Technical Data Sheet

ATI 18CrCb™

Stainless Steel: Ferritic

(UNS S44100)

GENERAL PROPERTIES

ATI's AL 18CrCb™ stainless steel is a heat-resisting ferritic grade providing good oxidation and corrosion resistance for applications like automotive exhaust system components. Ferritic alloys are not inherently strong at elevated temperatures, but columbium additions coupled with appropriate solution annealing markedly improve long-time creep-rupture strength properties. ATI 18CrCb™ alloy is dual stabilized with columbium and titanium to provide good weld ductility and resistance to intergranular corrosion in the weld heat affected zone.

ATI 18CrCb™ alloy has been developed for the severe tube bending and forming operations typical in automotive exhaust manifold fabrication. Tight control on carbon and nitrogen levels plus improved mill processing result in enhanced formability in terms of higher tube bending speeds and lower breakage or scrap rate.

STRUCTURE

ATI 18CrCb™ stainless steel is a ferritic alloy, i.e., the matrix has a body-centered cubic (BCC) crystal structure. Angular carbonitrides of titanium and columbium are randomly dispersed throughout the structure.

Excess columbium is taken into solid solution during high temperature annealing and precipitates as very fine particles of Laves phase (Fe_2Cb) upon either slow cooling or upon holding at intermediate temperatures (1500-1700°F, 816-927°C). Strengthening by this dispersion is responsible for improved elevated temperature strength.

TYPICAL COMPOSITION

Element	Weight %
Carbon	0.015
Manganese	0.40
Phosphorous	0.025
Sulfur	0.002
Silicon	0.50
Chromium	18.0
Nickel	0.20
Titanium	0.20
Columbium	0.60
Nitrogen	0.020
Aluminium	0.05
Iron	Balance

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PHYSICAL PROPERTIES

Coefficient of Linear Thermal Expansion for ATI 18CrCb™ Alloy

Temperature Range		Coefficients	
°C	°F	10^{-6}cm/cm/°C	10^{-6}in/in/°F
20-100	68- 212	9.2	5.1
20-300	68- 572	10.3	5.7
20-500	68- 932	10.6	5.9
20-700	68-1292	10.8	6.0
20-800	68-1472	11.3	6.3
20-900	68-1652	11.9	6.6

ATI 18CrCb™ Alloy	
Density - lb/in^3 (g/cm^3)	0.2978 (7.711)
Electrical Resistivity microhm-cm at 68°F (20°C)	58.7

MECHANICAL PROPERTIES

Short Time Tensile Properties.

Typical Annealed Tensile Properties ATI 18CrCb™ Alloy	
Yield Strength Ksi MPa	48.0 331
Tensile Strength Ksi MPa	74.0 510
Elongation % in 2”	29.0
Hardness Rb	48.0

Elevated temperature tensile properties are shown in the following table on the next page and compared with ATI 409HP™ and ATI 439HP™ alloys. At 1300°F (704°C) and above, the yield and tensile strengths of ATI 18CrCb™ and ATI 439HP™ alloys are about double those of ATI 409HP™ alloy. It is assumed that the solid solution strengthening effects of chromium in AL 439HP™ alloy and chromium plus columbium in ATI 18CrCb™ alloy provide the improved short time tensile properties above 1200°F (649°C).

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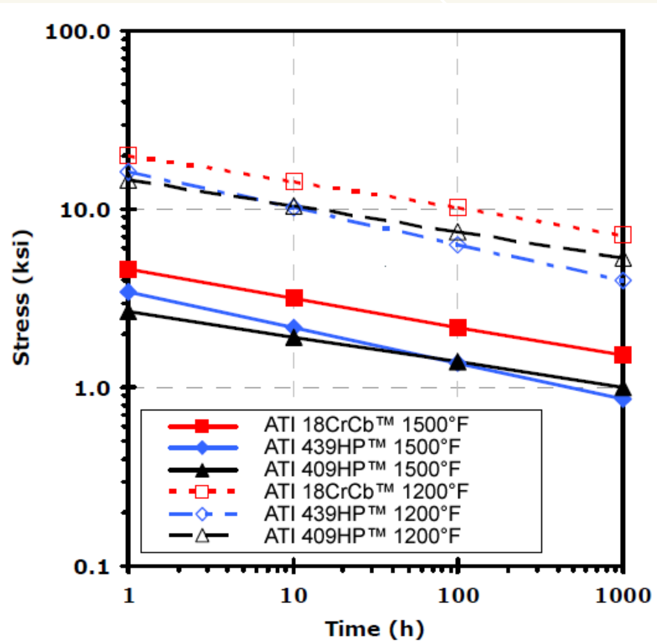
Elevated Temperature Tensile Properties

