ATI

Technical Data Sheet

ATI 409HP™

Stainless Steel: Ferritic

(UNS S40900, S40945, S40910, S40920, S40930)

GENERAL PROPERTIES

ATI 409HP™ (UNS S40900) ferritic stainless steel was introduced by ATI in 1961 to provide improved oxidation and corrosion resistance for automotive exhaust systems in comparison to carbon steel. The alloy was designated “MF-1“, indicating its end use: automotive mufflers. The good fabricability of this alloy, combined with its basic corrosion resistance and economy have significantly broadened the utility of ATI 409HP™ stainless.

Since its introduction, the ATI 409HP™ alloy has been widely used in automotive exhaust systems for manifolds, exhaust pipes, catalytic converters, mufflers, tail pipes and other components. ATI 409HP™ stainless steel sheet has also found many other applications such as in culverts, home heating systems, automotive thermostats and fuel filters, electrical transformer cases, caskets, heat exchanger tubing, and various farm equipment components. Plate has been used as blades and vanes in standby power generation turbines and as jet engine sound-deadening devices at airports.

The performance of ATI 409HP™ (UNS S40900) ferritic stainless steel in most applications is excellent. However, some industry applications have resulted in intergranular corrosion of weld heat-affected zones. The result of research into this problem led to ASTM’s re-definition of ATI 409HP™ stainless steel. The old UNS S40900 with 0.08% carbon maximum and Ti>5xC was found to be inadequate, but there was no consensus among users how to define the new grade. Therefore, three new grades of ATI 409HP™ stainless steel were created,

UNS S40910, S40920, and S40930, all with reduced (0.03% maximum) carbon but with somewhat different stabilization formulae. Under ASTM A240, orders for S40900 material may be fulfilled by supplying any one of the new 409 grades unless the purchaser states additional requirements. Composition requirements for the three varieties of ATI 409HP™ alloy are shown in the composition table below.

The ATI 409HP™ stainless steel alloys contain nominally 11 percent chromium for greatly enhanced corrosion resistance in comparison to carbon steel. It is an excellent choice for all automotive exhaust system applications where 11 percent chromium provides sufficient resistance to oxidation and corrosion. Hot end exhaust applications may require an 18 percent chromium alloy such as ATI 439 (18 Cr-Ti, UNS S43035), ATI 468™ (18 Cr-Ti + Cb, UNS S46800), ATI 436S™ (18 Cr-1.2 Mo-Ti), or ATI 441HP™ (18 Cr-0.5 Cb-Ti) alloys. Other nonautomotive applications also will benefit from the excellent fabricability which the ATI 409HP™ alloy provides.

The UNS S40930 alloy contains balanced amounts of titanium and columbium to provide resistance to sensitization and intergranular corrosion which might occur in the heat affected zones of welds or in base metal following other thermal exposures. A low incidence of titanium nitride surface imperfections is also a characteristic of this alloy. The balance of stabilizing elements is designed to optimize weldability without post-weld annealing to restore ductility.

ATI 409Cb™ alloy (UNS S40945) was developed to eliminate the problems encountered when brazing S40900 stainless steel that was stabilized only with Ti. The dual-stabilized S40930 version of ATI 409HP™ alloy usually provides the same benefit and now is used for brazing applications.

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COMPOSITION

Specified composition ranges of the various ATI 409HP™ alloys are shown below:

Element	Weight %	Weight %	Weight %
UNS	S40910	S40920	S40930
Carbon	0.03 max	0.03 max	0.03 max
Manganese	1.00 max	1.00 max	1.00 max
Phosphorus	0.040 max	0.040 max	0.040 max
Sulfur	0.010	0.010	0.010
Silicon	1.00 max	1.00 max	1.00 max
Chromium	10.5-11.7	10.5-11.7	10.5-11.7
Nickel	0.50 max	0.50 max	0.50 max
Titanium	0.50 max	0.15-0.50	0.05 min
Niobium	0.17 max	0.10 max	0.70 max
Nitrogen	0.030 max	0.030 max	0.030 max
Iron	Balance	Balance	Balance
Stabilization	Ti = 6 (C+N) min.	Ti = 8 (C+N) min.	(Ti+Cb) = 0.08 + 8 (C+N) min., 0.75 max

PHYSICAL PROPERTIES

The ATI 409HP™ alloy is characterized by a single-phase ferritic microstructure for all normal processing temperatures. Scattered titanium and/or columbium carbonitride precipitates are present in the microstructure. Chemical composition is carefully balanced to avoid formation of austenite and, consequently, martensite on exposure to annealing temperatures or in heat-affected zones of welds. Many of the ferritic stainless steels suffer embrittlement after long exposure to temperatures in the 700-1100°F (370-590°C) range. This embrittlement, which is most rapid at about 885°F (475°C) is often called “885°F embrittlement” (475°C embrittlement). It is caused by the precipitation of a chromium-rich second phase called alpha-prime. The rate of 885°F embrittlement is strongly dependent upon the chromium content of the alloy. Alloys like ATI 409HP™ stainless with less than 12% Cr, rarely exhibit any 885°F embrittlement.

