316/316L, 317/317L - Stainless Steel: Austenitic

(UNS S31600, S31603, S31700, S31703)

INTRODUCTION

316 (UNS S31600), 316L (S31603), 317 (S31700) and 317L (S31703) alloys are molybdenum-bearing austenitic stainless steels which are more resistant to general corrosion and pitting/crevice corrosion than the conventional chromium-nickel austenitic stainless steels such as ATI 304. These alloys also offer higher creep, stress-to-rupture and tensile strength at elevated temperature. 317 and 317L alloys containing 3 to 4% molybdenum are preferred to 316 or 316L alloys which contain 2 to 3% molybdenum in applications requiring enhanced pitting and general corrosion resistance.

Austenitic stainless steels with higher molybdenum or molybdenum plus nitrogen content which provide even greater resistance to pitting crevice corrosion and general corrosion are also available in flat-rolled products.

In addition to excellent corrosion resistance and strength properties, the 316/316L, 317/317L Cr- Ni-Mo alloys also provide excellent fabricability and formability which are typical of the austenitic stainless steels.

316/316L, 317/317L

PRODUCT FORMS

316/316L, 317/317L stainless steels are available in the form of sheet, strip and plate to ASTM A240 and ASME SA-240.

Element	Percentage by Weight (maximum unless range is specified)			
	316	316L	317	317L
Carbon	0.08	0.030	0.08	0.030
Manganese	2.00	2.00	2.00	2.00
Silicon	0.75	0.75	0.75	0.75
Chromium	16.00	16.00	18.00	18.00
	18.00	18.00	20.00	20.00
Nickel	10.00	10.00	11.00	11.00
	14.00	14.00	15.00	15.00
Molybdenum	2.00	2.00	3.00	3.00
	3.00	3.00	4.00	4.00
Phosphorus	0.045	0.045	0.045	0.045
Sulfur	0.030	0.030	0.030	0.030
Nitrogen	0.10	0.10	0.10	0.10
Iron	Bal.	Bal.	Bal.	Bal.

SPECIFICATIONS & CERTIFICATES

Because of the extensive use of 316/316L, 317/317L austenitic stainless steels and their broad specification coverage, the following list of specifications is representative, but not complete. 316/316L, 317/317Lstainless steel product forms are assigned allowable stresses in Section II, Part D of the ASME Boiler and Pressure Vessel Code. For the 316 and 317 alloys, the maximum use temperature is 1500°F (816°C), whereas for 316L and 317L alloys the limit is 850°F (454°C) for Section VIII, Division 1 applications.

All of the grades are accepted for use in food preparation and storage by the National Sanitation Foundation and for contact with dairy products by the Dairy and Food Industries Supply Association-Sanitary Standards Committee. 316 and 316L, in particular, are standard materials used in each industry. These also find many uses in the brewery and other beverage industries, pharmaceutical and bioprocessing industries.

Product Form	Specification	
	ASTM	ASME
Plate, Sheet and Strip	A 240	SA-240
Seamless and/or Welded Tubing	A 249/A 249M (316, 316L, 317 only). A 554	SA-249/SA-249M (316, 316L, 317 only)
Seamless and/or Welded Pipe	A 312/A 312M, A 409/A 409M (316, 316L, 317 only)	SA-312/SA-312M, SA-409/SA-409M (316, 316L, 317 only)
Bar, Wire	A 276 (316, 316L, 317 only). A478, (316, 316L, 317 only). A479/A 479M, (316, 316L, 317 only).	SA-479/SA-479M (316, 316L, 317 only)
Billet, Forgings	A 314 (316, 316L, 317 only). A473 (316, 316L, 317 only).	
Flanges, Fittings	A 182/A 182M, A 403/A 403M	SA-182/SA-182M, SA-403/SA-403M

TYPICAL COMPOSITION

Chemical composition as represented by ASTM A240 and ASME SA-240 specifications are indicated in the table below.

