439 STAINLESS STEEL

UNS S43900

AK Steel

- More Oxidation Resistant Than Type 409
- More Corrosion Resistant Than Type 409

Applications Potential

Oxidation resistance and corrosion resistance superior to Type 409 make AK Steel 439 attractive for numerous automotive exhaust applications. Suggested applications include tubular manifolds and other exhaust system areas where temperatures may exceed the oxidation limit of Type 409 or where aqueous corrosion resistance, particularly to chlorides, is needed.

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AK Steel 439 is a ferritic stainless steel that outperforms Type 409 in both oxidation resistance and corrosion resistance. Special adjustment to chemical composition combined with special processing give this alloy excellent formability that is reproducible, coil after coil and heat after heat. This provides special advantages when producing difficult-to-form exhaust system components.

Composition

	ASTM A 240 UNS S43035 %	AK Steel 439 %
Carbon	0.07 max.	0.025 max.
Manganese	1.00 max.	0.50 max.
Phosphorus	0.040 max.	0.040 max.
Sulfur	0.030 max.	0.030 max.
Silicon	1.00 max.	0.75 max.
Chromium	17.0-19.0	17.0-19.0
Nickel	0.50 max.	0.50 max.
Nitrogen	0.04 max.	0.030 max.
Titanium	≥ 0.20 + 4(C+N) - 1.10 max.	≥ 0.20 + 4(C+N) - 0.50 max.
Aluminum	0.15 max.	0.15 max.

Available Forms

AK Steel 439 is available in thicknesses from .015" to 0.100" (0.38 to 2.54 mm) in widths up to and including 48" (1219 mm). For other sizes, inquire.

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 unit of area (stress) is the newton 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/m^2) 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 = 1 kip/in^2 (ksi) = 6.8948 meganewtons/m^2 (MN/m^2) = 6.8948 megapascals (MPa).

Mechanical Properties

Table 1

Typical Mechanical Properties

UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell B
66 - 70 (455 - 483)	43 - 48 (296 - 331)	32 - 36	74 - 78

Table 2

Properties Acceptable for Material Specifications (per ASTM A 240)

UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell B
60 (414) min.	30 (207) min.	22 min.	89 max.

Table 3

Effect of Cold Work on Mechanical Properties

Condition	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell
Annealed	70.0 (483)	44.0 (303)	35.0	B77.0
Cold Worked 5%	77.5 (534)	73.0 (503)	22.0	89.2
Cold Worked 10%	87.1 (601)	84.9 (585)	9.0	93.0
Cold Worked 14.8%	94.0 (640)	91.9 (633)	6.0	95.0
Cold Worked 29.9%	105.9 (730)	103.7 (715)	4.0	97.0
Cold Worked 45.4%	115.3 (795)	113.0 (779)	3.0	C20.0

Table 4

Effect of 900°F (482°C) Properties Exposure on Room Temperature Mechanical Properties

Condition	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Hardness Rockwell
Annealed	70.0 (483)	44.0 (303)	35.0	B77.0
Annealed + 10 hours @900°F (482°C)	72.7 (501)	48.8 (337)	33.5	B80.5
Annealed + 100 hours @900°F (482°C)	90.0 (621)	74.2 (511)	25.2	B93.0
Annealed + 100 hours @900°F (482°C)+ 1 hour @ 1100°F (593°C)*	71.1 (491)	45.8 (316)	32.0	B79.0
Annealed +1000 hours @900°F (482°C)	114.4 (768)	98.2 (677)	21.5	C20.0
Cold Worked 30%	105.9 (730)	103.7 (715)	4.0	B97.0
Cold Worked 30% + 100 hours @900°F (482°C)	123.2 (849)	115.2 (794)	13.2	C25.2
Cold Worked 30% + 100 hours @900°F (482 °C) + 1 hour @1100 °F (593°C)*	105.2 (725)	96.4 (665)	12.0	B99.0

*All values are average of duplicate tests except * denotes a single test.

