Technical Datasheet

CarTech® Custom Age 625 PLUS® Alloy

Identification

U.S. Patent Number

- 5,556,594

UNS Number

- N07716

Type Analysis

Single figures are nominal except where noted.

Carbon (Maximum)	0.03 %	**Manganese (Maximum)**	0.20 %
Phosphorus (Maximum)	0.015 %	**Sulfur (Maximum)**	0.010 %
Silicon (Maximum)	0.20 %	**Chromium**	19.00 to 22.00 %
Nickel	59.00 to 63.00 %	**Molybdenum**	7.00 to 9.50 %
Titanium	1.00 to 1.60 %	**Columbium/Niobium**	2.75 to 4.00 %
Aluminum (Maximum)	0.35 %	**Iron**	Balance

General Information

Description

CarTech Custom Age 625 PLUS alloy is a precipitation hardenable, nickel-base alloy which, in many environments, displays corrosion resistance similar to that of Alloy 625 and superior to that of Alloy 718.

A yield strength (0.2% offset) above 120 ksi (827 MPa) can be obtained by aging without prior warm or cold working. The precipitation hardening capability is particularly important in applications where large-section size or intricate shape precludes warm working.

In the age hardened (high strength) condition, CarTech Custom Age 625 PLUS alloy offers exceptional resistance to stress corrosion cracking as well as general, pitting and crevice corrosion.

Applications

CarTech Custom Age 625 PLUS alloy could be considered for applications where severely corrosive environments are a concern, such as those encountered in deep sour gas wells as well as in a variety of refinery and chemical process industry applications.

In addition, CarTech Custom Age 625 PLUS alloy could be considered a candidate for use in marine environments, where CarTech 625 has been used successfully. The higher strength capability of CarTech Custom Age 625 PLUS alloy may be particularly useful for fasteners and shafts.

Corrosion Resistance

Resistance to Stress Corrosion Cracking

Custom Age 625 PLUS alloy provides a unique combination of strength plus resistance to stress corrosion cracking, sulfide stress cracking, pitting and crevice corrosion. This alloy exhibits corrosion resistance superior to that of aged Alloy 718 and similar to that of cold worked Alloy 625.

Several stress corrosion test environments were used to evaluate Custom Age 625 PLUS alloy. Autoclave tests were used to simulate severe down-hole oil and gas field environments. All material for these tests was "well aged" at 500 or 600°F (260 or 316°C) for 1000 hours to simulate thermal exposure down-hole. U-bends were then stressed with Alloy C-276 fasteners and exposed at 400 and 425°F (204 and 219°C) as shown in the Autoclave Test Results table, see hyperlink entitled "Autoclave Test Results - Various Alloys". These samples were examined at 20x after a 4 week exposure.

Custom Age 625 PLUS alloy resisted cracking at both test temperatures. Its performance was equal or superior to Alloy 625 and superior to Alloy 718.

To evaluate performance in an elevated temperature environment not containing elemental sulfur (S), C-ring specimens were stressed to 100% of the longitudinal 0.2% yield strength in an autoclave containing deaerated 25% NaCl + 1200 psi H_2S + 600 psi CO_2. Exposure was 400°F (204°C) for three months, followed by 500°F (260°C) for one month. Results confirmed the superiority of Custom Age 625 PLUS alloy versus Alloy 718, see hyperlink entitled "Autoclave Test Results - Custom Age 625 PLUS Alloy vs Alloy 718".

Slow strain rate tensile tests were conducted at 300°F (149°C) to qualify Custom Age 625 PLUS alloy for applications in Mobile Bay. In this test, samples are tested in an inert environment, and also in a stress corrosion inducing environment. A ratio is calculated for time to failure in the corrosive environment versus the inert environment and a value greater than 0.80 indicates good resistance. No secondary cracking on the uniform gage length is allowed. Material for testing was solution treated plus double aged.

Additional slow strain rate tests were conducted on material with a 1350°F (732°C) primary age in a severe oil field environment at 350°F (177°C). The environment contained sour brine (16.5% NaCl + 150 psi H_2S and 150 psi CO_2, added at room temperature) with 10 g/l elemental sulfur. The ratios of time to fail (environment/inert) were 0.94 and 0.97, with no secondary cracking, as shown in the hyperlink entitled "Slow Strain Rate Tensile Test (SSRT)".

To evaluate the effect of lower temperature sour environments, sulfide stress corrosion cracking tests were conducted in the NACE TM0177 environment. This consists of a room temperature solution of 5% sodium chloride and 0.5% acetic acid, continuously purged with hydrogen sulfide. Custom Age 625 PLUS alloy samples were "well aged" at 500 and 600°F (260 and 316°C) and transverse cut U-bends were prepared and coupled to steel. These samples resisted sulfide stress corrosion cracking over the 1000 hour test period.