Representative physical properties of ATI 409HP™ alloy are given below.

Physical Property	U.S. Customary		Metric	
Density	0.280 lb/in^3			7.76 g/cm^3
Mean Coefficient of Thermal Expansion	68 - 212°F 68 - 500°F 68 - 900°F 68 - 1200°F	5.84 x 10^{-6} in/in/°F 6.12 x 10^{-6} in/in/°F 6.60 x 10^{-6} in/in/°F 6.86 x 10^{-6} in/in/°F	20 - 100°C 20 – 260cC 20 - 482°C 20 - 649°C	10.52 x 10^{-6} cm/cm/°C 11.11 x 10^{-6} cm/cm/°C 11.88 x 10^{-6} cm/cm/°C 12.34 x 10^{-6} cm/cm/°C
Specific Heat	68°F	0.114 Btu/lb ·°F	20°C	477 J/kg·K
Thermal Conductivity	68 - 212°F	14.4 Btu/ft ·hr ·°F	20 - 100°C	25.0 W/m·K
Elastic Modulus	68°F	29 x 10^6 lb/in^2	20°C	200 GPa
Curie Temperature, Tc	1350°F		732°C	
Electrical Resistivity	-		60 µΩ-cm	

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MECHANICAL PROPERTIES

Room Temperature

Representative typical room temperature tensile properties for the ATI 409HP™ stainless steel sheet or strip in the annealed condition are as follows:

0.2% Yield Strength,	35,000 psi (241 MPa)
Ultimate Tensile Strength	63,000 psi (434 MPa)
Elongation, % in 2" (51 mm)	33
Hardness, HRB	71

Comparison with properties given in ASTM A240/A240M shows that these typical properties for ATI 409HP™ alloy easily meet the requirements for 409 ferritic stainless steel (UNS S40900).

These properties illustrate that ATI 409HP™ products provide an excellent combination of strength and ductility at room temperature which contribute to ease of fabrication.

Elevated Temperature

Typical elevated temperature mechanical properties for ATI 409HP™ alloy (UNS S40900) are compared to similar properties for ATI 439HP (UNS S43035) ferritic stainless steel below:

Temperature °F (°C)	ATI 409HP™ (UNS S40900)			ATI 439™ (UNS S43035)		
	0.2% Yield% Strength, ksi (MPa)	Ultimate Tensile Strength, ksi (MPa)	Elongation, % in 2" (51 mm)	0.2% Yield% Strength, ksi (MPa)	Ultimate Tensile Strength, ksi (MPa)	Elongation, % in 2" (51 mm)
RT	34.5 (238)	62.0 (427)	33	44.0 (303)	65.6 (452)	34
200 (93)	29.9 (206)	53.9 (371)	31	38.0 (262)	64.0 (441)	32
400 (204)	23.3 (160)	49.9 (344)	27	33.0 (227)	60.0 (413)	28
600 (316)	21.2 (146)	48.3 (333)	23	29.0 (200)	56.5 (389)	22
800 (427)	20.3 (140)	44.4 (306)	21	26.5 (182)	52.0 (358)	20
1000 (538)	17.7 (122)	39.4 (271)	18	24.1 (166)	40.5 (279)	15
1200 (649)	16.6 (114)	30.0 (207)	15	16.5 (114)	25.3 (174)	17
1400 (760)	8.0 (55)	16.5 (114)	23	6.7 (46)	10.0 (69)	36
1600 (871)	3.0 (21)	3.3 (23)	59	4.0 (27)	5.2 (36)	50

As shown by the data, the strength of the 11%Cr ATI 409HP™ alloy is generally less than that of the ATI 18%Cr Type 439 (UNS S43035) alloy except in the temperature range of 1200 to 1400°F (649-760°C), while ductility of the two alloys is similar. At 1600°F (871°C) the strength of the ATI 409HP™ alloy, like that of Type 439 and conventional ATI 409HP™ alloy, drops to low levels while elongation values increase markedly.