CORROSION RESISTANCE

General Corrosion

316/316L, 317/317L alloys are more resistant to atmospheric and other mild types of corrosion than the 18-8 stainless steels. In general, media that do not corrode 18-8 stainless steels will not attack these molybdenum-containing grades. One known exception is highly oxidizing acids such as nitric acid to which the molybdenum-bearing stainless steels are less resistant.

316 and 317 alloys are considerably more resistant than any of the other chromium-nickel types to solutions of sulfuric acid. At temperatures as high as 120°F (49°C), 316 and 317 alloys are resistant to concentrations of this acid up to 5 percent. At temperatures under 100°F (38°C), both types have excellent resistance to higher concentrations. Service tests are usually desirable as operating conditions and acid contaminants may significantly affect corrosion rate. Where condensation of sulfur-bearing gases occurs, these alloys are much more resistant than other types of stainless steels. In such applications, however, the acid concentration has a marked influence on the rate of attack and should be carefully determined.

The molybdenum-bearing 316 and 317 stainless steels also provide resistance to a wide variety of other environments. As shown by the laboratory corrosion data below, these alloys offer excellent resistance to boiling 20% phosphoric acid. They are also widely used in handling hot organic and fatty acids. This is a factor in the manufacture and handling of certain food and pharmaceutical products where the molybdenum-containing stainless steels are often required in order to minimize metallic contamination.

Generally, the 316 and 316L stainless grades can be considered to perform equally well for a given environment. The same is true for 317 and 317L alloys. A notable exception is in environments sufficiently corrosive to cause intergranular corrosion of welds and heat-affected zones on susceptible alloys. In such media, the 316L and 317L alloys are preferred over 316 and 317 alloys, respectively, for the welded condition since low carbon levels enhance resistance to intergranular corrosion.

General Corrosion in Boiling Solutions

Boiling Test Solution	Corrosion Rate, Mils/Yr (mm/a)			
	316L		317L	
	Base Metal	Welded	Base Metal	Welded
20% Acetic Acid*	0.12 (<0.01)	0.12 (<0.01)	0.48 (0.01)	0.36 (0.01)
45% Formic Acid	23.4 (0.59)	20.9 (0.53)	18.3 (0.46)	24.2 (0.62)
1% Hydrochloric Acid*	226 (5.74)	300 (7.62)	54.2 (1.38)	51.4 (1.31)
10% Oxalic Acid	48.2 (1.22)	44.5 (1.13)	44.9 (1.14)	43.1 (1.09)
20% Phosphoric Acid*	0.20 (<0.01)	0.20 (<0.01)	0.72 (0.02)	0.60 (0.02)
10% Sulfamic Acid	124 (3.16)	119 (3.03)	94.2 (2.39)	97.9 (2.49)
10% Sulfuric Acid	635 (16.1)	658 (16.7)	298 (7.57)	356 (9.05)
10% Sodium Bisulfate	71.5 (1.82)	56.2 (1.43)	55.9 (1.42)	66.4 (1.69)
50% Sodium Hydroxide	77.6 (1.97)	85.4 (2.17)	32.8 (0.83)	31.9 (0.81)

* Samples activated

Pitting/Crevice Corrosion

Resistance of austenitic stainless steels to pitting and/ or crevice corrosion in the presence of chloride or other halide ions is enhanced by higher chromium (Cr), molybdenum (Mo), and nitrogen (N) content. A relative measure of pitting resistance is given by the PREN (Pitting Resistance Equivalent, including Nitrogen) calculation, where PRE_N = Cr+3.3Mo+16N. The PRE_N of

316 and 316L alloy (24.2) is better than that of 304 alloy (PRE_N=19.0), reflecting the better pitting resistance which 316 (or 316L) alloy offers due to its Mo content. 317 (and 317L) alloy, with 3.1% Mo and PREN=29.7, offers even better resistance to pitting than the 316 alloys.

304 stainless steel is considered to resist pitting and crevice corrosion in waters containing up to about 100 ppm chloride. The Mo- bearing 316 and 317 alloys will handle waters with up to about 2000 and 5000 ppm chloride, respectively.

Although these alloys have been used with mixed success in seawater (19,000 ppm chloride), they are not recommended for such use.