Double-cantilever beam (DCB) samples were machined according to the NACE test method. Fatigue-precracked and wedge-loaded specimens with stress intensities of 53/56 ksi(sqrt(in)) (58/59 MPa(sqrt(m))) were coupled to mild steel and exposed to the NACE TM0177 environment for a period of 28 days. Custom Age 625 PLUS alloy resisted cracking in this environment and no crack propagation occurred. This confirmed results on statically loaded tensile specimens which were tested at 100% of the yield strength and showed no failure in 720 hours (30 days).

Stress corrosion cracking tests were also conducted using transverse cut U-bend samples in magnesium chloride boiling at 311°F (155°C) in accordance with ASTM G36. Samples were exposed for 1000 hours (42 days).

This is a very severe test for chloride stress corrosion cracking. It is not designed to simulate service, but may serve as a useful laboratory test to rank materials for some environments. Custom Age 625 PLUS alloy outperformed Alloy 718 in these tests, see hyperlink entitled "Chloride Stress Corrosion Cracking Test Results".

Resistance to Pitting and Crevice Corrosion

Pitting and crevice corrosion are often more important than general corrosion resistance. These forms of attack can provide notches where fatigue or stress corrosion cracking can initiate in some materials.

Pitting resistance was evaluated using pitting temperature tests in a ferric chloride/hydrochloric acid solution and in a "green death" solution (one of several simulated service environments). Machine ground 1" x 2" x 1/8" samples were exposed for 24 or 96 hours at increasingly higher temperatures until attack was noted at 20x. Resistance at higher temperatures indicates superior performance, see hyperlink entitled "Pitting Temperature Test Results".

Resistance to crevice corrosion was evaluated using constant-temperature weight-loss tests in the ferric chloride/hydrochloric acid solution and crevice temperature tests in "yellow death" solution (another laboratory simulated service environment), see hyperlink entitled "Crevice Corrosion Test Results".

Crevice samples were fabricated according to ASTM G48. Teflon* cylinders were secured to the opposite surfaces of pitting coupons using crossed rubber 0-rings.

In these crevice corrosion tests, Custom Age 625 PLUS alloy displayed pitting and crevice corrosion resistance similar to that of Alloy 625 and superior to that of Alloy 718.

*Dupont Trademark

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		

Autoclave Test Results — Custom Age 625 PLUS Alloy vs. Alloy 718

Deaerated 25% NaCl + 1200 psi H_2S + 600 psi CO_2. C-Ring test specimens stressed to 100% of yield strength. Exposed 400°F (204°C) for 3 months + 500°F (260°C) for 1 month.

Alloy	0.2% Yield Strength		Number of C-Rings Cracked/Number Tested
	ksi	MPa	
Custom Age 625 PLUS alloy	124	855	0/2
	130	896	0/2
	137	945	0/2
Alloy 718	115	793	1/2

Autoclave Test Results — Various Alloys

25% NaCl + 0.5 g/l S + 1400 psi H_2S at 400 and 425°F (204 and 219°C). Samples examined after 4 week exposure. U-bend test specimens.

Well Age Exposure (1000 Hours)	Specimen Orientation	Bend Location	Number of U-Bends Cracked/Number Tested	
			400°F (204°C)	425°F (219°C)
Custom Age 625 PLUS alloy — solution treated + aged				
None	Transverse†	1/4-Radius	0/2	0/2
500°F (260°C)	Transverse†	1/4-Radius	0/2	1/2
600°F (316°C)	Transverse†	1/4-Radius	0/2	0/2
600°F (316°C)	Longitudinal	Mid-Radius	–	0/2
600°F (316°C)	Longitudinal	Surface	0/2	0/2
Alloy 625 — cold rolled				
600°F (316°C)	Transverse	–	0/2	2/2
Alloy 718 — solution treated + aged				
600°F (316°C)	Transverse†	Mid-Radius	2/2	2/2

†Transverse specimens cut in the radial direction.

Bar size—4–6" (101.6–152.4 mm) diameter

Chloride Stress Corrosion Cracking Test Results — Various Alloys

Boiling 45% $MgCl_2$ at 311°F (155°C). U-bend test specimens. Samples well aged in air at 600°F (316°C) for 720 hours after heat treating or cold rolling. 1000 hour exposure.

Alloy	Condition	0.2% Yield Strength		Results C = Cracking NC = No Cracking
		ksi	MPa	
Custom Age 625 PLUS alloy	Solution Treated & Aged	130	896	C, NC
Custom Age 625 PLUS alloy	Solution Treated & Aged	139	958	NC, NC
Alloy 625	Cold Rolled	121	834	NC, NC
Alloy 718	Solution Treated & Aged	132	910	C, C
Alloy 718	Solution Treated & Aged	141	972	C, NC

Crevice Corrosion Test Results — Various Alloys

Alloy	Condition	$FeCl_3/HCl$[1] Weight Loss (mg/cm^2)		Yellow Death[2] Crevice Temp. (°C)
		40°C	55°C	
Custom Age 625 PLUS alloy	Solution Treated & Aged	1.2	6.0	40, 40
Alloy 625	Cold Rolled	3.7	13.7	35, 40
Alloy 718	Solution Treated & Aged	35.0	47.2	≤25, ≤25

[1]6 w/o $FeCl_3$ + 1 w/o HCl; 40 or 55°C, 72 hours.

