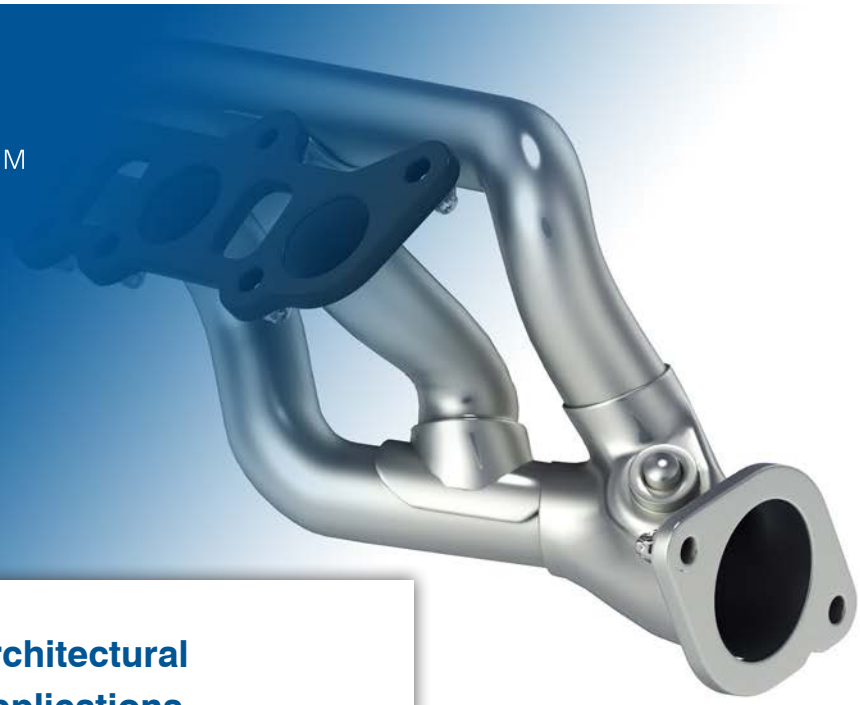
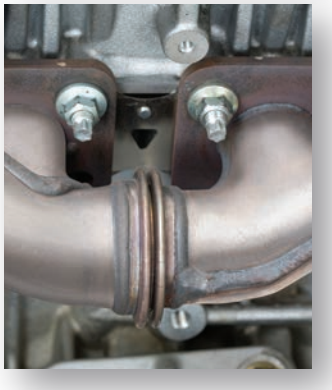
CLIFFS

18 Cr-Cb™

STAINLESS STEEL





Architectural Applications

Catalytic Converters

Heat Exchangers

Mufflers

Cleveland-Cliffs **18 Cr-Cb**™ is a highly-effective automotive exhaust material, especially for high-temperature component applications. The alloy exhibits superior oxidation resistance and better creep strength than Type 409 and Type 439. Potential applications include exhaust system catalytic converters, mufflers and pipes, heat-exchangers and heat-exchanger tubing and nonstructural furnace parts. Other applications include appliances, food and kitchen equipment, as well as architectural structures such as elevator and decorative panels.

Product Description

Cleveland-Cliffs 18 Cr-Cb Stainless Steel is a ferritic stainless steel that is stabilized with both titanium (Ti) and niobium (Nb). In service, the alloy exhibits age-strengthening at exhaust operating temperatures resulting in excellent creep resistance. The dual stabilization prevents carbide sensitization during welding and high temperature exposures, and makes the alloy thermally non-hardenable.

Composition		(wt %)
Carbon	(C)	0.03 max.
Manganese	(Mn)	1.0 max.
Phosphorus	(P)	0.04 max.
Sulfur	(S)	0.03 max.
Silicon	(Si)	1.0 max.
Chromium	(Cr)	17.5 – 19.5
Nickel	(Ni)	1.0 max.
Nitrogen	(N)	0.03 max.
Titanium	(Ti)	0.10 – 0.50
Niobium	(Nb)	0.30 + 9xC min., 0.90 max.

