Technical Datasheet CARPENTER TECHNOLOGY

CarTech® 15Cr-5Ni Stainless

Identification

UNS Number

• S15500

Type Analysis

Single figures are nominal except where noted.

Carbon (Maximum)	0.07 %	**Manganese (Maximum)**	1.00 %
Phosphorus (Maximum)	0.040 %	**Sulfur (Maximum)**	0.015 %
Silicon (Maximum)	1.00 %	**Chromium**	14.00 to 15.50 %
Nickel	3.50 to 5.50 %	**Copper**	2.50 to 4.50 %
Columbium + Tantalum	0.15 to 0.45 %	**Iron**	Balance

General Information

Description

CarTech 15Cr-5Ni is a martensitic precipitation hardening stainless steel offering high strength and hardness along with excellent corrosion resistance. Generally similar to CarTech Custom 630 (17Cr-4Ni) in composition and properties, CarTech 15Cr-5Ni is chemically balanced to eliminate all but trace amounts of delta ferrite, thus providing superior transverse toughness and ductility plus a high degree of forgeability.

CarTech 15Cr-5Ni has fabrication characteristics similar to those of other precipitation hardening stainlesses, and can be aged-hardened by a single step, low temperature treatment.

It has been used for applications requiring high transverse strength and toughness, such as valve parts, fittings and fasteners, shafts, gears, engine parts, chemical process equipment, paper mill equipment, aircraft components and nuclear reactor components.

Elevated Temperature Use

15Cr-5Ni alloy has displayed excellent resistance to oxidation up to approximately 1100°F (593°C). Long-term exposure to elevated temperatures can result in reduced toughness in precipitation hardenable stainless steels. The reduction in toughness can be minimized in some cases by using higher aging temperatures. Short exposures to elevated temperatures can be considered, provided the maximum temperature is at least 50°F (28°C) less than the aging temperature.

Corrosion Resistance

The general-corrosion resistance of Carpenter 15Cr-5Ni alloy is comparable to that of Type 304 and similar to that of Carpenter Custom 630 (17Cr-4Ni) in most media. Good resistance to stress-corrosion cracking is gained by hardening at temperatures of 1025ºF (551ºC) and higher. Compared to Carpenter Custom 630 (17Cr-4Ni), Carpenter 15Cr-5Ni alloy shows substantially better stress-corrosion-cracking resistance in boiling 42% MgCl2 solution and slightly superior resistance in H2S NaCl-Acetic Acid solutions. Erosion-corrosion resistance of Carpenter 15Cr-5Ni is also good due to its good combination of corrosion resistance and high hardness.

For optimum corrosion resistance, surfaces must be free of scale, coatings applied for drawing and heading, lubricants, and foreign particles. After fabrication of parts, cleaning and/or passivation should be considered.

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	Restricted
Phosphoric Acid	Restricted	Acetic Acid	Moderate
Sodium Hydroxide	Moderate	Salt Spray (NaCl)	Good
Sea Water	Restricted	Humidity	Excellent

Typical General-Corrosion Resistance

Condition	5 w/o Salt Spray Fog at 95°F (35°C) 10 Days	Boiling 65 w/o HNO_3 Average of 5 48-Hr. Periods mpy	1 w/o HC1 at 95°F (35°C) Average of 5 48-Hr. Periods mpy
H 900	0% rust	100	25
H 1025	0-5% rust	127	85
H 1150	0-5% rust	100	730

