18 SR®

STAINLESS STEEL

Baffle Plates

Furnace Equipment

Heaters

Industrial Ovens

Kiln Liners

18 SR® STAINLESS STEEL is especially valuable for applications requiring high-temperature scaling resistance. This product's properties are superior to Types 409, 430, 304, 309 and 310 under cyclic conditions. In addition, it is more economical than many of the higher-temperature stainless steels. Typical uses include industrial ovens, blowers, exhaust systems, furnace equipment, heaters, induction furnaces and furnace tubes, annealing boxes, baffle plates, heat exchangers, resistor grids, kiln liners and pyrometer tubes.

Product Description

Cleveland-Cliffs 18 SR Stainless Steel provides excellent resistance to high-temperature scaling. In addition, this material is readily welded by conventional methods. It is not subject to troublesome embrittlement or loss of corrosion resistance in the heat-affected zones that affects many other straight chromium alloys.

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)	17.0 – 18.0
Nitrogen	(N)	0.03 max.
Aluminum	(Al)	1.5 – 2.0
Titanium	(Ti)	0.10 – 0.50

AVAILABLE FORMS

Cleveland-Cliffs produces 18 SR Stainless Steel in coils and cut lengths in thicknesses from 0.015 – 0.100 in. (0.38 – 2.54 mm) and widths up to and including 48 in. (1219 mm). Cleveland-Cliffs 18 SR Stainless Steel is sold with a functional ground finish. For other thicknesses or surface finishes, contact your Cleveland-Cliffs sales representative. Values shown in this bulletin were established in U.S. customary units. The metric equivalents of the U.S. customary units shown may be approximate.

PHYSICAL PROPERTIES

Density, lbs./in.3 (g/cm^3)	0.27 (7.45)

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
78 (538)	56 (386)	30	84

TABLE 2 – ELEVATED TEMPERATURE TENSILE PROPERTIES

Temperature, F (C)	UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)
Room	78 (538)	56 (386)
1000 (538)	49 (338)	34 (234)
1100 (593)	36 (248)	28 (193)
1200 (649)	26 (179)	22 (152)
1300 (704)	16 (110)	14 (97)
1400 (760)	13 (90)	7 (48)
1500 (816)	11 (76)	5 (34)
1600 (871)	5 (34)	3 (21)

TABLE 3 – ELEVATED TEMPERATURE FATIGUE STRENGTH

Alloy	Fatigue Strength* at 1500 °F (816 °C), ksi. (MPa)
Type 409	1.0 (7)
Type 439	1.4 (10)
Cleveland-Cliffs 11 Cr-Cb™ SS	3.0 (21)
Cleveland-Cliffs 18 Cr-Cb™ SS	3.0 (21)
Cleveland-Cliffs 18 SR SS	2.0 (14)

**Stress for 10^7 cycles.*
Tension/Tension r = 0.1

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)
Cleveland-Cliffs 11 Cr-Cb™ SS	5.1 (34.7)	3.7 (25.9)	1.8 (12.6)	1.4 (9.8)
Cleveland-Cliffs 18 Cr-Cb™ SS	5.8 (39.6)	4.4 (30.8)	2.4 (16.8)	1.8 (12.6)
Cleveland-Cliffs 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)

