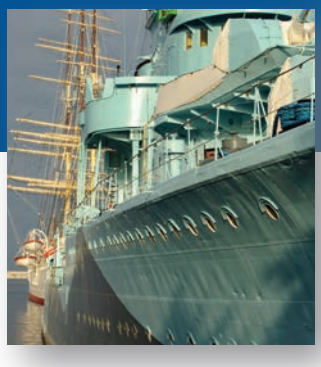
CLIFFS

316 / 316L
STAINLESS STEEL



- **Chemical Processing Equipment**
- **Exhaust Manifold**
- **Furnace Pans**
- **Marine Exposed Tubing**

TYPE 316 is widely used in applications requiring corrosion resistance superior to Type 304, or good elevated temperature strength. Typical uses include exhaust manifolds, furnace parts, heat exchangers, jet engine parts, pharmaceutical and photographic equipment, valve and pump trim, chemical equipment, digesters, tanks, evaporators, pulp, paper and textile processing equipment, parts exposed to marine atmospheres and tubing. Type 316L is used extensively for weldments where its immunity to carbide precipitation due to welding assures optimum corrosion resistance.

Product Description

Type 316L is an extra-low carbon variation of Type 316 that eliminates harmful carbide precipitation due to welding.

Composition		Type 316 (wt %)	Type 316L (wt %)
Carbon	(C)	0.08 max.	0.03 max.
Manganese	(Mn)	2.00 max.	2.00 max.
Phosphorus	(P)	0.045 max.	0.045 max.
Sulfur	(S)	0.030 max.	0.03 max.
Silicon	(Si)	0.75 max.	0.75 max.
Chromium	(Cr)	16.0 – 18.00	16.0 – 18.00
Nickel	(Ni)	10.00 – 14.00	10.00 – 14.00
Molybdenum	(Mo)	2.00 – 3.00	2.00 – 3.00
Nitrogen	(N)	0.10 max.	0.10 max.
Iron	(Fe)	Balance	Balance

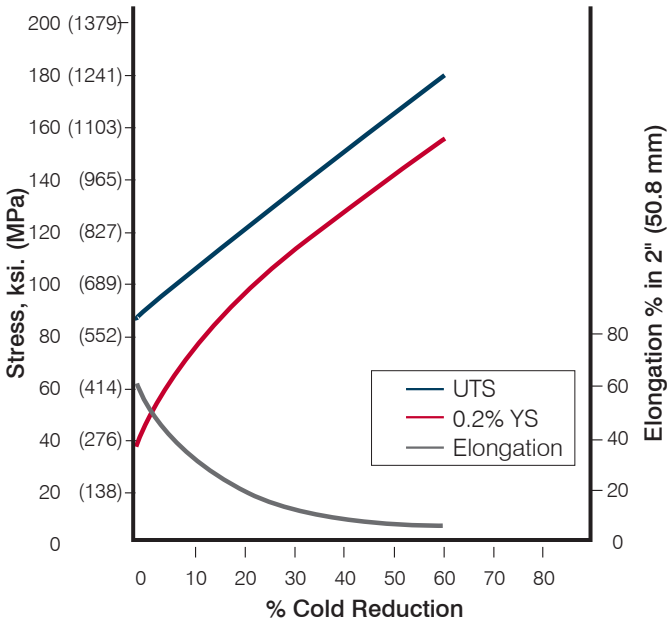
AVAILABLE FORMS

Cleveland-Cliffs produces Type 316 and 316L in thicknesses from 0.01 – 0.1874 in. (0.25 – 4.76 mm) and widths up to 48 in. (1219 mm). For other thicknesses and widths, contact your Cleveland-Cliffs sales representative.

METRIC PRACTICE

Values shown in this bulletin were established in U.S. customary units. The metric equivalents may be approximate.

FIGURE 1 – EFFECT OF COLD WORK ON TENSILE PROPERTIES



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
91 (627)	42 (290)	55	79

TABLE 2 – ELEVATED TEMPERATURE MECHANICAL PROPERTIES

Temperature, °F (°C)	UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)
400 (204)	81 (558)	35 (241)	51
600 (316)	78 (538)	31 (214)	48
800 (427)	76 (524)	28 (190)	47
1000 (538)	70 (483)	24 (165)	44
1200 (649)	57 (393)	21 (145)	40
1400 (760)	35 (241)	18 (124)	37
1600 (871)	24 (165)	16 (110)	44

TABLE 3 – STRESS RUPTURE PROPERTIES

Temperature, °F (°C)	Stress, ksi. (MPa), for rupture in:		
	1,000 hours	10,000 hours	100,000 hours
1100 (593)	36.0 (248)	28.0 (193)	25.0 (172)
1200 (649)	24.0 (165)	16.5 (114)	13.5 (94)
1300 (704)	15.5 (106)	10.0 (69)	7.0 (48)
1400 (760)	10.0 (69)	6.0 (41)	3.5 (24)
1500 (816)	6.0 (41)	3.5 (24)	2.0 (14)
1600 (871)	3.5 (24)	—	—

