cold working, sheet and strip products will typically have higher strength than plate, which is a hot rolled product.

Room Temperature Tensile Properties (Min.)

Product	Ultimate Strength ksi	Ultimate Strength MPa	0.2% Yield Strength ksi	0.2% Yield Strength MPa	Elongation in 2" or 50 mm %	Hardness (Max.) BHN	Hardness (Max.) R_C
Sheet / Strip (≤ 0.187" or 5 mm)	101	700	75	515	30	293	31
Plate (>0.187" or 5 mm)	95	655	65	450	30	293	31

ELEVATED TEMPERATURE MECHANICAL PROPERTIES

ASME Boiler and Pressure Vessel Code Case 2735 places an upper temperature limit of 650°F (343°C) on the use of ATI 2102® lean duplex stainless steel. While duplex stainless steels may form detrimental phases during extended exposure above 600°F (315°C), ATI 2102® LDSS is less susceptible to the formation of intermetallic phases because it contains less chromium and molybdenum in combination with high nitrogen. However, after extended periods of exposure to temperatures above 650°F, a full

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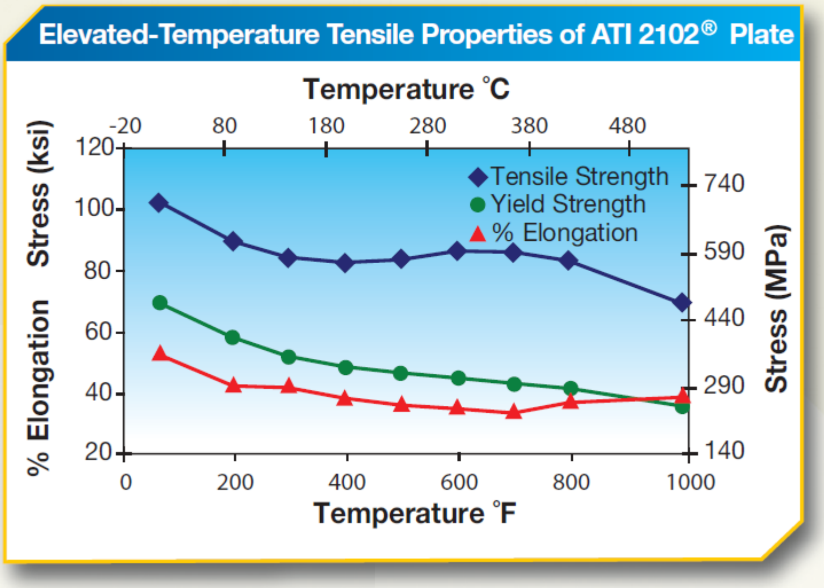
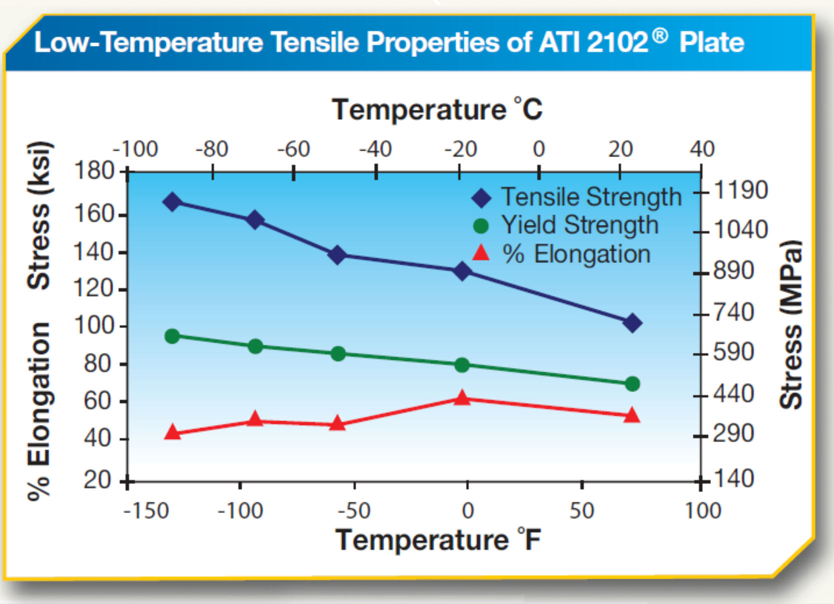
anneal followed by air or water-cooling is suggested because of the potential for 885°F (475°C) embrittlement. A full anneal is also the preferred method of relieving forming stresses. The chart below shows the tensile properties of ATI 2102® plate material after a 30-minute soak at temperatures up to 1000°F (538°C).