Properties

Physical Properties

Specific Gravity		
Condition A	7.75	
Condition H 1075	7.81	
Condition H 1150	7.82	
Condition H 900	7.80	
Density		
Condition A	0.2800	lb/in³
Condition H 900	0.2820	lb/in³
Condition H 1075	0.2820	lb/in³
Condition H 1150	0.2830	lb/in³
Mean Specific Heat		
32 to 212°F, Condition A	0.1100	Btu/lb/°F
32 to 212°F, Condition H 900	0.1000	Btu/lb/°F
Mean CTE		
70 to 200°F, Condition A	6.00	$\times 10^{-6}$ in/in/°F
70 to 400°F, Condition A	6.00	$\times 10^{-6}$ in/in/°F
70 to 600°F, Condition A	6.20	$\times 10^{-6}$ in/in/°F
70 to 800°F, Condition A	6.30	$\times 10^{-6}$ in/in/°F
-100 to 70°F, Condition H 900	5.80	$\times 10^{-6}$ in/in/°F
70 to 200°F, Condition H 900	6.00	$\times 10^{-6}$ in/in/°F
70 to 400°F, Condition H 900	6.00	$\times 10^{-6}$ in/in/°F
70 to 600°F, Condition H 900	6.30	$\times 10^{-6}$ in/in/°F
70 to 800°F, Condition H 900	6.50	$\times 10^{-6}$ in/in/°F
70 to 200°F, Condition H 1075	6.30	$\times 10^{-6}$ in/in/°F
70 to 400°F, Condition H 1075	6.50	$\times 10^{-6}$ in/in/°F
70 to 600°F, Condition H 1075	6.60	$\times 10^{-6}$ in/in/°F
70 to 800°F, Condition H 1075	6.80	$\times 10^{-6}$ in/in/°F
-100 to 70°F, Condition H 1150	6.10	$\times 10^{-6}$ in/in/°F
70 to 200°F, Condition H 1150	6.60	$\times 10^{-6}$ in/in/°F
70 to 400°F, Condition H 1150	6.90	$\times 10^{-6}$ in/in/°F
70 to 600°F, Condition H 1150	7.10	$\times 10^{-6}$ in/in/°F
70 to 800°F, Condition H 1150	7.20	$\times 10^{-6}$ in/in/°F
70 to 900°F, Condition H 1150	7.30	$\times 10^{-6}$ in/in/°F

Thermal Conductivity		
300°F, Condition H 900	124.0	BTU-in/hr/ft²/°F
500°F, Condition H 900	135.0	BTU-in/hr/ft²/°F
860°F, Condition H 900	156.0	BTU-in/hr/ft²/°F
900°F, Condition H 900	157.0	BTU-in/hr/ft²/°F
Poisson's Ratio		
Condition H 900	0.272	
Condition H 1075	0.272	
Condition H 1150	0.272	
Modulus of Elasticity (E)		
72°F, Condition H 900, Longitudinal	28.7	x 10^3 ksi
100°F, Condition H 900, Longitudinal	28.5	x 10^3 ksi
199°F, Condition H 900, Longitudinal	28.0	x 10^3 ksi
300°F, Condition H 900, Longitudinal	27.6	x 10^3 ksi
399°F, Condition H 900, Longitudinal	27.1	x 10^3 ksi
500°F, Condition H 900, Longitudinal	26.7	x 10^3 ksi
601°F, Condition H 900, Longitudinal	26.2	x 10^3 ksi
Modulus of Rigidity (G)		
73°F, Condition H 900, Longitudinal	11.2	x 10^3 ksi
73°F, Condition H 1025, Longitudinal	11.0	x 10^3 ksi
73°F, Condition H 1075, Longitudinal	10.0	x 10^3 ksi
73°F, Condition H 1150, Longitudinal	10.0	x 10^3 ksi
Electrical Resistivity		
73°F, Condition A	589.0	ohm-cir-mil/ft
73°F, Condition H 900	463.0	ohm-cir-mil/ft

Condition	A	H 900	H 1075	H 1150
Specific gravity	7.75	7.80	7.81	7.82
Density—lb/in³	0.280	0.282	0.282	0.283
kg/m³	7750	7800	7810	7820

Mean Specific Heat	A Btu/lb•°F	A J/kg•K	H 900 Btu/lb•°F	H 900 J/kg•K	H 1075	H 1150
32 to 212°F (0 to 100°C)	0.11	460	0.10	419	—	—

Electrical resitivity (RT)	A	H 900	H 1075	H 1150
ohm-cir mil/ft	589	463	—	—
microhm-mm	980	770	—	—

