PRODUCT DATA BULLETIN

409 STAINLESS STEEL

UNS S40920

- Lowest Cost Stainless
- Good Oxidation Resistance
- Good Formability
- Various Qualities Available to Meet Specific Needs

Economical Oxidation Resistance

Applications Potential

AK Steel 409 Stainless Steels are especially useful for applications requiring oxidation or corrosion protection beyond the capability of carbon steel and some coated steels.

Current uses include automotive and truck exhaust systems, including tubular manifolds, agricultural spreaders, gas turbine exhaust silencers, and heat exchangers. AK Steel 409 Stainless Steels are also useful for "difficult-to-form" hardware such as fuel filters.

AK Steel 409 Stainless Steels have the lowest price of all our stainless steels. These alloys provide an excellent combination of economy and good resistance to oxidation and corrosion for automotive exhaust and non-exhaust applications.

These stainless steels are essentially non-hardenable by heat treatment because of their titanium and low-carbon levels. The titanium additions not only stabilize the steels to prevent hardening during welding, but also prevent the formation of harmful chromium carbides.

Laboratory tests and service records show these alloys have about the same corrosion resistance as hardened Type 410 stainless steel. Welds and weld areas perform nearly as well as the base metal in corrosion resistance and forming.

Available Forms

AK Steel produces 409 stainless coils and cut lengths in thicknesses 0.015" to 0.250" (0.381 to 6.350 mm) in widths up to and including 48" (1219 mm). For welded applications over 0.120" (3.048 mm) thick, AK Steel Type 409 Ni Stainless Steel will provide improved toughness and weldability.

The surface finish of 409 stainless is obtained by annealing and pickling after rolling. The pickled surface is relatively dull and, like other titanium stabilized stainless steels, it may have some cosmetic titanium streaks. Therefore, where a uniform surface finish is required, these stainless steels may not be satisfactory. In cases where surface appearance is important, and titanium streaks are objectionable, AK Steel 400 Stainless Steel should be considered.

AK Steel also offers 409 stainless steels especially suited for special quality requirements. These specially routed versions provide benefits such as cold work embrittlement resistance, low roping, low ridging, high resistance to thinning or deep drawing at minimal extra cost.

Composition

	ASTM A240 UNS S40920 %	AK Steel 409 %
Carbon	0.03 max	0.02 max
Manganese	1.00 max	0.75 max
Phosphorus	0.040 max	0.040 max
Sulfur	0.02 max	0.020 max
Silicon	1.00 max	1.00 max
Chromium	10.50 - 11.70	10.50 - 11.70
Nickel	0.50 max	0.50 max
Nitrogen	0.03 max	0.02 max
Titanium	8x(C+N) min 0.15 - .50	8x(C+N) min 0.15 - .50

Metric Practice

The values shown in this bulletin were established in U. S. customary units. The metric equivalents of U. S. customary units shown may be approximate. Conversion to the metric system, known as the International System of Units (SI), has been accomplished in accordance with ASTM E380.

The newton (N) has been adopted by the SI as the metric standard unit of force. The term for force per square meter (N/m^2). Since this can be a large number, the prefix mega is used to indicate 1,000,000 units and the term meganewton per square meter (MN/m2) is used. The unit (N/m^2) has been designated a pascal (Pa). The relationship between the U. S. and the SI units for stress is: 1000 pounds/in^2 (psi) = 1 kip/in^2 (ksi) = 6.8948 meganewtons/m^2 (MN/m^2) = 6.8948 megapascals (MPa). Other units are discussed in ASTM E380.

Mechanical Properties

Table 1

Typical Mechanical Properties
(Annealed Condition)

	ASTM A240 UNS S40920	AK Steel 409 0.040" - 0.070" (1.016 - 1.778 mm)
Ultimate Tensile Strength, ksi (MPa)	55 (379) min	60 - 68 (414 - 469)
0.2% Yield Strength, ksi (MPa)	25 (172) min	35 - 41 (241 - 283)
Elongation, % in 2" (50.8 mm)	20 min	31-39
Hardness, Rockwell	B88 max	B66-B72

Table 2

Properties Acceptable for Material Specification
0.041" to 0.075" (1.04 to 1.78 mm)

UTS, ksi (MPa)	55 min (345)
0.2% YS, ksi (MPa)	30 min (207)
Elongation, % in 2"	25 min
Hardness, Rockwell	B76 max

Table 3

Density, lb/in^3 (kg/m^3)	0.280 (7740)
Specific Electrical Resistance microhm-cm	60.0
Modulus of Elasticity in Tension at room temperature psi (MPa)	30.2 x 10^6 (20.8 x 10^4)

