Technical Datasheet CARPENTER TECHNOLOGY

CarTech® 625 Alloy

Identification

UNS Number

- N06625

DIN Number

- 2.4856

Type Analysis

Single figures are nominal except where noted.

Carbon (Maximum)	0.10 %	**Manganese (Maximum)**	0.50 %
Phosphorus (Maximum)	0.015 %	**Sulfur (Maximum)**	0.015 %
Silicon (Maximum)	0.50 %	**Chromium**	20.00 to 23.00 %
Nickel	Balance	**Molybdenum**	8.00 to 10.00 %
Cobalt (Maximum)	1.00 %	**Titanium (Maximum)**	0.40 %
Aluminum (Maximum)	0.40 %	**Columbium + Tantalum**	3.15 to 4.15 %
Iron (Maximum)	5.00 %		

General Information

Description

CarTech 625 alloy is a nonmagnetic, corrosion- and oxidation-resistant, nickel-base alloy. Its outstanding strength and toughness in the temperature range cryogenic to 2000°F (1093°C) are derived primarily from the solid solution effects of the refractory metals, columbium and molybdenum, in a nickel-chromium matrix. The alloy has excellent fatigue strength and stress-corrosion cracking resistance to chloride ions.

Some typical applications for CarTech 625 alloy have included heat shields, furnace hardware, gas turbine engine ducting, combustion liners and spray bars, chemical plant hardware and special seawater applications.

Corrosion Resistance

Pyromet alloy 625 has withstood many corrosive environments. In alkaline, salt water, fresh water, neutral salts, and in the air, almost no attack occurs. The nickel and chromium provide resistance to oxidizing environments. Nickel and molybdenum provide for resistance to nonoxidizing atmospheres. Pitting and crevice corrosion are prevented by molybdenum. Niobium stabilizes the alloy against sensitization during welding. Chloride stress-corrosion cracking resistance is excellent. The alloy resists scaling and oxidation at high temperatures.

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

Properties

Physical Properties

Density	0.3050	lb/in³
Mean Specific Heat	0.09800	Btu/lb/°F

Mean CTE	
200°F	7.10 x 10 $^{-6}$ in/in/°F
400°F	7.30 x 10 $^{-6}$ in/in/°F
600°F	7.40 x 10 $^{-6}$ in/in/°F
800°F	7.60 x 10 $^{-6}$ in/in/°F
1000°F	7.80 x 10 $^{-6}$ in/in/°F
1200°F	8.20 x 10 $^{-6}$ in/in/°F
1400°F	8.50 x 10 $^{-6}$ in/in/°F
1600°F	8.80 x 10 $^{-6}$ in/in/°F
1700°F	9.00 x 10 $^{-6}$ in/in/°F

Coefficient of Thermal Expansion

Temperature		10^{-6}/°F	10^{-6}/°C
°F	°C		
at 200	93	7.1	12.8
400	204	7.3	13.1
600	316	7.4	13.3
800	427	7.6	13.7
1000	538	7.8	14.0
1200	649	8.2	14.8
1400	760	8.5	15.3
1600	871	8.8	15.8
1700	927	9.0	16.2

Thermal Conductivity	
-250°F	50.00 BTU-in/hr/ft²/°F
-200°F	52.00 BTU-in/hr/ft²/°F
-100°F	58.00 BTU-in/hr/ft²/°F
0°F	64.00 BTU-in/hr/ft²/°F
70°F	68.00 BTU-in/hr/ft²/°F
100°F	70.00 BTU-in/hr/ft²/°F
200°F	75.00 BTU-in/hr/ft²/°F
400°F	87.00 BTU-in/hr/ft²/°F
600°F	98.00 BTU-in/hr/ft²/°F
800°F	109.0 BTU-in/hr/ft²/°F
1000°F	121.0 BTU-in/hr/ft²/°F
1200°F	132.0 BTU-in/hr/ft²/°F
1400°F	144.0 BTU-in/hr/ft²/°F
1600°F	158.0 BTU-in/hr/ft²/°F
1800°F	175.0 BTU-in/hr/ft²/°F

Thermal Conductivity
Material heat treated at 2100°F (1149°C) for 1 hour.