[2]4 w/o NaCl + 0.1 w/o $Fe_2(SO_4)_3$ + 0.01 M HCl; temperatures increased every 96 hours in 5°C intervals; specimens wet ground between exposures.

Pitting Temperature Test Results (°C) — Various Alloys

Alloy	Condition	$FeCl_3/HCl$[1]	Green Death[2]
Custom Age 625 PLUS alloy	Solution Treated & Aged	>98, >98	75,80
Alloy 625	Cold Rolled	>98, >98	80,90
Alloy 718	Solution Treated & Aged	56, 62	45,45

[1]6 w/o $FeCl_3$ + 1 w/o HCl; temperature increased every 24 hours in 2.5°C intervals; no preparation of specimens between exposures.

[2]7 v/o H_2SO_4 + 3 v/o HCl + 5 w/o $CuCl_2{\bullet}2H_2O$ + 5 w/o $FeCl_3{\bullet}6H_2O$; temperature increased every 96 hours in 5°C intervals; specimens ground between exposures.

Slow Strain Rate Tensile Test (SSRT) — Custom Age 625 PLUS Alloy

1.6" (40.6 mm) diameter bar at 300°F (149°C).

Parameter	Primary Aging Temperature		
	1325°F (718°C)	1350°F (732°C)	1375°F (746°C)
0.2% Yield Strength			
ksi	120.0	129.5	136.5
MPa	827.4	892.8	941.1
TTF (Env/Inert)			
Average	.92	.98	.91
Range	.87/.99	.93/1.07	.81/.96

Deaerated 25% NaCl + 0.5% acetic acid and 100 psi hydrogen sulfide added at 75°F (24°C).

No secondary cracking.

Properties

Physical Properties

Density	0.3040	lb/in³
Mean Specific Heat	0.1000	Btu/lb/°F
Mean CTE		
77 to 212°F, Solution Treated	7.10	x 10 $^{-6}$ in/in/°F
77 to 392°F, Solution Treated	7.30	x 10 $^{-6}$ in/in/°F
77 to 572°F, Solution Treated	7.50	x 10 $^{-6}$ in/in/°F
77 to 752°F, Solution Treated	7.60	x 10 $^{-6}$ in/in/°F
77 to 932°F, Solution Treated	7.80	x 10 $^{-6}$ in/in/°F
77 to 1112°F, Solution Treated	8.00	x 10 $^{-6}$ in/in/°F
77 to 1292°F, Solution Treated	8.30	x 10 $^{-6}$ in/in/°F
77 to 212°F, Solution Treated and Aged	7.00	x 10 $^{-6}$ in/in/°F
77 to 392°F, Solution Treated and Aged	7.20	x 10 $^{-6}$ in/in/°F
77 to 572°F, Solution Treated and Aged	7.40	x 10 $^{-6}$ in/in/°F
77 to 752°F, Solution Treated and Aged	7.60	x 10 $^{-6}$ in/in/°F
77 to 932°F, Solution Treated and Aged	7.80	x 10 $^{-6}$ in/in/°F
77 to 1112°F, Solution Treated and Aged	8.00	x 10 $^{-6}$ in/in/°F
77 to 1292°F, Solution Treated and Aged	8.30	x 10 $^{-6}$ in/in/°F

Mean coefficient of thermal expansion

Temperature Range		Solution Treated[1]		Solution Treated and Aged[2]	
77°F to	25°C to	10^{-6}/°C	10^{-6}/°F	10^{-6}/°C	10^{-6}/°F
212°F	100°C	12.9	7.1	12.6	7.0
392°F	200°C	13.1	7.3	13.0	7.2
572°F	300°C	13.4	7.5	13.4	7.4
752°F	400°C	13.7	7.6	13.7	7.6
932°F	500°C	14.0	7.8	14.0	7.8
1112°F	600°C	14.4	8.0	14.4	8.0
1292°F	700°C	15.0	8.3	15.0	8.3

[1]Solution treated 1900°F (1038°C)/3hr/AC

[2]Solution treated plus aged 1350°F (732°C)/8hr/FC to 1150°F (621°C)/8hr/AC

Modulus of Elasticity (E)	30.0	x 10 ^{3} ksi
Electrical Resistivity (70°F)	782.0	ohm-cir-mil/ft
Melting Range	2300 to 2470	°F

Magnetic Properties

Magnetic Permeability	1.0010	Mu

Typical Mechanical Properties

As discussed in the heat treatment section, both single aging and double aging treatment may be employed to achieve a 0.2% yield strength over the range of approximately 100 to 150 ksi (690 to 1035 MPa).