Table 4

Effect of Cold Work on Mechanical Properties
0.078" (1.98 mm) Thick Initial Gauge

Condition	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell
Annealed	64.4 (444)	37.5 (258)	35.8	B69.2
Cold Worked 5%	67.2 (463)	57.5 (396)	25.2	B83.5
Cold Worked 10%	74.5 (514)	73.5 (505)	16.0	B87.0
Cold Worked 16.4%	82.1 (566)	81.3 (580)	9.5	B90.8
Cold Worked 32.5%	99.3 (685)	96.4 (665)	–	B95.8
Cold Worked 45.4%	104.4 (719)	102.1 (704)	3.0	B97.2

Table 5

Effect of 900ºF (492ºC) on Room-Temperature Properties and
Room-Temperature Properties after 30% Cold Work

Unlike higher alloyed ferritic stainless steels, AK Steel 409 Stainless Steels annealed and cold worked do not show any detrimental effect on ductility after exposure of up to 1,000 hours within the 885ºF (474ºC) embrittlement range.

Condition	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell
Annealed	64.4 (444)	37.5 (258)	35.8	B69.2
Annealed + 10 hrs @900ºF (492ºC)	64.0 (441)	38.4 (265)	35.0	B70.0
Annealed + 100 hrs @900ºF (492ºC)	64.2 (443)	39.3 (271)	35.0	B71.5
Annealed + 1000 hrs @900ºF	64.8 (447)	39.8 (275)	34.0	B70.2
Cold Worked 30%	99.3 (685)	96.4 (631)	–	B95.8
Cold Worked 30% + 100 hrs @ 900ºF (492ºC)	99.5 (687)	96.6 (632)	13.0	B98.5

Table 6

Typical Short-Time Elevated-Temperature Properties
(Average of duplicate tests on randomly selected coils)

Temperature ºF	Temperature ºC	UTS ksi (MPa)	0.2% YS ksi (MPa)
Room		59.0 (407)	33.9 (233)
400	204	52.0 (358)	25.0 (172)
700	427	48.0 (330)	23.0 (159)
1000	538	34.9 (241)	17.4 (120)
1200	649	22.8 (157)	12.5 (86)
1300	704	10.6 (73)	7.5 (52)
1400	760	6.1 (42)	4.4 (30)
1500	816	4.2 (29)	3.0 (21)
1600	871	3.0 (21)	2.4 (16)

Table 7

Elevated-Temperature Fatigue Strength (Tension/Tension R=0.1)

Temperature °F	°C	Fatigue Strength to Surpass 10^7 Cycles ksi (MPa)
70	21	47 (324)
700	371	45 (310)
1100	593	17.0 (117)
1300	704	5.0 (34)
1500	816	1.5 (10)

Table 8

Stress Rupture Properties
0.045" – 0.060" (1.14 – 1.52 mm)

Temperature		Maximum Stress to Failure, ksi (MPa)	
°F	°C	100 hours	1000 hours
1300	704	4.1 (27.5)	3.2 (22.0)
1500	816	1.5 (10.3)	0.9 (6.2)

