ALLEGHENY LUDLUM

An Allegheny Teledyne Company

Technical Data BLUE SHEET

Allegheny Ludlum Corporation ◆ Pittsburgh, PA

Stainless Steel AL 433™

Ferritic Stainless Steel

GENERAL DESCRIPTION

AL 433™ is a stainless steel in the ferritic family of alloys with Type 409 and Type 439. The AL 433 alloy contains 20% chromium for pitting and crevice corrosion resistance in the presence of chlorides and resistance to oxidation at elevated temperatures. An addition of 0.5% copper adds to corrosion resistance. Columbium (niobium) in the amount of about 0.5% is added for elevated temperature strength. The Cb addition also provides resistance to intergranular corrosion. Corrosion and oxidation resistance and elevated temperature strength of the AL 433 alloy are superior to those properties for Type 409 and Type 439 alloys which have lower chromium contents. Formability and weldability of the AL 433 alloy are very good, in common with Allegheny Ludlum Type 409 and Type 439 alloys. These characteristics make the AL 433 alloy an excellent candidate for elevated temperature applications where strength, combined with fabricability are needed.

COMPOSITION

Typical composition of the AL 433 alloy is:

Element	Weight Percent
Carbon	0.01
Manganese	0.30
Phosphorous	0.021
Sulfur	0.001
Silicon	0.39
Chromium	20.0
Nickel	0.25
Columbium	0.54, 0.8 max
Copper	0.50
Nitrogen	0.019
Cb/(C+N) ≥	10.0

PHYSICAL PROPERTIES

The AL 433 alloy has a body-centered cubic, ferritic microstructure at all temperatures below the melting point. Fine columbium carbides may be visible in the ferrite matrix microstructure.

Representative physical properties of the AL 433 alloy are compared with similar data for Type 409 below.

	Type 409	AL 433™
Density (lb./in³)		
	0.28	0.28
Mean Coefficient of Thermal Expansion (in/in/°F)		
68 - 212°F	6.0×10^{-6}	5.8×10^{-6}
68 - 500°F	6.1×10^{-6}	6.0×10^{-6}
68 - 900°F	6.3×10^{-6}	6.4×10^{-6}
68 - 1200°F	6.4×10^{-6}	6.5×10^{-6}
Specific Heat, 68°F: (Btu/lb°F)		
68°F	0.114	0.110
Thermal Conductivity (Btu/hr·ft·°F)		
68 - 212°F	14.4	12.1
Elastic Modulus (Psi)		
	29×10^{6}	29×10^{6}

Referenced data are typical and should not be construed as maximum or minimum values for specification or for final design. Data on any particular piece of material may vary from those shown above.

MECHANICAL PROPERTIES

Representative room temperature tensile properties for the AL 433 alloy in the annealed condition are as follows:

0.2% Yield Strength (Psi)	Ultimate Tensile Strength (Psi)	Elongation (% in 2")	Hardness Rb
46,700	63,450	31	79

Type 409 and the AL 433 alloy elevated temperature mechanical properties are compared below.

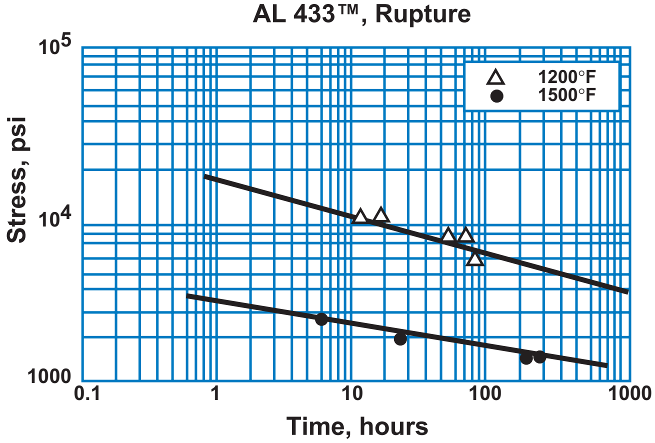
Elevated Temperature Tensile Properties

Temperature °F	Type 409			AL 433™		
	0.2% Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	Elongation (% in 2")	0.2% Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	Elongation (% in 2")
RT	34.5	62.0	33	47.0	71.4	32
200	29.9	53.9	31	41.1	63.9	29
400	23.3	49.9	27	34.1	58.2	27
600	21.2	48.3	23	30.1	58.0	22
800	20.3	44.4	21	29.4	55.4	18
1000	17.7	39.4	18	26.9	49.5	16
1200	16.6	30.0	15	18.6	41.5	18
1400	8.0	16.5	23	11.5	21.0	25
1600	3.0	3.3	59	6.2	8.5	37