Table 5

Short-Time Elevated Temperature Strength

Alloy	Property	Temperature, °F (°C) 1000 (538)	1200 (649)	1400 (760)	1500 (816)	1600 (876)
409	UTS, ksi (MPa)	34.9 (240)	22.8 (157)	6.1 (42)	4.2 (29)	3.0 (21)
	0.2% YS, ksi (MPa)	17.4 (120)	12.5 (86)	4.4 (30)	3.0 (21)	2.4 (17)
439	UTS, ksi (MPa)	37.8 (260)	18.0 (124)	6.1 (42)	4.4 (30)	3.2 (22)
	0.2% YS, ksi (MPa)	21.5 (148)	12.2 (84)	4.6 (32)	3.4 (23)	2.6 (18)
Type 304*	UTS, ksi (MPa)	56.0 (386)	45.0 (310)	28.0 (193)	23.0 (159)	16.5 (114)
	0.2% YS, ksi (MPa)	18.0 (124)	16.0 (110)	13.5 (94)	12.0 (83)	10.0 (69)
ALUMINIZED STEEL Type 1	UTS, ksi (MPa)	20.7 (144)	10.3 (71)	5.4 (37)	4.0 (28)	3.6 (23)
	0.2% YS, ksi (MPa)	15.2 (104)	88.1 (56)	3.7 (27)	3.2 (22)	2.0 (14)

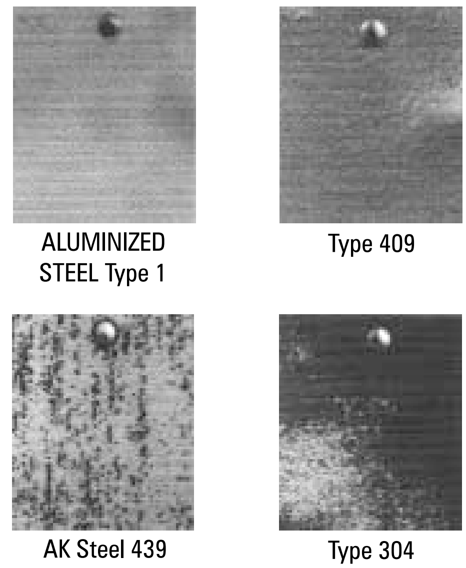
*From "Mechanical & Physical Properties of the Austenitic Chromium-Nickel Stainless Steels at Elevated Temperatures," INCO, 1963, Page 3.

Table 6
Elevated Temperature Fatigue Strength

Fatigue Strength to Surpass 10^7 Cycles ksi (MPa)

Temperature, °F (°C)	409	AK Steel 439
1300 (704)	5.0 (34)	4.0 (28)
1500 (816)	1.5 (10)	1.4 (10)

Figure 1
1700°F (927°C) Cyclic Oxidation
2044 Cycles



Visual Comparison of Cyclic Oxidation Coupons after 1022 hours of testing at 1700°F (927°C).

Table 7
Stress Rupture Properties

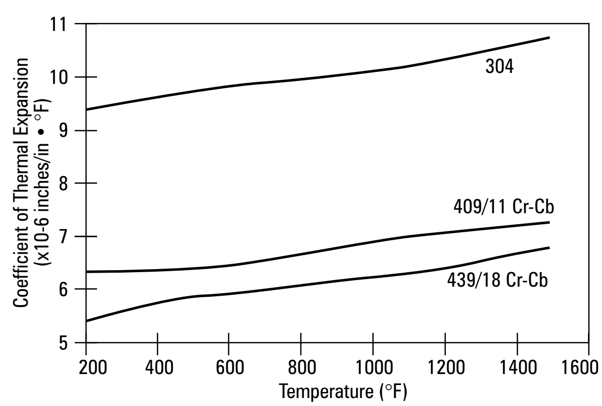
Temperature, 1300°F (704°C)		Temperature, 1500°F (815°C)	
Stress, ksi (MPa) 100 Hours	Stress, ksi (MPa) 1,000 Hours	Stress, ksi (MPa) 100 Hours	Stress, ksi (MPa) 1,000 Hours
4.0 (27.5)	3.0 (20.7)	1.6 (11.0)	1.0 (6.9)