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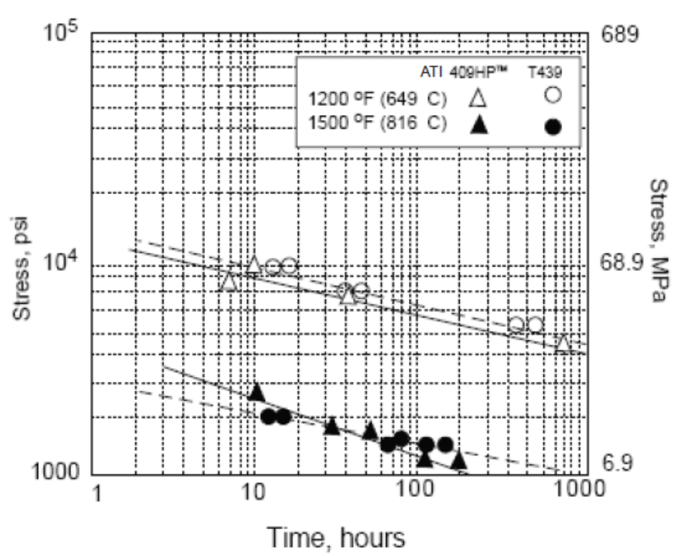
Stress Rupture

Stress rupture data at 1200 (649°C) and 1500°F (816°C) for the ATI 409HP™ alloy are compared to similar data for ATI 439 alloy in Figure 1. At 1200°F (649°C) the rupture data for the two alloys are similar, with the ATI 439 alloy exhibiting slightly longer time to rupture at a particular stress. At 1500°F (816°C) the ATI 439 alloy exhibits longer time to rupture than the ATI 409HP™ alloy at stresses of 1500 psi (10.3 MPa) and lower, which is a result of the higher chromium content of the ATI 439 alloy.

Figure 1. Comparison of stress rupture properties of ATI 409HP™ and ATI 439 ferritic stainless steels



Fatigue

Fatigue tests in bending on annealed ATI 409HP™ (UNS S40900) alloy strip have shown the 10 million cycle fatigue (endurance) limit to be 30,000 to 34,000 psi (207-234 MPa). This is typical of the ATI 409HP™ alloy and is consistent with other data which show ferritic stainless steels to exhibit endurance limits typically equal to 50 to 55 percent of their tensile strengths.

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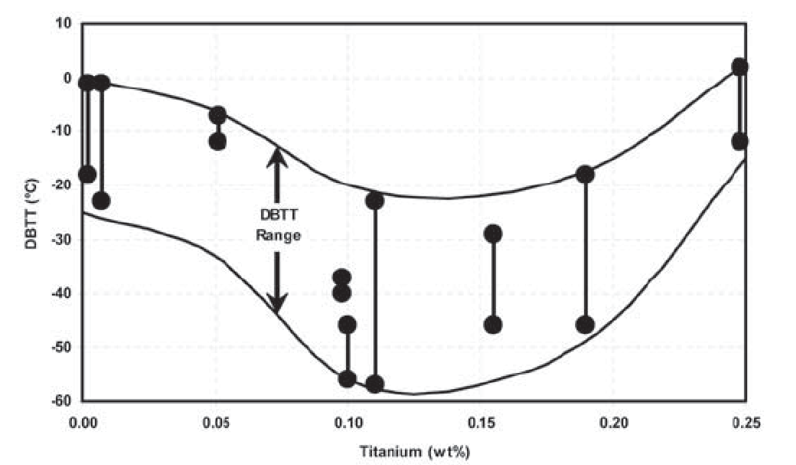
Toughness

Like other ferritic stainless steels and carbon steel the ATI 409HP™ alloy experiences a transition from ductile to brittle fracture behavior in impact loading as temperature is decreased. The temperature at which this occurs, the "ductile-to-brittle transition temperature" (DBTT), is a function of many factors including thermal processing, microstructure, state of stress, rate of loading, notch acuity, thickness, composition and material uniformity. Normally, plate gages [3/16 inch (4.77 mm) thickness and greater] of ATI 409HP™ stainless steel (UNS S40900) exhibit DBTT values which are above room temperature, i.e. 150 - 250°F (66-121°C). These high DBTT values point to possible difficulties with brittle cracking during plate fabrication. The ATI 409HP™ alloy with Cb (UNS S40930) light gage plate product [3/16 inch (5.77 mm)] has shown DBTT values much closer to room temperature or below, suggesting a distinct fabrication advantage in comparison to the standard ATI 409HP™ (UNS S40910 or S40920) product. ATI 409HP™ alloy sheet has shown a DBTT of -50°F (-46°C) in both longitudinal and transverse directions at 0.079" (2 mm) thickness. This DBTT is well below typical fabrication and use temperatures, indicating the material should behave in a ductile manner during fabrication procedures. Thinner gage sheet or strip would be expected to display even lower DBTT. The toughness of fully-stabilized ATI 409HP™ welded material varies with titanium content as shown in Figure 2 below.

Figure 2. Variations in Weld DBTT with Titanium content for 1.5 mm thick ATI 409HP™ material.



CORROSION RESISTANCE

The AL 409HP™ alloy offers substantially improved corrosion resistance in comparison to carbon steels. However, its corrosion resistance is lower in comparison to other more costly stainless steels with higher chromium, and particularly molybdenum content. Nevertheless, the AL 409HP™ alloy offers sufficient resistance to corrosion and oxidation to be used in many automotive and non-automotive applications.