Temperature °F	Temperature °C	Btu · in/ft² • hr • °F	W/m • K
at −250	−157	50	7.2
−200	−129	52	7.5
−100	−73	58	8.4
0	−18	64	9.2
70	21	68	9.8
100	38	70	10.1
200	93	75	10.8
400	204	87	12.5
600	316	98	14.1
800	427	109	15.7
1000	538	121	17.5
1200	649	132	19.0
1400	760	144	20.8
1600	871	158	22.8
1800	982	175	25.2

Poisson's Ratio	
70°F	0.308
200°F	0.310
400°F	0.312
600°F	0.313
800°F	0.312
1000°F	0.321
1200°F	0.328
1400°F	0.329

Modulus of Elasticity (E)	
70°F	29.8 x 10^3 ksi
200°F	29.2 x 10^3 ksi
400°F	28.4 x 10^3 ksi
600°F	27.5 x 10^3 ksi
800°F	26.6 x 10^3 ksi
1000°F	25.6 x 10^3 ksi
1200°F	24.4 x 10^3 ksi
1400°F	23.1 x 10^3 ksi

Modulus of Elasticity (Dynamic)

Temperature		Tensile (E)		Shear (G)		Poisson's Ratio (calculated)
°F	°C	psi x 10^6	MPa x 10^3	psi x 10^6	MPa x 10^3	
70	21	29.8	205	11.4	79	0.308
200	93	29.2	201	11.2	77	0.310
400	204	28.4	196	10.8	74	0.312
600	316	27.5	190	10.5	72	0.313
800	427	26.6	183	10.1	70	0.312
1000	538	25.6	177	9.7	67	0.321
1200	649	24.4	168	9.2	63	0.328
1400	760	23.1	159	8.7	60	0.329
1600	871	—	—	8.2	57	—

Modulus of Rigidity (G)		
70°F	11.4	x 10 ^{3} ksi
200°F	11.2	x 10 ^{3} ksi
400°F	10.8	x 10 ^{3} ksi
600°F	10.5	x 10 ^{3} ksi
800°F	10.1	x 10 ^{3} ksi
1000°F	9.70	x 10 ^{3} ksi
1200°F	9.20	x 10 ^{3} ksi
1400°F	8.70	x 10 ^{3} ksi
1600°F	8.20	x 10 ^{3} ksi
Electrical Resistivity		
70°F	776.0	ohm-cir-mil/ft
100°F	780.0	ohm-cir-mil/ft
200°F	794.0	ohm-cir-mil/ft
400°F	806.0	ohm-cir-mil/ft
600°F	812.0	ohm-cir-mil/ft
800°F	818.0	ohm-cir-mil/ft
1000°F	830.0	ohm-cir-mil/ft
1200°F	830.0	ohm-cir-mil/ft
1400°F	824.0	ohm-cir-mil/ft
1600°F	818.0	ohm-cir-mil/ft
1800°F	812.0	ohm-cir-mil/ft
2000°F	806.0	ohm-cir-mil/ft

Electrical Resistivity
Material heat treated at 2100°F (1149°C) for 1 hour

Temperature		ohm-cir. mil/ft.	microhm · mm
°F	°C		
at 70	21	776	1290
100	38	780	1300
200	93	794	1320
400	204	806	1340
600	316	812	1350
800	427	818	1360
1000	538	830	1380
1200	649	830	1380
1400	760	824	1370
1600	871	818	1360
1800	982	812	1350
2000	1093	806	1340

Curie Temperature	< -320	°F
Melting Range	2350 to 2460	°F

Magnetic Properties

Magnetic Permeability (200 Oe)	1.0006	Mu

Typical Mechanical Properties

Creep Strength
High solution annealed material

Test Temperature		Stress (psi) (MPa) to Produce the Indicated Plastic Strain at											
		100 hrs.				1000 hrs.				10,000 hrs.			
		1%		5%		1%		5%		1%		5%	
°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
1200	649	52,000	359	55,000	379	38,000	262	45,000	310	27,500	190	31,000	214
1300	704	31,000	214	36,000	248	22,500	155	26,000	179	16,500	114	18,000	124
1400	760	17,500	121	22,500	155	13,000	90	16,000	110	8,500	59	11,500	79
1500	816	9,500	66	14,000	97	6,500	45	9,000	62	4,500	31	6,500	45
1600	871	5,500	38	7,500	52	3,500	24	5,500	38	2,500	17	4,000	28