Physical Properties

Figure 1: Specific Heat

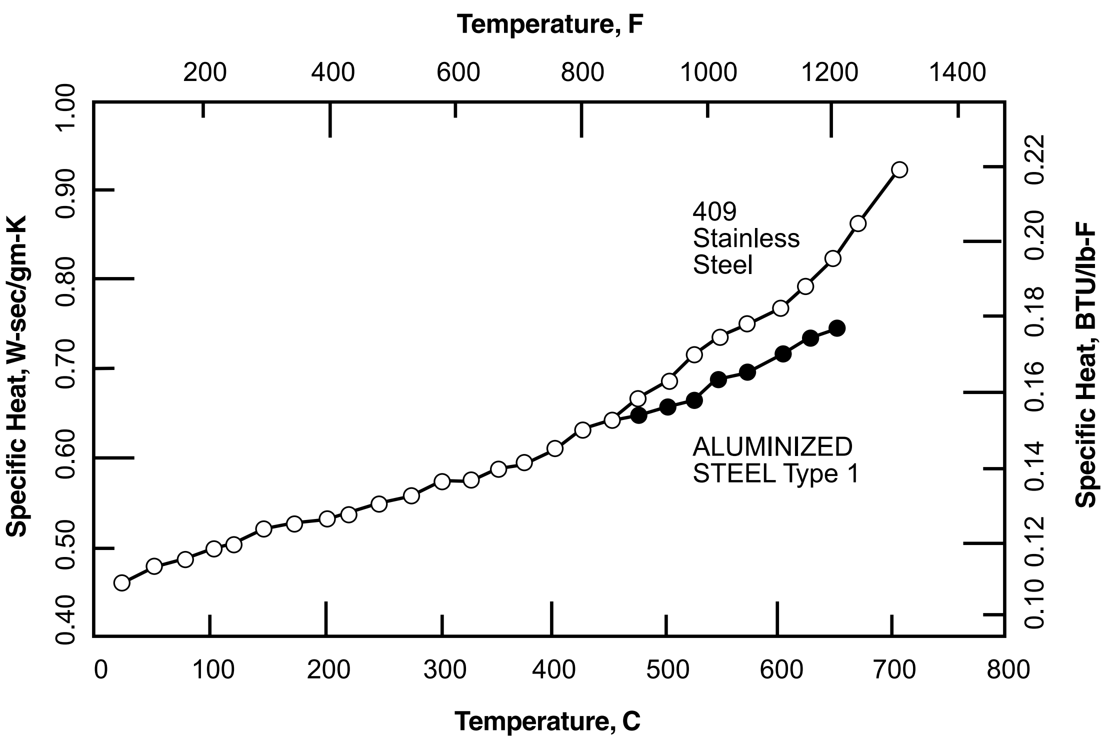


Figure 2: Elevated Temperature Thermal Expansion Data

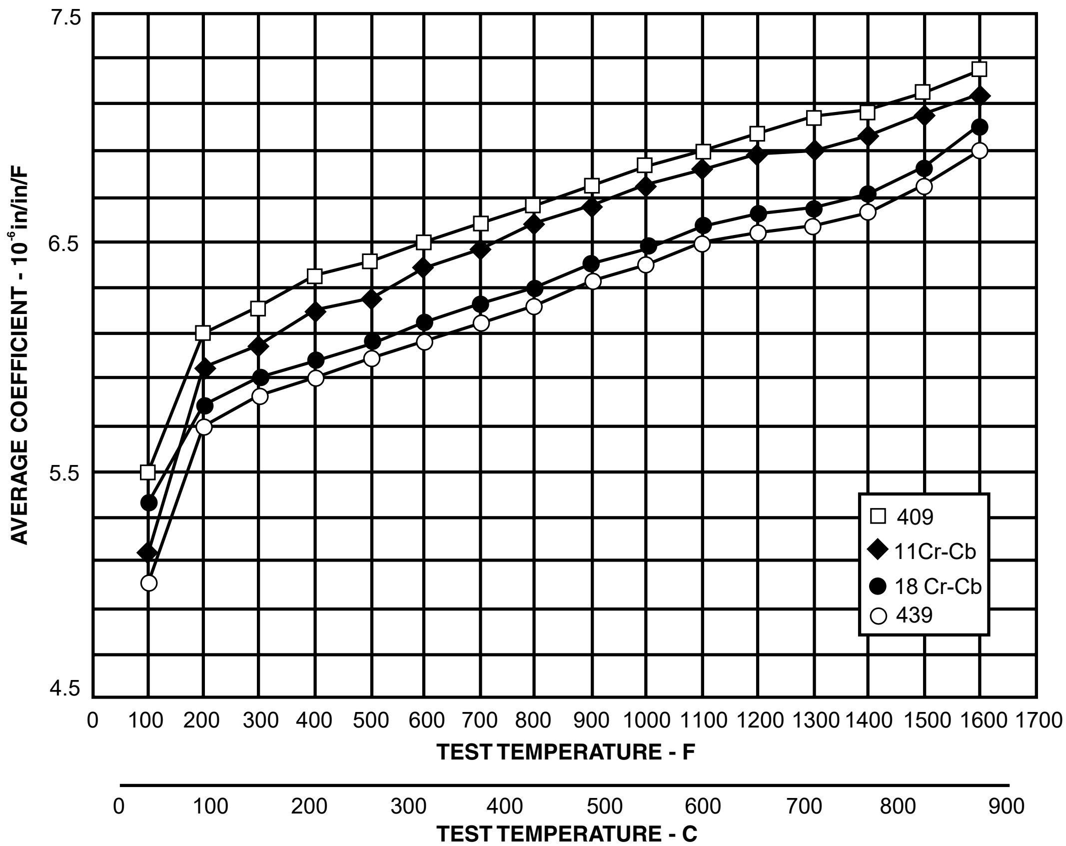


Table 9: Thermal Conductivity, Specific Heat And Diffusivity

Temperature		Conductivity		Specific Heat		Diffusivity	
°F	°C	W/(m-°K)	BTU/(hr-ft-°F)	J/(Kg-°K)	BTU/(lb-°F)	mm2/sec	ft2/hr
73	23	25.7	14.8	466	0.111	7.26	0.281
212	100	25.8	14.9	492	0.118	6.90	0.267
392	200	26.4	15.2	529	0.126	6.55	0.254
572	300	27.1	15.7	567	0.135	6.29	0.244
752	400	26.9	15.6	608	0.145	5.82	0.226
932	500	27.5	15.9	680	0.162	5.31	0.206
1112	600	26.9	15.5	767	0.183	4.61	0.179
1292	700	25.4	14.7	921	0.220	3.62	0.140
1472	800	30.7	17.7	882*	0.211	4.57	0.177
1598	870	32.3	18.7	846*	0.202	5.02	0.194