Atmospheric

The ATI 409HP™ alloy, like other 11% Cr alloys, offers good resistance to corrosion in the atmosphere compared to carbon steel.

Chlorides

The ATI 409HP™ alloy offers excellent resistance to stress corrosion cracking in chloride-containing environments, in common with other ferritic stainless steels. However, the pitting and crevice corrosion resistance of ATI 409HP™ alloys in general in the presence of chlorides is minimal as illustrated by the following data in Figure3.

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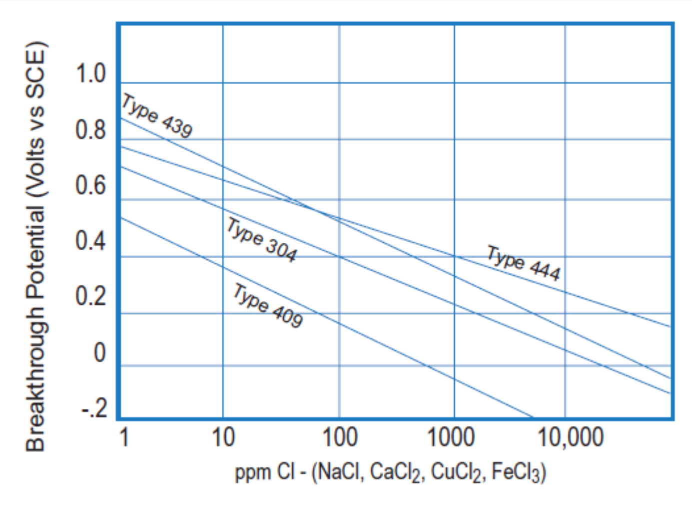
Figure 3. Pitting resistance of stainless steels



ATI 409HP™ alloy is easily pitted, as indicated by relatively low breakdown potential values in even low chloride water. Alloys with higher chromium content, such as the ferritic ATI 439 or austenitic ATI 304 alloys, both of which contain 18 percent chromium, offer substantially better pitting and crevice corrosion resistance, as indicated by higher breakdown potential values. Alloys with higher chromium and also molybdenum, such as the ATI 444 alloy (18 Cr-2 Mo), offer further improvement in pitting and crevice corrosion resistance in the presence of chlorides. This is illustrated in the table below, where the electrochemical pitting potential (Volts vs. SCE) required to initiate pitting on the ATI 409HP™ alloy in 1000 ppm chloride water at 75 °F (24°C), pH5, is compared to data for ATI 433 (20 Cr) and ATI 444 (18Cr-2Mo) ferritic alloys.

Alloy	Chromium, Weight Percent	Molybdenum, Weight Percent	Pitting Potential (Volts vs. SCE)
ATI 409HP™	11	–	0.23
ATI 433™	20	–	0.42
ATI 444™	18	2	0.52

General Corrosion

Corrosion data from boiling acid and salt solutions provide a comparison of resistance of ATI 409HP™ alloy to that of ATI 439 ferritic stainless steel and ATI 304 austenitic stainless steel in the table below.

Boiling Solution	Corrosion Rate in Inches Per Month and (Millimeters per year)					
	ATI 409HP™		ATI 439™		ATI 304™	
20% Acetic Acid	0.0101	(3.08)	0.0003	(0.09)	0.00001	(0.003)
65% Nitric Acid	0.0274	(8.35)	0.0020	(0.61)	0.0007	(0.22)
20% Phosphoric Acid	0.0017	(0.52)	0.00002	(0.006)	0.00002	(0.006)
10% Sodium Bisulfate	0.2058	(62.7)	0.00001	(0.003)	0.005	(1.53)
10% Sulfamic Acid	0.2712	(82.7)	0.00008	(0.025)	0.013	(4.0)
10% Oxalic Acid	0.1510	(46.0)	0.18	(55.0)	0.004	(1.22)

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Although ATI 439 and ATI 304 stainless steels exhibit useful corrosion resistance [0.0017 inches per month, (0.5 mm/year), or less] in many of these environments, the ATI 409HP™ alloy only offers an acceptable corrosion rate in the 20% phosphoric acid environment. ATI 409HP™ alloys are generally only suited to lower concentrations and/or lower temperatures of these and other corrosive solutions. It is advisable to request data for specific environments or test alloy coupons, to determine suitability of ATI 409HP™ alloy for the application. Contact your ATI representative for more information.

Automotive Exhaust System Environments

Two corrosion tests designed to simulate automotive exhaust system conditions were used to compare performance of ATI 409HP™ alloy with that of other ferritic alloys.