Direct Aging:
Also discussed in the heat treatment section was a technique called direct aging which provides higher strength than normally achieved by aging following solution treating. Tensile properties achieved on two different diameter bars via several aging treatments are shown in the hyperlink entitled "Effect of direct Aging Treatment on Temperature Mechanical Properties".

Comparative Data:
Room temperature mechanical properties have been determined on a 6.25" (159 mm) diameter solution treated bar following the two-step 1350/1150°F (732/621°C) aging treatment. To develop comparative data, Alloy 625 was wold rolled to obtain similar strength levels. Alloy 718 was precipitation hardened using a typical oil field heat treatment.

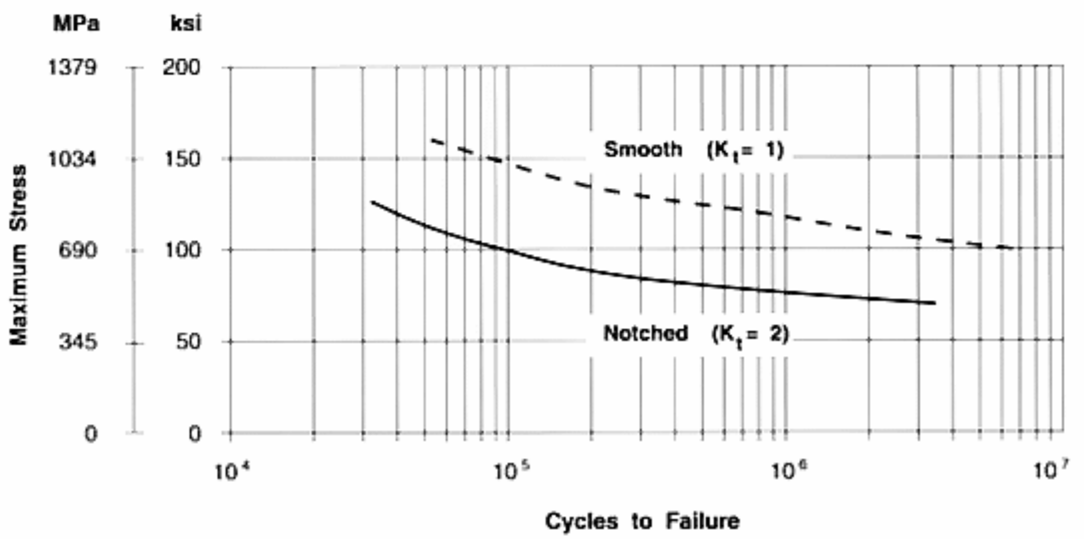
Well Aging:

Some samples were "well aged" at 600°F (316°C) to simulate thermal exposure down-hole. The "well age" had no effect on the tensile properties of either Custom Age 625 PLUS alloy or Alloy 718, but a reduced yield strength was noted in Alloy 625.

Cold Work Plus Aging:
As discussed in the section on heat treatment, this method of increasing strength depends on the percentage of cold work employed and the subsequent aging treatment. J Data for selected combinations of cold work plus age that provide an idea of achievable mechanical properties are shown in the hyperlink entitled "Effect of Cold Work Plus Aging on Typical Mechanical Properties".

Mechanical Properties as a Function of Size:
Mechanical property data have been obtained on Custom Age 625 PLUS alloy at various sizes. The Typical Room Temperature Tensile Properties Chart indicates that similar results can be expected for sizes between 0.163 and 7.25" (4.14 and 184.2 mm) using the 1900°F (1038°C) solution treatment plus the 1350/1150°F (732/621°C) double aging treatment.

Axial Fatigue Properties — Custom Age 625 PLUS Alloy
Solution treated and aged 6.0" (152 mm) diameter bar.
Heat treatment: 1900°F (1038°C) 1 hr, air cooled + 1350°F (732°C) 8 hr, furnace cooled to 1150°F (621°C) 8 hr, air cooled. Longitudinal mid-radius specimens.
Frequency = 1750 cpm. R-Factor = 0.05.
130 ksi yield strength, 181 ksi tensile strength, 35% elongation, 55% reduction of area.



Effect of Aging Treatment on Room Temperature Tensile Properties — Custom Age 625 PLUS Alloy

Aging Treatment[b]	Room Temperature Tensile[a] 0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area	Hardness HRC
	ksi	MPa	ksi	MPa			
1350°F/4hr/AC	103	710	162	1117	48	63	30
1350°F/8hr/AC	113	779	166	1145	41	59	34
1325°F/8hr/FC to 1150°F/8hr/AC	120	827	177	1220	37	57	35/36
1350°F/8hr/FC to 1150°F/8hr/AC	130	896	181	1248	32	54	38
1375°F/8hr/FC to 1150°F/8hr/AC	138	952	184	1269	32	51	39/40

[a]Averages of duplicate tests of transverse, radial cut specimens of 6.25" (159 mm) round bar.
[b]Solution treated 1900°F (1038°C)/2hr/AC prior to aging as shown.

