CLIFFS

NITRONIC® 19D

LEAN DUPLEX STAINLESS STEEL

Chemical Processing

Desalination/Water Treatment

Oil Field

Undersea Tubing

CLEVELAND-CLIFFS **NITRONIC® 19D STAINLESS STEEL** is a molybdenum-free, low-nickel lean duplex stainless steel. The combination of strength, corrosion resistance, ease of forming and welding make Cleveland-Cliffs NITRONIC 19D Stainless Steel a good choice in many applications. The alloy can be used as a corrosion-resistant, high-pressure alternative for undersea umbilical tubing, and it is a cost-effective alternative to higher-cost alloys. Cleveland-Cliffs NITRONIC 19D Stainless Steel may also be used for the production of annealed tubing for oilfield applications, desalination and water treatment, chemical processing, storage tanks and architectural structures.

Product Description

Cleveland-Cliffs NITRONIC 19D Stainless Steel is a lean duplex stainless steel with a mixed ferrite and austenite structure. This alloy provides high yield strength, good drawing and welding characteristics, excellent chloride stress corrosion cracking resistance and high cyclic oxidation resistance up to 1800 °F (982 °C). It also exhibits high ductility (super plasticity) at high temperatures up to 1800 °F (982 °C). Compared to similar duplex stainless alloys such as Type 2205, Cleveland-Cliffs NITRONIC 19D Stainless Steel is more economical, but less corrosion resistant, due to lower alloy content, particularly molybdenum.

Composition		Typical (wt %)	ASTM A240 (wt %)
Carbon	(C)	0.02	0.030 max.
Manganese	(Mn)	5.00	4.0 – 6.0
Silicon	(Si)	0.40	1.00 max.
Chromium	(Cr)	20.00	19.5 – 21.5
Nickel	(Ni)	1.60	1.0 – 3.0
Copper	(Cu)	0.30	1.00 max.
Nitrogen	(N)	0.13	0.05 – 0.17
Iron	(Fe)	Balance	Balance

AVAILABLE FORMS

Cleveland-Cliffs NITRONIC 19D Stainless Steel is produced in cold-rolled annealed and pickled strip with a 2D finish. Available in thicknesses from 0.028 – 0.14 in. (0.71 – 3.56 mm).

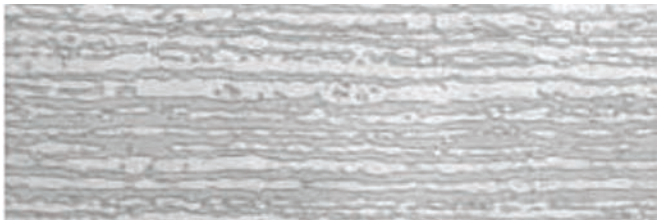
PHYSICAL PROPERTIES

Density, g/cm^3 (lbs./in^3)	7.72 (0.278)

MICROSTRUCTURE

Cleveland-Cliffs NITRONIC 19D Stainless Steel is alloy balanced to yield a microstructure consisting of 30 – 60% ferrite (bcc) and 40 – 70% austenite (fcc) in the wrought form. A typical wrought microstructure is shown in Figure 1. When examined metallographically, the cross-section of a sheet sample usually appears as a layered structure of alternating ferrite (bcc) and austenite (fcc) grains. This is sometimes called a pancake structure.

FIGURE 1



Typical longitudinal microstructure of NITRONIC 19D at 500X.

Mechanical Properties

TABLE 1 – PROPERTIES ACCEPTABLE FOR MATERIAL SPECIFICATION

	UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Rockwell Hardness, C
0.028 – 0.084 in. (0.71 – 2.13 mm)	90 (620) min.	65 (448) min.	25 min.	25 max.

TABLE 2 – TYPICAL ROOM TEMPERATURE MECHANICAL PROPERTIES

	UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Rockwell Hardness, C
0.028 – 0.084 in. (0.71 – 2.13 mm)	115 (793)	75 (517)	40	20

TABLE 3 – TYPICAL ELEVATED TEMPERATURE MECHANICAL PROPERTIES

Orientation At Temperature	UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)
1600 °F (871 °C) Longitudinal Transverse	 12.1 (83.4) 10.1 (69.6)	 8.4 (57.9) 6.9 (47.6)	 82.3 88.0
1800 °F (982 °C) Longitudinal Transverse	 5.5 (37.9) 4.0 (27.6)	 3.3 (22.8) 2.3 (15.8)	 113.0 143.0
2000 °F (1093 °C) Longitudinal Transverse	 2.6 (17.9) 1.9 (13.1)	 1.3 (9.0) 0.8 (5.5)	 236.5 179.5