Physical Properties

FIGURE 1 – ELECTRICAL RESISTIVITY VS. TEMPERATURE

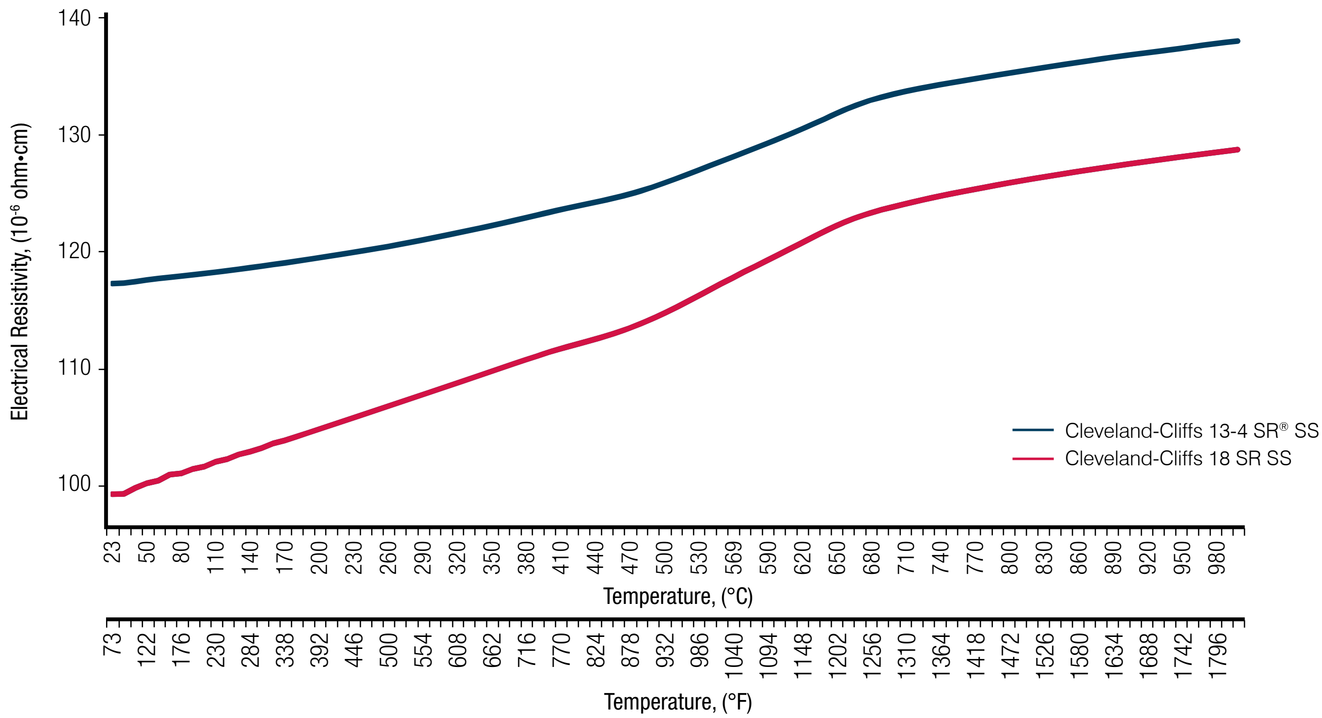
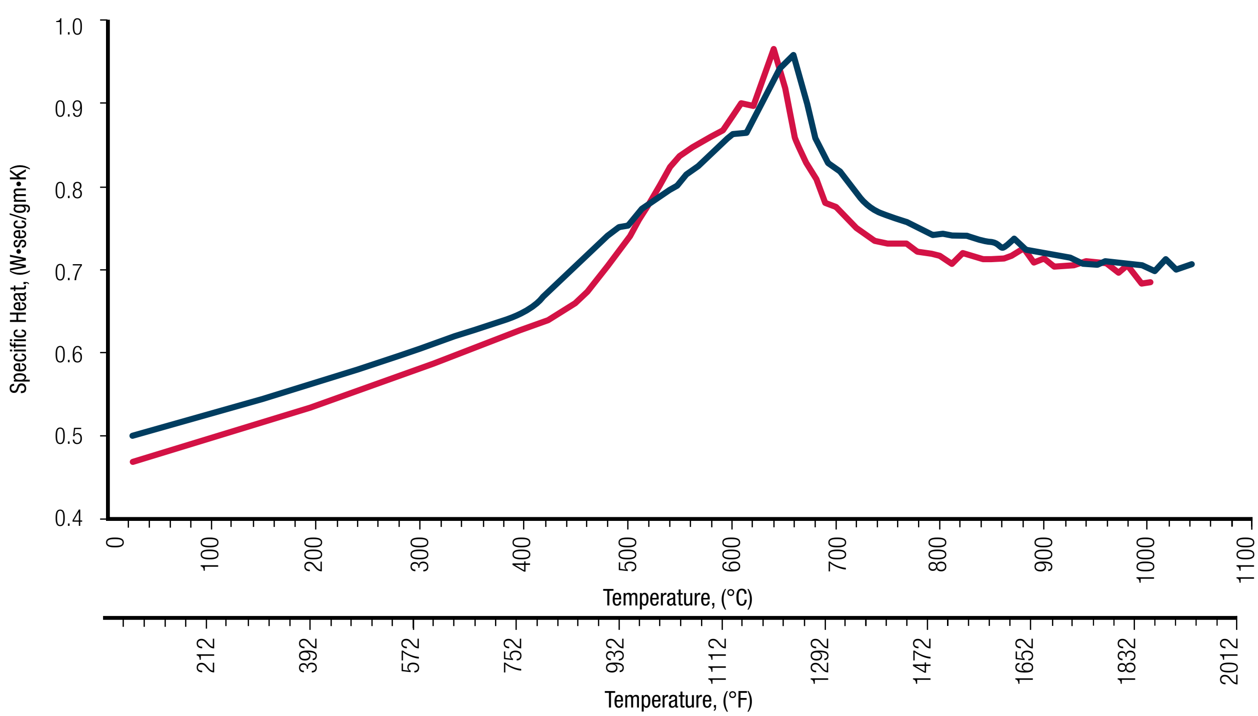