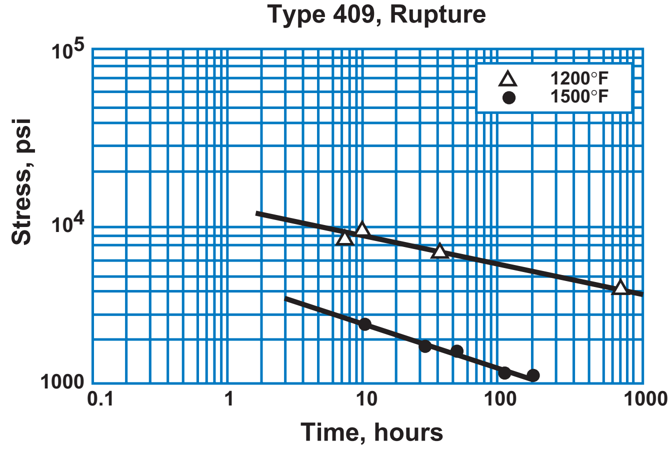
Both tensile and yield strength of the AL 433 alloy are significantly higher than those of Type 409 across the temperature range (75 - 1600°F). Elongation values are similar. The higher strength of the AL 433 alloy is attributable to the higher chromium and in particular the columbium addition.

Stress rupture plots for Type 409 and the AL433 alloy at 1200 and 1500°F are shown on page 4. The effect of the columbium in raising stress rupture properties of AL 433 alloy relative to Type 409 at 1200°F, and particularly 1500°F, is evident in comparing the two stress rupture plots.

AL 433™, Rupture



Type 409, Rupture



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OXIDATION RESISTANCE

Results from exposure of AL 433 alloy in still air at various elevated temperatures for 100 hours are compared to similar data for Types 409 and 439 stainless steels below:

100-Hour Oxidation in Still Air Weight Gain, mg/cm^2			
Temperature °F	**Type 409**	**AL 433™**	**Type 439**
1400	0.17	0.17	0.24
1500	0.37	0.16	0.35
1600	9.09	0.36	0.43
1700	89.00	0.73	1.28
1800	129.00	1.04	1.93
1900	181.00	1.00	2.91

CORROSION RESISTANCE

With 20% chromium, the AL 433 alloy provides better general corrosion resistance and pitting or crevice corrosion resistance than Type 409 (11% Cr) or Type 439 (18% Cr). The ferritic structure of AL 433 alloy provides excellent resistance to chloride stress corrosion cracking. The columbium addition assures stabilization and resistance to sensitization and intergranular corrosion.

The electrochemical potential (Volts vs SCE) required to cause pitting on the AL 433 alloy is compared with data from Type 409, and Type 444 ferritic alloys in a 1000 ppm chloride (as NaCl) aqueous solution at 75°F and pH5.

Alloy	Chromium	Molybdenum	Pitting Potential (Volts vs SCE)
Type 409	11	--	0.23
AL 433™	20	--	0.42
Type 444	18	2	0.52

These data illustrate that the AL 433 alloy, with 20 percent chromium, is significantly more resistant to pitting (higher pitting potential) than Type 409. The AL 433 alloy, however, is not as resistant to pitting as the Type 444 alloy, containing 18 percent chromium and 2 percent molybdenum.

A comparison of the corrosion resistance of Type 409 and AL 433 ferritic stainless steels in two tests which simulate automotive exhaust system conditions is presented as follows:

EXHAUST SYSTEM CYCLIC CONDENSATE CORROSION TEST

Type 409 and AL 433 alloy samples were placed in a one liter tall form beaker containing 100 ml of a simulated exhaust system condensate test solution consisting of:

Chloride ion - 1000 or 2000 ppm
Carbonate ion - 2000 ppm
Ammonium ion - 3740 ppm
Sulfate ion - 5000 ppm
Nitrate ion - 100 ppm
pH 8.7 - 8.9

This beaker of solution with alloy samples was then exposed to repeated controlled cycles consisting of:

a) heating to 482°F in one hour,
b) hold for two hours,
c) cool down to ambient temperature in three hours.