Physical Properties
Density 0.278 lbs/in³ (7685 kg/m³)
Electrical Resistivity 24.80 µohm-in

Young's Modulus versus temperature, psi (Mpa)

Temperature, °F (°C)	Young's Modulus
70 (21)	$28.4 \times 10^6 (193 \times 10^3)$
300 (148)	$27.4 \times 10^6 (190 \times 10^3)$
500 (260)	$26.6 \times 10^6 (183 \times 10^3)$
700 (427)	$26.2 \times 10^6 (181 \times 10^3)$
900 (482)	$24.5 \times 10^6 (169 \times 10^3)$
1100 (593)	$22.3 \times 10^6 (154 \times 10^3)$
1300 (704)	$20.1 \times 10^6 (139 \times 10^3)$

Figure 2
Coefficient of Thermal Expansion
Versus Temperature

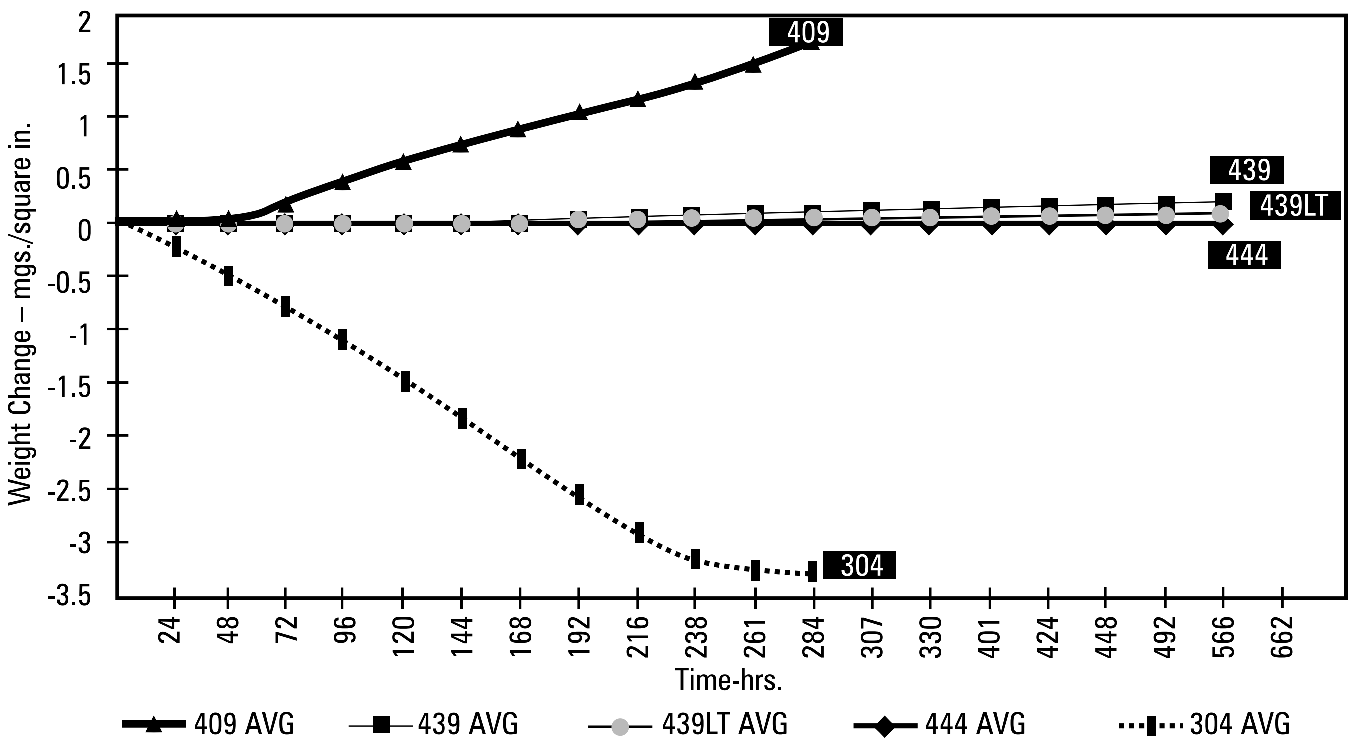


Oxidation Resistance

Results of cyclic oxidation tests of ALUMINIZED STEEL Type 1 and Type 409, AK Steel 439 and Type 304 stainless steels are shown in Figures 1 and 2 and Table 7. AK Steel 439 exhibits considerably better oxidation resistance than Type 409 at the 1700°F (927°C) temperature.

Figure 3

1700°F (927°C) Cyclic Oxidation 1022 hours of exposure



Corrosion Resistance

AK Steel 439 Stainless Steel exhibits better corrosion resistance in synthetic muffler condensate than Type 409. Test results are shown in Figure 3.

Table 8

Pitting Potential

Alloy	Potential vs. Ag/AgCl@p(E) = 0.8, mV
409	180
439	300
436S	600
304	750

The critical pitting potential (CPP) was determined by determining the pitting potential (E_{pit}) of 25 to 35 different samples for each material potentiodynamically in 3.5% NaCl (VWR Scientific) and plotting the probability of pitting as a function of potential. The CPP was defined as the potential at 80% probability of pitting. All tests were performed in a flooded gasket cell to minimize crevice corrosion at the sample/cell interface. An Ag/AgCl (SSC) reference electrode and graphite counter electrode were used. Prior to scanning, the solution was deaerated for 10 minutes via N_2 purging. The scan rate used was 0.5 mV/second and the exposed sample area was 1 cm_2. Prior to testing, all samples were degreased in hot alkaline cleaner, rinsed with deionized water and dried with forced air.

Figure 4

Continuous Condensate Corrosion Test

Prior to exposure to the condensate solution, samples were oxidized at 585°F (343°C) for five hours. Half the length of the 3.5 inch by 1.5 inch (8.9 x 3.8 cm) coupons were immersed in 500 ml of condensate. Condensate levels in each flask were kept constant by means of water chilled glass condenser tops. Temperature of the condensate was maintained at 112°F (80°C) through the used of a constant temperature bath. Samples of the same material were removed periodically and the pit depths measured using a calibrated optical microscope using ASTM G46. Average pit depths were calculated by taking an average of the ten deepest pits.

