PRODEC® Type 316, Type 316L UNS S31600, UNS S31603

A special quality of standard Type 316/316L with composition and processing for enhanced machinability.

Description

PRODEC® 316/316L is an improved version of standard Type 316/316L. With advanced ladle metallurgy techniques, the steel is processed for improved machinability and outstanding uniformity. PRODEC 316/316L offers faster machining speeds, longer tool life, improved part quality, and lower total cost of machined parts.

PRODEC 316/316L is nonmagnetic in the annealed condition but may become slightly magnetic as a result of welding.

Dual Certification

It is common for PRODEC 316L to be dual certified as PRODEC 316 and PRODEC 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

PRODEC 316/316L meets the same AMS, ASTM, ASME, QQS, and MIL-S specifications as standard Type 316/316L.

Product Forms Available

Plate
Bar

Corrosion Resistance

PRODEC 316/316L provides improved resistance to pitting and crevice corrosion in environments containing chlorides and other halides.

Although improvements in machinability in the past have been associated with reduced corrosion resistance, PRODEC 316/316L has been shown to have corrosion resistance within the range typically expected of Type 316/316L stainless steel.

Machinability

PRODEC 316/316L is melted to a closely controlled chemistry and ladle treated to achieve control of the composition, amount, size, shape, and distribution of the nonmetallic inclusions (sulfides and oxides) normally occurring within a standard stainless steel. These inclusions provide for chip breaking and for reduced wear of carbide tooling at high machining speeds. PRODEC 316/316L permits higher machining speeds, longer tool life, and superior part quality with reduced total cost for finished parts.

The following tables give some speeds and feeds obtained in tests for PRODEC 316/316L, providing guidelines for possible adaptation to particular machining programs. The data provided are based on achieving tool lives of 15 minutes for cemented carbides and 60 minutes for high speed steel tools.

Turning

Table 1

Feed (in/rev)	Cutting depth (in)	Cutting speed, sfm			
		Cemented carbides			High speed steel
		C7	C6	C5	
< 0.012	0.08	780	620	—	95
0.012-0.020	0.08-0.20	—	560	460	80
0.020-0.040	0.20-0.40	—	295	260	50

Threading

Table 2

Tool	Speed (sfm)
Cemented Carbide (C6-C5)	295-425
High Speed Steel	50-65

Reaming

Table 3

Ream diameter (in)	Cutting Speed (sfm) Cemented carbide	High speed steel	Feed (in/rev)
< 0.40	165	33-50	0.004-0.008
0.40-0.80	165	33-50	0.012
> 0.80	165	33-50	0.012-0.016

Coolant/lubricant: emulsion or cutting oil

Cut Off

Table 4

Tool	Speed (sfm)	Feed (in/rev)
Cemented Carbide (C5)	295-460	0.003-0.008
High Speed Steel	100	0.002

Drilling — High Speed Steel Twist Drills

Table 5

Drill diameter (in)	Speed rpm	sfm	Feed (in/rev)
0.04	3200-3800	33-38	0.002
0.12	1600-1800	50-57	0.004
0.20	1080-1270	57-66	0.008
0.40	540-640	57-66	0.012
0.60	360-430	57-66	0.014
0.80	270-320	57-66	0.016
1.20	180-220	57-66	0.018

Notes:
1. Cutting Fluid: Ample flow of 10% emulsion coolant.
2. With short NC drills, feed can be increased about 40%.
3. When hole depth exceeds 4x diameter, clear chips from hole.
4. With TiN-Coated HSS drills, speed can be increased 10%.
5. For rotating drill and fixed workpiece, as in drilling a hole in a plate, the maximum speed should not exceed 50 sfm.

Drilling — Indexable Insert Drills Cemented Carbides

Table 6

Drill diameter (in)	Speed (sfm)	Feed (in/rev)	Type of carbide Center	Periphery
0.80	655-820	0.004	C6	C7
1.20	655-820	0.005	C6	C7
1.60	655-820	0.006	C6	C7
2.00	655-820	0.008	C6	C7

Notes:
Cutting Fluid—Pressure: >44 psi; Amount: > 6.5 gal/min
Cutting data for indexable insert drills are highly dependent on the make of drill; the manufacturer's recommendations should be considered.

Heat Treatment Annealing

PRODEC 316/316L should be heated to 1900°F minimum, then water quenched or rapidly cooled by other means.

Hardening

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

Mechanical Properties at Room Temperature

Table 7

	Typical*	ASTM 316	ASTM 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 8

	PRODEC 316	PRODEC 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

Physical Properties

Table 9

Density, lb/in^3	0.285
Modulus of Elasticity, psi	29×10^6
Coefficient of Thermal Expansion, 68-212°F,/°F	9.4×10^{-6}
Thermal Conductivity, Btu/h ft°F	8.7
Heat Capacity, Btu/lb°F	0.12
Electrical Resistivity, Ω-inch	27.6×10^{-6}

Milling

Table 10

Operation	Cemented carbide			High speed steel	
	Speed (sfm)	Feed (in/tooth)	Type of carbide	Speed (sfm)	Feed (in/tooth)
Face Milling	490-820	0.006-0.012	C7-C6	80-100	0.005-0.008
Side Milling	590-790	0.010-0.012	C7-C6	80-100	0.005-0.008
End Milling	490-720	0.004-0.008	C7-C6	80-100	0.001-0.006
End Milling (Solid cemented carbide)	165-330	0.002-0.008	C5	—	—

Corrosion Performance of Stainless Steels

Table 11 compares Type 316L (2.7 Mo) with other stainless steels in a variety of common corrosive environments. The table shows the lowest temperature at which the corrosion rate exceeds 5 mpy. All testing was done in accordance with the requirements of the Materials Technology Institute of the Chemical Process Industries (MTI).

Workability
Cold Working

PRODEC 316/316L is readily formed and fabricated through a full range of cold working

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

Table 11

Corrosion Environment	654 SMO®	254 SMO®	904L	Type 316L (2.7 Mo)	Type 304	Outokumpu 2507	2205 Code Plus Two®	Outokumpu 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_2O_5	Cl^-	F^-	H_2SO_4	Fe_2O_3	Al_2O_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

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

PRODEC 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.

Welding

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

Technical Support

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

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

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

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Outokumpu is a global leader in stainless steel with the vision to be the undisputed number one. Customers in a wide range of industries use our stainless steel and services worldwide. Being fully recyclable, maintenance-free, as well as very strong and durable material, stainless steel is one of the key building blocks for sustainable future.

What makes Outokumpu special is total customer focus – all the way, from R&D to delivery. You have the idea. We offer world-class stainless steel, technical know-how and support. We activate your ideas.

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