0.875 in. plate

TABLE 4 – EFFECT OF COLD WORK ON MECHANICAL PROPERTIES

% Cold Reduction	UTS, ksi. (MPa)	0.2% YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Rockwell Hardness*	n-Value
0	98.8 (681)	63.4 (437)	35	B92	0.17
4.0	104.2 (718)	87.6 (604)	30	B97	0.16
9.8	113.5 (782)	101.9 (702)	24	B100	—
15.1	120.7 (812)	113.9 (785)	15	C24	—
20.7	130.0 (896)	119.9 (827)	12	C27	—
40.7	154.2 (1063)	141.2 (974)	5	C30	—
57.8	172.0 (1186)	158.1 (1090)	6	C33	—

**Lab work-hardened samples average of duplicate tests. All at 0.080 in. final gauge.*

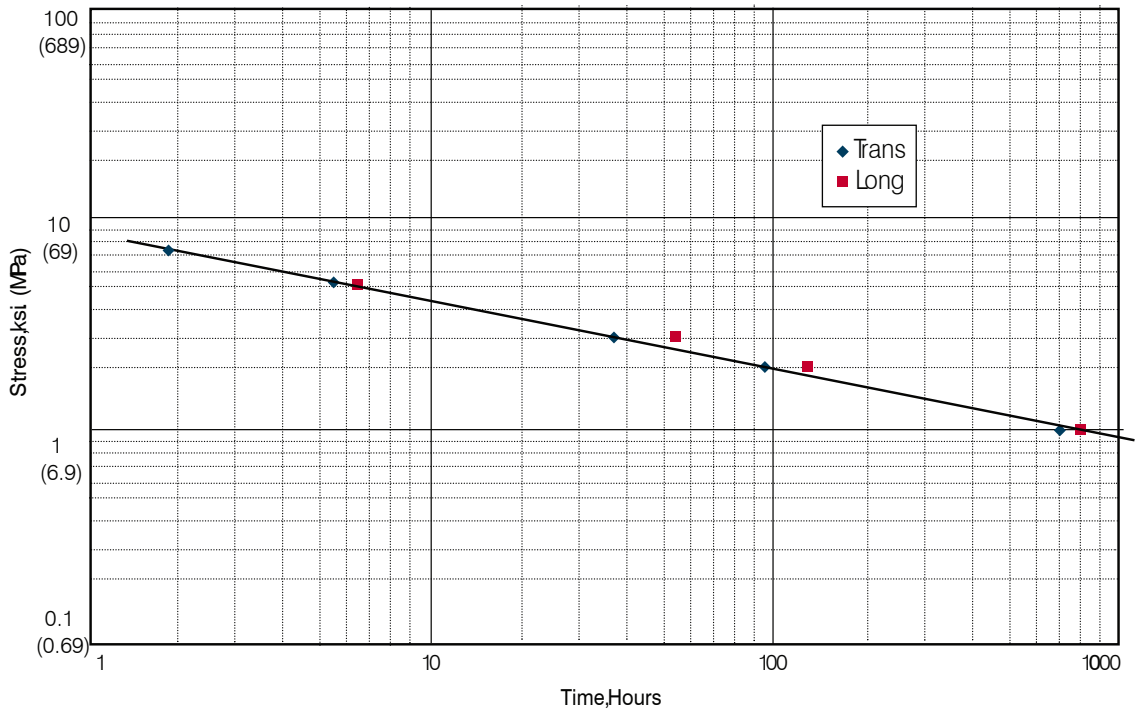
Mechanical Properties

TABLE 5 – EFFECT OF TEMPERATURE ON CHARPY V-NOTCH PROPERTIES (0.1875 in. PLATE)
Impact Strength (Energy/Unit Area), in.•lb./in.^{2} (J/cm^2) at Test Temperature

Orientation	73 °F (23°C)	0 °F (-18 °C)	-22 °F (-30 °C)	-100 °F (-73 °C)	-150 °F (-101 °C)
Longitudinal*	16786 (293.8)	10555 (184.7)	9703 (169.8)	7904 (138.3)	6347 (111.1)
Transverse†	4793 (83.9)	4428 (77.5)	3962 (69.3)	3111 (54.4)	2891 (50.6)

**Specimen axis parallel to rolling direction with notch through the plate.*
†Specimen axis transverse to rolling direction with notch through the plate.