* EXTRAPOLATED VALUES

Table 10: Modulus of Elasticity Test Data

E = average Young's modulus of elasticity at temperature, based on triplicate longitudinal sample tests.

Temperature °F	Temperature °C	Test E psi x 10^6	Test E MPa x 10^4	ASME[1] E psi x 10^6	ASME[1] E MPa x 10^4
70	21	30.2	20.8	29.2	20.1
200	93	29.4	20.3	28.5	19.6
300	149	–	–	27.9	19.2
400	204	28.9	19.9	27.3	18.8
500	260	–	–	26.7	18.4
600	316	27.9	19.2	26.1	18.0
700	371	–	–	25.6	17.6
800	427	26.1	18.0	24.7	17.0
900	482	–	–	23.2	16.0
1000	538	23.5	16.2		
1200	649	16.6	11.4		

Notes: (1) Data from 1989 ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Table AMG-2, Cromium steels 12Cr - 17Cr (Group F). Note that 409 is nominally 11Cr.

Corrosion Resistance

In general, the corrosion resistance of AK Steel 409 Stainless Steel is about the same as Type 410 stainless steel. This is confirmed by standard and special corrosion tests, as well as extensive service experience. Tests also have been conducted to simulate exhaust system conditions as shown in the Figures that follow.

Corrosion resistance of welds and weld areas is nearly comparable to that of the base metal. In this respect, AK Steel 409 stainless is superior to Type 410 stainless steel because welding does not greatly impair the corrosion resistance of weld areas prone to chromium carbide sensitization.

AK Steel 409 stainless contains a certain number of surface inclusions which are the normal result of titanium stabilization additions to improve the steel. Occasionally, rusting may occur at these inclusion sites and lead to problems with cosmetic appearance. As a result, this steel is not suggested for applications where surface appearance is a factor.

Figure 3a: Cold End Salt Corrosion: Bold Exposure

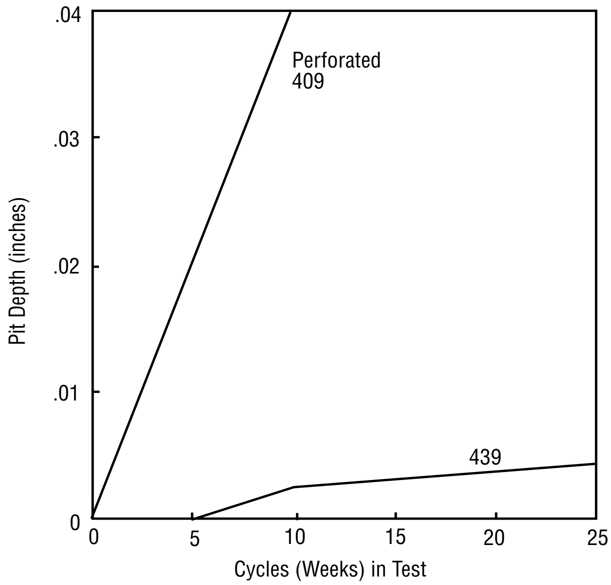
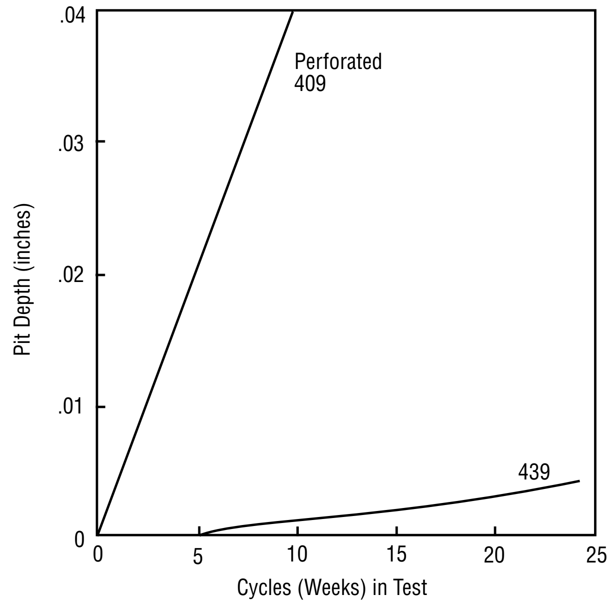


Figure 3b: Cold End Salt Corrosion: in Crevice



Cold End Synthetic Salt Corrosion Test

1 Test Cycle = 1 Week **Daily**...15 minute dip in 5% NaCl and air dry for 1.25 hours...humidity cabinet at 85% RH for 22.5 hours. Temperature is cycled through 95 to 140°F eight times in 22.5 hours. **Once a week**...1 hour at 600°F.