A. Exhaust System Condensate Corrosion Tests

This test is designed to simulate effects of condensates which form inside automotive exhaust systems. Samples are placed in a one liter tall form beaker containing 100 ml of a simulated exhaust system condensate consisting of water with:

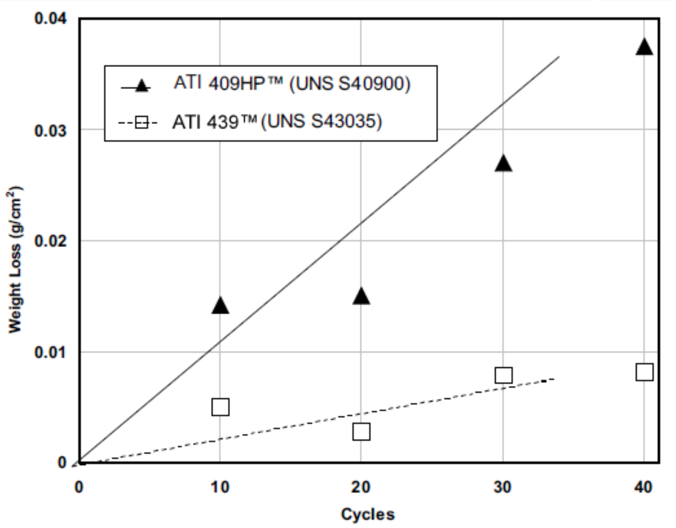
- 1000 ppm chloride ion
- 2000 ppm carbonate ion
- 3740 ppm ammonium ion
- 5000 ppm sulfate ion
- 100 ppm nitrate ion
- pH 8.7 - 8.9

The alloy sample is immersed in the beaker containing solution and then exposed to controlled temperature cycles consisting of

a) heating from ambient temperature to 482°F (250°C) in one hour,
b) holding at 482°F (250°C) for two hours,
c) cooling to ambient temperature in three hours.

Since only a solid residue remains from the original test solution following the six hour test cycle, another 100 ml of test solution is added to the beaker with the alloy sample and the cycle is repeated. Samples exposed to 10, 20, 30, 40, etc. cycles are cleaned to bare metal and weighed. Weight loss (corrosion) data for the ATI 409HP™ alloy (UNS S40900) are compared to Type 439 alloy (UNS S43035) in Figure 4.

Figure 4. Results of cyclic corrosion testing in exhaust system condensate.



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The data in Figure 4 show that Type 439 (UNS S43035) with its higher chromium content (18%) is shown to offer significantly improved corrosion resistance (lower weight loss) in comparison to ATI 409HP™ alloys. It should be pointed out that chlorides, which may be present on engine startup of new automobiles or new catalytic convertors due to carryover from catalytic converter manufacture, makes the initial condensate more aggressive than would be expected at normal automotive operating conditions.

Although the test solution is slightly alkaline when introduced into the beaker (pH about 8.8), conditions become more and more acidic with increasing number of cycles, eventually reaching pH 3 after 10 or more cycles. These acid conditions are believed to simulate conditions on the inside of an exhaust system where condensation occurs and which cause corrosion.

B. Exhaust System Cyclic Oxidation/Corrosion Tests

The outside surface of an automotive exhaust system in use is hot and exposed to air. Resistance to oxidation, therefore, is important for an exhaust system alloy. Road deicing salts may also come in contact with the exhaust system alloy. Road deicing salts may come in contact with the exhaust system alloy, so pitting and/or crevice corrosion resistance is also an important characteristic for exhaust system alloys.

ATI 409HP™ alloy and other stainless steels were exposed to a cyclic oxidation/corrosion test to provide comparative data. The test consists of heating alloy samples in air at 1200°F (649°C) for one hour followed by natural cooling in air to ambient temperature. The oxidized samples are then exposed per ASTM B117 to a 5 percent salt spray at 95°F (35°C) for 24 hours, to complete the cycle. Weight loss (corrosion) is determined at five cycle intervals. Data for ATI 409HP™ alloy following 100 cycles are compared to similar data for ferritic ATI 439 and 444 stainless steels, austenitic ATI 304 stainless steel and nickel alloy 625 below.

Cyclic Oxidation/Corrosion Test Results

Alloy		Typical Composition, Weight Percent			Weight Change (%) Following 100 Test Cycles
		Cr	Mo	Ni	
ATI 409HP™	(UNS S40900)	11	–	–	-57.4
ATI 439™	(UNS S43035)	18	–	–	-28.9
ATI 444™	(UNS S44400)	18	2	–	-8.1
ATI 304™	(UNS S30400)	18	–	8	-47.5
ATI 625™	(UNS N06625)	21	9	62	+0.1

The ATI 409HP™ alloy experienced weight loss after the first cycle in this severe test, which continued with each succeeding cycle until, after 100 cycles, more than half the sample weight was lost to corrosion. The alloys with 18 percent chromium, ATI 439 and ATI 304 alloys, experienced less but still significant weight loss. The presence of 2 percent molybdenum in addition to 18 percent chromium in the ATI 444 alloy provided the lowest weight loss (corrosion) of the stainless steels tested. Complete resistance (slight weight gain) was shown by the nickel-base ATI 625 alloy which has excellent resistance to both oxidation and corrosion by chlorides.