Alloy	Composition (Weight Percent)			PRE [1] N	CCT [2] °F (°C)	CPT [3] °F (°C)
	Cr	Mo	N			
304	18.0	--	0.06	19.0	<27.5 (<-2.5)	-- --
316	16.5	2.1	0.05	24.2	27.5 (-2.5)	59 (15.0)
317	18.5	3.1	0.06	29.7	35.0 (1.7)	66 (18.9)
904L	20.5	4.5	0.05	36.2	68.0 (20.0)	104 (40.0)

[1] Pitting Resistance Equivalent, including Nitrogen, PREN=Cr+3.3Mo+16N

[2] Critical Crevice Corrosion Temperature, CCCT, based on ASTM G-48B (6%$FeCl_3$ for 72 hr, with crevices) [3]Critical Pitting Temperature, CPT, based on ASTM G-48A (6%$FeCl_3$ for 72 hr)

Intergranular Corrosion

Both 316 and 317 alloys are susceptible to precipitation of chromium carbides in grain boundaries when exposed to temperatures in the 800°F to 1500°F (427°C to 816°C) range. Such “sensitized” steels are subject to intergranular corrosion when exposed to aggressive environments. Where short periods of exposure are encountered, however, such as in welding,

317 alloy with its higher chromium and molybdenum content is more resistant to intergranular attack than 316 alloy for applications where light gage material is to be welded. Heavier cross sections over 7/16 inch (11.1 mm) usually require annealing

even when 317 alloy is used.

For applications where heavy cross sections cannot be annealed after welding or where low temperature stress relieving treatments are desired, the low carbon 316L and 317L alloys are available to avoid the hazard of intergranular corrosion. This provides resistance to intergranular attack with any thickness in the as-welded condition or with short periods of exposure in the 800-1500°F (427-826°C) temperature range. Where vessels require stress relieving treatment, short treatments falling within these limits can be employed without affecting the normal excellent corrosion resistance of the metal. Accelerated cooling from higher temperatures for the “L” grades is not needed when very heavy or bulky sections have been annealed.

316L and 317L alloys possess the same desirable corrosion resistance and mechanical properties as the corresponding higher carbon 316 and 317 alloy, and offer an additional advantage in highly corrosive applications where intergranular corrosion is a hazard. Although the short duration heating encountered during welding or stress relieving does not produce susceptibility to intergranular corrosion, it should be noted that continuous or prolonged exposure at 800-1500°F (427-816°C) can be harmful from this standpoint with 316L and 317L alloys. Also stress relieving between 1100-1500°F (593- 816°C) may cause some slight embrittlement of these types.

Stress Corrosion Cracking

Austenitic stainless steels are susceptible to stress corrosion cracking (SCC) in halide environments. Although the 316 and 317 alloys are somewhat more resistant to SCC than the 18 Cr-8 Ni alloys because of their molybdenum content, they still are quite susceptible. Conditions which produce SCC are:

(1) presence of halide ions (generally chloride), (2) residual tensile stresses, and (3) temperatures in excess of about 120°F (49°C). Stresses result from cold deformation or thermal cycles during welding. Annealing or stress relieving heat treatments may be effective in reducing stresses, thereby reducing sensitivity to halide SCC. Although the low carbon “L” grades offer no advantage as regards SCC resistance, they are better choices for service in the stress relieved condition in environments which might cause intergranular corrosion.

Duplex (austenitic-ferritic) stainless steels, such as 2205 alloys, provide greater resistance to chloride SCC.

Intergranular Corrosion Tests

ASTM A 262 Evaluation Test	Corrosion Rate, Mils/Yr (mm/a)		
	316	316L	317L
Practice B Base Metal Welded	36 (0.9) 41 (1.0) Intergranular Corrosion	26 (0.7) 23 (0.6)	21 (0.5) 24 (0.6)
Practice E Base Metal Welded	No Fissures on Bend Some Fissures on Weld (unacceptable)	No Fissures No Fissures	No Fissures No Fissures
Practice A Base Metal Welded	Step Structure Ditched (unacceptable)	Step Structure Step Structure	Step Structure Step Structure