Mean Coefficient of Thermal Expansion	A 10^{-6}/°F	A 10^{-6}/K	H 900 10^{-6}/°F	H 900 10^{-6}/K	H 1075 10^{-6}/°F	H 1075 10^{-6}/K	H 1150 10^{-6}/°F	H 1150 10^{-6}/K
-100 to 70°F (-73 to 21°C)	—	—	5.8	10.4	—	—	6.1	11.0
70 to 200°F (21 to 93°C)	6.0	10.8	6.0	10.8	6.3	11.3	6.6	11.9
70 to 400°F (21 to 204°C)	6.0	10.8	6.0	10.8	6.5	11.7	6.9	12.4
70 to 600°F (21 to 316°C)	6.2	11.2	6.3	11.3	6.6	11.9	7.1	12.8
70 to 800°F (21 to 427°C)	6.3	11.3	6.5	11.7	6.8	12.2	7.2	13.0
70 to 900°F (21 to 482°C)	—	—	—	—	—	—	7.3	13.1

Thermal Conductivity °F	°C	A	H 900 Btu-in/ft²•h•°F	H 900 W/m•K	H 1075	H 1150
300	149	—	124	17.9	—	—
500	260	—	135	19.5	—	—
860	460	—	156	22.5	—	—
900	482	—	157	22.6	—	—

Poisson's Ratio	A	H 900	H 1075	H 1150
	—	0.272	0.272	0.272

Modulus of Elasticity and Rigidity—See Mechanical Properties.

Typical Mechanical Properties

Cryogenic Mechanical Properties:

Carpenter 15Cr-5Ni alloy retains satisfactory levels of ductility at cryogenic temperatures, the best cryogenic performance being obtained on material aged at the higher aging temperatures. The best notch toughness at cryogenic temperatures for the alloy is obtained with the H 1150M condition.

Typical Mechanical Properties
Longitudinal direction, intermediate location

Condition	0.2% Yield Strength		Ultimate Tensile Strength		Elongation in 2" (50.8 mm)	% Reduction of Area	Hardness		Charpy V-Notch Impact Strength		Modulus of Elasticity (E)*		Modulus of Rigidity (G)	
	ksi	MPa	ksi	MPa			Rockwell C	Brinell	ft-lb	J	ksi	MPa	ksi	MPa
A	—	—	—	—	—	—	35	341	—	—	—	—	—	—
H 900	185[a]	1276	200	1378	14	50	44	420	15	20	28.5x10^3	197.6x10^3	11.2x10^3	77.3x10^3
H 925	175	1207	190	1309	14	54	42	409	25	34	—	—	—	—
H 1025	165	1138	170	1173	15	56	38	352	35	48	—	—	11.0x10^3	75.9x10^3
H 1075	150	1035	165	1138	16	58	36	341	40	54	—	—	10.0x10^3	69.0x10^3
H 1100	135	931	150	1035	17	58	34	332	45	61	—	—	—	—
H 1150	125	862	145	1000	19	60	33	311	50	68	—	—	10.0x10^3	69.0x10^3
H 1150M	85	584	125	882	22	68	27	277	100	138	—	—	—	—

[a] compressive yield strength for Condition H 900 is 178 ksi (1228 MPa)

*The modulus values for 15Cr-5Ni alloy at elevated temperature can be conveniently expressed as a percent of the room temperature values as follows:

72°F(22°C)—100.0%	400°F(204°C)—94.7%
100°F(38°C)—99.6%	500°F(260°C)—93.0%
200°F(93°C)—97.8%	600°F(316°C)—91.4%

Typical Room Temperature Mechanical Properties
Transverse direction, intermediate location

Condition	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 2" (50.8 mm)	% Reduction of Area	Hardness		Charpy V-Notch Impact Strength	
	ksi	MPa	ksi	MPa			Rockwell C	Brinell	ft-lb	J
H 900	185	1276	200	1378	10	30	44	420	7	10
H 925	175	1207	190	1309	11	35	42	409	17	23
H 1025	165	1138	170	1173	12	42	38	352	27	37
H 1075	150	1035	165	1138	13	43	36	341	30	41
H 1100	135	931	150	1035	14	44	34	332	30	41
H 1150	125	862	145	1000	15	45	33	311	50	63
H 1150M	85	584	125	862	18	50	27	277	100	136

