

INCONEL 617 TECHNICAL DATA

Type Analysis

Element	Min	Max
Carbon	0.05	0.15
Nickel	Remainder	
Iron	--	3.00
Silicon	--	0.50
Manganese	--	0.50
Cobalt	10.0	15.0
Chromium	20.0	24.0
Titanium	--	0.60
Phosphorus	--	0.015
Sulfur	--	0.015
Molybdenum	8.00	10.0
Aluminum	0.80	1.50
Boron	--	0.006
Copper	--	0.50

Description

Alloy 617 is a solid-solution, nickel-chromium-cobalt-molybdenum alloy with an exceptional combination of high-temperature strength and oxidation resistance. The alloy also has excellent resistance to a wide range of corrosive environment, and it is readily formed and welded by conventional techniques.

The high nickel and chromium contents make the alloy resistant to a variety of both reducing and oxidizing media. The aluminum, in conjunction with the chromium, provides oxidation resistance at high temperatures. Solid-solution strengthening is imparted by the cobalt and molybdenum.

Application

The combination of high strength and oxidation resistance at temperatures over 1800°F makes alloy 617 an attractive material for such components as ducting, combustion cans, and transition liner in both aircraft, and land based gas turbines. Because of its resistance to high-temperature corrosion, the alloy is used for catalyst-grid supports in the production of nitric acid, for heat-treating baskets, and for reduction boats in the refining of molybdenum. Alloy 617 also offers attractive properties for components of power-generating plants, both fossil-fueled and nuclear.

Physical Properties

The alloy's low density, compared with tungsten-containing alloys of similar strength, is significant in applications such as aircraft gas turbines where high strength-to-weight ratio is desirable.

Density, lb/cu in.....	0.302
kg/cu m.....	8360
Melting Range, °F.....	2430/2510
°C.....	1332-1377
Specific heat at 78°F (26°C)	
Btu/lb-°F....	0.100
J/kg-°C.....	419
Electrical Resistivity at 78°F (26°C)	
ohm-cir mil/ft.....	736
æê-m.....	1.223

Electrical and Thermal Properties

Temperature	Electrical Resistivity	Thermal Conductivity*	Coefficient of Expansion**	Specific Heat***
°F	ohm-circ mil/ft	Btu - in/ft ² - hr - °F	10(-6)in./in./°F	Btu/lb-°F
78	736	94	--	0.100
200	748	101	6.4	0.104
400	757	113	7.0	0.111
600	764	125	7.4	0.117
800	770	137	7.6	0.124
1000	779	149	7.7	0.131
1200	793	161	8.0	0.137
1400	807	173	8.4	0.144
1600	803	185	8.7	0.150
1800	824	197	9.0	0.157
2000	--	209	9.2	0.163
°C	æm	W/m-°C	æm/m/°C	J/kg-°C
20	1.222	13.4	--	419
100	1.245	14.7	11.6	440
200	1.258	16.3	12.6	465
400	1.278	19.3	13.6	515
600	1.308	22.5	14.0	561
800	1.342	25.5	15.4	611
1000	1.378	28.7	16.3	662

*Calculated from electrical resistivity.

**Mean coefficient of linear expansion between 78°F and temperature shown.

***Calculated values.

Modulus of Elasticity*

Temperature	Tensile Modulus	Shear Modulus	Poisson's Ratio**
°F(°C)	10(6)psi(GPa)	10(6)psi(GPa)	
74(25)	30.6(211)	11.8(81)	0.30
200(100)	30.0(206)	11.6(80)	0.30
400(200)	29.0(201)	11.2(77)	0.30
600(300)	28.0(194)	10.8(75)	0.30
800(400)	26.9(188)	10.4(72)	0.30
1000(500)	25.8(181)	9.9(70)	0.30
1200(600)	24.6(173)	9.5(66)	0.30
1400(700)	23.3(166)	9.0(64)	0.30
1600(800)	21.9(149)	8.4(61)	0.30

*Determined by dynamic method

**Calculated from moduli of elasticity

Mechanical Properties

Product Form	Production Method	Yield Strength (0.2% Offset)		Tensile Strength		Elongation, %	Reduction of Area, %	Hardness BHN
		1000 psi	MPa	1000 psi	MPa			
Plate	Hot Rolling	46.7	322	106.5	734	62	56	172
Bar	Hot Rolling	46.1	318	111.5	769	56	50	181
Tubing	Cold Drawing	55.6	383	110.0	758	56	--	193
Sheet or Strip	Cold Rolling	50.9	351	109.5	755	58	--	173