Halide (Chloride) Stress Corrosion Tests

Test	U-Bend (Highly Stressed) Samples		
	316	316L	317L
42% Magnesium Chloride, Boiling	Cracked, 4-24 hours	Cracked, 21-45 hours	Cracked, 72 hours
33% Lithium Chloride, Boiling	Cracked, 48-569 hours	Cracked, 21-333 hours	Cracked 22-72 hours
26% Sodium Chloride, Boiling	Cracked, 530-940 hours	No Cracks 1002 hours	Cracked 1000 hours
40% Calcium Chloride, Boiling	Cracked, 144-1000 hours	--	--
Seacoast Exposure, Ambient Temperature	No Cracking	No Cracking	No Cracking

OXIDATION RESISTANCE

The 316 and 317 alloys exhibit excellent resistance to oxidation and a low rate of scaling in air atmospheres at temperatures up to 1600-1650°F (871-899°C). The performance of 316 alloy is generally somewhat inferior to that of 304 stainless steel which has slightly higher chromium content (18% vs.16% for 316 alloy). Since the rate of oxidation is greatly influenced by the atmosphere encountered and by operating conditions, no actual data can be presented which are applicable to all service conditions.

PHYSICAL PROPERTIES

Structure

When properly annealed, 316 and 317 stainless steels are primarily austenitic. Small quantities of ferrite may or may not be present. When slowly cooled or held in the temperature range 800-1500°F (427-816°C), carbides are precipitated, and the structure consists of austenite plus carbides.

Melting Range:

2540-2630°F (1390-1440°C)

Density:

0.29 lb/in^3 (8.027 g/cm^3)

Modulus of Elasticity in Tension:

29 x 106 psi (200 Gpa)

Modulus of Shear:

11.9 x 106 psi (82 Gpa)

Coefficient of Linear Thermal Expansion

Temperature Range		Coefficients	
°F	°C	in/in/°F	cm/cm/°C
68 - 212	20 - 100	$9.2x10^{-6}$	$16.5x10^{-6}$
68 - 932	20 - 500	$10.1x10^{-6}$	$18.2x10^{-6}$
68 - 1832	20 - 1000	$10.8x10^{-6}$	$19.5x10^{-6}$

Thermal Conductivity

Temperature Range		Btu•in/ hr•ft^2 •°F	W/m·K
°F	°C		
68-212	20-100	100.8	14.6

The overall heat transfer coefficient of metals is determined by factors in addition to thermal conductivity of the metal. The ability of the 18-8 stainless grades to maintain clean surfaces often allows better heat transfer than other metals having higher thermal conductivity.

Specific Heat

°F	°C	Btu/lb•°F	J/kg•K
68	20	0.108	450
200	93	0.116	485

Electrical Resistivity

Type	Value at 68°F (20°C)	
	Microhm-in.	Microhm-cm.
316	29.1	74.0
317	31.1	79.0

Magnetic Permeability

Austenitic stainless steels are nonmagnetic in the annealed, fully austenitic condition. The magnetic permeability of the 316 and 317 alloys in the annealed condition is generally less than 1.02 at 200 H (oersteds). Permeability values for cold deformed material vary with composition and the amount of cold deformation but are usually higher than that for annealed material. Typical data are available on request.

MECHANICAL PROPERTIES

Room Temperature Tensile Properties

Minimum mechanical properties for annealed 316/316L, 317/317Laustenitic stainless steel plate, sheet and strip as required by ASTM specifications A240 and ASME specification SA-240, are shown below.

JACQUET

316/316L, 317/317L

Property	Minimum Mechanical Properties Required by ASTM A 240, and ASME SA-240			
	316 (S31600)	316L (S31603)	317 (S31700)	317L (S31703)
Yield Strength 0.2% Offset psi (MPa)	30,000 (205)	25,000 (170)	30,000 (205)	30,000 (205)
Ultimate Tensile Strength psi (MPa)	75,000 (515)	70,000 (485)	75,000 (515)	75,000 (515)
Percent Elongation in 2 in. or 51 mm	40.0	40.0	35.0	40.0
Hardness, Max. Brinell (RB)	217 (95)	217 (95)	217 (95)	217 (95)

Effect of Cold Work

Deformation of austenitic alloys at room, slightly elevated or reduced temperature produces an increase in strength accompanied by a decrease in elongation. Representative room temperature properties of 316/316L, 317/317Lsheet in the annealed and cold worked conditions are shown in the following tables. 316 and 316L, 317 and

317L flat rolled products are generally available in the annealed condition. Data for cold rolled strips are included as a guide to indicate the effects of cold deformation on properties during fabrication operations such as drawing and forming.

