CARPENTER TECHNOLOGY

DATASHEET

15CR-5NI

Applicable specifications: AMS 5658, 5659, 5862; ASME SA705; ASTM A564, A705, A693 (Grade XM-12 for all ASTM)

Associated specifications: UNS S15500

Type analysis

Single figures are nominal except where noted.

Iron	Balance	**Chromium**	14.00–15.50 %	**Nickel**	3.50–5.50 %
Copper	2.50–4.50 %	**Manganese**	Max 1.00 %	**Silicon**	Max 1.00 %
Columbium + Tantalum	0.15–0.45 %	**Carbon**	Max 0.070 %	**Phosphorus**	Max 0.040 %
Sulfur	Max 0.015 %				

Forms manufactured

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

Description

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

15Cr-5Ni has fabrication characteristics similar to those of other precipitation hardening stainless steels and can be age 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

Key Properties:

- High transverse strength and toughness
- Excellent corrosion resistance
- High forgeability

Markets:

- Aerospace
- Energy
- Industrial
- Transportation

Applications:

- Valve and engine parts
- Fittings and fasteners, shafts, gears
- Industrial equipment
- Aircraft and nuclear reactor components

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Corrosion resistance

The general-corrosion resistance of 15Cr-5Ni is comparable to Type 304 and similar to Custom 630 (17Cr-4Ni) in most media. Good resistance to stress-corrosion cracking is gained by hardening at temperatures of 1025°F (551°C) and higher. Compared to Custom 630 (17Cr-4Ni), 15Cr-5Ni shows substantially better stress-corrosion-cracking resistance in boiling 42% $MgCl_2$ solution and slightly superior resistance in H_2S NaCl-acetic acid solutions. Erosion-corrosion resistance of 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 (Excellent, Good, Moderate, Restricted) is intended for comparative purposes only and is derived from experiences with wrought product. Additive manufactured material may perform differently; corrosion testing is recommended. Factors that 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	BOLLING 65 W/O HNO3 AVG. OF 5 48-HR PERIODS MPY	1 W/O HC1 AT 95°F (35°C)AVG. 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

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Physical properties

PROPERTY	Condition / At or From	English Units	Metric Units
SPECIFIC GRAVITY	Condition A	7.75	7.75
	Condition H 900	7.80	7.80
	Condition H 1075	7.81	7.81
	Condition H 1150	7.82	7.82
DENSITY	Condition A	0.2800 lb/in^3	7750 kg/m^3
	Condition H 900	0.2820 lb/in^3	7800 kg/m^3
	Condition H 1075	0.2820 lb/in^3	7810 kg/m^3
	Condition H 1150	0.2830 lb/in^3	7820 kg/m^3
MEAN SPECIFIC HEAT	32 to 212°F (0 to 100°C) Condition A	0.1100 Btu/lb/°F	460 J/kg·K
	32 to 212°F (0 to 100°C) Condition H 900	0.1000 Btu/lb/°F	419 J/kg·K
MEAN COEFFICIENT OF THERMAL EXPANSION (CTE)	70 to 200°F (21 to 93°C) Condition A	6.00 x 10^{-6} in/in/°F	10.8 x 10^{-6} length/length/K
	70 to 400°F (21 to 204°C) Condition A	6.00 x 10^{-6} in/in/°F	10.8 x 10^{-6} length/length/K
	70 to 600°F (21 to 316°C) Condition A	6.20 x 10^{-6} in/in/°F	11.2 x 10^{-6} length/length/K
	70 to 800°F (21 to 427°C) Condition A	6.30 x 10^{-6} in/in/°F	11.3 x 10^{-6} length/length/K
	-100 to 70°F (-73 to 21°C) Condition H 900	5.80 x 10^{-6} in/in/°F	10.4 x 10^{-6} length/length/K
	70 to 200°F (21 to 93°C) Condition H 900	6.00 x 10^{-6} in/in/°F	10.8 x 10^{-6} length/length/K
	70 to 400°F (21 to 204°C) Condition H 900	6.00 x 10^{-6} in/in/°F	10.8 x 10^{-6} length/length/K
	70 to 600°F (21 to 316°C) Condition H 900	6.30 x 10^{-6} in/in/°F	11.3 x 10^{-6} length/length/K
	70 to 800°F (21 to 427°C) Condition H 900	6.50 x 10^{-6} in/in/°F	11.7 x 10^{-6} length/length/K
	70 to 200°F (21 to 93°C) Condition H 1075	6.30 x 10^{-6} in/in/°F	11.3 x 10^{-6} length/length/K
	70 to 400°F (21 to 204°C) Condition H 1075	6.50 x 10^{-6} in/in/°F	11.7 x 10^{-6} length/length/K
	70 to 600°F (21 to 316°C) Condition H 1075	6.60 x 10^{-6} in/in/°F	11.9 x 10^{-6} length/length/K
	70 to 800°F (21 to 427°C) Condition H 1075	6.80 x 10^{-6} in/in/°F	12.2 x 10^{-6} length/length/K