Stability of Properties

Alloy 617 exhibits unusually good metallurgical stability for an alloy of its strength level. Studies involving exposure of material to temperatures of 1100°F to 1400°F showed that although the alloy experiences increases in strength and decreased in ductility it forms no embrittling phases. The table below shows changes in tensile and impact properties after exposures extending to 12,000 hours at elevated temperatures. All samples were in the solution-annealed condition before exposure. The strengthening is attributable to carbide formation and, at exposure temperatures of 1200°F to 1400°F, to precipitation of gamma prime phase.

Exposure Temperature		Exposure Time, h	Yield Strength (0.2% Offset)		Tensile Strength		Elongation, %	Impact Strength	
°F	°C		1000 psi	MPa	1000 psi	MPa		ft-lb	J
No Exposure		--	46.3	319	111.5	769	68	171	232
1100	595	100	46.5	321	111.5	769	69	213	289
		1000	51.8	357	116.5	803	67	223	302
		4000	55.7	384	117.5	810	67	181	245
		8000	59.5	410	121.5	838	61	98	133
		12000	67.6	466	132.0	910	34	69	94
1200	650	100	51.8	357	114.5	789	69	191	259
		1000	66.6	459	133.5	920	37	35	47
		3640	76.3	526	142.0	979	33	35	47
		8000	76.5	527	144.0	993	28	40	54
		12000	77.5	534	144.0	993	32	38	52
1300	705	100	58.7	405	126.5	872	38	57	77
		1000	70.5	486	138.0	952	33	48	65
		4000	70.6	487	138.0	952	36	48	65
1400	760	100	58.3	402	126.5	872	35	56	76
		1000	56.3	388	126.0	879	37	63	85
		4000	58.1	401	128.5	886	38	62	84
		8000	58.5	403	130.0	896	40	64	87
		12000	56.4	389	129.5	893	38	67	91

Corrosion Resistance

The composition of alloy 617 includes substantial amounts of nickel, chromium, and aluminum for a high degree of resistance to oxidation and carburization at high temperatures. Those elements, along with the molybdenum content, also enable the alloy to withstand many wet corrosive environments.

Oxidation and Carburization

The excellent resistance of alloy 617 to oxidation results from the alloy's chromium and aluminum contents. At elevated temperatures, those elements cause the formation of a thin, subsurface zone of oxide particles. The zone forms rapidly upon exposure to high temperatures until it reaches a thickness of 0.001 to 0.002 in. The oxide zone provides the proper diffusion conditions for the formation of a protective chromium oxide layer on the surface of the metal. It also helps to prevent spalling of the protective layer. Alloy 617 has excellent resistance to carburization. The table below shows the superiority of alloy 617 over alloys of similar strength in a gas-carburization test at 1800°F. The weight-gain measurements indicate the amount of carbon absorbed during the test period.

Results of 100-h Carburization Tests in Hydrogen/2% Methane at 1800°F (980°C)

Material	Weight Gain, g/m ²
Alloy 617	35
Alloy 263	82
Alloy 188	86
Alloy L-605	138

Corrosion by Acids

Alloy 617 has good resistance to a variety of both reducing and oxidizing acids. The chromium in the alloy confers resistance to oxidizing solutions while the nickel and molybdenum provide resistance to reducing conditions. The molybdenum also contributes resistance to crevice corrosion and pitting.

In boiling nitric acid, at concentrations under 20%, corrosion rates are less than 1mpy (0.025mm/yr). At 70% concentration, the rate is a relatively low 20mpy (0.5 mm/yr). The rates were determined from tests of 72 hrs duration.

In sulfuric acid, alloy 617 has shown useful resistance to concentrations of up to about 30% at a temperature of 175°F and about 10% at boiling temperature. The table below gives the results of laboratory tests in sulfuric acid. Test duration was 72 hrs except for tests in boiling 30% and 40% solutions, which were of 48 hrs duration.