A solid residue only remains after the six-hour cycle. Another 100 ml of test solution was then added to the beaker with sample and residue and the cycle was repeated. Samples exposed to 10, 20, 30, etc., cycles were cleaned to bare metal and weight loss (corrosion) was determined. Data are plotted on the following page for the 2000 ppm chloride solution.

The superior corrosion resistance of the AL 433 alloy in this 2000 ppm chloride ion environment is obvious in the plot on page 4. Similar results were obtained when 1000 ppm chloride was present, but weight loss following the various cycles was less. Although the test solution is slightly alkaline when introduced into the beaker (pH about 8.8), conditions become more acidic with increasing number of cycles, eventually reaching pH 3 with 10 or more cycles. These test conditions are believed to parallel the service conditions encountered by exhaust system alloys where condensation occurs.

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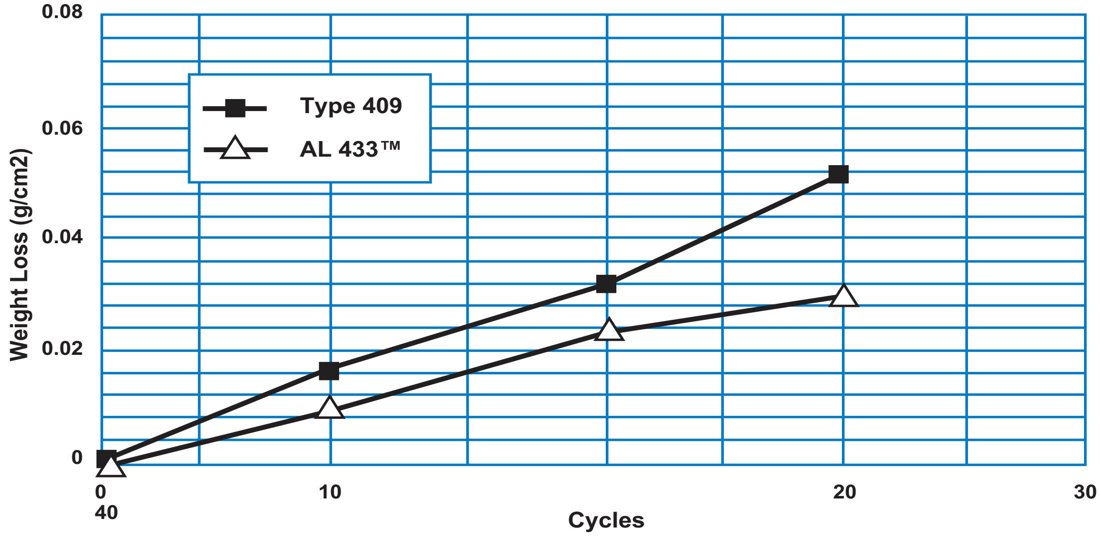
Condensate Corrosion Test



EXHAUST SYSTEM CYCLIC OXIDATION/CORROSION TEST

The hot outside of an automotive system is exposed to air. Therefore, resistance to oxidation is important for an exhaust system alloy. These alloys may also be exposed to road de-icing salts requiring resistance to pitting and/or crevice corrosion from the salts.

Cyclic oxidation/corrosion tests were conducted on Type 409 and the AL 433 alloy for comparison purposes. In this test, alloy samples are heated in air at 1200°F for one hour, cooled to ambient temperature, and then exposed 24 hours in a salt spray cabinet for each cycle. Weight loss is determined at five cycle intervals. Results from Type 409 and the AL 433 alloy in the oxidation/corrosion test are shown below. Again, the superior performance of the AL 433 alloy is evident.

Whereas corrosion was evident on the Type 409 alloy sample following the first oxidation/corrosion cycle, the AL 433 alloy did not show significant weight loss until the samples have been exposed to more than 40 cycles. The higher chromium of the AL 433 alloy provides better oxidation resistance and resistance to pitting or crevice corrosion by chlorides, resulting in significantly less weight loss than the Type 409 alloy in this severe test.