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Physical properties

PROPERTY	At or From	English Units	Metric Units
MEAN COEFFICIENT OF THERMAL EXPANSION (CTE)	-100 to 70°F (-73 to 21°C) Condition H 1150	6.10×10^{-6} in/in/°F	11.0×10^{-6} length/length/K
	70 to 200°F (21 to 93°C) Condition H 1150	6.60×10^{-6} in/in/°F	11.9×10^{-6} length/length/K
	70 to 400°F (21 to 204°C) Condition H 1150	6.90×10^{-6} in/in/°F	12.4×10^{-6} length/length/K
	70 to 600°F (21 to 316°C) Condition H 1150	7.10×10^{-6} in/in/°F	12.8×10^{-6} length/length/K
	70 to 800°F (21 to 427°C) Condition H 1150	7.20×10^{-6} in/in/°F	13.0×10^{-6} length/length/K
	70 to 900°F (21 to 482°C) Condition H 1150	7.30×10^{-6} in/in/°F	13.1×10^{-6} length/length/K
THERMAL CONDUCTIVITY	300°F (149°C) Condition H 900	124.0 Btu-in/hr/ft^2/°F	17.9 W/m·K
	500°F (260°C) Condition H 900	135.0 Btu-in/hr/ft^2/°F	19.5 W/m·K
	860°F (460°C) Condition H 900	156.0 Btu-in/hr/ft^2/°F	22.5 W/m·K
	900°F (482°C) Condition H 900	157.0 Btu-in/hr/ft^2/°F	22.6 W/m·K
POISSON'S RATIO	Condition H 900	0.272	0.272
	Condition H 1075	0.272	0.272
	Condition H 1150	0.272	0.272
MODULUS OF ELASTICITY (E)	72°F, Condition H 900, Longitudinal	28.7×10^3 ksi	—
	100°F, Condition H 900, Longitudinal	28.5×10^3 ksi	—
	199°F, Condition H 900, Longitudinal	28.0×10^3 ksi	—
	300°F, Condition H 900, Longitudinal	27.6×10^3 ksi	—
	399°F, Condition H 900, Longitudinal	27.1×10^3 ksi	—
	500°F, Condition H 900, Longitudinal	26.7×10^3 ksi	—
	601°F, Condition H 900, Longitudinal	26.2×10^3 ksi	—

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Physical properties

PROPERTY	At or From	English Units	Metric Units
MODULUS OF RIGIDITY (G)	73°F, Condition H 900, Longitudinal	11.2×10^3 ksi	—
	73°F, Condition H 1025, Longitudinal	11.0×10^3 ksi	—
	73°F, Condition H 1075, Longitudinal	10.0×10^3 ksi	—
	73°F, Condition H 1150, Longitudinal	10.0×10^3 ksi	—
ELECTRICAL RESISTIVITY	73°F, Condition A	589.0 ohm-cir-mil/ft	980.0 microhm-mm
	73°F, Condition H 900	463.0 ohm-cir-mil/ft	770.0 microhm-mm

Mechanical properties

Cryogenic mechanical properties

15Cr-5Ni 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 IN (50 MM)	REDUCTION OF AREA
	ksi	MPa	ksi	MPa	%	%
A	—	—	—	—	—	—
H 900	185[1]	1276	200	1378	14	50
H 925	175	1207	190	1310	14	54
H 1025	165	1138	170	1173	15	56
H 1075	150	1035	165	1138	16	58
H 1100	135	931	150	1035	17	58
H 1150	125	862	145	1000	19	60
H 1150M	85	584	125	882	22	68