Effect of Annealing Temperature
Hot rolled rod

Annealing Temp. 1 hour		Ultimate Tensile Strength		0.2% Yield Strength		% Elongation in 2" (50.8 mm)	% Reduction of Area	Rockwell B Hardness
°F	°C	psi	MPa	psi	MPa			
As Rolled		147,500	1017	92,000	634	46.0	55.3	98
1400	760	145,500	1003	90,800	626	43.0	49.5	101
1500	816	143,500	989	85,000	586	42.0	45.7	101
1600	871	145,500	1003	87,200	601	39.0	41.5	101
1700	927	147,000	1014	86,000	593	40.0	48.0	103
1800	982	143,500	989	83,600	576	44.0	48.0	101
1850	1010	142,500	983	78,600	542	46.0	53.0	99
1900	1038	142,500	983	66,300	457	49.0	51.5	95
2000	1093	124,000	855	52,500	362	64.0	62.5	93
2100	1149	116,000	800	50,000	345	62.0	61.0	89
2200	1204	116,500	803	48,000	331	72.0	61.3	88

Elevated Temperature Tensile Properties
Hot rolled, solution annealed rod 2150°F (1177°C)

Test Temperature		Ultimate Tensile Strength		0.2% Yield Strength		% Elongation
°F	°C	psi	MPa	psi	MPa	
400	204	116,500	803	43,000	296	57.0
600	316	112,500	776	40,000	276	58.0
800	427	109,500	755	37,000	255	60.0
1000	538	106,500	734	35,000	241	62.0
1200	649	104,000	717	37,000	255	71.0
1400	760	75,000	517	40,000	276	91.0
1600	871	38,000	262	32,000	221	110.0
1800	982	18,000	124	16,000	110	120.0

Elevated Temperature Tensile Properties
Low solution anneal

Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 2" (50.8 mm)
°F	°C	psi	MPa	psi	MPa	
400	204	66,000	455	134,000	924	45.0
600	316	63,000	434	132,000	910	42.5
800	427	61,000	421	131,500	907	45.0
1000	538	60,500	417	130,000	896	48.0
1200	649	60,000	414	119,000	820	34.0
1400	760	58,500	403	78,000	538	59.0
1600	871	39,000	269	40,000	276	117.5
1800	982	17,000	117	17,000	117	143.0

Keyhole Charpy Impact Energy
Hot rolled stock

Test Temperature		Orientation	Impact Strength	
°F	°C		ft-lb	J
85	29	Longitudinal	48, 49, 50	65, 66, 68
85	29	Transverse	46, 49, 51.5	62, 66, 70
-110	- 79	Longitudinal	39, 44, 49	53, 60, 66
-110	- 79	Transverse	39, 42, 44	53, 57, 60
-320	-196	Longitudinal	35, 35, 35.5	47, 47, 48
-320	-196	Transverse	31, 32, 36	42, 43, 49

Room Temperature Tensile Properties
As-drawn wire annealed at 2150°F (1177°C), 5 minutes, air cooled

Wire Diameter		% Cold Reduction	Tensile Strength		Yield Strength 0.2% offset		% Elongation in 10" (0.25 m)
in	mm		psi	MPa	psi	MPa	
0.397	10.08	0	138,000	167	61,500	83	52.3
0.036	0.91	19	174,500	237	153,250	208	17.5
0.0318	0.808	37	220,000	298	205,000	278	2.0
0.0285	0.724	49	246,000	334	218,000	296	2.0
0.0253	0.643	60	269,000	365	253,000	343	2.4
0.0226	0.574	68	283,000	384	242,000	328	2.2
0.020	0.51	75	293,000	397	251,000	340	2.0
0.0179	0.455	80	295,250	400	220,000	298	3.8
0.0159	0.404	84	303,000	411	250,500	340	3.4
0.0142	0.361	87	306,000	415	252,750	343	3.0
0.0126	0.320	90	316,250	429	269,000	365	2.6
0.0111	0.282	92	316,000	428	264,000	358	2.3
0.0099	0.251	94	322,250	437	274,500	372	3.0

Room Temperature Tensile Properties
Hot rolled, low solution annealed bar, exposed 100 hours at the indicated temperatures

Exposure Temperature		Ultimate Tensile Strength		0.2% Yield Strength		% Elongation
°F	°C	psi	MPa	psi	MPa	
1200	649	170,000	1172	121,000	834	35.0
1300	704	159,500	1100	106,000	731	35.0
1400	760	148,000	1020	91,000	627	35.5
1500	816	145,000	1000	82,000	565	37.0
1600	871	143,500	989	81,000	558	38.0
1700	927	135,000	931	74,000	510	43.0
1800	982	129,000	889	51,000	352	54.0