FIGURE 2 – SPECIFIC HEAT VS. TEMPERATURE



Physical Properties

FIGURE 3 – MEAN COEFFICIENT OF THERMAL EXPANSION

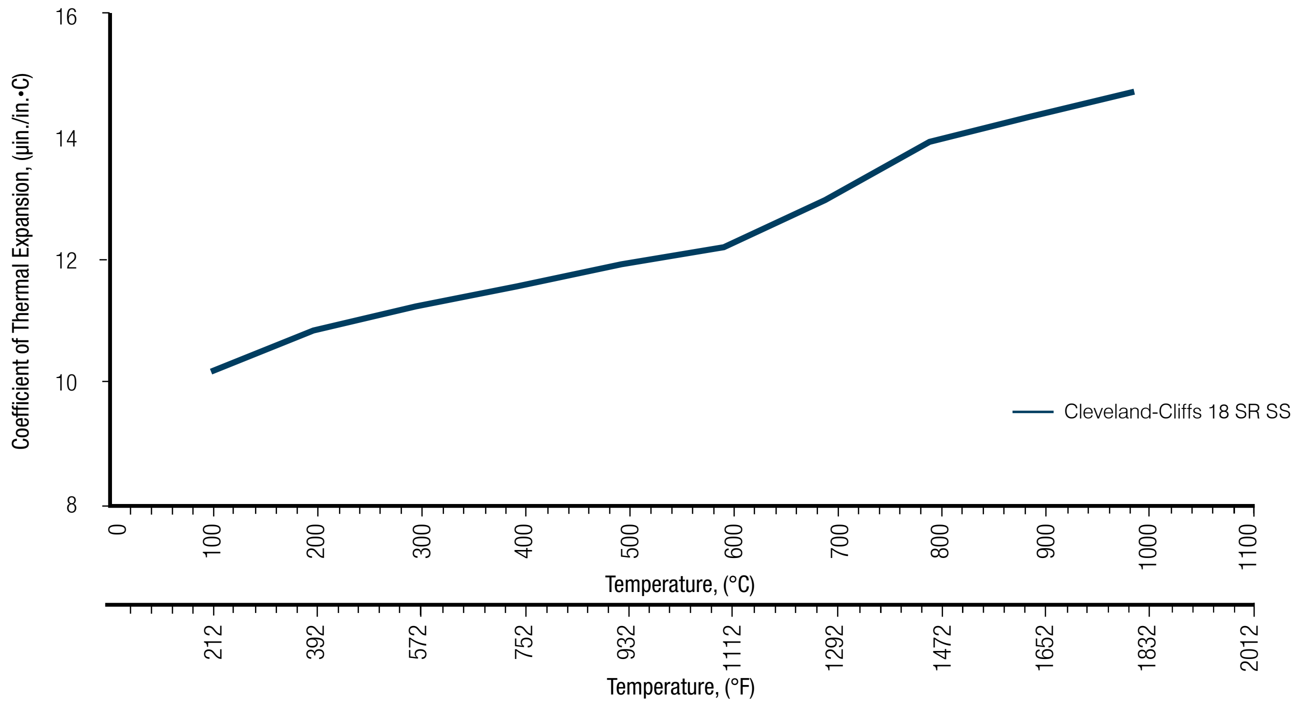


FIGURE 4 – THERMAL CONDUCTIVITY

*(BTU•in./hr•ft²•°F)

Oxidation Resistance

The comparison in the figure below is based on laboratory tests of weight gain versus temperature and data available in the literature. The upper limit of 2000 °F (1093 °C) on Cleveland-Cliffs 18 SR Stainless Steel is based on 100-hour tests in still air in which the alloy was tested at as high as 2200 °F (1204 °C) and exhibited weight gains of 33 mg/in.^{2} at 2000 °F (1093 °C), these rates were 25 mg/in.^{2} in very thin thicknesses < 0.018 in. (0.045 mm), the upper oxidation limit is lower.

FIGURE 5 – OXIDATION DATA – 100-HOUR TESTS IN STILL AIR

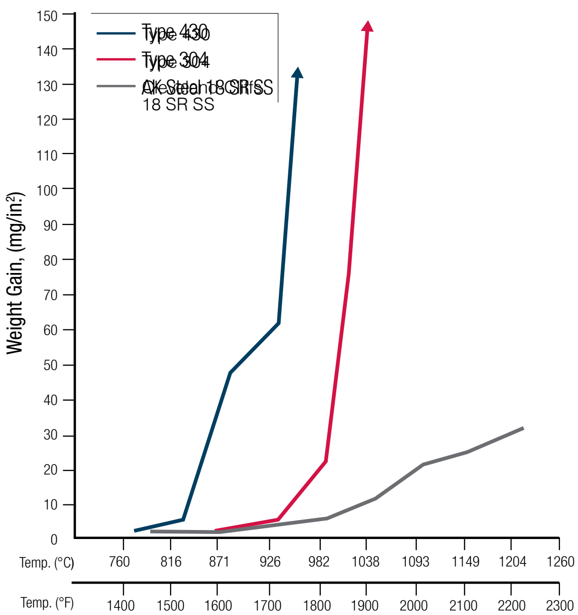


TABLE 5 – WEIGHT CHANGE AFTER 1600 – 1700 °F (871 – 927 °C) EXPOSURE*