AVAILABLE FORMS

Cleveland-Cliffs produces 18 Cr-Cb Stainless Steel in coils and cut lengths in thicknesses from 0.018 – 0.100 in., (0.457 – 2.54 mm) and widths up to and including 48 in. (1219 mm). For other thicknesses, contact your Cleveland-Cliffs sales representative.

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.

Mechanical Properties

TABLE 1 – TYPICAL ROOM TEMPERATURE MECHANICAL PROPERTIES

UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Rockwell Hardness, B
72 (496)	47 (324)	30	80

TABLE 2 – PROPERTIES ACCEPTABLE FOR MATERIAL SPECIFICATION

UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Rockwell Hardness, B
60 (414) min.	38 (262) min.	25.0 min.	88 max.

EFFECT OF COLD WORK ON MECHANICAL PROPERTIES

Like most metals, Cleveland-Cliffs 18 Cr-Cb Stainless Steel work hardens when fabricated. Data in Table 3 show the work-hardening behavior as measured by tensile tests on laboratory cold-rolled sheet samples.

TABLE 3 – EFFECT OF COLD WORK ON MECHANICAL PROPERTIES*

Condition	UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Rockwell Hardness
Annealed	69.0 (476)	42.8 (296)	34.0	B76
CW 5.0%	76.1 (525)	71.9 (496)	20.8	B88
CW 10.0%	82.8 (571)	79.6 (549)	10.2	B92
CW 14.7%	89.4 (617)	87.5 (604)	5.5	B93
CW 29.8%	105.4 (727)	104.4 (720)	2.8	B97
CW 44.1%	114.8 (792)	112.6 (776)	2.0	C21

**Annealed 18 Cr-Cb, 0.051 in. (1.14 mm) thickness.*

TABLE 4 – STRESS RUPTURE PROPERTIES OF STAINLESS STEEL AUTOMOTIVE EXHAUST ALLOYS

Alloy	Exposure Temperature			
	1300 °F (704 °C)		1500 °F (816 °C)	
	Stress, ksi. (Mpa), for rupture in:			
	100 hours	1000 hours	100 hours	1000 hours
Type 409	4.1 (28.7)	3.2 (22.4)	1.5 (10.5)	0.9 (6.3)
Type 439	4.0 (28.0)	3.0 (21.0)	1.6 (11.2)	1.0 (7.0)
11 Cr-Cb SS	5.1 (34.7)	3.7 (25.9)	1.8 (12.6)	1.4 (9.8)
18 Cr-Cb SS	5.8 (39.6)	4.4 (30.8)	2.4 (16.8)	1.8 (12.6)
18 SR® SS	3.8 (28.6)	2.6 (45.2)	1.7 (11.9)	0.9 (6.3)
Type 304	16.9 (116.3)	11.6 (80.2)	6.2 (41.5)	3.7 (25.9)

Mechanical Properties

TABLE 5 – SHORT-TIME ELEVATED TEMPERATURE TENSILE PROPERTIES

		Temperature, °F (°C)					
Property	Alloy	1000 (538)	1200 (649)	1300 (704)	1400 (760)	1500 (816)	1600 (871)
UTS, ksi. (MPa)	Type 409	34.9 (241)	22.8 (157)	10.5 (73)	6.1 (42)	4.2 (2.9)	3.0 (21)
	Type 439	37.8 (261)	18.0 (124)	9.5 (66)	6.1 (42)	4.4 (30)	3.2 (22)
	18 Cr-Cb SS	54.3 (374)	43.5 (300)	21.4 (148)	9.3 (64)	7.3 (50)	5.2 (36)
	Type 304	62.9 (434)	47.1 (325)	36.3 (250)	27.8 (192)	21.0 (145)	16.5 (114)
0.2% YS, ksi. (MPa)	Type 409	17.4 (120)	12.5 (86)	7.5 (52)	4.4 (30)	3.0 (21)	2.4 (16)
	Type 439	21.5 (148)	12.2 (84)	7.1 (49)	4.6 (32)	3.4 (23)	2.6 (18)
	18 Cr-Cb SS	25.4 (175)	21.1 (145)	13.6 (94)	6.8 (47)	5.8 (40)	4.2 (29)
	Type 304	22.0 (152)	20.0 (138)	18.0 (124)	15.0 (103)	13.0 (90)	10.0 (69)