Typical Room Temperature Mechanical Properties of Consumable-Electrode-Remelted Material
Longitudinal direction, intermediate location of 12" (305 mm) square billet

Condition	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 2" (50.8 mm)	% Reduction of Area	Rockwell C Hardness	Charpy V-Notch Impact Strength	
	ksi	MPa	ksi	MPa				ft-lb	J
A	130	897	162	1118	13	56	32	—	—
H 900	178	1228	192	1325	12	47	41	6*	8
H 1025	158	1090	164	1132	14	62	36	30	41
H 1150	116	800	139	959	20	69	29	80	109

*This cannot be considered as a minimum impact value for this condition. If toughness is a design criterion, this heat treatment should be used with caution.

Typical Room Temperature Mechanical Properties of Consumable-Electrode-Remelted Material
Transverse direction, intermediate location of 12" (305 mm) square billet

Condition	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 2" (50.8 mm)	% Reduction of Area	Rockwell C Hardness	Charpy V-Notch Impact Strength	
	ksi	MPa	ksi	MPa				ft·lb	J
H 900	178	1228	193	1332	11	46	41	6*	8
H 1025	159	1097	164	1132	14	57	36	25	34
H 1150	115	793	138	952	20	64	29	70	95

*This cannot be considered as a minimum impact value for this condition. If toughness is a design criterion, this heat treatment should be used with caution.

Typical Room Temperature Torsional Properties

Condition	Unit Shear Strength (at elastic limit)		Modulus of Rupture		Modulus of Rigidity (G)	
	ksi	MPa	ksi	MPa	ksi	MPa
H 900	98	676	171	1180	11.2×10^3	77.3×10^3
H 1025	86	593	141	973	11.0×10^3	75.9×10^3
H 1075	68	469	135	931	10.0×10^3	69.0×10^3
H 1150	43	297	124	856	10.0×10^3	69.0×10^3

Heat Treatment

Carpenter 15Cr-5Ni is normally supplied in the solution-treated condition (Condition A). It can be hardened by heating solution-treated material to a temperature of 900ºF (482ºC) to 1150ºF (621ºC) for one to four hours, depending on the temperature, then air cooling.

Solution Treatment

Heat at 1900ºF (1038ºC) ±25ºF (±14ºC), for ½ hour, cool to below 90ºF (32ºC) so that the material is completely transformed to martensite. Sections under 3" (76 mm) can be oil quenched and sections over 3" (76 mm) should be rapidly air cooled.

Do not use in this condition without age hardening due to low toughness, poor impact strength and susceptibility to stress-corrosion cracking.

Deformation (Size Change) in Hardening

Upon aging, a predictable size change will occur for 15Cr-5Ni. For the H 900 treatment, a contraction of 0.0004 to 0.0006 in./in. (m/m) is obtained. Aging at 1150°F (621°C) causes a contraction of 0.0008 to 0.0010 in./in. (m/m).

Age

Heat Treatment - Condition H 900
(Precipitation or Age Hardened): Heat solution-treated material at 900ºF (482ºC) for 1 hour and air cool.

Heat Treatment - H 925, H 1025, H 1075, H 1100, H 1150
(Precipitation or Age Hardened): Heat solution-treated material at specified temperature ±15ºF (±8ºC) for 4 hours and air cool.

Heat Treatment - Condition H 1150M
(Precipitation or Age Hardened): Heat solution-treated material at 1400ºF (760ºC) ±15ºF (±8ºC) for 2 hours, air cool; then heat at 1150ºF (621ºC) ±15ºF (±8ºC) for 4 hours and air cool.

Workability

Hot Working

Carpenter 15Cr-5Ni alloy can be readily forged, hot headed and upset. Material which is hot worked must be solution treated prior to hardening if the material is to respond properly to hardening.