Rotating Beam Fatigue Strength
Bar stock

Condition 1 hour, AC		Test Temperature		Stress for Cycles to Fail							
				10^5		10^6		10^7		10^8	
°F	°C	°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	MPa
As Rolled		R.T.	R.T.	133,000	917	104,000	717	100,000	689	100,000	689
1800	982	R.T.	R.T.	—	—	96,000	662	92,000	634	90,000	621
1800	982	800	427	—	—	96,000	662	92,000	634	90,000	621
1800	982	1000	538	91,000	627	87,000	600	84,000	579	81,000	558
1800	982	1200	649	80,000	552	76,000	524	72,000	496	69,000	475
1800	982	1400	760	—	—	65,000	448	57,000	393	57,000	393
1800	982	1600	871	—	—	36,000	248	24,000	165	12,000	83
2150	1177	R.T.	R.T.	72,000	496	68,000	469	68,000	469	68,000	469
2150	1177	800	427	69,000	476	67,000	462	66,000	455	66,000	455
2150	1177	1000	538	64,000	441	63,000	434	63,000	434	63,000	434
2150	1177	1200	649	58,000	400	57,000	393	57,000	393	57,000	393
2150	1177	1400	760	49,000	338	47,000	324	45,000	310	45,000	310
2150	1177	1600	871	—	—	39,000	269	33,000	228	27,000	186

Rupture Strength
High solution annealed material

Test Temperature		Stress to Produce Rupture at the Indicated Time (hrs.)									
		10 hrs.		100 hrs.		1000 hrs.		10,000 hrs.		100,000 hrs.	
°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
1200	649	75,000	517	60,000	414	53,000	365	40,000	276	31,000	214
1300	704	59,000	407	45,000	310	35,000	241	27,000	186	21,000	145
1400	760	40,000	276	30,000	207	22,000	152	17,000	117	13,000	90
1500	816	28,000	193	19,000	131	14,000	97	9,000	62	6,000	41
1600	871	17,000	117	12,000	83	7,500	52	5,000	34	3,500	24

Note: The notch bar (K_t 3.25) life is greater than the smooth bar life.

Rupture Strength
Low solution annealed material

Test Temperature		Stress to Produce Rupture at the Indicated Time (hrs.)							
		10 hrs.		100 hrs.		1000 hrs.		10,000 hrs.	
°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	Mpa
1200	649	—	—	75,000	517	58,500	403	42,500	293
1300	704	64,000	441	47,500	328	34,500	238	22,500	155
1400	760	40,000	276	28,000	193	18,000	124	12,000	83
1500	816	25,000	172	15,000	103	—	—	—	—

Note: The notch bar (K_t 3.25) life is greater than the smooth bar life.

Typical Room Temperature Tensile Properties

Form and Condition	Tensile Strength		Yield Strength 0.2% offset		% Elongation in 2" (50.8 mm)	% Reduction of Area
	psi	MPa	psi	MPa		
ROD AND BAR						
As-Rolled	120,000/160,000	827/1103	60,000/110,000	414/758	30/60	40/60
Low Sol. Anneal	120,000/150,000	827/1034	60,000/ 95,000	414/655	30/60	40/60
High Sol. Anneal	105,000/130,000	724/ 896	42,000/ 60,000	290/414	40/65	60/90
STRIP						
Low Sol. Anneal	120,000/140,000	827/ 965	60,000/ 75,000	414/517	30/55	—

Heat Treatment

Pyromet alloy 625 has three basic heat treatments:

(1)High Solution Anneal --- 2000/2200°F (1093/1204°C), air quench or faster.

(2)Low Solution Anneal --- 1700/1900°F (927/1038°C), air quench or faster.

(3)Stress Relieve --- 1650°F (899°C), air quench.

The time at the above temperatures depends on volume and section thickness. Strip, for example, would require shorter times than large sections. Temperatures for treatments No. 1 and No. 2 are generally held for 1/2 to 1 hour, 1 to 4 hours for treatment No. 3.

Treatment No. 1 is not commonly used for applications below 1500°F (816°C). It is generally used above 1500°F (816°C) and where resistance to creep is important. The high solution anneal is also used to develop the maximum softness for mill processing operations such as cold rolling or drawing.

Treatment No. 2 is the most used treatment and develops an optimum combination of tensile and rupture properties from ambient temperatures to 1900°F (1038°C). Ductility and toughness at cryogenic temperatures are also very good.