Alloy	288 Cycles	480 Cycles	750 Cycles	958 Cycles
Type 430	63.6	Destroyed	–	–
Type 309	1.7	-30.0	-153.0	-210.0
Cleveland-Cliffs 18 SR SS	1.9	2.7	3.4	3.8

**mg/in.^{2} - 15 minutes heating - 15 minutes cooling.*

TABLE 6 – WEIGHT CHANGE AFTER 1800 – 1900 °F (982 – 1038 °C) EXPOSURE*

Alloy	130 Cycles	368 Cycles	561 Cycles	753 Cycles	1029 Cycles
Type 309	-156.0	-500.0	-1150.0	-1560.0	-2310.0
Type 310	9.5	-73.0	-189.0	-405.0	-690.0
Cleveland-Cliffs 18 SR SS	4.2	6.8	9.6	13.9	19.5
RA 330	8.3	12.2	-75.0	-345.0	-590.0

**mg/in.^{2} - 15 minutes heating - 15 minutes cooling.*

Corrosion Resistance

Cleveland-Cliffs 18 SR Stainless Steel provides improved pitting corrosion resistance over the lower chromium (Cr) ferritic stainless steels. Overall resistance to hot salt, chloride pitting, and internal exhaust condensate are comparable to the variety of other 18% chromium ferritic stainless steels in these environments.