The alloy has shown moderate to poor resistance to hydrochloric acid. Laboratory tests at 175°F have produced corrosion rates of 150 mpy (3.8 mm/yr) at 10% concentration, 95 mpy (2.4 mm/yr) at 20% concentration, and 50 mpy (1.3 mm/yr) at 30% concentration.

Alloy 617 has excellent resistance to phosphoric acid. The table below also gives rates for phosphoric acid containing 1% of hydrofluoric acid. Test duration was 72 hrs. In hydrofluoric acid, alloy 617 exhibits useful resistance to the vapor phase at concentrations up to about 20%. The alloy has poor resistance to the liquid acid.

Corrosion Rates in Sulfuric Acid

Acid Concentration %	Corrosion Rate*			
	175°F (80°C)		Boiling Temperature	
	mpy	mm/yr	mpy	mm/yr
5	--	--	24	0.61
10	2	0.05	28	0.71
20	32	0.81	97	2.46
30	44	1.12	464	11.89
40	40	1.02	838	21.29
50	94	2.39	--	--

*Average of two tests.

Corrosion Rates in Phosphoric Acid

Acid Concentration %	Corrosion Rate*					
	H ₃ PO ₄ , 175°F (80°C)		H ₃ PO ₄ , Boiling		H ₃ PO ₄ + 1% HF 175°F (80°C)	
	mpy	mm/yr	mpy	mm/yr	mpy	mm/yr
10	0.2	0.005	0.1	0.003	0.9	0.023
20	0.2	0.005	0.4	0.010	2	0.05
30	0.4	0.010	0.5	0.013	1	0.03
40	0.4	0.010	5	0.13	6	0.15
50	0.7	0.018	31	0.79	8	0.20
60	0.4	0.010	50	1.27	6	0.15
70	0.4	0.010	38	0.97	0.6	0.015
85	0.6	0.015	26	0.66	0.4	0.010

*Average of two tests.

Corrosion Rates in Hydrofluoric Acid at 175°F

Acid Concentration %	Corrosion Rate*			
	Vapor Phase		Liquid Phase	
	mpy	mm/yr	mpy	mm/yr
10	44	1.12	126	3.20
20	32	0.81	302	7.67
30	82	2.08	396	10.06
40	85	2.16	424	10.77
48	104	2.64	428	10.87

*Average of two tests.

Machinability

Alloy 617 has good fabricability. Forming, machining, and welding are carried out by standard procedures for nickel alloys. Techniques and equipment for some operations may be influenced by the alloy's strength and work-hardening rate.

Hot and Cold Forming

Alloy 617 has good hot formability, but it requires relatively high forces because of its inherent strength at elevated temperatures. In general, the hot-forming characteristics of alloy 617 are similar to those of Inconel alloy 625. The temperature range for heavy forming or forging is 1850 to 2200°F. Light working can be done at temperatures down to 1700°F.

Alloy 617 is readily cold formed by conventional procedures although its work-hardening rate is high. For best results, the alloy should be cold formed in the fine-grain condition, and frequent intermediate anneals should be used. Annealing for cold forming should be done at 1900°F.

Heat Treatment

Alloy 617 is normally used in the solution-annealed condition. That condition provides a coarse grain structure for the best creep-rupture strength. It also provides the best bend ductility at room temperature. Solution annealing is performed at a temperature of 2150°F for a time commensurate with section size. Cooling should be by water quenching or rapid air cooling.

Joining

Alloy 617 has excellent weldability. Inconel Filler Metal 617 is used for gas-tungsten-arc and gas-metal-arc welding. The composition of the filler metal matches that of the base metal, and deposited weld metal is comparable to the wrought alloy in strength and corrosion resistance. The table below lists typical room temperature tensile properties of all-weld-metal specimens from welded joints.

Room-Temperature Tensile Properties in As-Welded Condition of Joints Welded with Inconel Filler Metal 617

Specimen	Yield Strength (0.2% Offset)		Tensile Strength		Elongation %	Reduction of Area %
	1000 psi	MPa	1000 psi	MPa		
All-Weld-Metal*	73.9	510	110.4	761	43.3	42.0
All-Weld-Metal**	78.6	542	119.3	823	37.3	38.3

*Gas-metal-arc process. Average of ten tests.

**Gas-tungsten-arc process. Average of seventeen tests.

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