TABLE 6 – STRESS RUPTURE ELEVATED TEMPERATURE PROPERTIES

Alloy	Stress to Rupture, ksi. (MPa)		Stress to Rupture, ksi. (MPa)	
	100 hours		1000 hours	
	1300 °F (704 °C)	1500 °F (816 °C)	1300 °F (704 °C)	1500 °F (816 °C)
Type 409	4.1 (28.3)	1.5 (10.3)	3.2 (22.1)	0.9 (6.2)
Type 439	4.0 (27.6)	1.6 (11.0)	3.0 (20.7)	1.0 (6.9)
18 Cr-Cb SS	5.8 (40.0)	2.4 (16.5)	4.4 (30.3)	1.8 (12.4)
Type 304	16.9 (116.0)	6.2 (42.7)	11.6 (80.0)	3.7 (25.5)

SAG RESISTANCE

The addition of niobium to Cleveland-Cliffs 18 Cr-Cb Stainless Steel, coupled with a final high-temperature solution anneal, imparts improved elevated temperature creep resistance over other standard ferritic stainless steels. Sag strength is represented in Figure 1 as a strip material's resistance to sagging under its own weight with the passage of time at a constant temperature. Samples for this 1600 °F (871 °C) exposure were 0.060 in. (1.52 mm) thick x 1 in. (25.4 mm) wide and were supported over a distance of 10 in. (254 mm). Figure 1 demonstrates the alloy's superior resistance to sag (creep) over Type 409.

Elevated-temperature fatigue strength problems are a major concern to ferritic stainless steel users, particularly when used in critical exhaust applications such as manifolds. Cleveland-Cliffs 18 Cr-Cb Stainless Steel provides improved resistance to elevated-temperature fatigue when compared to standard aluminized steel or Type 409.

FIGURE 1 – 1600 °F (871 °C) SAG TEST

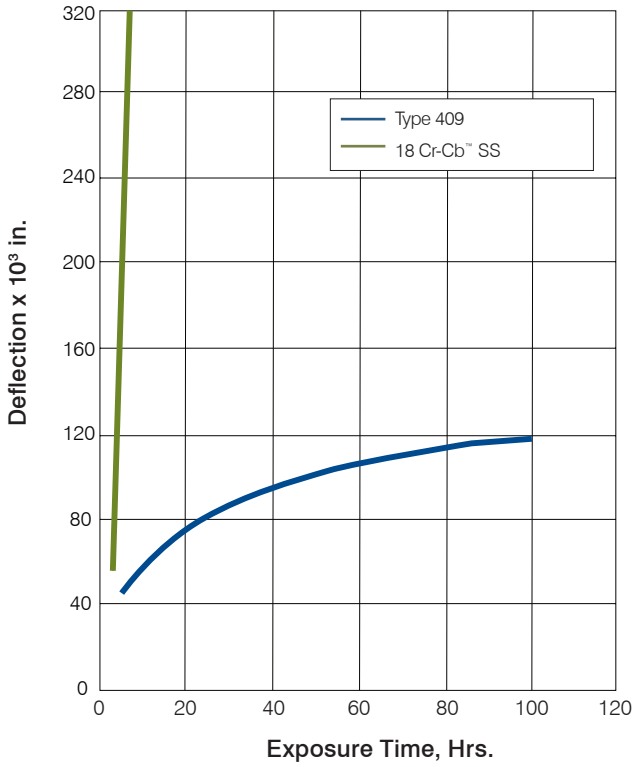


TABLE 7 – ELEVATED TEMPERATURE FATIGUE STRENGTH (STRENGTH TO SURPASS 10^7 CYCLES)

Alloy	Fatigue Strength*, ksi. (MPa)	
	1300 °F (704 °C)	1500 °F (816 °C)
Aluminized Steel Type 1	3.1 (22)	1.5 (10)
Type 409	6.6 (45)	2.0 (14)
18 Cr-Cb SS	7.5 (52)	3.0 (21)

Mechanical Properties

885 °F (474 °C) EMBRITTLEMENT

Most 18 Cr-Cb ferritic alloys exhibit a significant loss of ductility when exposed to the temperature range of 800 – 1000 °F (427 – 538 °C). This phenomenon is known as 885 °F (474 °C) embrittlement.