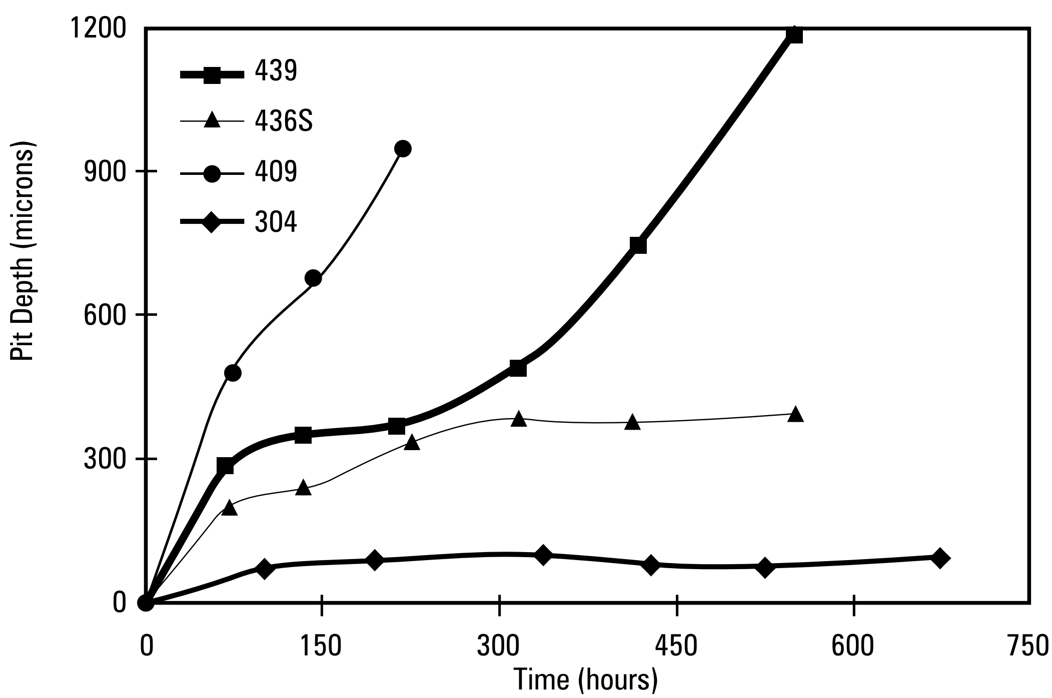


Figure 5

Cyclical Corrosion Test
(Cold End Exhaust Comparative Test)

4" x 2" (10.2 x 5.1 cm) panels were exposed to 436°F (260°C) for one hour once every week, and subjected to six hour cycles in salt solution for 15 minutes followed by drying for 20 minutes at 40°F (4°C) and 35% relative humidity followed by five hours and 25 minutes of 85% relative humidity exposure at 76°F (24°C) for the remainder of the week.