TEST SETUP:

- Partial immersion of 3 x 4 in. (7.6 x 10.2 cm) coupon in synthetic condensate

Test Solution:

- 5,000 ppm SO_4^{2-}
- 100 ppm Cl^-
- 100 ppm NO_3^-
- 100 ppm Formic Acid
- Solution pH is adjusted to 3.3 – 3.5 using sulfuric acid by adding approximately 300 – 400 ppm SO_4^{2-}

TEST CYCLE PROCEDURE:

- Heat 1 hour at 932 °F (500 °C)
- Humidity exposure for 6 hours at 140 °F (60 °C)/85% RH
- 16 hours exposed to boiling test solution (boil to dryness)

FIGURE 7

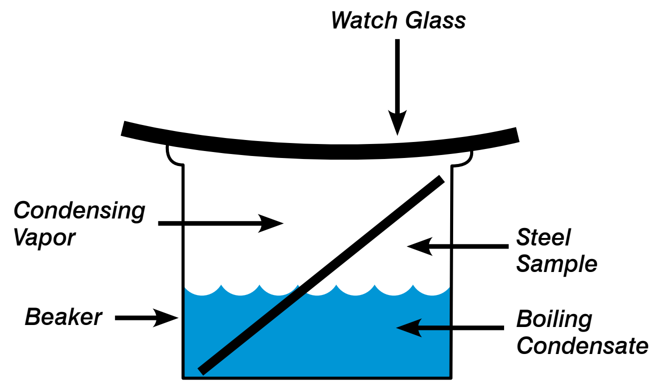
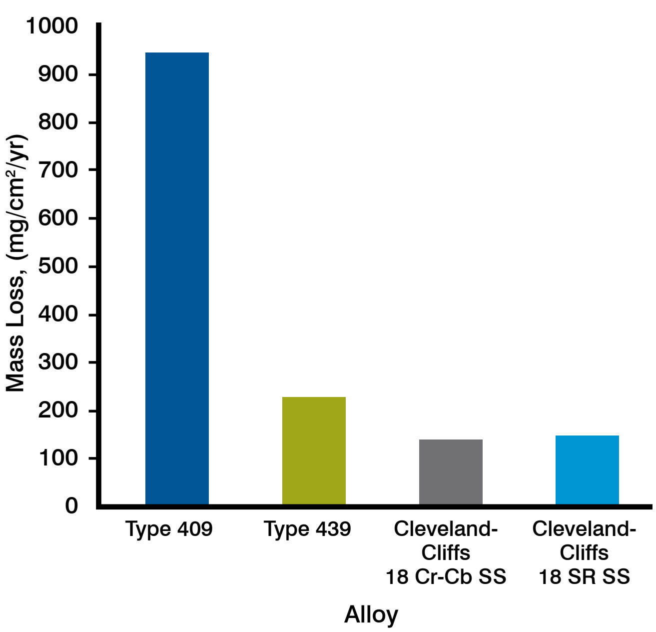
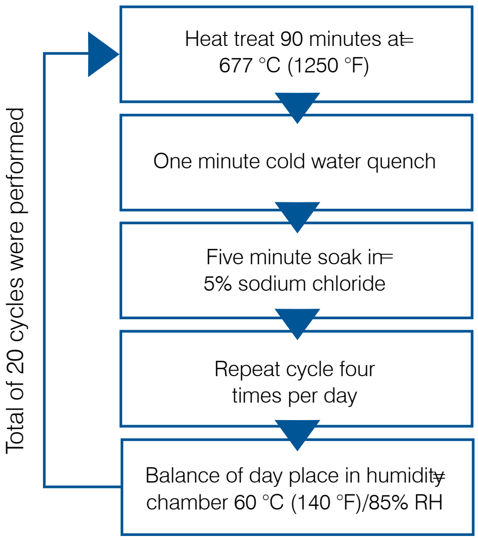