Intergranular Corrosion

The previous version of ATI 409HP™ alloy (UNS S40900) composition did not provide freedom from sensitization of weld heat-affected zones or base metal following certain thermal exposures. Industry reported field failures of welded automotive exhaust system components and other non-automotive fabrications like as-welded heat exchanger tubing, has occurred on ATI 409HP™ alloy even though it met the former ASTM stabilization requirement of

Ti = 6x carbon, minimum.

The failures were caused by intergranular corrosion of weld heat-affected zones.

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The new ASTM stabilization requirements have been made more stringent to dramatically improve resistance to sensitization (precipitation of chromium carbides) and the possibility of intergranular corrosion. The UNS S40930 alloy, which is stabilized with titanium and columbium, has the highest stabilization requirement of

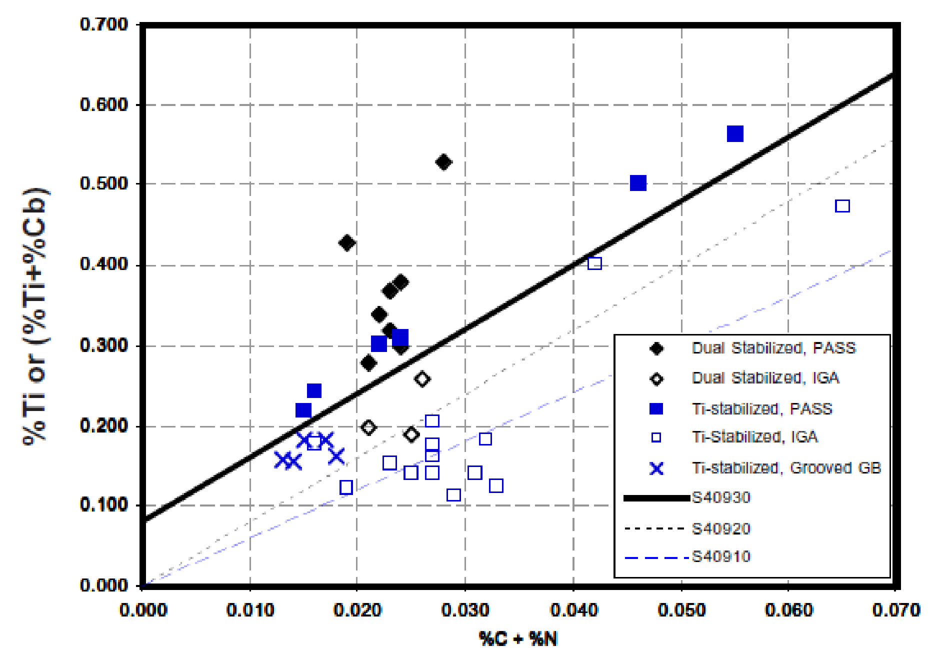
Ti + Cb≥ 0.08 + 8 (C+N).

This criterion applies to ATI 409HP™ alloys whether stabilized with titanium or titanium plus columbium, as shown in Figure 5[(1)(2)].

(1) Ref: I. A. Franson and J. D. Fritz, "Stabilization Requirements for T409 (UNS S40900) Ferritic Stainless Steel", SAE Technical Paper Series 971005 presented at the Corrosion Prevention (SP-1265) session of SAE International Congress and Exposition, Detroit, Michigan, February 24-27, 1997.

(2) J. D. Fritz and I. A. Franson, "Sensitization and Stabilization of ATI 409HP™ Ferritic Stainless Steel", Materials Protection, Vol. 36, No. 8, (1997), pp. 57-61.

Figure 5: Relation of Ti or Ti+Cb to C+N for stabilization of ATI 409HP™ ferritic stainless steel.



Thirty six commercial heats of ATI 409HP™ alloy were produced to investigate stabilization requirements. All of these heats contained titanium. Eleven of these heats also contained columbium as a stabilizing element, in addition to titanium. Unlike other ferritic stainless steels, no standard ASTM procedure for detecting chromium depletion and sensitization in 11% Cr ferritic alloys exists. Tests that do exist in ASTM A763 for higher Cr alloys are far too severe for the ATI 409HP™ alloys. Strip samples with carefully inert gas shielded autogenous gas tungsten arc (GTA or TIG) welds were exposed to a boiling Cu/6.0%CuSO4/0.5% H2SO4 solution.

ATI corrosion scientists showed this test to be able to detect chromium depletion accompanying chromium carbide precipitation in 11 percent chromium ferrite.