Cleveland-Cliffs 18 Cr-Cb Stainless Steel is less susceptible to this phenomenon than other 18 Cr alloys such as Type 439. Tensile results after exposure for 1000 hours at 900 °F (482 °C) are shown in Table 8 for 18 Cr-Cb and Type 439 stainless steels.

TABLE 8 – EFFECT OF 900 °F (482 °C) EXPOSURE ON ROOM-TEMPERATURE PROPERTIES

Alloy	Condition	UTS, ksi. (MPa)	1.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Rockwell Hardness
18 Cr-Cb SS	Annealed	69.0 (476)	42.8 (297)	34.0	B76
	1000 hours @900 °F (482 °C)	79.6 (549)	61.6 (425)	30.0	B84
Type 439	Annealed	71.1 (491)	44.0 (303)	33.0	B77
	1000 hours @900 °F (482 °C)	111.4 (768)	98.2 (677)	21.5	C20

PHYSICAL PROPERTIES

Density, lbs/in.^{3} (g/cm^3)	0.277 (7.65)
Electrical Resistivity, $\mu\Omega$•in. ($\mu\Omega$•cm)	18 Cr-Cb SS

Oxidation Resistance

The 17.5% minimum-chromium content of Cleveland-Cliffs 18 Cr-Cb Stainless Steel provides an improved oxidation-resistance level compared to lower chromium alloys such as Type 409 stainless steel. Under cyclic heating conditions, this alloy will outperform austenitic alloys of similar chromium content like Type 304 stainless steel due to the ferritic alloy's lower coefficient of thermal expansion. (See Figure 2 and Table 9.)

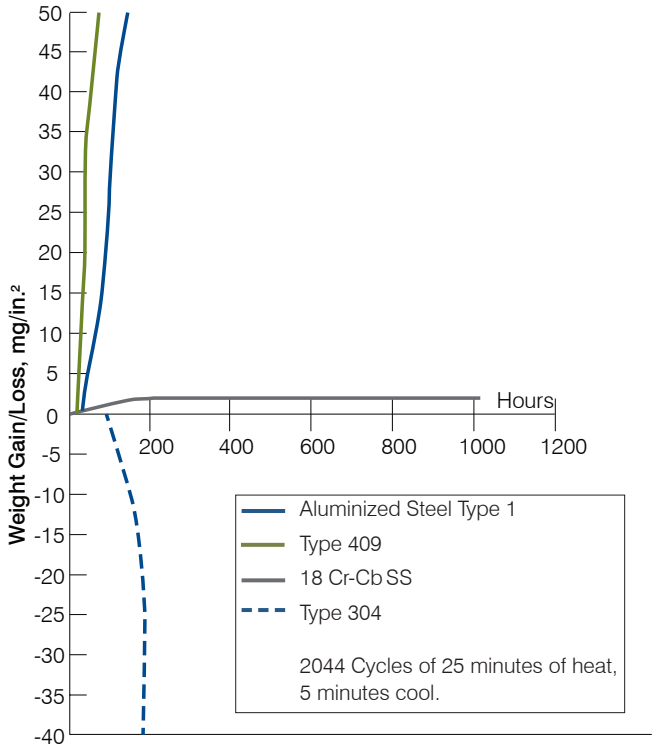
Under laboratory stimulated exhaust gas atmosphere, the material demonstrated lower weight gains compared to Type 409, with no indication of catastrophic attack up to 1650 °F (899 °C)