FIGURE 6 – INTERNAL CONDENSATE CORROSION COMPARISONS



Corrosion Resistance



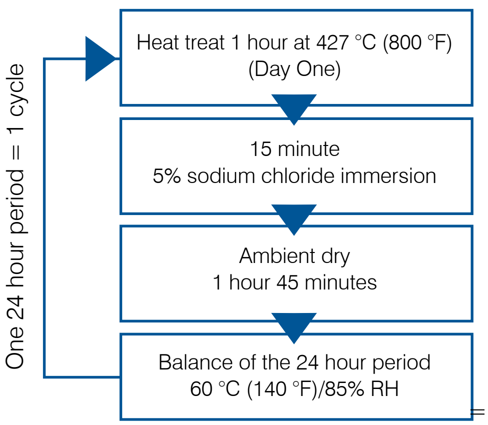


FIGURE 8 – HOT SALT CORROSION TEST

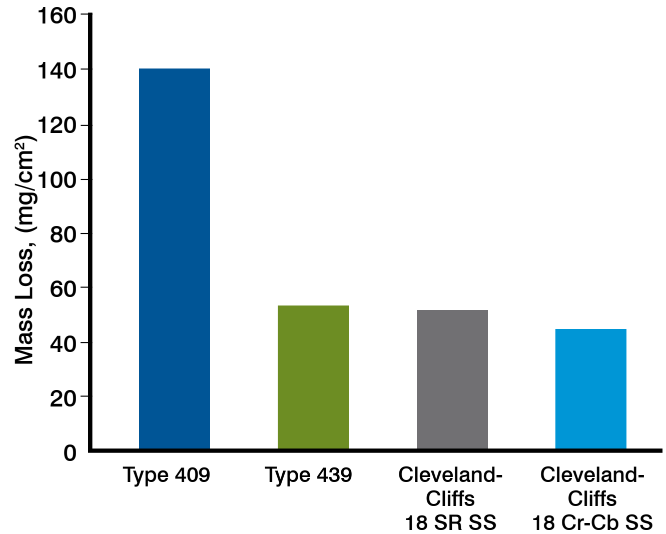


FIGURE 9 – MUFFLER CONDENSATE TEST

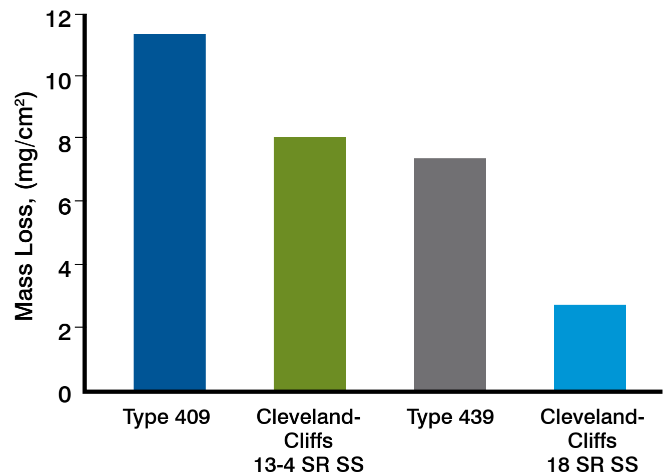
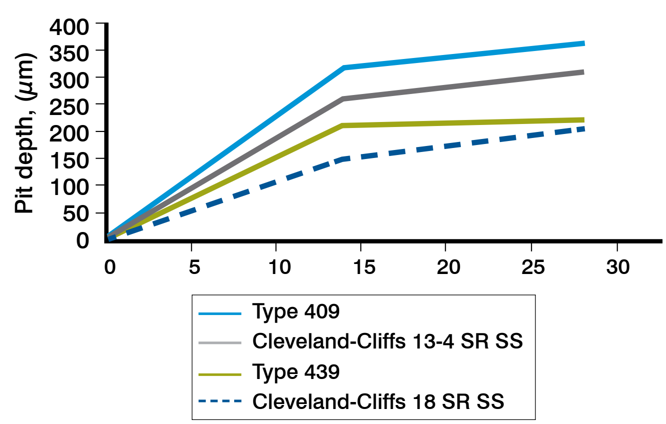