Figure 4a: Synthetic Condensate Corrosion: Bold Exposure

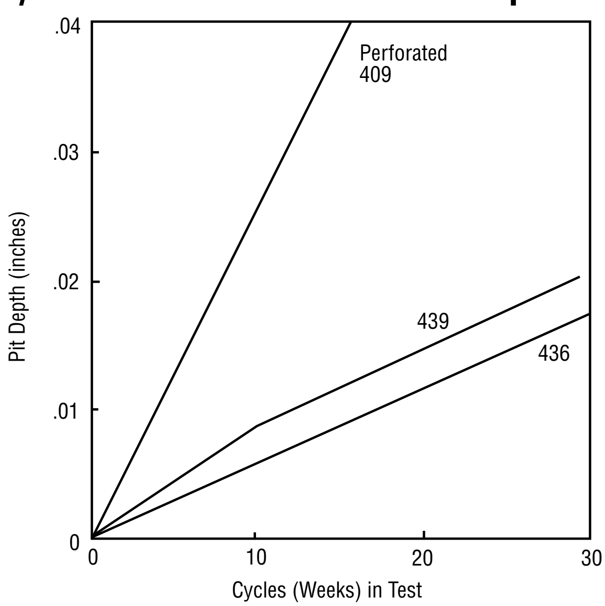
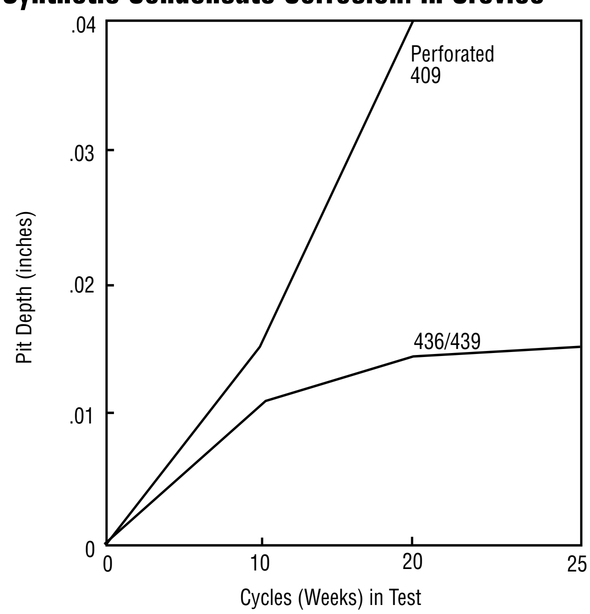


Figure 4b: Synthetic Condensate Corrosion: in Crevice



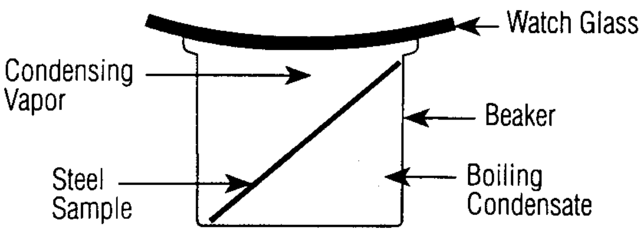
Cold End Synthetic Condensate Corrosion Test

1 Test Cycle = 1 Week **Daily**...15 minute dip in a solution of 5000 ppm sulfate and 50 ppm chlorides at pH 2.5 and air dry for 1.25 hours...humidity cabinet at 85% RH and 140°F for 22.5 hrs. **Once a week**...1 hour at 600°F.

General Note: ALT1 Carbon Steel is not included above. It does not fail by pitting but fails due to general and/or galvanic corrosion at welds, cut edges and cold worked areas. Field experience shows ALT1 durability to be approximately 50% that of T409.