TABLE 9 – 1700 °F (927 °C) CYCLIC OXIDATION* OXIDATION WEIGHT GAIN, mg/in.²

Alloy	Hours of Testing										
	24.5	46.5	163	210	257	321	393.5	511.5	610	777.5	1022
Aluminized Steel Type 1	22.1	36.8	65.4	117	152	—	—	—	—	—	—
Type 409	18.3	93.9	310	—	—	—	—	—	—	—	—
18 Cr-Cb SS	0.9	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.4	1.2	0.8
Type 304	1.1	1.2	1.1	-9.8	-36.9	-112	-322	-710	—	—	—

Cycle: 25 minutes heat, 5 minutes cool. Average of duplicate tests.

FIGURE 2 – 1700 °F (927 °C) CYCLIC OXIDATION



Corrosion Resistance

Cleveland-Cliffs 18 Cr-Cb Stainless Steel is notably superior to Type 409 in wet corrosion resistance, particularly to chlorides, and is more resistant to Synthetic Muffler Condensate attack, as shown in Table 10 and FIgure 4. Note the lower corrosion rate of Cleveland-Cliffs 18 Cr-Cb Stainless Steel, approaching the corrosion of Cr-Ni Stainless Steel.

TABLE 10 – SYNTHETIC MUFFLER CONDENSATE RESISTANCE*

Alloy	Corrosion Rate, mills per year
Aluminized Steel Type 1	8.0 – 24.0**
Type 409	7.17
18 Cr-Cb SS	4.69
Type 304	3.07

*Average of duplicate tests.

**Experience has shown this to be a typical range.

FIGURE 3 – MUFFLER CONDENSATE CORROSION RESISTANCE

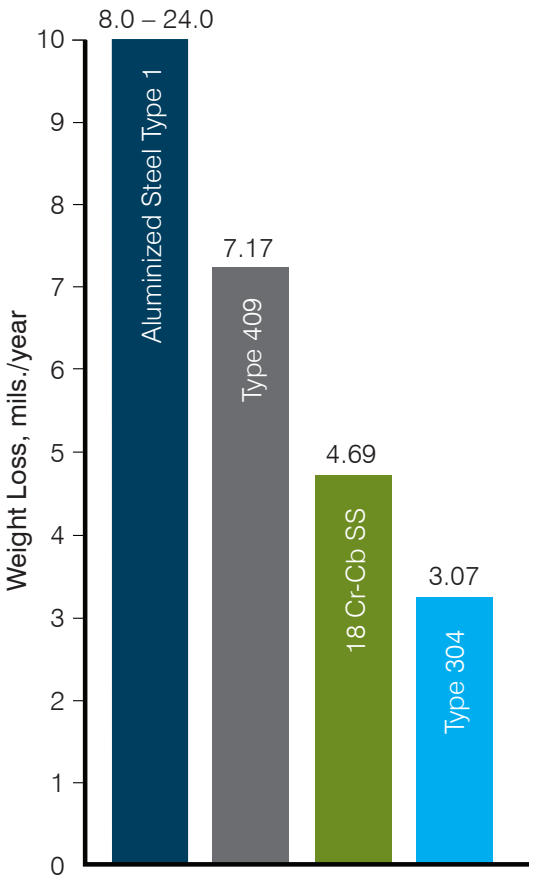
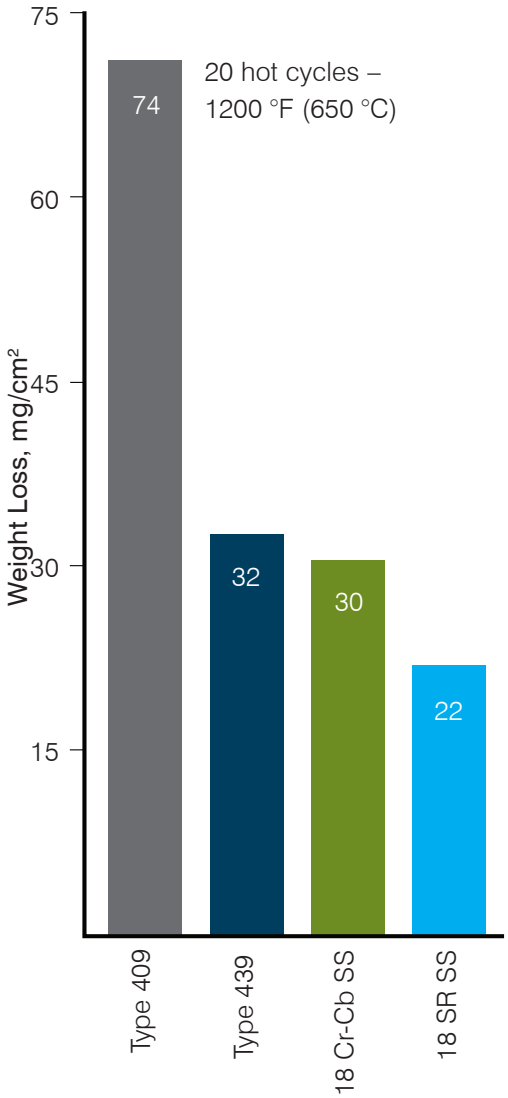