Compositions of Cold Worked Materials Tested at Room Temperature

Alloy	C	Mn	Cr	Ni	Mo
316	0.051	1.65	17.33	13.79	2.02
316L	0.015	1.84	16.17	10.16	2.11
317	0.062	1.66	18.60	13.95	3.30
317L	0.025	1.72	18.48	12.75	3.15

316 Alloy - 0.040-inch (1.0 mm) thick — Representative Room Temperature Properties

Percent Cold Reduction	Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation, Percent in 2 in. (51 mm)
	psi	MPa	psi	MPa	
Annealed	38,500	265	84,600	583	61.0
10	71,300	492	94,500	652	40.0
20	98,600	680	111,600	769	21.0
31	119,500	824	133,000	917	11.0
49	135,800	936	148,000	1,020	6.0
60	150,300	1,036	169,600	1,170	3.5

316L Alloy - 0.059-inch (1.5-mm) thick — Representative Room Temperature Properties

Percent Cold Reduction	Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation, Percent in 2 in. (51 mm)
	psi	MPa	psi	MPa	
Annealed	43,300	299	88,750	612	54.0
10	77,550	535	101,800	702	38.3
20	101,000	696	121,750	839	22.8
31	119,300	822	144,200	994	15.3
49	145,000	1,000	174,500	1,203	7.8
60	166,000	1,144	194,450	1,341	5.8

317 Alloy - 0.036-inch (0.9 mm) thick — Representative Room Temperature Properties

Percent Cold Reduction	Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation, Percent in 2 in. (51 mm)
	psi	MPa	psi	MPa	
Annealed	38,300	264	85,500	588	55.0
15	70,000	483	112,000	772	29.0
30	116,000	800	130,700	901	13.0
45	138,500	955	154,900	1,068	7.0
60	151,400	1,044	171,500	1,182	4.0

317L Alloy - 0.105-inch (2.6 mm) thick — Representative Room Temperature Properties

Percent Cold Reduction	Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation, Percent in 2 in. (51 mm)
	psi	MPa	psi	MPa	
Annealed	48,700	336	89,050	614	48.0
15	99,250	684	112,350	775	23.3
30	119,250	822	142,050	979	15.3
45	140,450	967	168,100	1,159	9.3
60	148,850	1,026	184,050	1,269	7.5

Elevated Temperature Tensile Properties

Representative short time elevated temperature tensile properties for 316/316L, 317/317L alloys of the following analyses are shown below.

Compositions of Materials Tested at Elevated Temperatures

Alloy	C	Mn	Cr	Ni	Mo	Fe
316	0.080	1.50	17.78	12.50	2.46	Bal.
316L	0.015	1.84	16.17	10.16	2.11	Bal.
317	0.061	1.30	19.18	14.19	3.57	Bal.
317L	0.025	1.72	18.48	12.75	3.15	Bal.

316 Alloy — Representative Elevated Temperature Properties

Test Temperature		Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation, Percent in 2 in. (51 mm)	Reduction in Area, Percent
°F	°C	psi	MPa	psi	MPa		
68	20	42,400	292	82,400	568	68.0	81.0
200	93	—	—	75,600	521	54.0	80.0
400	204	—	—	71,400	492	51.0	78.0
600	316	—	—	71,150	491	48.0	71.0
800	427	26,500	183	71,450	493	47.0	71.0
1000	538	23,400	161	68,400	472	55.0	70.0
1200	649	22,600	156	50,650	349	24.0	32.0
1400	760	—	—	30,700	212	26.0	35.0
1600	871	—	—	18,000	124	47.0	40.0

