Technical Datasheet

CarTech® 680 Alloy

Identification

UNS Number
- N06002

DIN Number
- 2.4613

Type Analysis

Single figures are nominal except where noted.

Carbon	0.05 to 0.15 %	**Manganese (Maximum)**	1.00 %
Phosphorus (Maximum)	0.040 %	**Sulfur (Maximum)**	0.030 %
Silicon (Maximum)	1.00 %	**Chromium**	20.50 to 23.00 %
Nickel	Balance	**Molybdenum**	8.00 to 10.00 %
Cobalt	0.50 to 2.50 %	**Tungsten**	0.20 to 1.00 %
Iron	17.00 to 20.00 %		

General Information

Description

CarTech 680 alloy is a nonmagnetic, heat and corrosion resistant, nickel-base alloy. It derives its exceptional properties, up to 2200°F (1200°C), from solid solution strengthening.

Applications

Typical applications have been turbine rotors, shafts, buckets, bolts; afterburner components; furnace hardware; and hardware in the chemical industry.

Corrosion Resistance

Immersion in 5% boiling nitric acid for 24 hours resulted in a corrosion rate of approximately 0.0056 inches (0.14 mm) penetration per year. Immersion in 25% boiling nitric acid resulted in a corrosion rate of approximately 0.0107 inches (0.271 mm) penetration per year. The approximate corrosion rate for immersion in 10% sulfuric acid solutions was 0.0136 inches (0.345 mm) penetration per year.

Important Note: *The following 4-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors which affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish and dissimilar metal contact.*

Nitric Acid	Good	Sulfuric Acid	Good
Phosphoric Acid	Good	Acetic Acid	Excellent
Sodium Hydroxide	Good	Salt Spray (NaCl)	Excellent
Sea Water	Excellent	Sour Oil/Gas	Good
Humidity	Excellent		

Properties

Physical Properties

Density	0.2970	lb/in³
Mean Specific Heat (158 to 212°F)	0.1040	Btu/lb/°F

Mean CTE	
79 to 200°F	7.70 x 10 $^{-6}$ in/in/°F
79 to 400°F	7.82 x 10 $^{-6}$ in/in/°F
79 to 600°F	7.90 x 10 $^{-6}$ in/in/°F
79 to 800°F	8.15 x 10 $^{-6}$ in/in/°F
79 to 1000°F	8.39 x 10 $^{-6}$ in/in/°F
79 to 1200°F	8.56 x 10 $^{-6}$ in/in/°F
79 to 1350°F	8.76 x 10 $^{-6}$ in/in/°F
79 to 1500°F	8.92 x 10 $^{-6}$ in/in/°F
79 to 1650°F	9.07 x 10 $^{-6}$ in/in/°F
79 to 1800°F	9.20 x 10 $^{-6}$ in/in/°F

Coefficient of Thermal Expansion

Temperature		Coefficient	
79°F to	26°C to	10^{-6}/°F	10^{-6}/°C
200	93	7.70	13.86
400	204	7.82	14.08
600	316	7.90	14.22
800	427	8.15	14.67
1000	538	8.39	15.10
1200	649	8.56	15.41
1350	732	8.76	15.77
1500	816	8.92	16.06
1650	899	9.07	16.33
1800	982	9.20	16.56

Thermal Conductivity	
70°F	62.80 BTU-in/hr/ft²/°F
200°F	76.00 BTU-in/hr/ft²/°F
300°F	83.50 BTU-in/hr/ft²/°F
500°F	94.40 BTU-in/hr/ft²/°F
700°F	108.1 BTU-in/hr/ft²/°F
900°F	128.2 BTU-in/hr/ft²/°F
1100°F	143.5 BTU-in/hr/ft²/°F
1300°F	158.5 BTU-in/hr/ft²/°F
1500°F	173.5 BTU-in/hr/ft²/°F
1700°F	188.5 BTU-in/hr/ft²/°F

Thermal Conductivity

Test Temperature		Btu-in/ft²/hr/°F	W/m•K
°F	°C		
70	21	62.8	9.1
200	93	76.0	11.0
300	149	83.5	12.0
500	260	94.4	13.6
700	371	108.1	15.6
900	482	128.2	18.5
1100	593	143.5	20.7
1300	704	158.5	22.9
1500	816	173.5	25.0
1700	927	188.5	27.2

Modulus of Elasticity (E)		
70°F	29.0	x 10^3 ksi
400°F, Strip	23.8	x 10^3 ksi
600°F, Strip	25.5	x 10^3 ksi
800°F, Strip	21.4	x 10^3 ksi
1000°F, Strip	24.3	x 10^3 ksi
1200°F, Strip	22.5	x 10^3 ksi
1400°F, Strip	20.1	x 10^3 ksi
1500°F	20.5	x 10^3 ksi
1600°F, Strip	18.7	x 10^3 ksi
1800°F	18.3	x 10^3 ksi