FIGURE 4 –HOT SALT CORROSION TEST



Test Procedure:

Sheet sample with 90° bend and 0.2 in. (5 mm) Olsen cup dome.

Hot Cycle:

Dip 5 min. in 5% NaCl and then expose 1200 °F (650 °C)/90 min., water quench 1 min., repeat 4 times/day, humidity 85% RH/140 °F (60 °C) 18 hours/day.

18 Cr-Cb™ STAINLESS STEEL

FORMABILITY

Cleveland-Cliffs 18 Cr-Cb Stainless Steel can be cut, blanked and formed. Brakes, presses and roll-forming normally used on carbon steel can be used on this alloy.

Caution: Cold weather impact loads should be avoided with material 0.100 in. (2.54 mm) and heavier, particularly with welds, because the Ductile-to-Brittle Transition Temperature (DBTT) could fall close to ambient temperature.

WELDABILITY

Cleveland-Cliffs 18 Cr-Cb Stainless Steel is generally considered to be weldable by common fusion and resistance welding processes, including laser and high frequency induction tube welding. This grade is generally considered to have diminished weldability compared to the most common alloy of this stainless class, Type 409. Application of weld heat can cause grain growth and reduced toughness in the heat affected zone. Use of a low heat input weld procedure, minimizing stress concentrations and warming parts slightly prior to forming will reduce the tendency for brittle weld fracture in subsequent processing. The balanced dual stabilized (titanium and niobium) Cleveland-Cliffs 18 Cr-Cb Stainless Steel chemistry is not susceptible to the formation of continuous intergranular carbides that could lead to intergranular corrosion. When a matching weld filler is required, Cleveland-Cliffs 18 Cr-Cb Stainless Steel (No AWS Class) and EC439Nb wires are often recommended for light gauge high temperature (>1000 °F) service where thermal cycling is expected. The addition of hydrogen to weld shielding gases for increased welding speed is discouraged, as the ferritic stainless steels are subject to hydrogen embrittlement. More information on the welding of ferritic stainless steels may be obtained from the following sources:

1. ANSI/AWS A5.9, A5.22, and A5.4 (stainless welding electrode specifications).
2. “Welding of Stainless Steels and Other Joining Methods,” SSINA, (www.ssina.com).

About Cleveland-Cliffs Inc.

Cleveland-Cliffs is the largest flat-rolled steel producer in North America. Founded in 1847 as a mine operator, Cliffs also is the largest manufacturer of iron ore pellets in North America. The Company is vertically integrated from mined raw materials, direct reduced iron, and ferrous scrap to primary steelmaking and downstream finishing, stamping, tooling, and tubing. The Company serves a diverse range of markets due to its comprehensive offering of flat-rolled steel products and is the largest supplier of steel to the automotive industry in North America. The Company is headquartered in Cleveland, Ohio with mining, steel and downstream manufacturing operations located across the United States and in Canada. For more information, visit www.clevelandcliffs.com.

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