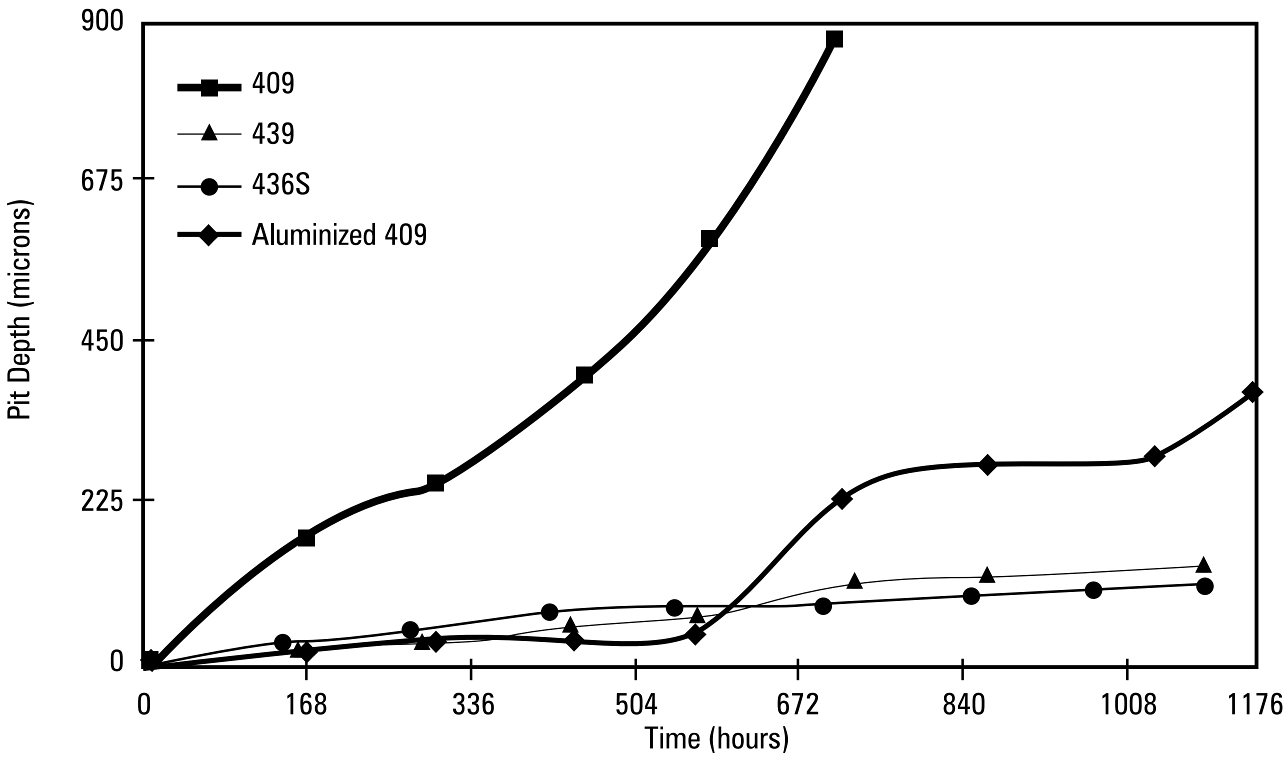


Figure 6

Cyclical Test
(Hot End Exhaust Comparative Test)

6" x 4" (15.2 x 10.2 cm) panels were tested as follows:

Monday through Friday – 4 cycles per day

Cycle 1: one hour at 936°F (538°C) and water quenched

Cycles 2, 3, 4, 5: one hour at 936°F (538°C), cooled