Boiling Beaker Internal Condensate Corrosion Comparisons

Figure 5



Test setup:

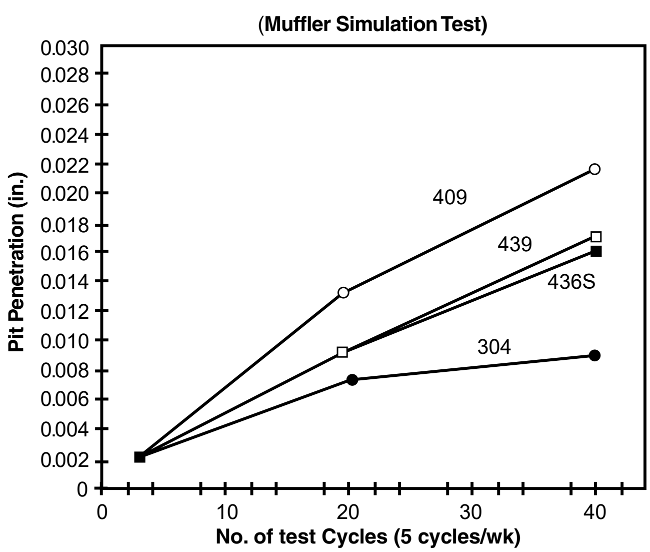
Partial immersion of 3"x4" coupon in synthetic condensate

Test solution:

5000 ppm SO_4^{-3}
100 ppm Cl^-
100 ppm NO_3^-
100 ppm HCOOH…Initial pH 5.3-5.5…Final pH 3.3-3.5

Test cycle procedure:

Boil condensate 16 hours, then heat 1 hour at 500°F
Expose 6 hours in 85% humidity at 125°F



High Temperature Salt Corrosion Resistance

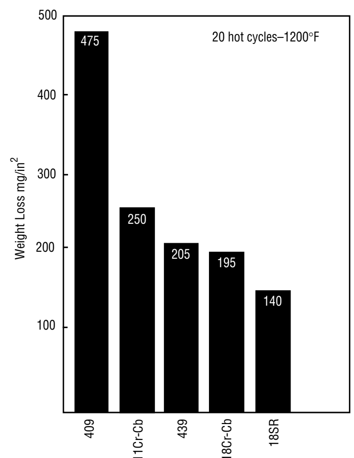
The following two accelerated lab tests were designed to simulate hot end (downpipe and converter) operating conditions.

Figure 6a: Test 1 evaluates the effect of residual salt reacting with exhaust components at elevated temperatures.

Figure 6b: Test 2 evaluates the effect of exterior salt reacting on an exhaust component at ambient temperatures after being exposed to high temperatures where thicker oxide layers developed.

Figure 6a: Test 1

Hot Salt Corrosion



Test Procedure:

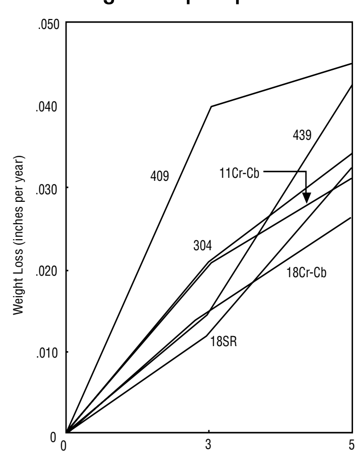
Sheet sample with 90° bend and 0.2"
Olson cup dome

Hot cycle:

dip 5 min. in 5% NaCl and then expose 1200°F/90 min.
water quench 1 min.
…repeat 4 times/day…
humidity (85%RH/ 140°F) 18 hours/day

Figure 6b: Test 2

Ambient Salt Corrosion
After High Temp Exposure



Test Procedure:

Sheet sample

Daily:

15 min. dip in 5% NaCl
air dry 1.25 hrs....humidity (85%RH/140°F)
22.5 hrs.

Weekly:

1400°F/1hr.
1 test cycle = 1 week

Oxidation Resistance

The temperature at which AK Steel 409 Stainless Steels start to exhibit destructive scaling in air is 1450°F (789°C). This is considered the general maximum service temperature for continuous exposure in air. However, maximum service temperatures will vary appreciably, depending on the atmospheres involved.