Properties

PHYSICAL PROPERTIES

Density, lbs/in.^{3} (g/cm^3)	0.29 (8.03)
Electrical Resistivity, $\mu\Omega$•in. ($\mu\Omega$•cm) 68 °F (20 °C)	 29.4 (74)
Thermal Conductivity, BTU/hr./ft./°F W/(m•K) 212 °F (100 °C) 932 °F (500 °C)	 9.4 (16.2) 12.4 (21.4)
Coefficient of Thermal Expansion, in./in./°F (μm/m/K) 32 – 212 °F (0 – 100 °C) 32 – 600 °F (0 – 315 °C) 32 – 1000 °F (0 – 538 °C) 32 – 1200 °F (0 – 649 °C)	 8.9 x 10^{-6} (16.0) 9.0 x 10^{-6} (16.2) 9.7 x 10^{-6} (17.5) 10.3 x 10^{-6} (18.5)
Modulus of Elasticity, ksi. (MPa) in tension in torsion	 28.0 x 10^3 (193 x 10^3) 11.2 x 10^3 (77 x 10^3)
Magnetic Permeability Annealed, (H/m at 200 Oersteds)	1.02 max.
Specific Heat, BTU/lbs./°F (kJ/g/K) 32 – 212 °F (0 – 100 °C)	 0.12 (0.50)
Melting Range, °F (°C)	2500 – 2550 (1371 –1399)

CORROSION RESISTANCE

Types 316 and 316L exhibit improve chloride corrosion resistance when compared to Type 304 due to the molybdenum addition to the steel. This allows for acceptable corrosion protection to marine atmospheres when pitting corrosion is concerned. They also provide good chemical resistance to most agents used in the paper, petroleum, food and dairy industries. They are useful in sulfuric acid environments up to 150 °F (60 °C) when concentrations are below 5%. They show excellent corrosion resistance to acetic, formic, phosphoric,and tartaric acids, as well as some concentrations and temperatures of bromide and iodide solutions. When welding operations are used, the lower carbon Type 316L allows for reduced risk of intergranular corrosion caused by chromium carbide precipitation.

HEAT TREATMENT

Annealing: Heat to 1900 – 2100 °F (1038 – 1149 °C), then rapidly quench.

COLD WORKING

Due to higher nickel content, these grades work harden at a lower rate than Type 304. In the annealed condition, they exhibit excellent ductility and may be readily roll formed, deep drawn, and bent. Annealing is essential to restore ductility and to lower hardness for subsequent forming operations. Severely formed parts should be annealed to remove stresses.

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FORMABILITY

Types 316 and 316L can be readily formed and drawn using the same methods as used with Type 301 and Type 304. Although the forming capability is very similar to Type 301, temperature variation will have less influence on material behavior. This product may become slightly magnetic when highly cold worked.

SPECIFICATIONS

Types 316 and 316L sheet and strip are covered by the following specifications:

Type 316	Type 316L
AMS 5524	AMS 5507
ASTM A240	ASTM A240

WELDABILITY

The austenitic class of stainless steels is generally considered to be weldable by the common fusion and resistance techniques. Special consideration is required to avoid weld "hot cracking" by assuring formation of ferrite in the weld deposit. These particular alloys are generally considered to have poorer weldability than Types 304 and 304L. A major difference is the higher nickel content for these alloys, which requires slower arc welding speed and more care to avoid hot cracking. When a weld filler is needed, AWS E/ER Type 316L and Type 16-8-2 are most often specified. Type 316 and its low-carbon "L" version are well known in reference literature, and more information can be obtained in the following references:

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).
3. ANSI/AWS B2.1.009:2002 (GTAW 300's @ 0.50 – 0.14 in.).
4. ANSI/AWS B2.1-8-024:2001 (GTAW 300's @ 0.125 – 1.5 in.).
5. ANSI/AWS B2.1-8-013:2002 (SMAW 300's @ 0.050 – 0.14 in.).
6. ANSI/AWS B2.1-8-023:94 (SMAW 300's @ 0.125 – 1.5 in.).
7. ANSI/AWS B2.1.005:2002 (GMAW 300's @ 0.050 – 0.14 in.).
8. "High Frequency Welding of Stainless Steel Tubes" by H.N. Udall and R.K. Nichols.
9. ANSI/AWS D1.6/D1.6M:2007 (Structural Welding Code – Stainless Steel).

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.

CLIFFS

CLEVELAND-CLIFFS INC.
200 Public Square
Suite 3300
Cleveland, OH 44114-2315
844.STEEL99 | 844.783.3599
clevelandcliffs.com

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