316L Alloy — Representative Elevated Temperature Properties

Test Temperature		Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation, Percent in 2 in. (51 mm)
°F	°C	psi	MPa	psi	MPa	
68	20	43,850	302	88,200	608	56.8
200	93	36,650	252	78,250	539	49.0
400	204	32,400	223	69,000	476	37.5
600	316	28,050	193	67,450	465	33.8
800	427	26,750	184	66,000	455	33.8
1000	538	25,900	179	64,350	444	36.8
1200	649	25,300	174	54,200	374	28.3
1400	760	22,100	152	42,000	290	25.0
1600	871	16,800	116	26,900	185	50.3

317 Alloy — Representative Elevated Temperature Properties

Test Temperature		Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation, Percent in 2 in. (51 mm)	Reduction in Area, Percent
°F	°C	psi	MPa	psi	MPa		
68	20	36,700	292	81,800	564	68.0	80.0
200	93	—	—	74,100	492	54.0	79.0
400	204	—	—	68,900	475	48.0	76.0
600	316	—	—	68,950	475	49.0	72.0
800	427	21,900	151	70,200	484	49.0	69.0
1000	538	20,200	139	65,700	453	52.0	68.0
1200	649	19,600	135	49,800	343	—	—
1400	760	—	—	31,600	218	33.0	37.0
1600	871	—	—	18,400	127	51.0	50.0

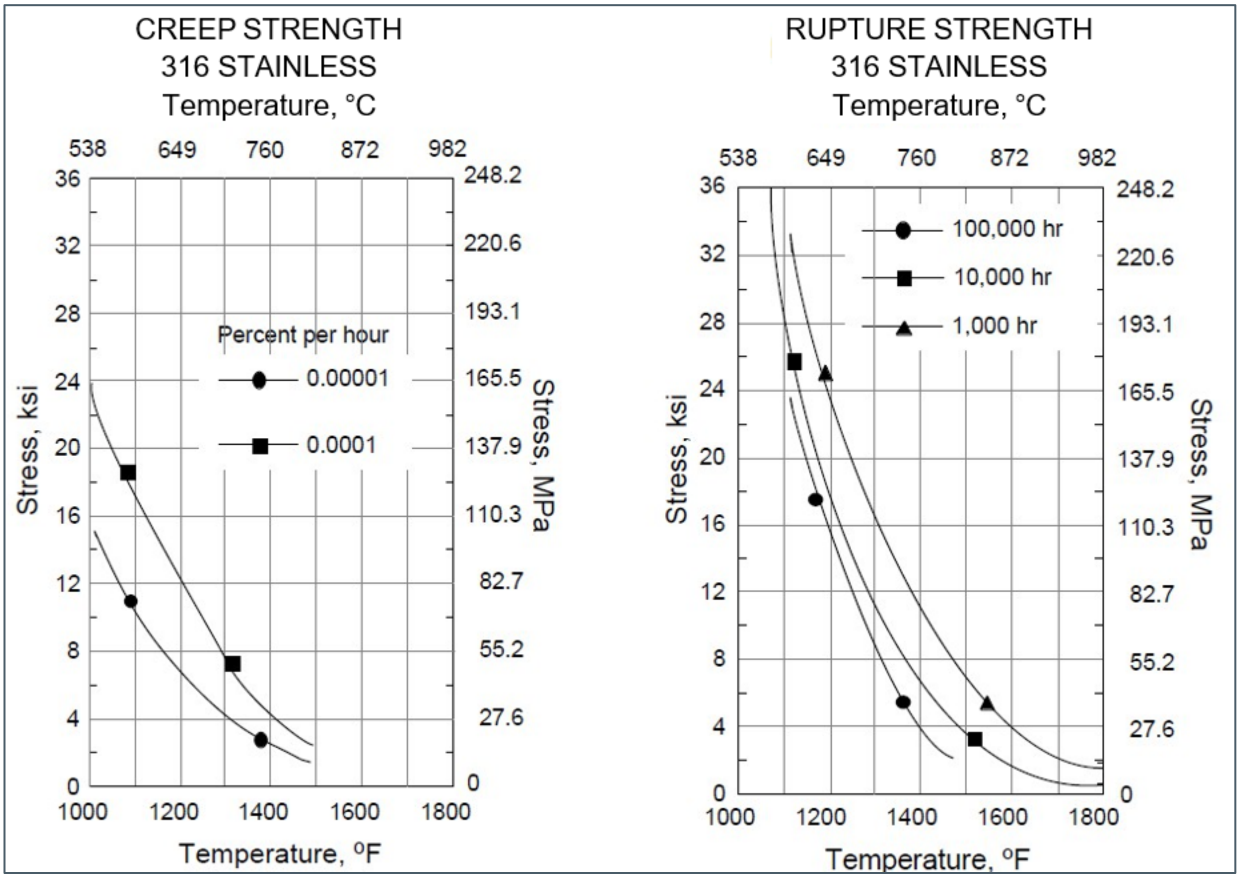
317L Alloy — Representative Elevated Temperature Properties