Yield Strength and Tensile Strength (ksi)						
Temperature	ATI 409HP™		ATI 439HP™		ATI 18CrCb™ Alloy	
	Y.S.	T.S.	Y.S.	T.S.	Y.S.	T.S.
RT	35.5	62.0	40.3	65.6	43.7	68.5
200	31.3	56.7	37.0	64.2	40.3	65.0
400	27.0	51.7	33.4	60.3	36.4	60.0
600	26.5	50.2	27.5	57.6	35.6	58.7
800	24.1	43.1	26.7	51.7	32.5	56.5
900	22.0	34.0	24.1	43.5	28.2	54.1
1000	21.0	29.6	22.8	36.7	24.0	53.1
1100	14.5	20.4	17.2	25.3	24.8	48.8
1200	8.5	11.7	12.0	15.0	19.0	25.4
1300	6.3	8.3	6.7	9.3	12.1	18.9
1400	5.0	6.3	5.0	6.1	9.8	11.0
1500	3.2	4.2	4.0	5.2	6.4	7.3
1600	-	-	-	-	3.7	4.4

STRESS RUPTURE PROPERTIES

The long duration of stress rupture and creep testing enables the Fe_2Cb Laves phase to precipitate, and 100 and 1,000 hour stress rupture properties reveal the beneficial strengthening effects due to columbium additions to ATI 18CrCb™ alloy.

Stress Rupture Properties



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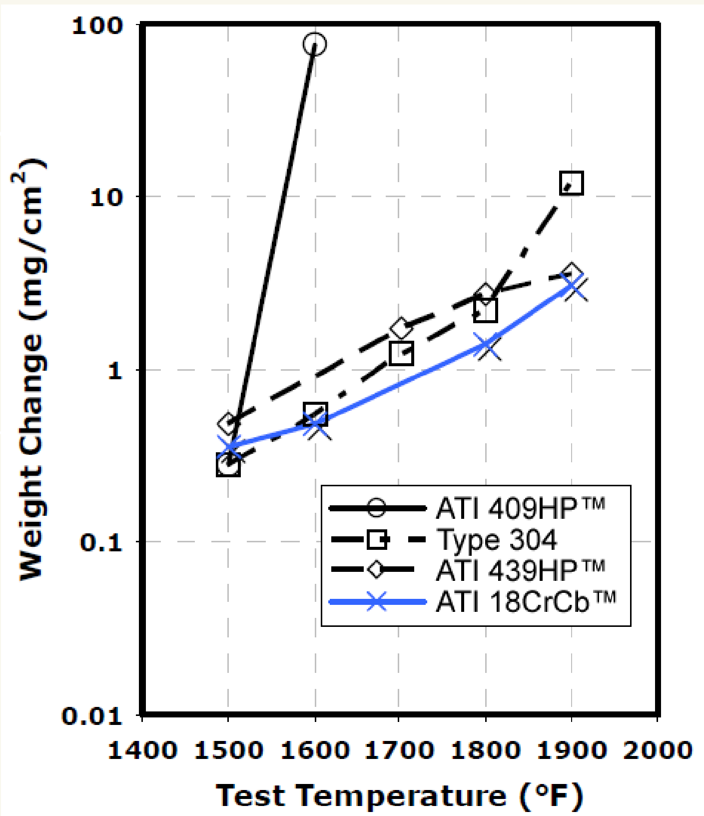
OXIDATION RESISTANCE

Laboratory cyclic and continuous oxidation data are useful for preliminary screening or ranking of candidate alloys for potential consideration in various applications. Tests are conducted in still air and the environment is oxidizing.

ATI 18CrCb™ alloy has very good resistance to progressive scaling in both continuous and cyclic oxidizing laboratory test environments. Continuous 100 hour tests are conducted in still air and total weight gain measurements are used to determine oxidation and progressive scaling resistance in the temperature range of 1500°F (816°C) to 1900°F (1038°C). These results are plotted in the following graph and compared with Type 304 and the ATI 409HP™ and ATI 439HP™ alloys.