Modulus of Elasticity

Temperature		Modulus of Elasticity	
°F	°C	psi x 10^6	MPa x 10^3
70	21	29.0	20.4
1500	816	20.5	14.4
1800	982	18.3	12.9

Electrical Resistivity (70°F)	712.4	ohm-cir-mil/ft
Melting Range	2300 to 2470	°F

Magnetic Properties

Magnetic Permeability (200 Oe)	1.0020	Mu

Typical Mechanical Properties

Bar—Stress Rupture Data
Heat treated at 2150°F (1177°C)—rapidly air cooled

Test Temperature		Average Initial Stress for Rupture at:									
		10 hours		50 hours		100 hours		500 hours		1000 hours	
°F	°C	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
1200	649	58	400	49	338	44	303	36	248	33	228
1350	732	40	276	30	207	26	179	20	138	—	—
1500	816	22	152	16	110	14	97	11	76	—	—
1650	899	—	—	10	69	8	55	6	41	5	34
1800	982	—	—	6	41	5	34	3	21	3	21

Bar—Typical Impact Strength
Solution annealed to Rockwell B 92.5

Test Temperature		Charpy Impact (V-notch)	
°F	°C	ft-lb	J
-300	-184	70.0	94
-200	-129	74.0	100
-100	- 73	86.0	117
0	- 18	89.5	121
75	24	88.5	120
400	204	92.5	125
800	427	109.5	149
1000	538	98.0	133
1200	649	97.0	132
1400	760	70.0	95
1600	871	55.0	75

Bar—Typical Short-Time Tensile Data
Solution treated by heating at 2150°F (1177°C) one hour, and water quenching

Test Temperature		Tensile Strength		Yield Strength 0.02%		Yield Strength 0.2%		% Elongation in 1" (25.4 mm)	% Reduction of Area
°F	°C	ksi	MPa	ksi	MPa	ksi	MPa		
70	21	115	792	44	303	52	358	50.0	65.0
400	204	102	703	30	206	39	269	51.0	59.5
600	316	98	676	29	200	36	248	53.5	59.5
1000	538	93	641	27	186	34	234	55.0	58.0
1200	649	87	600	27	186	32	220	55.0	47.0
1400	760	67	462	29	200	35	241	38.0	39.0
1600	871	42	290	28	193	34	234	56.0	57.0
1800	982	23	158	15	103	21	144	55.0	50.0

Strip—Secondary Creep Rates
Solution treated at 2150/2175°F (1177/1190°C) and rapidly air cooled

Test Temperature		Stress for Minimum Creep Rate of: 0.0001% hour		0.00001% hour	
°F	°C	ksi	MPa	ksi	MPa
1200	649	16	110	12	83
1350	732	11	76	8	55
1500	816	8	55	7	48
1650	982	3	21	2	14

Strip—Stress Rupture
Heat treated at 2150°F (1177°C)—rapidly air cooled

Test Temperature		Average Initial Stress for Rupture at: 10 hours		50 hours		100 hours		500 hours		1000 hours	
°F	°C	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
1200	649	58	400	48	331	42	290	34	234	31	214
1350	732	36	248	29	200	26	179	20	138	18	124
1500	816	21	145	16	110	14	97	11	76	9	62
1650	899	12	83	9	62	8	55	6	41	5	34
1800	982	7	48	4	28	3	21	2	14	—	—

Strip—Typical Short-Time Tensile Data
0.109 in (2.77 mm) thick—as cold reduced

Condition	Ultimate Tensile Strength		0.2% Offset Yield Strength		% Elongation in 2" (50.8 mm)
	ksi	MPa	ksi	MPa	
Reduced 5%	123	848	81	558	32
Reduced 15%	137	944	106	731	20
Reduced 30%	161	1110	134	924	7

Strip—Typical Short-Time Tensile Data—Elevated Temperature
0.109 in. (2.77 mm) thick, heat treated at 2150°F (1177°C)—rapidly air cooled

Test Temperature		Ultimate Tensile Strength		0.2% Offset Yield Strength		% Elongation in 2" (50.8 mm)	Modulus of Elasticity	
°F	°C	ksi	MPa	ksi	MPa		psi x 10⁶	MPa x 10³
400	204	103	710	48	331	40.5	23.8	164
600	316	100	690	42	290	40.0	25.5	176
800	427	99	682	43	296	44.0	21.4	148
1000	538	94	648	41	283	45.0	24.3	168
1200	649	83	572	40	276	37.0	22.5	155
1350	732	72	496	36	248	31.5	—	—
1400	760	63	434	37	255	37.0	20.1	139
1500	816	52	358	37	255	33.5	—	—
1600	871	36	248	25	172	50.5	18.7	129
1650	899	32	220	26	179	47.0	—	—
1800	942	21	144	17	117	43.0	—	—
1900	1038	16	110	—	—	37.0	—	—
2000	1093	9	62	—	—	39.0	—	—
2200	1204	4	28	—	—	40.0	—	—
2300	1260	3	20	—	—	21.0	—	—