Forging

Heat uniformly to 2150/2200ºF (1177/1204ºC) and hold one hour at temperature before forging. Do not forge below 1850º F (1010ºC). To obtain optimum grain size and mechanical properties, forgings should be cooled in air to below 90ºF (32ºC) before further processing. Forgings must be solution treated prior to hardening.

Cold Working

Carpenter 15Cr-5Ni alloy can be fabricated by cold working (i.e., heading, rolling, etc.) to an extent which is limited by the high initial yield strength. This alloy is generally used in the form of bars and forgings not requiring much forming.

Machinability

Carpenter 15Cr-5Ni alloy is readily machined in both the solution-treated and various age-hardened conditions. In the solution-treated condition, it machines similarly to stainless Types 302 and 304. The machinability will improve as the hardening temperature is increased.

Condition H 1150M provides optimum machinability. Having procured condition H 1150M for best machinability, higher mechanical properties can only be developed by solution treating and heat treating at standard hardening temperatures.

Following are typical feeds and speeds for Carpenter 15Cr-5Ni alloy.

Typical Machining Speeds and Feeds – Carpenter 15Cr-5Ni

The speeds and feeds in the following charts are conservative recommendations for initial setup. Higher speeds and feeds may be attainable depending on machining environment.

Turning—Single-point and Box Tools

Depth of Cut (Inches)	Micro-Melt® Powder HS Tools			Carbide Tools (Inserts)			
	Tool Material	Speed (fpm)	Feed (ipr)	Tool Material	Speed (fpm) Uncoated	Speed (fpm) Coated	Feed (ipr)
Annealed							
.150	M48, T15	72	.015	C6	270	350	.010
.025	M48, T15	84	.007	C7	325	425	.005
Aged							
.150	M48, T15	48	.010	C6	190	250	.010
.025	M48, T15	54	.005	C7	225	290	.005

Turning—Cut-Off and Form Tools

High Speed Tools		Speed (fpm)	Feed (ipr)						
			Cut-Off Tool Width (Inches)				Form Tool Width (Inches)		
Micro-Melt® Powder HS Tools	Carbide Tools		1/16	1/8	1/4	1/2	1	1-1/2	2
Annealed									
M48, T15		72	.001	.0015	.002	.0015	.001	.0007	.0005
	C6	216	.003	.005	.007	.005	.004	.0035	.0035
Aged									
M48, T15		36	.001	.001	.0015	.0015	.001	.0005	.0005
	C6	132	.003	.003	.0045	.003	.002	.002	.002

Rough Reaming

Micro-Melt® Powder HS Tools		Carbide Tools		Feed (ipr) Reamer Diameter (inches)					
Tool Material	Speed (fpm)	Tool Material	Speed (fpm)	1/8	1/4	1/2	1	1-1/2	2
Annealed									
M48, T15	72	C2	190	.003	.005	.008	.011	.015	.018
Aged									
M48, T15	36	C2	100	.001	.001	.001	.001	.001	.001

Drilling

High Speed Tools									
Tool Material	Speed (fpm)	Feed (inches per revolution) Nominal Hole Diameter (inches)							
		1/16	1/8	1/4	1/2	3/4	1	1-1/2	2
Annealed									
M42	50	.001	.002	.004	.007	.008	.010	.012	.015
Aged									
M42	35	-	.001	.002	.003	.004	.004	.004	.004

Die Threading

FPM for High Speed Tools				
Tool Material	7 or less, tpi	8 to 15, tpi	16 to 24, tpi	25 and up, tpi
Annealed				
M2, M7, M10	5 – 12	8 – 15	10 – 22	15 – 27
Aged				
T15, M42	4 – 8	6 – 10	8 – 12	10 – 15

Milling, End-Peripheral

Depth of Cut (inches)	Micro-Melt® Powder High Speed Tools						Carbide Tools					
	Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in)				Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in)			
			1/4	1/2	3/4	1-2			1/4	1/2	3/4	1-2
Annealed												
.050	M48 T15	108	.001	.002	.003	.004	C2	275	.001	.002	.004	.006
Aged												
.050	M48 T15	72	.0005	.001	.002	.003	C2	90	.001	.002	.003	.004

Tapping

High Speed Tools	
Tool Material	Speed (fpm)
Annealed	
M7, M10	12 – 25
Aged	
M7, M10 Nitrided	5 – 15

Broaching

Micro-Melt® Powder High Speed Tools		
Tool Material	Speed (fpm)	Chip Load (ipt)
Annealed		
M48, T15	9.6	.002
Aged		
M48, T15	12	.002

Additional Machinability Notes

When using carbide tools, surface speed feet/minute (sfpm) can be increased between 2 and 3 times over the high speed suggestions. Feeds can be increased between 50 and 100%.