FIGURE 2 – NITRONIC 19D STAINLESS STEEL STRESS RUPTURE @ 1500 °F (816 °C) (0.079 in. SHEET)



Mechanical Properties

FIGURE 3 – NITRONIC 19D STAINLESS STEEL IN TENSION TEST

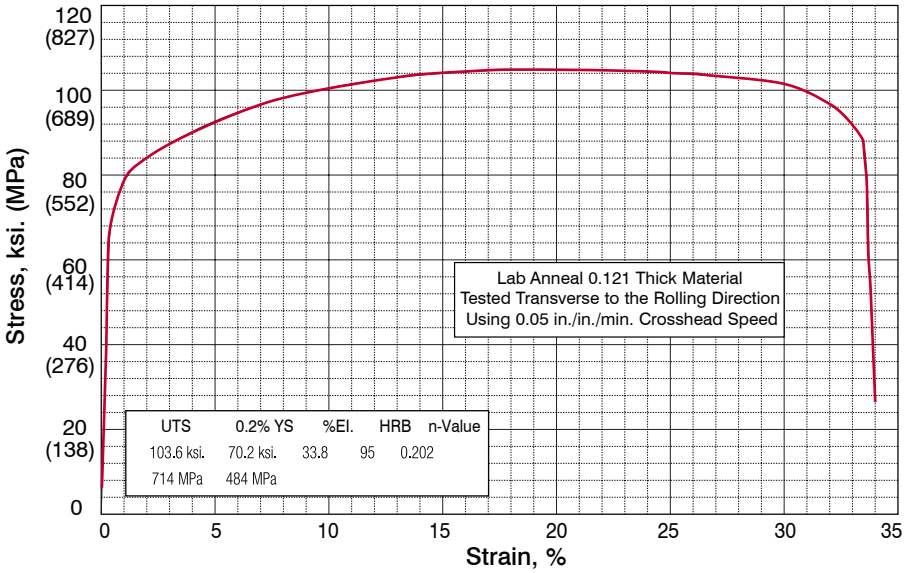


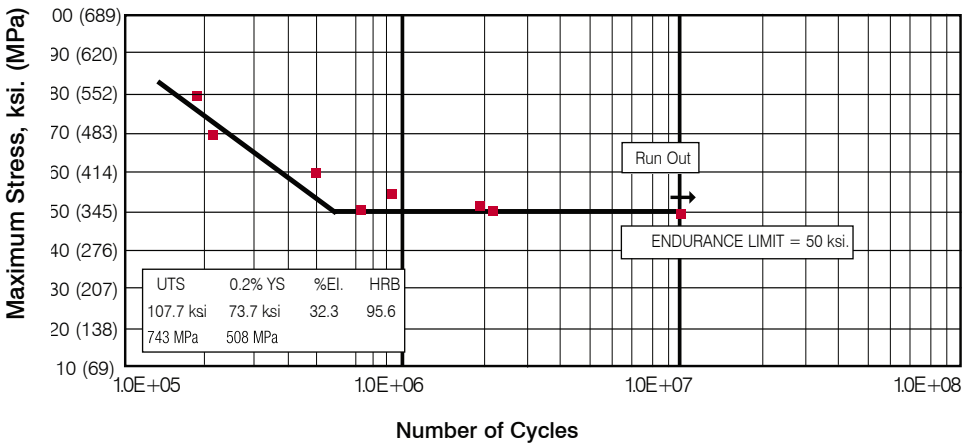
TABLE 6 – LOW CYCLE STRAIN CONTROLLED FATIGUE RESISTANCE

Temperature	R-ratio	Frequency, Hz	Strain Range, %	Cycles to Failure
1600 (871)	-1	0.5	1.06	1447
	-1	0.5	0.80	2451
	-1	0.5	0.60	4714
	-1	0.5	0.30	21652
	-1	0.5	0.16	125775
1800 (982)	-1	0.5	0.80	1792
	-1	0.5	0.40	4245
	-1	0.5	0.20	28274
	-1	0.5	0.16	37470

ASTM E606

Mechanical Properties

FIGURE 4 – CONTROLLED FORCE AMPLITUDE REVERSE BEND FATIGUE



R = -1, Transverse (0.037 in. (0.94 mm) annealed sheet.
ASTM E466

TABLE 7 – CYCLIC OXIDATION RESISTANCE

Alloy	Weight Change, mg/in²	Rank
18 Cr-Cb™ SS	15.1	1
NITRONIC 19D SS	26.6	2
Type 310	2.2	3*
Cleveland-Cliffs Type 2205	-31.0	4

1800 °F (982 °C): 25 minutes heating, 5 minutes cooling. Specimens weighed daily for a total of 670 cycles.

**Ranked 3 due to oxide spalling after day 8.*

CORROSION RESISTANCE

CHLORIDE STRESS CRACKING

Cleveland-Cliffs NITRONIC 19D Stainless Steel, like other duplex stainless steels, offers superior chloride stress corrosion cracking resistance relative to fully austenitic stainless steels like Types 304 and 316.