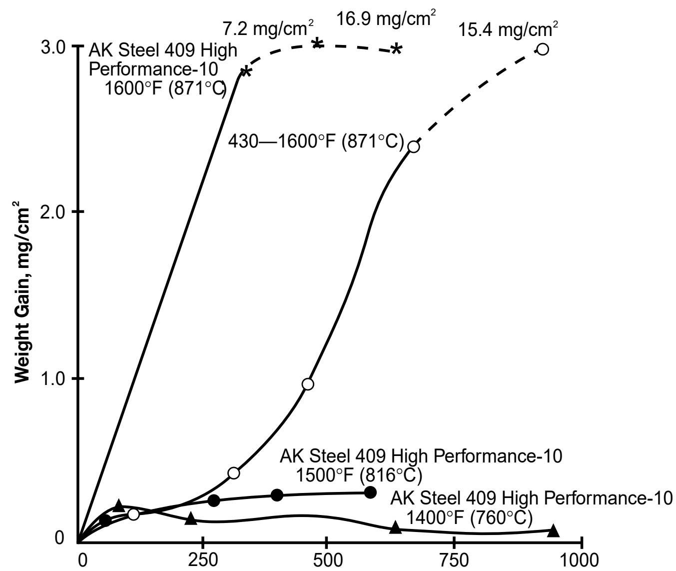
Table 11

Continuous Service Scaling Tests

	Typical Weight Gain, mg/in²* Temperature, °F (°C)	
Alloy	1400 (760)	1550 (843)
AK Steel 409	0.33 to 0.44	0.78 to 0.99
Type 430	0.22 to 0.31	0.78 to 1.01
Type 304	0.19 to 0.26	0.51 to 0.57

*Constant temperature for 100-hour exposure in air.

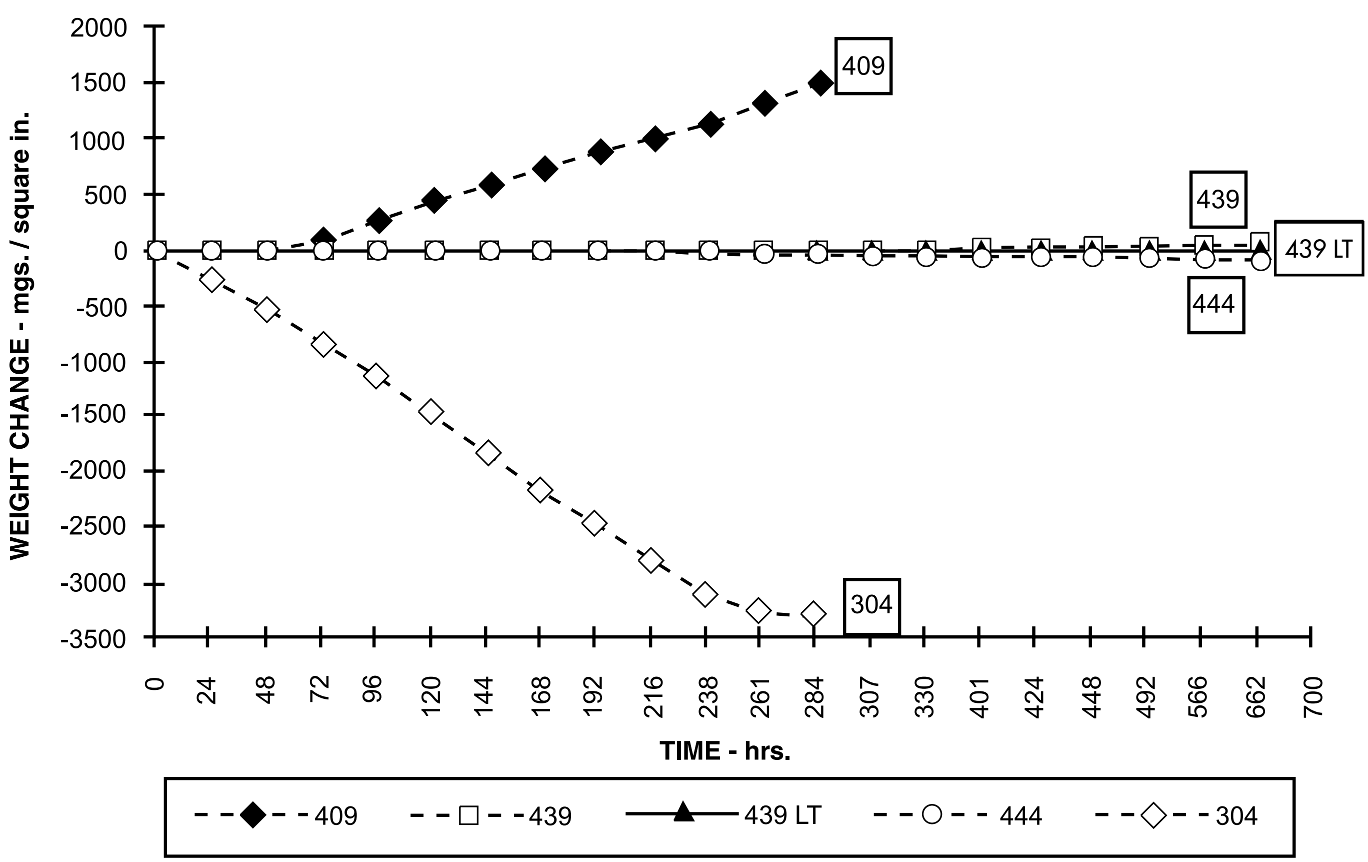
Figure 7: Cyclic Service Scaling Tests*



*Cyclic Oxidation Resistance in a Combusted Gas Atmosphere—Cycle of 25 Minutes Heat/5 Minutes Cool.