Test Temperature		Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation, Percent in 2 in. (51 mm)
°F	°C	psi	MPa	psi	MPa	
68	20	46,250	319	88,500	610	49.8
200	93	38,650	266	80,350	554	42.8
400	204	33,500	231	73,350	506	38.8
600	316	29,100	201	70,550	486	35.3
800	427	26,450	182	69,750	481	34.3
1000	538	25,100	173	68,400	472	36.5
1200	649	23,650	163	59,700	412	31.5
1400	760	22,750	157	45,000	310	32.8
1600	871	19,150	132	29,050	200	50.0

Stress Rupture and Creep Properties

At temperatures of about 1000°F (538°C) and higher, creep and stress rupture become considerations for the austenitic stainless steels. Considerable variation in the creep strength and stress rupture strength values is reported by various investigators.

Representative data for annealed 316 stainless steel are presented below. Values for 317 alloy for all practical purposes will be similar.



Impact Resistance

The annealed austenitic stainless steels maintain a high level of impact resistance even at cryogenic temperatures, a property which, in combination with their low temperature strength and fabricability, has led to their extensive use in cryogenic applications. Representative Charpy V-notch impact data for annealed 316 alloy at room temperature are shown below.

Temperature		Energy Absorbed	
°F	°C	Ft-lb	J
75	23	65 - 100	88 - 134

Fatigue Strength

The fatigue strength or endurance limit is the maximum stress below which material is unlikely to fail in 10 million cycles in air environment. For austenitic stainless steels as a group, the fatigue strength is typically about 35 percent of the tensile strength. Substantial variability in service results is experienced since additional variables such as corrosive conditions, form of stress and mean value, surface roughness, and other factors affect fatigue properties. For this reason, no definitive endurance limit values can be given which are representative of all operating conditions.

HEAT TREATMENT

Annealing

The austenitic stainless steels are provided in the mill annealed condition ready for use. Heat treatment may be necessary during or after fabrication to remove the effects of cold forming or to dissolve precipitated chromium carbides resulting from thermal exposures. For the 316 and 317 alloys the solution anneal is accomplished by heating in the 1900 to 2150°F (1040 to 1175°C) temperature range followed by air cooling or a water quench, depending on section thickness. Cooling should be sufficiently rapid through the 1500- 800°F (816-427°C) range to avoid re-precipitation of chromium carbides and provide optimum corrosion resistance. In every case, the metal should be cooled from the annealing temperature to black heat in less than three minutes.

The 316 and 317 alloys cannot be hardened by heat treatment.

Forging

Initial	2100 - 2200°F (1150 - 1205°C)
Finishing	1700 - 1750°F (927 - 955°C)

FABRICATION

The austenitic stainless steels, including the 316 and 317 alloys, are routinely fabricated into a variety of shapes ranging from the very simple to very complex.

These alloys are blanked, pierced, and formed on equipment essentially the same as used for carbon steel. The excellent ductility of the austenitic alloys allows them to be readily formed by bending, stretching, deep drawing and spinning. However, because of their greater strength and work harden-ability, the power requirements for the austenitic grades during forming operations is considerably greater than for carbon steels. Attention to lubrication during forming of the austenitic alloys is essential to accommodate the high strength and galling tendency of these alloys.