LOW-TEMPERATURE TENSILE PROPERTIES

The chart to the right shows the measured tensile properties of ATI 2102® plate material between room temperature and -130°F (-90°C). As the temperature decreases, the material's yield and tensile strengths both increase. However, the percent elongation does not decrease significantly, and remains above 40% at the lowest temperature tested. This outstanding low-temperature ductility is, at least in part, due to deformation-induced martensite, which forms when the material is strained at low temperatures.



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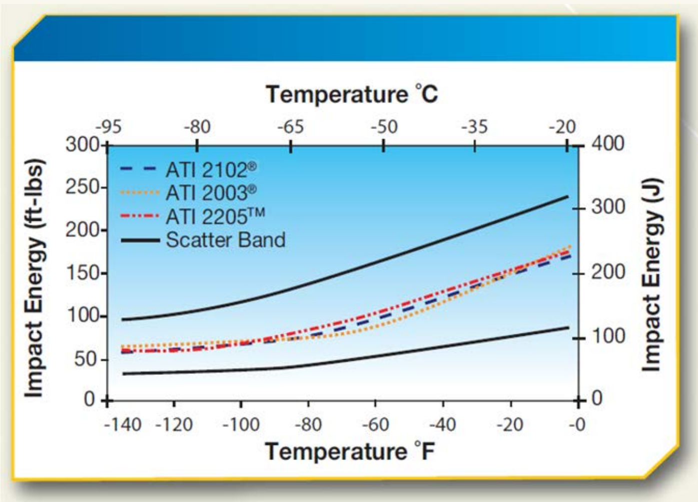
LOW-TEMPERATURE IMPACT PROPERTIES

ATI 2102® LDSS displays outstanding low-temperature toughness for a duplex stainless steel. As shown in the figure, ATI 2102® plate has comparable toughness to ATI 2205 alloy and ATI 2003 LDSS at sub-zero temperatures. In these tests ATI 2102® plate easily exceeds the commonly specified Charpy V-notch impact energy of 40 ft-lbs at -40°F (54 J at -40°C), as well as the Norsok requirement of 45 J at -46°C (33 ft-lbs at -51°F). For welded fabrications, welding processes that produce weld deposits having low oxygen content, such as GMAW or GTAW, are recommended for optimal low-temperature toughness. Post-weld heat treatment may also improve impact resistance.



Typical low-temperature Charpy impact energy of 0.625" (16.5mm) ATI 2102™ plate compared to ATI 2003® and ATI 2205™ plates of similar thickness (L-T orientation).

FORMABILITY

ATI 2102® LDSS can be successfully cold-bent and expanded to the same extent as other duplex stainless steels. Because of the higher strength and lower ductility of duplex grades, greater loads and more generous bend radii are required for forming compared to conventional austenitic materials. It is suggested that bend radii of at least two times the metal thickness be used when forming duplex stainless steels. Allowances will also need to be made for a larger springback than is seen with lower strength materials.

HEAT TREATMENT

ATI 2102® LDSS should be annealed between 1850 and 2010°F (1010-1100°C) and cooled quickly. Annealing near 2010°F will increase the amount of ferrite present in the microstructure compared to that resulting from annealing near 1850°F.

WELDING

ATI 2102® LDSS can be welded by most methods used to weld stainless steels. Autogenous welding with a nitrogen addition will give reasonably good results in comparison to higher alloyed duplex grades, which generally require a post-weld heat treatment for welds made without filler metal. Non-filler metal welds will have optimal strength and corrosion resistance following a solution anneal, while filler-metal welds normally do not require a post-weld heat treatment.

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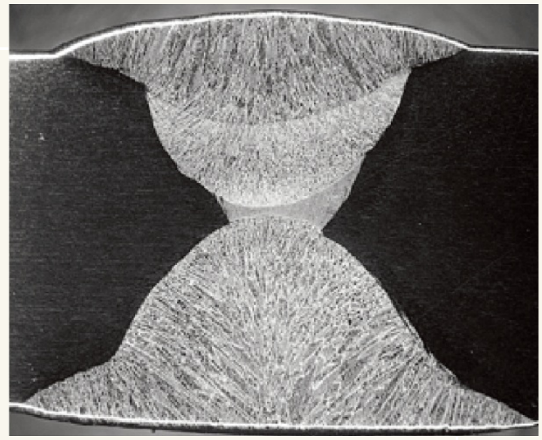
Commercially available overmatched filler metals are suggested for welding ATI 2102® alloy. Such filler metals (for example, AWS E2209) contain more nickel than the base metal in order to produce a phase balance within the weld that is approximately the same as that of the base metal. When ATI 2102® alloy is welded to different metals, a filler metal should be chosen that contains a sufficient quantity of austenite forming elements. Weld procedures for ATI 2102 alloy have been developed using GTAW, GMAW, SAW, and FCAW. Details are available upon request.