Results of the intergranular corrosion tests on the 36 compositions of ATI 409HP™ alloys are presented in Figure 5. It should be noted from the plotted data that 17 of the 36 heats showed evidence of intergranular corrosion (IGA) of welds and/or weld heat-affected zones, while 5 exhibited the less-severe Grain Boundary (GB) grooving response. Only the UNS S40930 stabilization formula was sufficient to prevent sensitization in all materials examined. Most commercial stabilized materials typically exhibit

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stabilization ratios significantly above the minimum requirements, and most environments are not as severe as the laboratory solution used above. Typically the S40910 or S40920 materials will thus exhibit sufficient intergranular corrosion resistance.

OXIDATION RESISTANCE

Laboratory oxidation tests provide useful information for preliminary screening or ranking of candidate alloys for various elevated temperature applications. Tests are conducted in still air, an oxidizing environment. A comparison of results from exposure of ATI 409HP™ and ATI 439 ferritic stainless steels in still air for 100 hours at various elevated temperatures is given below:

100 Hour Oxidation in Still Air

Temperature °F (°C)	Weight Gain (mg/cm^2)	
	ATI 409HP™	ATI 439™
1400 (760)	0.15	0.10
1500 (816)	0.90	0.25
1600 (871)	5.0	0.50
1700 (927)	20.0	1.00
1800 (982)	66.0	1.50
1900 (1038)	156.0	2.30

The data illustrate that ATI 409HP™ alloy with 11 % chromium provides significant resistance to oxidation up to about 1400°F (760°C). Higher temperatures lead to unacceptably high rates of scaling and loss of material. ATI 439 alloy (UNS S43035) with 18 percent chromium provides useful resistance to oxidation to at least 1600°F (871°C).

FABRICATION

The ATI 409HP™ alloy is readily formed, machined and welded using standard common procedures applicable to other stainless steels and low carbon steels.

Formability

The formability and forming procedures for ATI 409HP™ alloy have much in common with carbon steel. ATI 409HP™ alloy and carbon steel are ferritic materials, i.e. have body-centered cubic crystal structures. Metallurgical formability factors for these materials are very similar. For instance, strain hardening exponent “n” values, which are a measure of work hardenability and stretch formability, fall in the range 0.22 to 0.25 for annealed ATI 409HP™ alloy. These values also are typical of low carbon steels, indicating stretch formability for the ATI 409HP™ alloy is similar to that of low interstitial carbon steels.

Deep drawability of ATI 409HP™ alloy is also similar to that of carbon steels used for deep drawing. Average strain ratio, r-Bar, values for ATI 409HP™ alloy sheet and strip typically fall in the range 1.2 to 1.6, which indicates good deep drawability, similar to that of drawing quality carbon steel.

A forming limit diagram (FLD) for ATI 409HP™ alloy sheet or strip [0.03 to 0.05 inch (0.76-1.27 mm) thickness], is shown in Figure 6. This diagram, used in conjunction with circle grid analysis, has proven to be of great value in applying the ATI 409HP™ alloy to solving forming problems.

Due to the possibility that the DBTT of ATI 409HP™ plate may be greater than room temperature, it may be necessary to heat plate to 300 to 500°F before performing severe forming, bending or punching operations. Generous forming radii and sufficient deburring of cut edges are also beneficial to forming.

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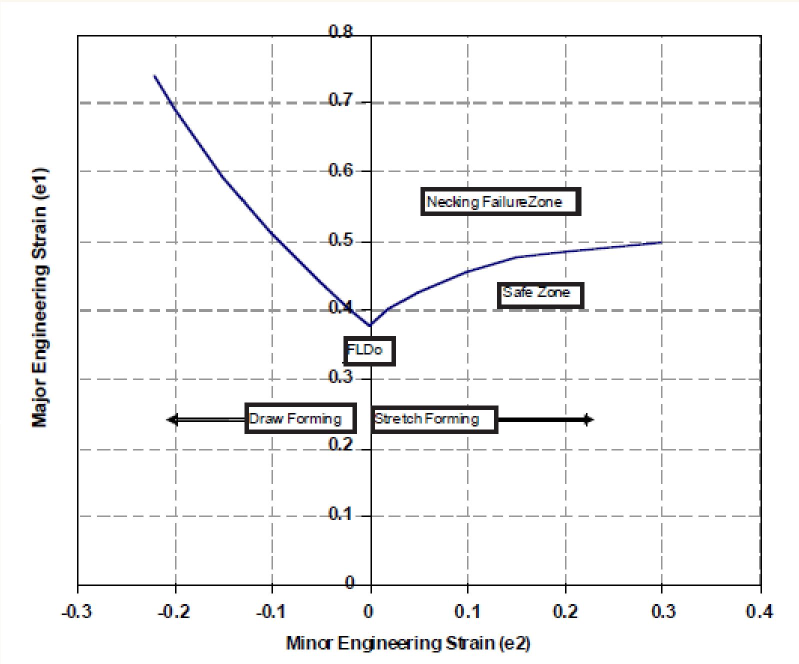
Figure 6: Forming Limit Diagram (FLD) for ATI 409HP™ (UNS S40900) sheet or strip at 0.030"-0.050" (0.76-1.27 mm) thickness.