Strip—Typical Short-Time Tensile Data
Room temperature

Form	Condition	Ultimate Tensile Strength		0.2% Offset Yield Strength		% Elongation in 2" (50.8 mm)
		ksi	MPa	ksi	MPa	
Strip 0.044 to 0.056 in. (1.12 to 1.42 mm)	Heat Treated at 2150°F (1177°C). Rapidly Air Cooled	113	780	54	372	41.1
Strip 0.060 to 0.083 in. (1.52 to 2.11 mm)	Heat Treated at 2150°F (1177°C). Rapidly Air Cooled	112	772	50	345	42.9
Strip 0.094 to 0.130 in. (2.39 to 3.30 mm)	Heat Treated at 2150°F (1177°C). Rapidly Air Cooled	114	786	52	358	41.1

Heat Treatment

Pyromet alloy 680 is a solid solution strengthened alloy and develops optimum mechanical properties through a simple heat treatment. Strip is solution heat treated at 2150°F (1177°C), followed by a rapid quench. Larger sections are solution heat treated at 2150/2175°F (1177/1190°C), followed by a rapid quench. The time at the solution temperature is dependent on the volume of material. The solution-treated hardness is approximately Rockwell B 90.

Aging heat treatments are not necessary because only a slight increase in hardness will occur with exposure to elevated temperatures, 1200/1600°F (649/871°C).

Increases in strength can be effected by hot/cold working and cold working.

Workability

Hot Working

Hot working is done from a maximum furnace temperature of 2200°F (1204°C). Below 1800°F (982°C), Pyromet alloy 680 loses malleability. For this reason, forgings should be reheated before the lower hot-working temperature is reached. Heating time is based on the allowance of one hour per inch (25.4 mm) of thickness. Low-sulfur fuels should be used.

Pyromet alloy 680 can be readily cold formed. The alloy does work harden, but ductility can be restored for further cold forming through process anneals.

Forming below 1200°F (649°C) increases the hardness and tensile strength; ductility decreases. Power requirements are somewhat higher than for the 300 series stainless steels.

Machinability

Single-point tungsten carbide tools - suggested tool angles are:
8 to 10 degrees top back-rake angle from cutting edge;
5 to 8 degrees top back-rake angle from nose;
5 to 7 degrees cutting clearance angle;
and 15 to 30 degrees lead angle.
Nose radius-1/32" to 1/16" (0.80 mm to 1.59 mm).

High-speed steel drills-grind to an included angle for 135 to 140 degrees, with a clearance angle of 10 degrees. Thin down the web to approximately one-third the web-thickness of a standard drill.

Increasing the speed and decreasing the feed results in better finishes. Excessive speeds are not recommended because the tools will break down.

A sulfur-base cutting fluid should be used. Ample coolant is suggested. Removal of cutting fluid is necessary before heat treating because the sulfur will offset the surface of the part.

A rigid work piece and a rigid tool are necessary for optimum machinability.

Weldability

Welding can be accomplished by the following methods: metallic-arc, inert-gas-shielded arc, submerged melt and sigma. The surfaces to be welded should be thoroughly cleaned and properly aligned to prevent contamination and stress raisers. U-joints are usually used for thicker sections; V-joints for thinner sections (<1/4") (<6.35 mm). Good weld penetration should be insured by either welding from both sides or by adjustment of the joint spacing and the use of a copper backing bar.

Other Information

Descaling (Cleaning)

Salt or sodium hydride baths are necessary to descale Pyromet alloy 680. After treatment in either of the baths, the material should be immersed in a sulfuric acid bath at 165°F (74°C) for approximately 3 minutes, followed by immersion in a nitric acid bath at 145°F (63°C) for approximately 25 minutes. Sulfuric solution: 16% by weight H2S04 and 1% by weight HCl. Nitric bath: 8% HN03 by weight and 3% HF by weight.

Applicable Specifications

- AMS 5536
- AMS 5588
- AMS 5754
- AMS 5798

Forms Manufactured

- Bar-Rounds
- Billet
- Strip
- Wire

Technical Articles

- A Guide to Etching Specialty Alloys for Microstructural Evaluation
- Trends in High Temperature Alloys

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