Treatment No. 3 is recommended for applications below 1200°F (649°C) when maximum fatigue, hardness, tensile and yield strength properties are desired. Ductility and toughness at cryogenic temperatures are excellent. When a fine grain size is desired for fatigue, tensile and yield strengths up to 1500°F (816°C), treatment No. 3 is sometimes used.

Workability

Hot Working

Hot working may be done at 2100°F (1149°C) maximum furnace temperature. Care should be exercised to avoid frictional heat build-up which can result in overheating, exceeding 2100°F (1149°C). Pyromet alloy 625 becomes very stiff at temperatures below 1850°F (1010°C). Work pieces that fall below this temperature should be reheated. Uniform reductions are recommended to avoid the formation of a duplex grain structure. Approximately 15/20% reduction is recommended for finishing.

Cold Working

Pyromet alloy 625 can be cold formed by standard methods. When the material becomes too stiff from cold working, ductility can be restored by process anneals.

Effect of Cold Work
Strip annealed at 1865°F (1019°C) before cold working

Strip Thickness		% Reduction of Area	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 2" (50.8 mm)	Rockwell C Hardness
in	mm		psi	MPa	psi	MPa		
0.113	2.87	Anld.	67,000	462	136,000	938	46.2	97 (Rb)
0.100	2.54	11	104,000	717	148,000	1020	37.0	29
0.090	2.29	20	137,000	945	163,000	1124	20.0	36
0.083	2.11	26	158,000	1089	178,000	1227	11.8	38
0.074	1.88	34	193,000	1331	200,000	1379	7.8	47
0.070	1.78	38	198,000	1365	209,000	1441	5.3	43
0.0615	1.56	46	210,000	1448	214,000	1475	4.6	44
0.0567	1.44	50	219,000	1510	223,000	1538	4.1	45
0.050	1.27	56	218,000	1503	230,000	1586	4.0	45
0.0452	1.15	60	228,000	1572	233,000	1606	4.3	45
0.0431	1.095	61	233,000	1606	238,000	1641	3.8	46
0.0414	1.052	64	230,000	1586	236,000	1627	3.1	46

Machinability

Low cutting speeds, rigid tools and work piece, heavy equipment, ample coolant and positive feeds are general recommendations.

High-Speed Cutting Tools for Lathe Turning Operations

Angle	Roughing	Finishing
Back rake	0°	8°
Positive side rake		14-18°
End clearance	6°	8°
End cutting edge	6°	25°
Side cutting edge	—	Up to 45°

Cutting Speeds for High-Speed Steels

Operation	Speed		Feed	
	sfpm	m/s	ipr	mm/rev
Turning	12-20	0.06/0.10	0.010	0.25
Drilling (.500"/12.70mm)	10-12	0.05/0.06	0.006/0.010	0.15/0.25
Tapping	5-10	0.03/0.05	—	—
Milling	10-20	0.05/0.10	—	—
Reaming	8-10	0.04/0.05	—	—

Additional Machinability Notes

Carbide tools should have smaller angles than high-speed tools and operating speeds can be higher.

A sulfur-base cutting fluid is recommended. Thoroughly clean work piece after machining to prevent surface contamination during subsequent heat treating. Chlorine additives would be an alternative.

Weldability

Welding can be accomplished by the gas-shielded processes using a tungsten electrode or a consumable electrode. Postweld heat treatments of the weld are not necessary to maintain corrosion resistance. Heavy restrained sections can be welded and the weld's mechanical properties follow the same trends as base metal properties. Standard practices such as clean surfaces, good joint alignment, U-joints for thicker sections, etc., should be followed.

Other Information

Descaling (Cleaning)

Sodium hydride baths are necessary to descale this alloy. After the sodium hydride treatment, the material should be immersed in a sulfuric acid bath 165°F (74°C) for approximately 3 minutes. A 25-minute immersion in a nitric-hydrofluoric bath 145°F (63°C) is then necessary. Rinse. Sulfuric solution: 16% by weight, H2S04. Nitric solution: 8% HNO3 by weight and 3% HF by weight. Acid etching for macro-inspection-expose material electrolytically to a 3-to-1 HCl to HN03 solution, saturated with CuCl2 at a current density of 0.645 amp/in2 (25.4 A/m).

Applicable Specifications

AMS 5599, 5666 and 5837.

- AMS 5666
- ASTM B446
- ASTM B475

Forms Manufactured

- Bar-Rounds
- Billet
- Strip
- Wire

Technical Articles

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

Disclaimer:
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