100 Hour Oxidation in Still Air



Very few service environments are continuous operations and more often temperatures are cycling. Thermal cycling induces differential thermal expansion and contraction of the developing oxide and metal substrate causing the scale to flake or spall. Ferritic stainless steels have relatively low coefficients of thermal expansion compared to the austenitic stainless alloys like Types 304, 309 and 310. The ferritic stainless steels are, therefore, more resistant to progressive scaling at higher temperatures under cyclic conditions than the austenitic grades.

Cyclic oxidation data has been developed over a temperature range of 1400°F (760°C) to 2200°F (1204°C). These results are shown in the following figure. Testing is conducted in still air where the procedure is to repetitively resistance heat 0.002” (.05 mm) thick x 0.250” (6.35 mm) wide strip samples to temperature for two minutes and subsequently cool to room temperature for two minutes. Failure occurs when the 0.002” (.05 mm) thick strip oxidizes through and breaks.

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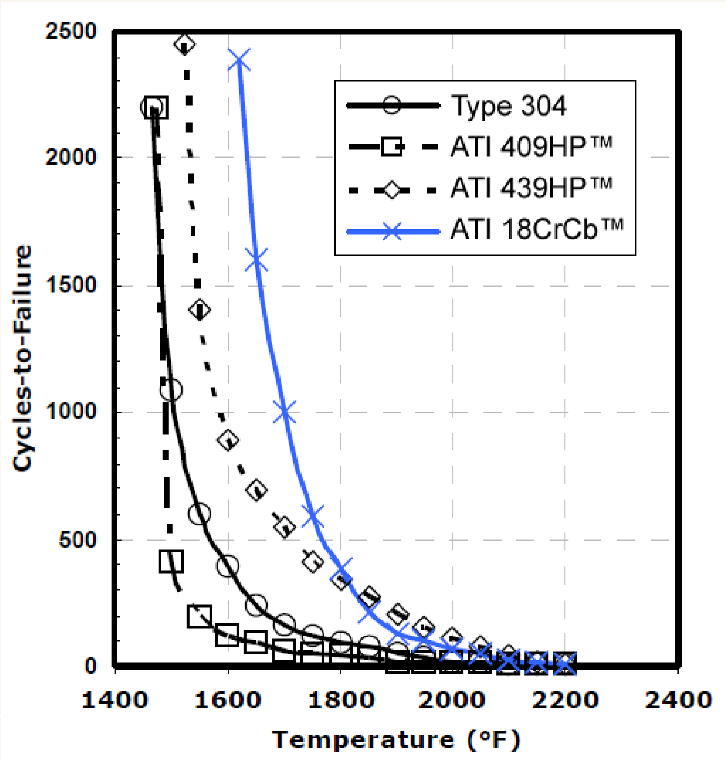
Cyclic Oxidation in Still Air



Projecting service temperature limits for a stainless alloy from either continuous or cyclic oxidation test modes requires arbitrarily selected failure criteria. In the continuous test mode, 1.5 mg/cm^2 weight gain or more is considered the point above which spalling and progressing scaling is occurring. Under the pure cyclic test conditions, 2,000 cycles has been selected to project maximum temperature limits. Results of these rating systems are shown in the following bar graph. The bar graph indicates a range of useful temperature limits for each alloy where the actual limit would depend on the number of thermal cycles during the life cycle and how rapidly the metal parts are heated and cooled. This interpretation projects a useful temperature range limit of approximately 1650°F (899°C) to 1850°F (1010°C) for ATI 18CrCb™ alloy. This compares to a lower useful temperature range projection of 1475°F (801°C) to 1550°F (843°C) for Type 409.

