

Type 316, Type 316L

UNS S31600, UNS S31603

A molybdenum-containing austenitic stainless steel with improved resistance to chlorides relative to Type 304/304L stainless steel.

Description

Type 316/316L is a molybdenum-containing austenitic stainless steel intended to provide improved corrosion resistance relative to Type 304/304L in moderately corrosive process environments, particularly those containing chlorides or other halides.

Type 316/316L is non-magnetic in the annealed condition but may become slightly magnetic as a result of welding.

Dual Certification

It is common for Type 316L to be dual certified as Type 316 and Type 316L when the material meets both the lower carbon limit of Type 316L and the slightly higher strengths of Type 316. The producer of the steel must certify the material as Type 316 if it is to be used as Type 316 instead of Type 316L.

Specifications

Type 316/316L can be supplied to meet AMS, ASTM, ASME, QQS, and MIL-S specifications.

Product Forms Available

Plate
Sheet
Tubular Products
Bar
Angle
Wire Rod
Billet
Welding Consumables

Corrosion Resistance

The addition of molybdenum provides improved resistance to pitting and crevice corrosion in environments containing chlorides and other halides.

Type 316/316L has been used in handling many chemicals used by the process industries, including pulp and paper, textile, food, pharmaceutical, medical, and other chemical processing.

Mechanical Properties at Room Temperature

Table 1

	Typical*	ASTM	
		Type 316	Type 316L
Ultimate Tensile Strength, ksi	85	75 min	70 min
0.2% Offset Yield Strength, ksi	44	30 min	25 min
Elongation in 2 inches, %	56	40 min	40 min
Reduction in Area, %	69	—	—
Hardness, Rockwell B	81	95 max	95 max

*0.375 inch plate

Chemical Composition, wt. pct.

Table 2

	Type 316	Type 316L
Carbon	0.08 max	0.030 max
Manganese	2.00 max	2.00 max
Phosphorus	0.045 max	0.045 max
Sulfur	0.03 max	0.030 max
Silicon	0.75 max	0.75 max
Chromium	16.0-18.0	16.0-18.0
Nickel	10.0-14.0	10.0-14.0
Molybdenum	2.00-3.00	2.00-3.00
Nitrogen*	0.10 max	0.10 max

*flat-rolled products only

Heat Treatment Annealing

Type 316/316L should be heated to 1900°F and water quenched or rapidly cooled by other means.

Hardening

Type 316/316L cannot be hardened by heat treatment. However, Type 316 can be hardened by cold working.

Physical Properties

Table 3

Density, lb/in ³	0.285
Modulus of Elasticity, psi	29 x 10 ⁶
Coefficient of Thermal Expansion, 68-212°F, /°F	8.9 x 10 ⁻⁶
Thermal Conductivity, Btu/ft hr°F	8.7
Heat Capacity, Btu/lb°F	0.12
Electrical Resistivity, Ω-inch	29.5 x 10 ⁻⁶

Workability Cold Working

Type 316/316L is readily formed and fabricated through a full range of cold working operations. It can be used in heading, drawing, bending, and upsetting. Any cold working operations will increase the strength and hardness of the material.

Hot Working

Type 316/316L can be forged in the 1700-2200°F range. For maximum corrosion resistance, forgings should be annealed at 1900°F minimum and water quenched or rapidly cooled by other means after hot working operations.

Lowest Temperature (°F) at Which the Corrosion Rate Exceeds 5 mpy

Table 4

Corrosion Environment	654 SMO®	254 SMO®	904L	Type 316L (2.7 Mo)	Type 304	2507	2205 Code Plus Two®	2304
0.2% Hydrochloric Acid	>Boiling	>Boiling	>Boiling	>Boiling	>Boiling	>Boiling	>Boiling	>Boiling
1% Hydrochloric Acid	203	158	122	86	86p	>Boiling	185	131
10% Sulfuric Acid	158	140	140	122	—	167	140	149
60% Sulfuric Acid	104	104	185	<54	—	<57	<59	<<55
96% Sulfuric Acid	86	68	95	113	—	86	77	59
85% Phosphoric Acid	194	230	248	203	176	203	194	203
10% Nitric Acid	>Boiling	>Boiling	>Boiling	>Boiling	>Boiling	>Boiling	>Boiling	>Boiling
65% Nitric Acid	221	212	212	212	212	230	221	203
80% Acetic Acid	>Boiling	>Boiling	>Boiling	>Boiling	212p	>Boiling	>Boiling	>Boiling
50% Formic Acid	158	212	212p	104	≤50	194	194	59
50% Sodium Hydroxide	275	239	Boiling	194	185	230	194	203
83% Phosphoric Acid + 2% Hydrofluoric Acid	185	194	248	149	113	140	122	95
60% Nitric Acid + 2% Hydrochloric Acid	>140	140	>140	>140	>140	>140	>140	>140
50% Acetic Acid + 50% Acetic Anhydride	>Boiling	>Boiling	>Boiling	248	>Boiling	230	212	194
1% Hydrochloric Acid + 0.3% Ferric Chloride	>Boiling, p	203ps	140ps	77p	68p	203ps	113ps	68p
10% Sulfuric Acid + 2000ppm Cl ⁻ + N ₂	149	104	131	77	—	122	95	<55
10% Sulfuric Acid + 2000ppm Cl ⁻ + SO ₂	167	140	122	<<59p	—	104	<59	<<50
WPA1, High Cl ⁻ Content	203	176	122	≤50	<<50	203	113	86
WPA2, High F ⁻ Content	176	140	95	≤50	<<50	167	140	95

ps = pitting can occur
ps = pitting/crevice corrosion can occur

WPA	P ₂ O ₅	Cl ⁻	F ⁻	H ₂ SO ₄	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂	CaO	MgO
1	54	0.20	0.50	4.0	0.30	0.20	0.10	0.20	0.70
2	54	0.02	2.0	4.0	0.30	0.20	0.10	0.20	0.70

Corrosion Performance of Stainless Steels

Table 4 compares several Outokumpu stainless steels in a variety of common corrosive environments. The lowest temperature at which the corrosion rate exceeds 5 mpy was determined. All testing was done in accordance with the requirements of the Materials Technology Institute of the Chemical Process Industries (MTI).

Welding

Type 316/316L is readily welded by a full range of conventional welding procedures (except oxyacetylene). AWS E316L/ER316L and other filler metals with molybdenum content higher than that of the base metal should be used with Type 316/316L stainless steel.

Machinability

Type 316/316L is a tough austenitic stainless steel subject to work hardening during deformation and, unless modified for improved machining response, resistant to chip breaking. The best machining

results are achieved with slower speeds, heavier feeds, excellent lubrication, sharp tooling, and powerful, rigid equipment.

Technical Support

Outokumpu Stainless, Inc. assists users and fabricators in the selection, qualification, installation, operation, and maintenance of Type 316/316L stainless steel. Technical personnel, supported by the research laboratory of Outokumpu Stainless, Inc., can draw on years of field experience with Type 316/316L to help you make the technically and economically correct materials decision.

Outokumpu Stainless is prepared to discuss individual applications and to provide data and experience as a basis for selection and application of Type 316/316L.

Outokumpu Stainless works closely with its distributors to ensure timely availability of Type 316/316L in the forms, sizes, and quantities required by the user. For assistance with technical questions and to obtain top quality Type 316/316L, call Outokumpu Stainless, Inc. at 1-800-833-8703.

4 Type 316, Type 316L

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