Effect of Aging Treatment on Room Temperature Tensile Properties – Custom Age 625 PLUS® Alloy

For applications requiring even higher strength (140 ksi/965 MPa min. yield strength), the heat treatment can be modified to obtain the following room-temperature tensile properties:

Aging Treatment[b]	Room Temperature Tensile[a]						Hardness HRC
	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area	
	ksi	MPa	ksi	MPa			
1400°F/8hr/FC to 1200°F/8hr/AC	146	1007	187	1287	31	41	40

(a) Averages of longitudinal, mid-radius tests representing 6 lots of 6.0"-8.50" (152-216 mm) round bar (30 tests).
(b) Solution treated 1900°F (1038°C)/2hr/AC prior to aging as shown.

Effect of Cold Work Plus Aging on Typical Mechanical Properties — Custom Age 625 PLUS Alloy

Bar cold drawn 37.5% to 0.535" (13.6 mm) diameter following an 1800°F (982°C) solution treatment

Heat Treatment	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation (4D)	% Reduction of Area
	ksi	MPa	ksi	MPa		
As Drawn	184	1269	234	1620	13	52
1200°F/4hr/FC to 1075°F/4hr/AC	262	1806	269	1855	12	36

Effect of Direct Aging Treatment on Room Temperature Mechanical Properties — Custom Age 625 PLUS Alloy

Aging Treatment	Location	Approx. Distance Below Finished Bar Surface	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation (4D)	% Reduction of Area	Hardness (HRC)
			ksi	MPa	ksi	MPa			
3.625" (92 mm) Diameter Bar									
1350°F/8h/FC to 1150°F/8h/AC	Center	1.81	159	1096	197	1358	29	51	–
	Mid-Radius	0.91	175	1207	206	1420	26	49	43
	5/8" Radius	0.68	186	1282	210	1448	25	52	–
	3/4" Radius	0.45	195	1344	216	1489	21	47	46
	7/8" Radius	0.23	198	1365	218	1503	23	49	–
1350°F/8h/AC	5/8" Radius	0.68	172	1186	200	1379	27	54	–
	7/8" Radius	0.23	185	1276	206	1420	23	48	–
1.500" (38 mm) Diameter Bar									
1350°F/8h/FC to 1150°F/8h/AC	Mid-Radius	0.38	192	1324	210	1448	21	45	44

Effect of Specimen Location and Orientation on Typical Room Temperature Mechanical Properties — Various Alloys
Averages of duplicate tests at room temperature.

Alloy	Specimen Orientation	Test Location	0.2% Yield Strength		Room Temperature Tensile: Ultimate Tensile Strength		% Elongation (4D)	% Reduction of Area	Hardness HRC	Charpy V-Notch Impact Energy*	
			ksi	MPa	ksi	MPa				ft-lb	J
Custom Age 625 PLUS alloy	Long.	Center	126	869	180	1241	35	52	36/38	75	102
	Long.	Mid-Radius	129	889	183	1262	33	56	37/38	74	100
	Trans.	Mid-Radius	128	883	179	1234	31	54	37/38	68	92
	Long.	Surface	139	958	190	1310	31	55	39	69	94
Alloy 625	Long.	–	132	910	154	1062	27	61	31/33	88	119
	Trans.	–	127	876	148	1020	24	47	31/33	46	62
Alloy 718	Long.	Mid-Radius	142	979	184	1269	28	48	38/39	58	79
	Trans.	Mid-Radius	141	972	183	1262	25	39	38/39	32	43

*Notch orientation — radial for Custom Age 625 PLUS alloy and short transverse for Alloy 625.

Alloy Conditions:

Custom Age 625 PLUS alloy — 6.25" (159 mm) round bar — 1900°F (1038°C)/2hr/AC + 1350°F (732°C)/8hr/FC to 1150°F (621°C)/8hr/AC.

Alloy 625 — Cold rolled 24% — 0.50" (13 mm) thick plate from 5.50" (140 mm) round bar.

Alloy 718 — 6" (152 mm) round bar — 1875°F (1024°C)/2hr/WQ + 1425°F (774°C)/8hr/AC.