TABLE 8 – CHLORIDE STRESS CRACKING RESISTANCE*

Alloy	Hours to Failure
NITRONIC 19D SS	720 hours with no failure
Type 304	127 hours

**0.056 in. (1.42 mm) strip at 1950 °F (1066 °C) anneal, 25% boiling sodium chloride @ pH = 1.5 (adjusted with phosphoric acid). U-bends, 1.25 in. (31.75 mm) diameter, specimen axis parallel to rolling direction.*

SIGMA EMBRITTLEMENT

Cleveland-Cliffs NITRONIC 19D Stainless Steel is highly resistant to embrittlement from sigma phase formation, even with exposure times of 100 hours. After three separate studies, it appears that this alloy is virtually immune to sigma formation with short-time exposure at any elevated temperature, while more highly alloyed alternatives Type 2205 and Type 2507 undergo significant embrittlement in just 10 minutes exposure to temperatures from 1400 – 1600 °F (760 – 871 °C).

FORMABILITY

Duplex steel is better than the ferritic grades, especially in heavy sections, but not quite as good as the austenitic stainless steels. Machining characteristics of this alloy are similar to those of Type 304.

TABLE 9 – FORMABILTY

Olsen Cup Height	0.33 – 0.45 in. (8.4 – 11.4 mm)
Bend Ductility	OT
n-Value*	0.19
Limiting Draw Ration (LDR)	2.0
Strain Ratio L	0.86
D	0.80
T	1.21
r-Bar	0.92

**n-Value is also referred to as the strain-hardening exponent.*

WELDABILITY

Welding of Cleveland-Cliffs NITRONIC 19D Stainless Steel should follow basically the same guidelines as the other duplex stainless steels, like Type 2205. However, it so effectively resists sigma phase formation that an upper limit on heat input for arc welding is not critical. High heat input during arc welding slows the cooling rate, allowing more time for the required transformation to a duplex structure in the weld metal and heat-affected zone (most literature suggests a minimum of 30% austenite). In Gas Tungsten ARC (GTA) welding, an addition of 2 – 5 % nitrogen to the argon shielding gas and the use of nitrogen backing gas will also assist in this transformation in the weld metal. When filler metal is required, one balanced more toward an austenitic structure is preferred for this reason. AWS A5.4/5.9 Classifications ER/EE2209 would also be good weld filler selections for this grade. A post-weld anneal of about 1900 °F (1037 °C) will also improve the phase balance, if neither of the preceding suggestions are feasible or adequate.

Like other duplex stainless steels, laser welding is an option that must be considered carefully, as the high solidification and cooling rates will yield a primarily ferritic weldment structure. Post-weld annealing would be very beneficial for such welds. The conventional processes of Gas Metal Arc Welding (GMAW) and Shielded Metal Arc Welding (SMAW) are both very feasible, and, again, high heat inputs should aid the transformation to a duplex structure.

TABLE 10 – THERMAL EXPANSION

Temperature °F	Relative Expansion %	Coefficient Expansion, ΔL/L/ °Fx10^{8}	Temperature °C	Relative Expansion %	Coefficient Expansion, ΔL/L/ °Fx10^{8}
175	0.076	7.04	75	0.069	12.58
275	0.151	7.30	125	0.138	13.08
375	0.229	7.46	175	0.207	13.36
475	0.309	7.59	225	0.279	13.58
575	0.392	7.72	275	0.352	13.79
675	0.475	7.83	325	0.427	13.99
775	0.561	7.98	375	0.503	14.16
875	0.647	8.02	425	0.580	14.32
975	0.734	8.08	475	0.658	14.46
1075	0.824	8.18	525	0.735	14.56
1175	0.917	8.29	575	0.817	14.72
1213	0.957	8.36	625	0.900	14.88
—	—	—	656	0.957	15.04

Average of triplicate tests on two specimens, heating curves.

TABLE 11 – AS-WELDED AUTOGENOUS GTA MECHANICAL PROPERTIES*

	UTS ksi. (MPa)	YS, ksi. (MPa)	Elongation % in 2 in. (50.8 mm)	Elongation % in 0.5 in. (12.7 mm)	Base Rockwell Hardness, B**	Weld Rockwell Hardness, B***
Weld*	100.2 (690.6)	69.4 (478.5)	20	33.9	94	94
Weld Dup.*	99.5 (686.0)	70.2 (484.0)	16	31.8	—	—
Base Metal**	103.0 (710.2)	69.3 (477.8)	32	—	96	—

*0.060 in. (1.5 mm) thickness.
**6 Replicates
***3 Replicates

+ Tensiles oriented with weld across the reduced section.
++ Duplicate transverse production values.
Note: 1) Elongations in 0.5 in. (12.7 mm) are more appropriate for welds. Fractures were in the weld metal.
2) Hardness results in "Weld" row are from separate coupon.

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

May 2021