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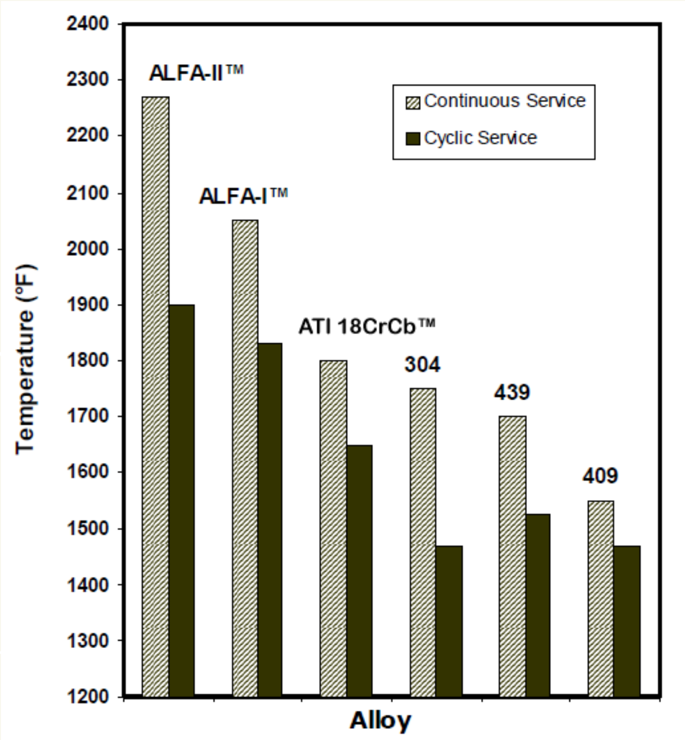
CORROSION RESISTANCE

Projected Maximum Use Temperature in Still Air Oxidizing Atmospheres



ATI 18CrCb™ alloy has generally good overall corrosion resistance typical for 18% chromium stainless steels. Like all ferritic stainless alloys, it is highly resistant to stress corrosion cracking. The following tables and figures show the relative corrosion resistance compared to Types 409, 439 and 304 in a variety of laboratory tests.

GENERAL CORROSION PROPERTIES

Welding

Corrosion Rates in Inches Per Month (Millimeters Per Annum)				
Medium	**ATI 18CrCb™**	**T-439**	**T-409**	**T-304**
20% Acetic Acid Boiling	.00000 (0.000)	.0003 (.09)	.0101 (3.08)	.00001 (.003)
65% Nitric Acid Boiling	.01303 (3.97)	.002 (.61)	.0274 (8.35)	.0007 (.22)
20% Phosphoric Acid Boiling	.00005 (.015)	.00002 (.006)	.0017 (.52)	.00002 (.006)
10%Sodium Bisulfate Boiling	.0010 (.304)	.00001 (.003)	.2058 (62.72)	.005 (1.53)
10%Sulfamic Acid Boiling	.0012 (.037)	.00008 (.025)	.2712 (82.66)	.013 (4.0)
10% Oxalic Acid Boiling	.14002 (42.68)	.18 (55.0)	.1510 (46.0)	.004 (1.22)

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5% Neutral Salt Spray Test-ASTM B117		
Alloy	**Time of Exposure Hours**	**% Surface Attack**
ATI 18CrCb™	100	0
409	100	1%
304	100	0

Typical Stress Corrosion Cracking Test Results In Boiling Solutions			
Alloy	**42% $MgCl_2$**	**33% LiCl**	**26% NaCl**
ATI 18CrCb™	R (216 hrs.)	R (501 hrs.)	R (1,005 hrs)
439	R (200 hrs.)	R (200 hrs.)	R (200 hrs.)
409	R (1,000 hrs)	F (500 hrs.)	R (1,000 hrs)
304L	F (20 hrs.)	F (96 hrs.)	F (744 hrs.)

Key: F=Fails; R=Resistant; ( ) test discontinued at indicated hours.

ATI 18CrCb™ alloy is weldable using traditional tungsten inert gas and metal arc inert gas procedures commonly used with stainless steel. When a filler wire is required, a matching composition electrode can be used with both alloys to maintain compatible corrosion and oxidation resistance in the weld area.

It is suggested that hydrogen not be mixed with the inert gas (unless post weld annealing is planned) because ferritic stainless steels are subject to hydrogen embrittlement.

Each alloy is dual stabilized with columbium and titanium to provide a ferritic microstructure up to the melting temperature.This stabilization with Cb and Ti getters both the carbon and nitrogen. Neither alloy is susceptible to continuous intergranular precipitation of carbides that may lead to sensitization and intergranular corrosion. Postweld heat treatment is, therefore, not required to restore weld and heat affected zone corrosion resistance.

ATI 18CrCb™ tubing has been commercially welded using the high frequency induction process. With either high frequency or arc welding, post weld annealing is suggested when the tube is going to be subsequently bent, formed or shaped. Annealing restores annealed properties to the cold worked tube and provides better ductility for further fabrication.

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