Effect of Specimen Location and Orientation on Typical Room Temperature Mechanical Properties – Custom Age 625 PLUS® alloy
For Higher-Strength Applications

Diameter inch (mm)	Specimen Orientation	Room Temperature Tensile[a]: 0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area	Hardness HRC	Charpy V-Notch Impact Energy[b] (-75°F)	
		ksi	MPa	ksi	MPa				ft-lb	J
6.0 (152)	Long.	146	1007	185	1277	31	41	39-40	48	65
6.0 (152)	Trans.	--	--	--	--	--	--	--	42	57
8.5 (216)	Long.	147	1016	190	1307	30	40	39-41	52	71
8.5 (216)	Trans.	--	--	--	--	--	--	--	42	57

(a) Averages of longitudinal, mid-radius tests representing multiple lots of mill-treated bars.
(b) Mid-radius location, radial notch orientation
Heat treatment - 1900°F (1038°C)/2hr/AC+1400°F (760°C)/8hr/FC to 1200°F (649°C)/8hr/AC

Elevated Temperature Tensile Properties—Custom Age 625 PLUS Alloy

Averages of duplicate tests of longitudinal specimens from mid-radius of 6.25" (159 mm) round bar. Heat treatment—1900°F (1038°C)/2hr/AC + 1350°F (732°C)/8hr/FC to 1150°F (621°C)/8hr/AC.

Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area
°F	°C	ksi	MPa	ksi	MPa		
75	24	128	883	183	1262	33	56
350	177	119	821	172	1186	34	59
450	232	116	800	167	1152	34	60
600	316	114	787	160	1104	32	58
800	427	114	787	155	1069	32	54
1000	538	114	787	153	1055	31	52
1200	649	112	773	155	1069	25	31

Stress Rupture Properties—Custom Age 625 PLUS Alloy

Heat treatmen: 1900°F (1038°C)/1 to 2 hr/AC + 1350°F (732°C)/8hr/FC to 1150°F (621°C)/8hr/AC. Average values.

Test Conditions	Stress Rupture		
	Life (Hours)	% Elongation in 4D	% Reduction of Area
	0.355" Dia.		
1000°F/140 ksi (538°C/965 MPa)	>673	19.5	22.5
1200°F/90 ksi (649°C/621 MPa)	480	42	44.5
1200°F/105 ksi (649°C/724 MPa)	103	34	40.5
	6.00" Dia.		
1000°F/140 ksi (538°C/965 MPa	266	32	24
1200°F/90 ksi (649°C/621 MPa)	245.5	48	69
1200°F/105 ksi (649°C/724 MPa)	51	33.5	44.5

Typical Room Temperature Mechanical Properties — Custom Age 625 PLUS Alloy

Material in solution treated condition

0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area	Hardness HRB
ksi	MPa	ksi	MPa			
55	379	121	834	61	73	88

Typical Room Temperature Tensile Properties — Custom Age 625 PLUS Alloy
Various sizes and forms. 1900°F (1038°C) solution treatment + 1350/1150°F (732/621°C) double aged material.

Size	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation	% Reduction of Area
	ksi	MPa	ksi	MPa		
0.163" Strip	130	896	187	1289	36	43
1/2x6" Plate	130	896	185	1276	31	55
5/8" Round	131	903	187	1289	30	57
3/4" Square	129	889	187	1289	33	57
2 1/2" Round	129	889	184	1269	32	55
4" Round	130	896	184	1269	32	57
5 1/2" Round	128	882	185	1276	32	56
6" Round	130	896	181	1248	30	52
7 1/4" Round	133	917	186	1282	32	50

Heat Treatment

Custom Age 625 PLUS alloy is typically supplied in one of two conditions. One is the solution treated condition heated 1900°F (1038°C) one to two hours, then air cooled. In this state, the product is ready to be age-hardened by any of a variety of heat treatments. It can also be supplied in the mill-aged condition to agreed upon property requirements.

From the solution treated condition, a variety of heat treatments are possible to achieve higher strength. Custom Age 625 PLUS alloy is strengthened by precipitation of gamma-double-prime phase [Ni3 (Nb, Ti)] during aging. Generally, the optimum combination of strength (120 to 140 ksi, 0.2% Y.S.) and corrosion resistance is obtained using a two-step aging process (double aging).

Double Age

This treatment consists of a primary age at 1325/1375°F (718/746°C) for 8 hours, followed by furnace cooling 100°F (55°C) per hour to 1150°F (621°C) and holding at heat for 8 hours, then allowing the material to air cool to room temperature. To achieve the popular yield strength range between 120 and 140 ksi (827 and 965 MPa) requires selection of 1350°F (732°C) as the primary aging temperature. Selecting 1325°F (718°C) will produce a slightly lower yield strength range. Selecting 1375°F (746°C) will produce a slightly higher yield strength range.

Hardness and strength increase as the primary aging temperature increases. Choosing the lowest primary aging temperature or the shortest total aging time consistent with the desired strength requirement is desirable in order to minimize intergranular precipitation of chromium and molybdenum-rich carbides.

Custom Age 625 PLUS alloy has been found to contract slightly (approx. 0.0005 in/in) during the double aging process.

Age

Single Aging

Single aging treatment at 1350°F (732°C) for 4 to 8 hours can be employed to obtain yield strengths of approximately 100 to 120 ksi (690 to 828 MPa).