Figure 8: Cyclic Oxidation Tests at 1700°F

30 min. cycle (25 min. heat - 5 min. cool)



Fabrication

AK Steel 409 Stainless Steels provide good fabricating characteristics and can be cut, blanked and formed without difficulty. These steels provide fabricating characteristics that are much improved when compared to standard ASTM A240 Type 409 stainless steel. Brakes and presses used normally on carbon steel can be used on AK Steel 409 Stainless Steels.

Forming practices indicate that sheet 0.050" to 0.187" (1.27 mm to 4.75 mm) requires a minimum bend radius equal to the metal thickness, 1T; and material over 0.187" (4.75 mm), a radius of 1-1/2 T.

Table 12

Cyclic Scaling With Temperature Variations expressed in weight loss (mgs/in^2)

1500°F (816°C) Cycles of 25 min. heat - 5 min. cool
1650°F (899°C) Excursions cycles daily for 2 hrs.

Alloy	564 cycles 1500°F (816°C)	564 cycles 1500°F/ 10 cycles 1650°F (899°C)
409	9.7	10.3
439	1.4	2.9
11Cr-Cb	1.4	2.4
304	-141	-253

While 1450°F (789°C) is considered the practical upper temperature oxidation service limit, brief excursions above 1600°F (871°C) can be tolerated.

Note the austenitic 304 alloy shows large negative weight changes indicating oxide spalling due to thermal expansion differences between the oxide and base metal.

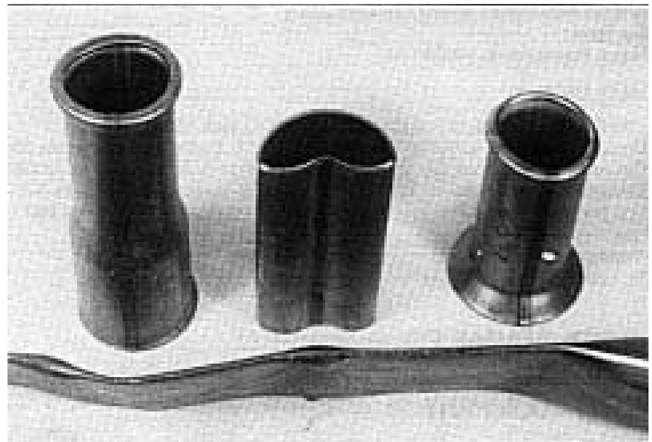
Standard forming tests show a typical Olsen Cup Height value of 0.400" (10.16 mm) and a Limiting Draw Ratio of 2.20 for AK Steel 409 Stainless Steels.

At times, forming ability has been affected by temperature – in particular ductile-to-brittle transition temperatures (DBTT). AK Steel 409 Ni Stainless Steel offers improved resistance to brittle impact fractures at lower temperatures. The DBTT for hot-rolled 0.200" (5.08 mm) thick material is below -20ºF (-29ºC), while after cold rolling to 0.075" (1.9 mm) thick material and annealing, the DBTT is below -75ºF (-59ºC).

AK Steel 409 Stainless Steel offers benefits in tubing applications. Using 409 stainless with notably improved levels of formability in exhaust tubing in the as-high frequency welded condition is shown in the following photograph (Figure 9).

The plastic strain ratio or r_m ($\bar{r}$) value may be thought of as a material's resistance to thinning during drawing or tube bending operations. The higher the value, the greater the resistance to tearing or thinning. These stainless steels have a typical r_m ($\bar{r}$) value of 1.1 to 1.7 based on chemistry and processing variations to control properties.

Figure 9



Welding

AK Steel 409 stainless is readily welded by arc welding processes. When gauge thickness and weld joint geometry permit the use of gas shielded metal-arc welding, joints having good properties are easily obtained. The electrode wires most often suggested are AWS ER309 or ER308L austenitic stainless steel when the application does not include exposure to high temperatures. AWS ER309 or ER308L stainless wire may also be employed for joining these stainless steels to mild steel. Thin wall components for elevated-temperature service should be weld fabricated with a matching weld filler such as 409 Cb. AWS ER430 and W18 Cr-Cb filler wires are suitable alternatives.

b