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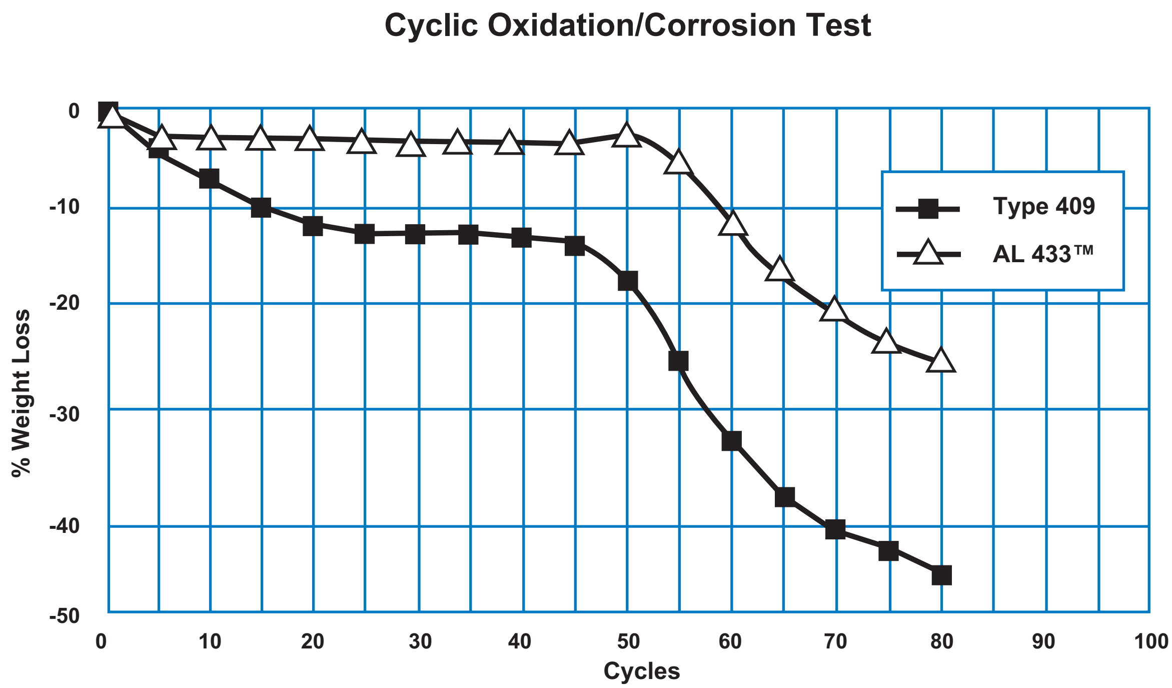

FABRICATION

The AL 433 alloy can be machined, welded and formed like other stabilized, ferritic stainless steels.

Machining AL 433 alloy compares more closely with carbon steel than with 300 series stainless steels. In this regard, the AL 433 alloy is similar to other ferritic stainless steels such as Type 409 and Type 439.

Weldability of AL 433 also is similar to that of other stabilized ferritic alloys. GTAW (TIG), GMA (MIG), high frequency and spot welding procedures are applicable to the AL 433 alloy. Conventional inert gas shielding is required for tungsten or metal arc processes. When properly welded, the AL 433 alloy retains corrosion resistance and most of the mechanical properties of the base metal in the weld deposit and heat-affected zone (HAZ). Weld deposits are fully ferritic and free of martensite. Columbium carbides may be visible in the weld microstructure.

Formability of the AL 433 alloy is similar to that of other ferritic stainless steels such as Allegheny Ludlum Type 409 and Type 439. The ferritic microstructure of the AL 433 alloy leads to strain hardening exponent "n" values of 0.23, similar to values for low carbon steels and other ferritic stainless steels such as Type 409 or Type 439. This translates into similar stretch formability for AL 433 alloy. Average strain ratio, $\overline{R}$, for AL 433 alloy strip is similar to that of AL 439 alloy and, therefore, indicates that drawability of this alloy is good and in common with other Allegheny Ludlum ferritic stainless alloys.

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Contact Information