Figures used for all metal removal operations covered are average. On certain work, the nature of the part may require adjustment of speeds and feeds. Each job has to be developed for best production results with optimum tool life. Speeds or feeds should be increased or decreased in small steps.

Shearing

Bars and forging billets should be cold cut by sawing. Abrasive wheel cutting can cause small surface cracks, particularly when cutting annealed stock and should be avoided.

Weldability

Carpenter 15Cr-5Ni can be satisfactorily welded by the shielded fusion and resistance welding processes. Oxyacetylene welding is not recommended, since carbon pickup in the weld may occur. When a filler metal is required, AWS E/ER630 welding consumables should be considered to provide welds with properties matching those of the base metal. When designing the weld joint, care should be exercised to avoid stress concentrators, such as sharp corners, threads, and partial-penetration welds. When high weld strength is not needed, a standard austenitic stainless filler, such as E/ER308L, should be considered.

Normally, welding in the solution-treated condition has been satisfactory; however, where high welding stresses are anticipated, it may be advantageous to weld in the overaged (H 1150) condition. Usually, preheating is not required to prevent cracking.

If welded in the solution-treated condition, the alloy can be directly aged to the desired strength level after welding. However, the optimum corrosion resistance is obtained by solution treating the welded part before aging. If welded in the overaged condition, the part must be solution treated and then aged.

Other Information

Descaling (Cleaning)

Descaling following forging and annealing can be accomplished by acid cleaning or grit blasting. The acid treatment consists of 2 minutes in 50% by volume muriatic acid at 180ºF (82ºC), followed by 4 minutes in a mixture of 15% by volume nitric acid, plus 3% by volume hydrofluoric acid at room temperature. Water rinse and desmut in 20% by volume nitric acid at room temperature. Repeat cleaning procedure as necessary but decrease the times by 50% (i.e., 1 and 2 minutes, respectively).

The heat tint from aging can be removed by polishing, vapor blasting or pickling 4 to 6 minutes in a mixture of 15% by volume nitric acid, plus 3% by volume hydrofluoric acid, followed by a water rinse. Repeat the acid cleaning procedure if necessary, but decrease the time by 2 to 3 minutes. Desmut in 20% by volume nitric acid at room temperature.

After acid cleaning, bake 1 to 3 hours at 300/350ºF (149/177ºC) to remove hydrogen.

Applicable Specifications

- AMS 5658
- AMS 5659
- AMS 5862
- ASME SA705
- ASTM A564 (Grade XM-12)
- ASTM A693 (Grade XM-12)
- ASTM A705 (Grade XM-12)

Forms Manufactured

- Bar-Rounds
- Billet
- Hollow Bar
- Wire
- Wire-Rod

Technical Articles

- A Guide to Etching Specialty Alloys for Microstructural Evaluation
- Alloy Selection for Cold Forming (Part I)
- Alloy Selection for Cold Forming (Part II)
- How to Passivate Stainless Steel Parts
- New Drop-In Version of 15Cr-5Ni Alloy Offers Superior Machinability, Meets AMS Specs
- New Ph Stainless Combines High Strength, Fracture Toughness and Corrosion Resistance
- New Requirements for Ferrous-Base Aerospace Alloys
- One of the Word's Most Powerful Revolvers Gets Lift From Aerospace Alloys
- Steels for Strength and Machinability
- Passivating and Electropolishing Stainless Steel Parts
- Selection of High Strength Stainless Steels for Aerospace, Military and Other Critical Applications

Edition Date: 3/15/04