one hour, immersed in 5% NaCl for five minutes.

Evening and Weekend: Cycled between 35% relative humidity at 40°F (4°C) for two hours and 85% relative humidity at 76°F (24°C) for two hours.

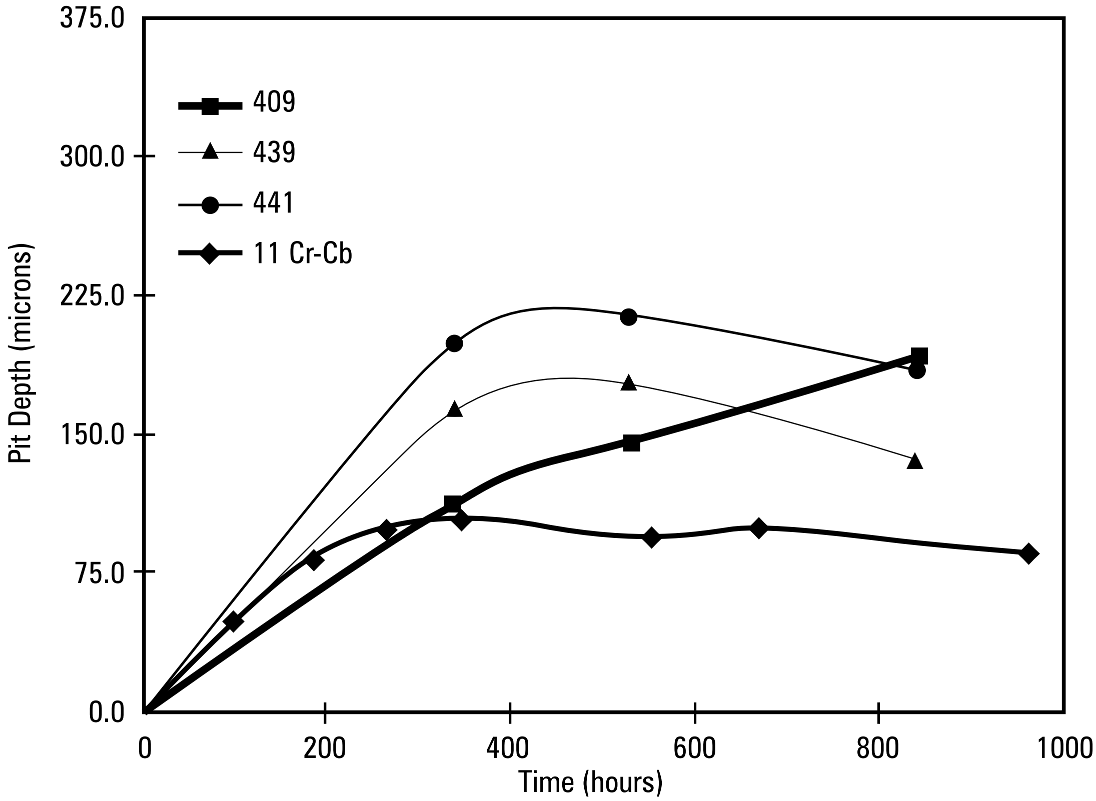


Figure 7

Cyclical Test
(Hot End Exhaust Comparative Test)