FIGURE 10 – SALT CYCLE TEST



Mechanical Properties

EMBRITTLEMENT

Cleveland-Cliffs 18 SR Stainless Steel and Type 446 were exposed in the annealed condition at 1400 °F (760 °C) for various times up to 3000 hours. After 3000 hours, neither material showed any sign of sigma phase or embrittlement.

As experience has been gained with the alloy, the chemistry has been rebalanced. As a result, resistance to 885 °F (475 °C) embrittlement has been improved. Although embrittlement develops, as the data in Table 7 indicate, a reasonable level of ductility remains after three weeks' exposure at 900 °F (482 °C).

Both alloys were also exposed in the annealed condition at 1100 °F (593 °C) for up to 2000 hours. After 2000 hours, no sigma phase was present in the 18 SR Stainless Steel alloy after 2000 hours at 1100 °F (593 °C). However, the material exhibited some loss of ductility when bent 180° flat on itself after 100 hours at 1100 °F (593 °C), apparently by the same mechanism as 885 °F (475 °C) embrittlement.

FORMABILITY

Use the same techniques employed with Type 430 to fabricate Cleveland-Cliffs 18 SR Stainless Steel. The Olsen Cup Value for this alloy is 0.330 as compared with 0.350 to 0.360 for Type 430. In the annealed condition, Cleveland-Cliffs 18 SR Stainless Steel exhibits good bend ductility. Up to 0.050 in. (1.3 mm), the alloy bends flat without breaking. Over 0.050 in. (1.3 mm), bends 180° can be made with a diameter of 1xT. The annealing temperature for this material is 1700 °F (927 °C) for one minute at temperature.

Caution: Cold weather impact loads should be avoided with material 0.125 in. (3.18 mm) and heavier, particularly with welds, because the Ductile-to-Brittle Transition Temperature (DBTT) could fall close to ambient temperature or above.

TABLE 7 – ROOM TEMPERATURE PROPERTIES AFTER EXPOSURE AT 900 °F (482 °C)*

Exposure Time 900 °F (482 °C)	0.2% YS, ksi. (MPa)	UTS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Rockwell Hardness
Unexposed	438 (63.6)	598 (86.8)	25.2	B89
1 week	682 (99.0)	771 (112.0)	17.8	C21
2 weeks	696 (100.7)	797 (115.7)	17.8	C23
3 weeks	697 (101.0)	798 (115.9)	17.2	C23

**Average of duplicate tests.*

WELDABILITY

The 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 diminished weldability when compared to the most common alloy of this stainless class, Type 409. A major difference is the high aluminum (Al) content for scaling resistance, which causes penetration and slagging problems during arc welding. Reducing weld travel speed generally improves results. When a weld filler is needed, AWS E/ER Cleveland-Cliffs 18 Cb is most often specified, and AWS E/ER 308L or 309L can be used at ambient temperatures when maximum weld ductility is required or when welding to dissimilar metals. Type 409 is well known in reference literature and more information can be obtained in the following ways:

1. ANSI/AWS A5.9, A5.22 and A5.4 (Stainless Steel 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 and direct reduced iron 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 steel supplier to the automotive industry in North America. Headquartered in Cleveland, Ohio, Cleveland-Cliffs employs approximately 25,000 people across its mining, steel and downstream manufacturing operations in the United States and Canada.

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July 2021