Direct Aging

A heat treatment designed to achieve significantly higher strength, even in large section sizes, has been described as "direct aging." In this case, material in the as-hot worked condition is not solution treated, but directly given the conventional double aging treatment of 1350°F (732°C) 8 hours, followed by furnace cooling to 1150°F (621°C) and holding at heat for 8 hours, followed by an air cool to room temperature. This provides considerably higher yield strength and tensile strength, but is accompanied by an increased amount of grain boundary precipitation. The effect of this precipitation on corrosion resistance depends on the corrosive environment, and should be evaluated as part of the alloy qualification process. It should be noted that direct aged material (192 ksi 0.2% Y.S.) was capable of passing a 1,000 hour test in the NACE TM0177 environment at room temperature.

Cold Work Plus Aging

Another technique for increasing the strength of the finished product is to combine the increase in strength provided by cold working with an additional increment provided by subsequent aging. Conceptually, annealed material is cold drawn or cold rolled by a certain amount, fabricated in this condition, then aged using one of the several aging treatments to achieve final properties.

Since the amount of cold work which can be induced is a function of product form and section size, each application should be engineered to optimize properties.

Workability

Hot Working

Custom Age 625 PLUS alloy may be hot worked using a maximum furnace temperature of 2100°F (1149°C). Exercise care in avoiding frictional heat build-up as this may cause the material to exceed the 2100°F (1149°C) maximum temperature.

This alloy becomes very stiff at temperatures below 1850°F (1010°C). Uniform reductions are recommended to avoid the formation of a duplex grain structure.

After hot working, the alloy should be solution treated to recrystallize the grain structure and to precipitate stabilizing niobium/titanium-rich carbides.

Cold Working

Because of the high level of ductility, Custom Age 625 PLUS alloy can be cold formed with relative ease, however, it work hardens quite rapidly so intermediate annealing may be required. Also note that cold worked areas will age harden more rapidly and to a higher level than unworked areas.

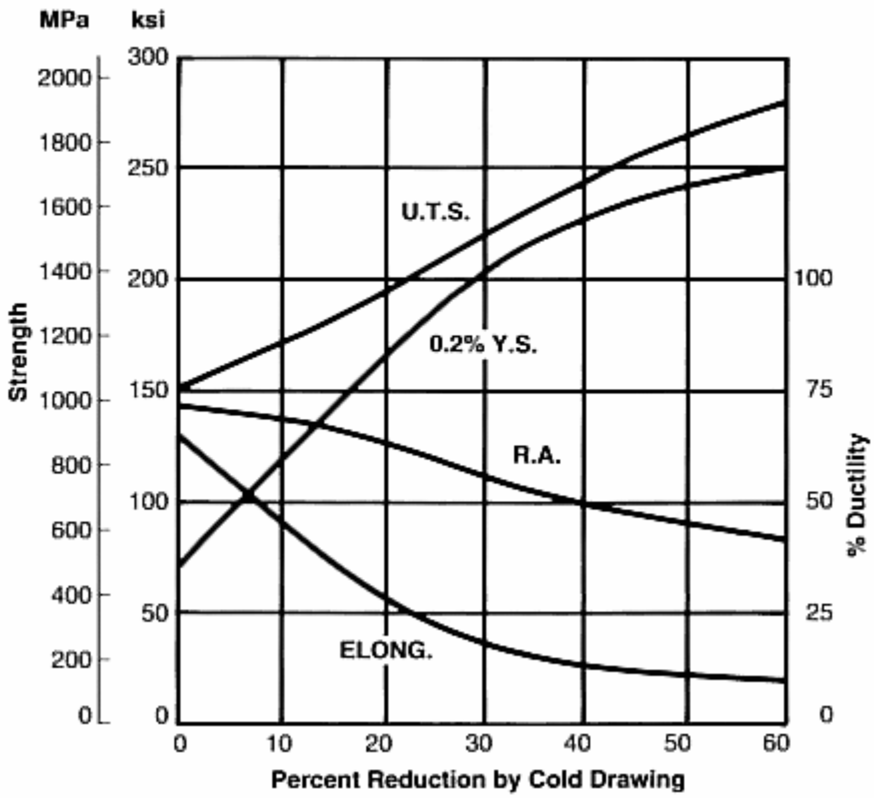
To achieve a normal aging response, the part must be solution treated after cold working and prior to aging.

Air cooling from the solution treating temperature is desirable for most section thicknesses to avoid thermal strains that can promote formation of intergranular carbides during aging.

Typical room temperature mechanical properties in the solution treated condition are illustrated in the hyperlink entitled "Typical room Temperature Mechanical Properties".

It is probable that there will be applications for cold drawn wire or cold rolled strip, with or without subsequent aging. The following graph illustrates the effect of cold work on the mechanical properties of wire.

Effect of Cold Work on Room Temperature Tensile Properties of Custom Age 625 PLUS Alloy Wire
0.05-0.10" (1.27-2.54 mm) diameter



Machinability

Custom Age 625 PLUS alloy can be machined in either the solution treated or age hardened condition.