Welding

The austenitic stainless steels are considered to be the most weldable of the stainless steels. They are routinely joined by all fusion and resistance welding processes. Two important considerations for weld joints in these alloys are: (1) avoidance of solidification cracking, and (2) preservation of corrosion resistance of the weld and heat-affected zones.

Fully austenitic weld deposits are more susceptible to cracking during welding. For this reason 316, 316L

317 and 317L “matching” filler metals are formulated to solidify with a small amount of ferrite in the microstructure to minimize cracking susceptibility.

For weldments to be used in the as-welded condition in corrosive environments, it is advisable to utilize the low carbon

316L and 317L base metal and filler metals. The higher the carbon level of the material being welded, the greater the likelihood the welding thermal cycles will allow chromium carbide precipitation (sensitization), which could result in intergranular corrosion. The low carbon “L” grades are designed to minimize or avoid sensitization.

High-molybdenum weld deposits may experience degraded corrosion resistance in severe environments due to micro-segregation of molybdenum. To overcome this effect, the molybdenum content of the weld filler metal should be increased. For some severe applications for the 317 alloys, weld deposits containing 4 percent or more of molybdenum may be desirable.

Type 904L (AWS ER 385, 4.5% Mo) or Alloy 625 (AWS ERNiCrMo-3, 9% Mo) filler metals have been used for this purpose.

Be careful to avoid copper or zinc contamination in the weld zone since these elements can form low melting point compounds which in turn can create weld cracking.

Cleaning

Despite their corrosion resistance, stainless steels need care during fabrication and use to maintain their attractive surface appearance even under normal service conditions.

During welding, it is important that surfaces are clean and that proper inert shielding gases are used. Scale or slag that forms from welding processes should be removed with a stainless steel wire brush. Use of carbon steel wire brushes leaves particles embedded in the surface which will eventually produce rusting. For more severe applications, welded areas should be treated with a descaling solution such as a mixture of nitric and hydrofluoric acids and, subsequently, these should be thoroughly washed off with clean water.

For stainless steel surfaces exposed in light inland industrial or milder service, minimum maintenance is required. Only sheltered areas need occasional washing with pressurized water. In heavy industrial or marine environments, frequent washing is advisable to remove dirt or salt deposits which might cause corrosion and impair the surface appearance of the stain-less steel surface.

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Many uses for stainless steel involve cleaning or sterilizing on a regular basis. Equipment is cleaned with specially formulated caustic or acid solutions, such as phosphoric or sulfamic acids, or organic solvents. Strongly reducing acids such as hydrofluoric or hydrochloric may be harmful to these stainless steels.

Cleaning solutions need to be drained and stainless steel surfaces rinsed thoroughly with fresh water.

Design can aid cleanability. Rounded corners, fillets and absence of crevices on stainless steel equipment facilitate cleaning as do smooth ground welds and polished surfaces.

SURFACE FINISHES

A range of stainless steel mill surface finishes is available. These are designated by a series of numbers:

Number 1 Finish – is hot rolled, annealed and descaled. It is available for plate and sheet and is used for functional applications where a smooth decorative finish is not important.

Number 2D Finish – is a dull finish produced by cold rolling, annealing and descaling. This finish is favorable for the retention of lubricants during drawing or other forming operations and is preferred for deep drawn and formed parts.

Number 2B Finish – is a brighter finish than 2D. It is produced much like the 2D finish except that a light temper pass is applied after final annealing on a cold mill with polished rolls. This is a general purpose finish used for all but severe cold forming. Because it is smoother as produced, it is more readily polished than the 1 or 2D finishes.

Number 2BA Finish – is a very smooth finish produced by cold rolling and bright annealing. A light cold mill pass using highly polished rolls produces a glossy finish. A 2BA finish may be used for lightly formed applications where a glossy finish is desired in the as-formed part.

Polished Finishes – a variety of ground finishes are available.

Because special equipment or processes are employed in developing these surface finishes, not all are available.