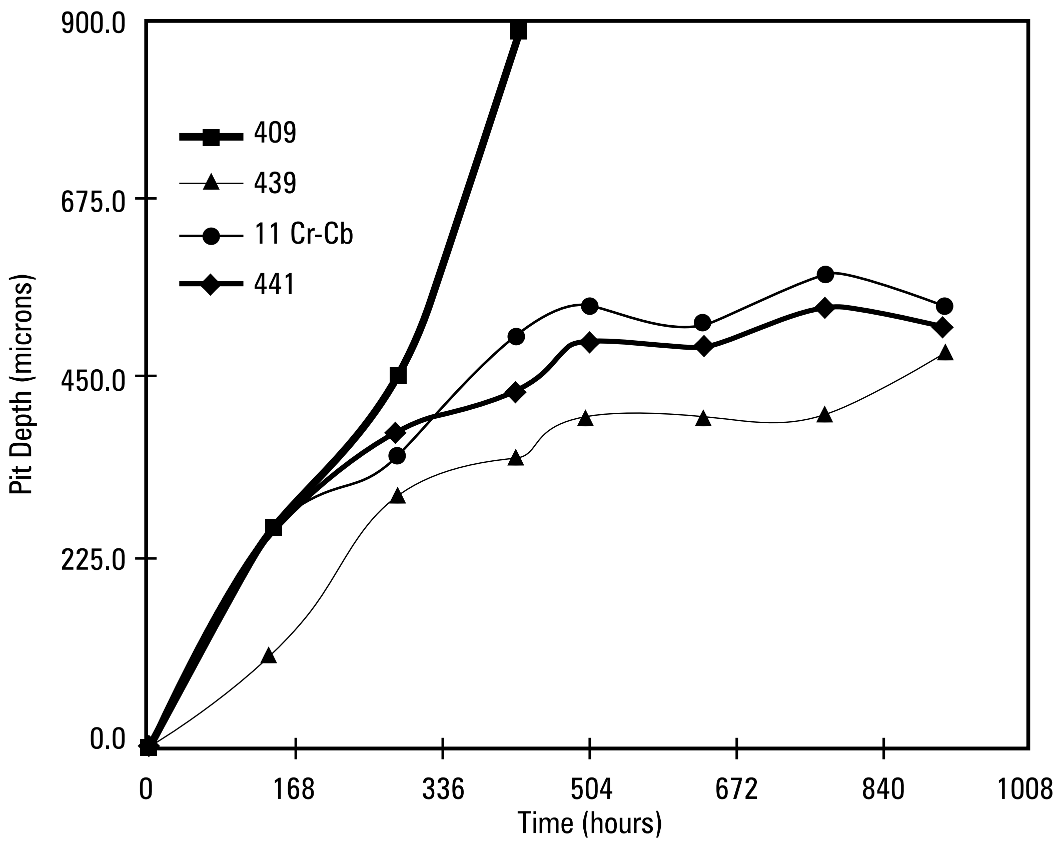
6" x 4" (15.2 x 10.2 cm) panels were tested as follows:

Monday through Friday – 4 cycles per day

Cycle 1: one hour at 936°F (538°C) and cooled for 15 minutes.

Cycles 2, 3, 4, 5: immersed in 5% NaCl for fifteen minutes and dried for 20 minutes at 35% relative humidity and 104°F (40°C), then raised temperature to 140°F (60°C) and humidity to 85% and held 5 hours and 25 minutes.