As with all nickel base alloys, a high work hardening rate dictates careful attention to machining parameters. Equipment must have ample power and be very rigid. Cutting tools must have smooth finishes and be very sharp. A continuous smooth cutting action should be maintained and light feeds should be avoided. An ample supply of coolant must be maintained.

In general, machining procedures similar to those used for Alloy 718 are suggested.

Single point turning should be done at 15 to 25 sfpm (surface speed feet/minute) with feed rates of 0.015 to 0.007 ipr (feed inches/revolution) when using M42 or equivalent high speed steel. With carbide tools, the speed may be increased to 50 to 100 sfpm at feeds of 0.015 to 0.005 ipr.

In drilling operations, speeds of 15 to 20 sfpm at feeds of 0.002 to 0.004 ipr are suggested when using high speed drills. Speeds 2 to 3 times faster may be employed with carbide drills.

Users have reported better chip characteristics when the material is in the aged condition.

Figures used for these metalworking operations are average. On certain work, the nature of the part may require adjustment of feeds and speeds. Feeds or speeds should be increased or decreased in small steps.

Weldability

Welding of Custom Age 625 PLUS alloy will be required for some applications. It may also serve as a higher-strength alternative to Alloy 625 weld wire.

Some nickel base alloys with high niobium content can be difficult to weld without fusion zone hot cracking.

Custom Age 625 PLUS alloy, in the solution treated and aged condition, has been compared to commercial heats of Alloy 718 and Alloy 625 using the Varestraint Test. The resistance to hot cracking of Custom Age 625 PLUS alloy was similar to that of Alloy 625 and superior to that of Alloy 718. Custom Age 625 PLUS alloy responded similarly in both the solution treated and aged conditions.

To generate mechanical property and corrosion data, strip was GTA-welded autogenously. No problems were encountered during welding. While strength will depend on weld size, the yield strength of autogenous-welded and double aged strip was similar to that of unwelded strip.

Half-inch thick plates were GTA-welded together with Custom Age 625 PLUS alloy filler wire. The welds were sampled as-welded, after direct aging, and after solution treating and aging. For results, refer to the hyperlinks entitled "Room Temperature Tensile Tests of All-Weld-Metal Specimens" and "Autogenous Welds (No Filler Metal)".

As welded strip showed resistance to pitting, sulfide stress cracking (NACE TM0177) and intergranular corrosion (ASTM A262-B, 24 hour exposure) similar to that of unwelded strip.

A post-weld solution treatment was necessary for aged material to improve resistance to sulfide stress corrosion cracking and intergranular corrosion. Refer to the "Autogenous Welds" hyperlink for details.

Custom Age 625 PLUS alloy can be applied as a weld overlay on carbon steel components to provide a corrosion resistant layer. Many such constructions are subsequently stress relieved at temperatures in the 1250°F (677°C) range. This will promote age hardening of the Custom Age 625 PLUS alloy such that useful increases in strength and hardness will be achieved.

Autogenous Welds (No Filler Metal) — Custom Age 625 PLUS Alloy
Solution Treat=1900°F (1038°C)/1hr/AC; Age=1350°F (732°C)/8hr/FC to 1150°F (621°C)/8hr/AC

Condition	Intergranular Corrosion Resistance in Boiling Ferric Sulfate/Sulfuric Acid (ASTM A262-B, 24 hrs)				Stress Cracking NACE TM0177 R.T./1000 hrs. (Cracking Time-hrs)
	Corr. Rate (mpy)	Max. Depth of Attack (mils)			
		Base	HAZ	Weld	
Solution + Weld + Age	163	1.6	9.7	3.3	0–240
Solution + Weld + Solution + Age	87	1.2	0.5	1.4	NC
Solution + Age + Weld	40	1.1	0	1.1	NC

NC = No Cracking

Room Temperature Tensile Tests of All-Weld-Metal Specimens — Custom Age 625 PLUS Alloy
0.252" (6.4 mm) diameter

Condition	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 1" (25.4 mm)	% Reduction of Area
	ksi	MPa	ksi	MPa		
Solution Treated & Double Aged Plate	124	855	182	1255	34	54
Welded with Custom Age 625 PLUS alloy wire As Welded	74	510	120	827	42	49
Above plus Double Aged	123	848	163	1124	22	34
Above, plus Solution Annealed & Double Aged	127	875	177	1220	26	51

Other Information

Applicable Specifications

Custom Age 625 PLUS alloy has been approved in NACE MR0175 up to Rockwell C 43 maximum hardness. It is also included in ASTM specification B805 and AMS 5864.

- AMS 5854
- ASTM B805
- NACE MR0175

Forms Manufactured

- Bar-Rounds
- Billet
- Strip
- Weld Wire
- Wire

Technical Articles

- A Guide to Etching Specialty Alloys for Microstructural Evaluation
- Selecting Alloys for Severely Corrosive Environments

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