ATI 409HP™ alloy has found extensive use in fabrication of automotive exhaust systems. Sheet products are routinely bent, sheared, blanked, punched, and perforated much like mild steel. Parts are draw- or stretch-formed into fairly complex shapes which had formerly been formed of carbon steel. Welded tubing of ATI 409HP™ alloy is routinely bent, flanged, expanded and reduced in a manner similar to when made from carbon steel. Recently, the ATI 409HP™ alloy has been used with great success with hydroforming procedures to produce desired shapes.

Machining

The machinability of ATI 409HP™ alloy compares more closely to that of carbon steel than to that of 300 Series austenitic stainless steels. A safe machining speed for the ATI 409HP™ alloy would be about 60 percent of the speed recommended for a similar machining operation on carbon steel grade B-1112, a free-machining grade often used as a standard. The presence of hard titanium and columbium (with S40930) carbonitride micro particles in the ATI 409HP™ alloy microstructure may lead to more rapid tool wear than is usually experienced with low-carbon steels.

Welding

The ATI 409HP™ alloy is readily welded using the conventional welding procedures common to carbon steel. These include high frequency, resistance, gas tungsten arc (GTAW or TIG), gas metal arc (GMAW or MIG), electron beam and laser techniques.

Although autogenous welds are common, particularly in manufacture of tubing, a filler metal, ATI 409HP™Cb, is often employed. Care should be exercised to assure the ATI 409HP™Cb weld filler metal composition is balanced to avoid martensite in the weld deposit. This could lead to excessive corrosion on the weld in comparison to ATI 409HP™ base metal, in acid environments such as automotive exhaust system condensates.

Austenitic stainless steel filler metals also are appropriate for joining the ATI 409HP™ alloy to itself, carbon steel, or austenitic stainless steels. Nickel alloy filler metals can also be considered for use with ATI 409HP™ alloy because of their more closely matching thermal expansion characteristics. Conventional inert gas (argon or helium) shielding gases are required with GTA or GMA welding processes.

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Because of its balanced chemistry and proper stabilization, the ATI 409HP™ alloy retains the corrosion resistance and mechanical properties of the base metal in the weld heat-affected zone, assuming that the weld is not contaminated with carbon and nitrogen. Contamination by carbon can be avoided taking proper steps to keep the weld clean. Contamination by nitrogen can be avoided by proper shielding with inert gases, e.g., argon or helium. Ductile-brittle transition temperatures (DBTT) of ATI 409HP™ (UNS S40900) alloy autogenous GTA weld metal, determined with sub-size Charpy v-notch impact specimens, are shown below. [3]

Alloy	DBTT Range, °F (°C)	
	0.059" (1.5 mm) Thickness	0.075" (1.9 mm) Thickness
ATI 409HP™ (A)	35 to -40 (-37 to -40)	-20 to -45 (-29 to -43)
ATI 409HP™ (B)	-51 to -69 (-46 to -56)	–

Two ATI 409HP™ (UNS S40900) compositions (Alloys A and B UNS S40930) exhibit low DBTT, demonstrating excellent weld toughness.

Brazing

The ATI 409HP™ (UNS S40930) alloy composition offers two distinct advantages in brazability in comparison to standard ATI 409HP™ (UNS S40900) alloy. First, the low titanium content of the ATI 409HP™ alloy has the advantage of minimization of titanium oxide which interferes with wettability of brazing alloys. Second, the excellent stabilization of ATI 409HP™ (UNS S40930) alloy with columbium in conjunction with the low titanium content provides strong resistance to sensitization during the braze cycle.

Procedures recommended for brazing ferritic stainless steels in general apply to ATI 409HP™ alloy as well.

SPECIFICATIONS

The ATI 409HP™ (UNS S40900) alloy is included in a number of ASTM and ASME specifications. Among these are:

Flat Rolled Products	Pipe and Tubing
	ASTM A268/A268M
ASTMA 176	ASME SA-268/SA-268M
ASTMA 240/A 240M	ASTMA 791/A 791M
ASME SA-240/SA 240M	ASTMA 803/A 803M

PRODUCT FORMS

The ATI 409HP™ stainless steel alloys are available as sheet, strip and plate product forms from ATI. Tube or pipe products using ATI 409HP™ alloy are available from tube/pipe manufacturers.

(3) Ref.: Stephen D. Washko and John F. Grubb, “The Effect of Niobium and Titanium Dual Stabilization on the Weldability of 11% Chromium Ferritic Stainless Steels”, Proceedings of International Conference on Stainless Steel 1991, Japan, ISIJ

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