Weekend: Repeated cycles 2, 3, 4 and 5.

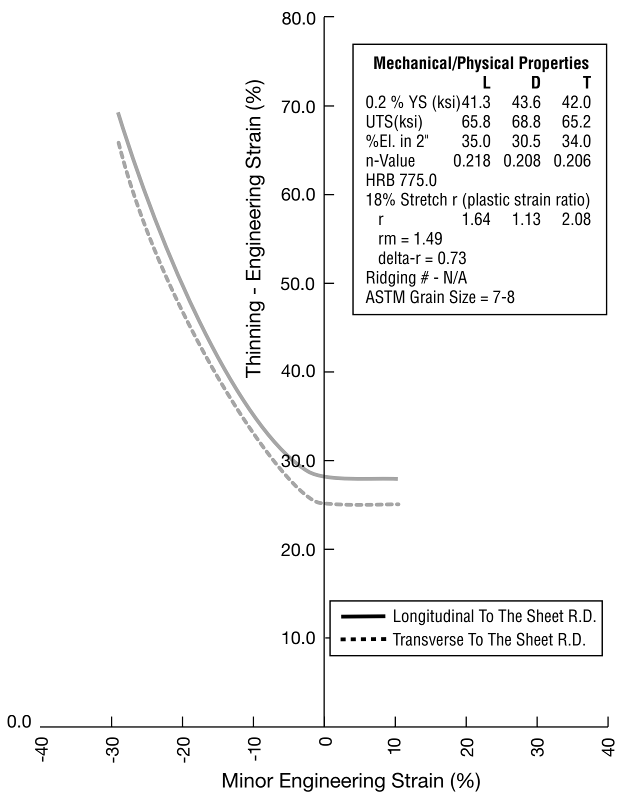


Formability

AK Steel 439 provides good formability. The Limiting Draw Ratio (LDR) for this alloy is 2.13.

Figure 8

Forming Limit Plot
For AK Steel 439-MD3, 0.058" Thick
Determined Using CamSys, 0.1" Square Grid Pattern



Weldability

This ferritic class of stainless steels is generally considered to be weldable by the common fusion and resistance techniques. Special consideration is required to avoid brittle weld fractures during fabrication by minimizing discontinuities, maintaining low weld heat input, and occasionally warming the part somewhat before forming. This particular alloy is generally considered to have somewhat poorer weldability when compared to the most common alloy of the stainless class, Type 409. When a weld filler is required, a matching wire or W18Cb is most often specified. Type 439 is well known in reference literature and more information can be obtained in the following ways:

1. ANSI/AWS A5.9, A5.2, and A5.4 (filler metals, minimum UTS and elongation).
2. "Welding of Stainless Steels and Other Joining Methods," SSINA, (800:982-0355).
3. "Welding Stainless Steels," FDB #SF-71.
4. "High Frequency Pipe & Tube Welding," by R.K. Nichols, Thermatool Corp. (203:468-4100).

Table 9

Mechanical Properties of Autogenous GTA Weldments at Room Temperature

Thickness in (mm)	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)	Fracture Location
0.0301 (0.77)	80.3 (553)	64.1 (442)	4.5	Weld

When use of a matching weld filler is required for GMA welding section sizes under 1/8" (3.17 mm) thick, ER18Cb (18 Cr-Cb weld filler) is suggested.

Table 10

Typical GMAW Mechanical Properties on 0.05" (1.27 mm) Sheet*

Temperature °F (°C)	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation % in 2" (50.8 mm)
Room	70 (483)	45 (310)	23.5
1400 (760)	6.3 (43)	4.2 (29)	43

*Weld Machined Flush

Conventional austenitic stainless steel fillers such as AusE/ER 309 are suggested for heavy section weldments when elevated temperature exposure is not anticipated. E/ER 330 is an alternative for high temperature exposure.

AK Steel

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