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LONGITUDINAL DIRECTION, INTERMEDIATE LOCATION								
CONDITION	HARDNESS		CHARPY V-NOTCH IMPACT STRENGTH		MODULUS OF ELASTICITY (E)[2]		MODULUS OF RIGIDITY (G)	
	HRC	BRINELL	ft-lb	J	KSI	MPA	KSI	MPA
A	35	341	—	—	—	—	—	—
H 900	44	420	15	20	28.5×10^3	197.6×10^3	11.2×10^3	77.3×10^3
H 925	42	409	25	34	—	—	—	—
H 1025	38	352	35	48	—	—	11.0×10^3	75.9×10^3
H 1075	36	341	40	54	—	—	10.0×10^3	69.0×10^3
H 1100	34	332	45	61	—	—	—	—
H 1150	33	311	50	68	—	—	10.0×10^3	69.0×10^3
H 1150M	27	277	100	138	—	—	—	—

[1] Compressive yield strength for Condition H 900 is 178 ksi (1228 MPa)

[2] The modulus values for 15Cr-5Ni at elevated temperatures 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 IN (50.8 MM)	REDUCTION OF AREA	HARDNESS		CHARPY V-NOTCH IMPACT STRENGTH	
	ksi	MPa	ksi	MPa	%	%	HRC	BRINELL	FT-LBS	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

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TYPICAL ROOM TEMPERATURE MECHANICAL PROPERTIES OF CONSUMABLE-ELECTRODE-REMELTED MATERIAL

LONGITUDINAL DIRECTION, INTERMEDIATE LOCATION OF 12 IN (305 MM) SQUARE BILLET

CONDITION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 2 IN (50.8 MM)	REDUCTION OF AREA	HARDNESS	CHARPY V-NOTCH IMPACT STRENGTH	
	ksi	MPa	ksi	MPa	%	%	HRC	FT-LBS	J
H 900	130	897	162	1118	13	56	32	—	—
H 925	178	1228	192	1325	12	47	41	6[1]	8
H 1025	158	1090	164	1132	14	62	36	30	41
H 1075	116	800	139	959	20	69	29	80	109

[1] 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 IN (305 MM) SQUARE BILLET

CONDITION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 2 IN (50.8 MM)	REDUCTION OF AREA	HARDNESS	CHARPY V-NOTCH IMPACT STRENGTH	
	ksi	MPa	ksi	MPa	%	%	HRC	FT-LBS	J
H 900	178	1228	193	1332	11	46	41	6[1]	8
H 925	159	1097	164	1132	14	57	36	25	34
H 1025	115	793	138	952	20	64	29	70	95

[1] 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

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Heat treatment

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 900°F (482°C) to 1150°F (621°C) for 1 to 4 hours, depending on the temperature, then air cooling.

Solution treatment	Heat at 1900°F (1038°C) ±25°F (±14°C), for ½ hour, cool to below 90°F (32°C) so that the material is completely transformed to martensite. Sections under 3 in (76 mm) can be oil quenched and sections over 3 in (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 900°F (482°C) for 1 hour and air cool. Heat Treatment, Conditions H 925, H 1025, H 1075, H 1100, H 1150 (precipitation or age hardened): Heat solution-treated material at specified temperature ±15°F (±8°C) for 4 hours and air cool. Heat Treatment, Condition H 1150M (precipitation or age hardened): Heat solution-treated material at 1400°F (760°C) ±15°F (±8°C) for 2 hours, air cool; then heat at 1150°F (621°C) ±15°F (±8°C) for 4 hours and air cool.

Workability

Hot working	15Cr-5Ni can be readily forged, hot headed, and upset. Material that is hot worked must be solution treated prior to hardening if the material is to respond properly to hardening.
Forging	Heat uniformly to 2150/2200°F (1177/1204°C) and hold 1 hour at temperature before forging. Do not forge below 1850°F (1010°C). To obtain optimum grain size and mechanical properties, forgings should be cooled in air to below 90°F (32°C) before further processing. Forgings must be solution treated prior to hardening.
Cold working	15Cr-5Ni can be fabricated by cold working (i.e., heading, rolling, etc.) to an extent that 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	15Cr-5Ni 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.