Submerged Arc Weld of ATI 2102® Plate made using 2209 Weld Wire

CORROSION RESISTANCE

General Corrosion Resistance

ATI 2102® alloy is resistant to dilute reducing acids, moderate concentrations of oxidizing acids, and low concentrations of organic acids. Data showing ATI 2102® alloy's performance in specific environments is available on request.

Plain and welded samples of ATI 2102® alloy were exposed for over 1000 hours in a salt fog cabinet per ASTM B117. No signs of rust or pitting were observed.

Chloride Stress Corrosion Cracking Resistance

While duplex stainless steels are not immune to chloride stress corrosion cracking (CSCC), they generally show more resistance than austenitic grades like Types 304 and 316. When U-bend specimens of ATI 2102® alloy were immersed in a boiling 26% NaCl solution for 1000 hours they did not crack. Samples of Types 304 and 316 were similarly tested, and both developed stress corrosion cracks in less than 1000 hours. The table below shows the results of these tests.

CSCC test results for U-Bend immersion testing in a boiling 26% sodium chloride solution

Alloy	Result
Type 304	Failed (850 Hours)
Type 316	Failed (530-940 Hours)
ATI 2102®	Passed (1000 Hours)
ATI 2003®	Passed (1000 Hours)
ATI 2205™	Passed (1000 Hours)

Pitting and Crevice Corrosion Resistance

A relative determination of the resistance to chloride-ion pitting and crevice corrosion can be measured using the method described in ASTM Standard G 150. The temperature at which attack is first observed is called the critical pitting temperature (CPT) and can be used as a relative measure of pitting corrosion resistance. The critical pitting temperature criterion is useful for ranking alloys, but does not necessarily indicate an absolute limiting temperature for the use of a particular alloy in chloride-bearing environments. As shown in the chart, annealed ATI 2102® alloy has a CPT of 22°C (72°F), which is slightly above that of Type 316L material.

The critical crevice corrosion temperature as measured by ASTM Standard G 48 usually follows the same trend among a group of alloys as the critical pitting temperature does. As the figure shows, ATI 2102® LDSS has a critical crevice corrosion temperature between those of Type 316L and ATI 2003 LDSS.

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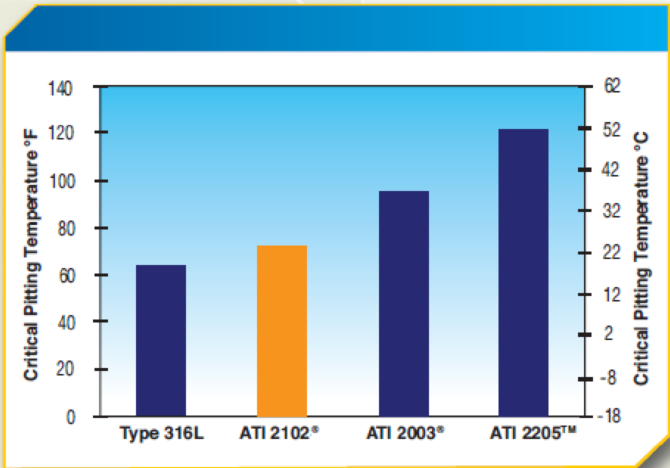
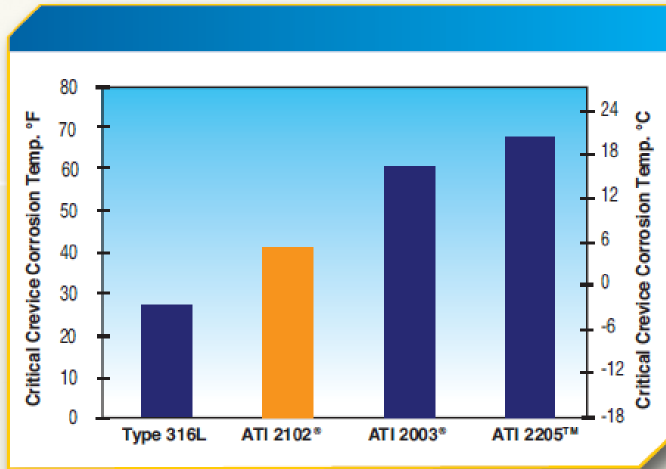


The Critical Pitting Temperature of ATI 2102® alloy compared to Type 316L, ATI 2003® LDSS, and ATI 2205™ DSS as measured by ASTM Standard G150.



The Critical Crevice Corrosion Temperature of ATI 2102® LDSS compared to Type 316L, ATI 2003® LDSS, and ATI 2205™ DSS as measured by ASTM G48 Practice B.

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