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Typical feeds and speeds

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

TURNING — SINGLE-POINT AND BOX TOOLS

CONDITION	DEPTH OF CUT, IN	HIGH-SPEED TOOLS			CARBIDE TOOLS (INSERTS)			
		SPEED, FPM	FEED, IPR	TOOL MATERIAL	SPEED, FPM		FEED, IPR	TOOL MATERIAL
					UNCOATED	COATED		
Annealed	.150	72	.015	M-48, T-15	270	350	.010	C-6
	.025	84	.007	M-48, T-15	325	425	.005	C-7
Aged	.150	48	.010	M-48, T-15	190	250	.010	C-6
	.025	54	.005	M-48, T-15	225	290	.005	C-7

TURNING — CUT-OFF AND FORM TOOLS

CONDITION	SPEED, FPM	FEED, IPR							TOOL MATERIAL	
		CUT-OFF TOOL WIDTH, IN			FORM TOOL WIDTH, IN				HIGH-SPEED TOOLS	CARBIDE TOOLS
		1/16	*1/8*	*1/4*	*1/2*	*1*	*1-1/2*	*2*		
Annealed	72	.001	.0015	.002	.0015	.001	.0007	.0005	M-48, T-15	—
	216	.003	.005	.007	.005	.004	.0035	.0035	—	C-6
Aged	36	.001	.001	.0015	.0015	.001	.0005	.0005	M-48, T-15	—
	132	.003	.003	.0045	.003	.002	.002	.002	—	C-6

ROUGH REAMING

CONDITION	HIGH-SPEED TOOLS		CARBIDE TOOLS		FEED, IPR, REAMER DIAMETER, IN					
	SPEED, FPM	TOOL MATERIAL	SPEED, FPM	TOOL MATERIAL	*1/8*	*1/4*	*1/2*	*1*	*1-1/2*	*2*
Annealed	72	M-48, T-15	190	C-2	.003	.005	.008	.011	.015	.018
Aged	36	M-48, T-15	100	C-2	.001	.001	.001	.001	.001	.001

DRILLING — HIGH-SPEED TOOLS

CONDITION	SPEED, FPM	FEED, IPR								TOOL MATERIAL
		NOMINAL HOLE DIAMETER, IN								
		1/16	*1/8*	*1/4*	*1/2*	*3/4*	*1*	*1-1/2*	*2*	
Annealed	50	.001	.002	.004	.007	.008	.010	.012	.015	M-42
Aged	35	—	.001	.002	.003	.004	.004	.004	.004	M-42

TAPPING — HIGH-SPEED TOOLS

CONDITION	SPEED, FPM	TOOL MATERIAL
Annealed	12–25	M-7, M-10
Aged	5–15	M-7, M-10 Nitrided

BROACHING — HIGH-SPEED TOOLS

CONDITION	SPEED, FPM	CHIP LOAD, IN PER TOOTH	TOOL MATERIAL
Annealed	9.6	.002	M-48, T-15
Aged	12	.002	M-48, T-15

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DIE THREADING — HIGH-SPEED TOOLS					
CONDITION	SPEED, FPM				TOOL MATERIAL
	7 OR LESS, TPI	8 TO 15, TPI	16 TO 24, TPI	25 AND UP, TPI	
Annealed	5–12	8–15	10–22	15–27	M-2, M-7, M-10
Aged	4–8	6–10	8–12	10–15	M-48, T-15

MILLING — END PERIPHERAL														
CONDITION	DEPTH OF CUT, IN	HIGH-SPEED TOOLS						CARBIDE TOOLS						
		SPEED, FPM	FEED, IN PER TOOTH				TOOL MATERIAL	SPEED, FPM	FEED, IPT				TOOL MATERIAL
			CUTTER DIAMETER, IN						CUTTER DIAMETER, IN PER TOOTH				
			1/4	1/2	3/4	1-2			1/4	1/2	3/4	1-2	
Annealed	.050	108	.001	.002	.003	.004	M-48, T-15	275	.001	.002	.004	.006	C-2
Aged	.050	72	.0005	.001	.002	.003	M-48, T-15	90	.001	.002	.003	.004	C-2

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	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.

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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 180°F (82°C), 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 300/350°F (149/177°C) to remove hydrogen.
High temperature exposure	15Cr-5Ni 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.

For additional information, please contact your nearest sales office:
info@cartech.com | 610 208 2000