CARPENTER® TECHNOLOGY

DATASHEET

CUSTOM 465®

Applicable specifications: AMS 5936, ASTM A564, ASTM A693, ASTM F899, MMPDS-01

Associated specifications: UNS S46500, U.S. Patent Numbers 5,681,528 and 5,855,844

Type analysis

Single figures are nominal except where noted.

Iron	Balance	**Chromium**	11.00–12.50 %	**Nickel**	10.75–11.25 %
Titanium	1.50–1.80 %	**Molybdenum**	0.75–1.25 %	**Manganese**	Max 0.25 %
Silicon	Max 0.25 %	**Carbon**	Max 0.02 %	**Phosphorus**	Max 0.015 %
Sulfur	Max 0.01%				

Forms manufactured

Bar-Flats	**Bar-Rounds**	**Bar-Squares**	**Billet**	**Strip**	**Wire**

Description

Custom 465 is a premium melted, martensitic, age-hardenable stainless steel alloy capable of ultimate tensile strength in excess of 250 ksi in the overaged (H 950) condition. This alloy was designed to have excellent notch tensile strength and fracture toughness in this condition.

Overaging to the H 1000 condition provides a superior combination of strength, toughness, and stress-corrosion cracking resistance compared with other high-strength precipitation hardenable stainless alloys such as Custom 455® or 13Cr-8Ni.

Custom 465 is used in a wide variety of markets and applications.

Key Properties:

- High tensile strength and toughness
- Excellent corrosion resistance

Markets:

- Aerospace
- Consumer
- Defense
- Industrial
- Medical
- Transportation

Applications:

- Aerospace: landing gear components, flap and slat track components, torque tubes, pneumatic cylinders, braces, struts, fuse pins, gimbals, and other structural elements
- Energy: drive shafts and other downhole drilling tools
- Medical and dental: torsion drivers, reamers, drills, scrapers, cutters, and suture needles
- Transportation: suspension coil springs, engine valve springs, torsion bars and instrumented wheel sensors

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Corrosion resistance

The general corrosion resistance of Custom 465 approaches that of 304 stainless. Exposure to 5% neutral salt spray at 95°F (35°C) (per ASTM B117) caused little or no rusting after 200 hours regardless of condition (i.e., annealed or H 900–H 1100 conditions).

Double-cantilever-beam tests conducted in 3.5% NaCl (pH 6) show Custom 465 to possess inherently good resistance to stress corrosion cracking that improves with increasing aging temperature.

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

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Physical properties

PROPERTY	Condition / At or From	English Units	Metric Units
DENSITY	Annealed/CT	0.2822 lb/in^3	7.81 g/cm^3
	Condition H 900	0.2825 lb/in^3	7.82 g/cm^3
	Condition H 950	0.2829 lb/in^3	7.83 g/cm^3
	Condition H 1000	0.2832 lb/in^3	7.84 g/cm^3
	Condition H 1050	0.2832 lb/in^3	7.84 g/cm^3
	Condition H 1100	0.2840 lb/in^3	7.86 g/cm^3
MEAN COEFFICIENT OF THERMAL EXPANSION (CTE)	77 to 212°F (25 to 100°C) Annealed/CT	5.72 x 10^{-6} in/in/°F	10.30 x 10^{-6} length/length/°C
	77 to 392°F (25 to 200°C) Annealed/CT	6.00 x 10^{-6} in/in/°F	10.80 x 10^{-6} length/length/°C
	77 to 572°F (25 to 300°C) Annealed/CT	6.06 x 10^{-6} in/in/°F	10.90 x 10^{-6} length/length/°C
	77 to 752°F (25 to 400°C) Annealed/CT	6.17 x 10^{-6} in/in/°F	11.10 x 10^{-6} length/length/°C
	77 to 932°F (25 to 500°C) Annealed/CT	6.06 x 10^{-6} in/in/°F	10.90 x 10^{-6} length/length/°C
	77 to 1112°F (25 to 600°C) Annealed/CT	5.48 x 10^{-6} in/in/°F	9.86 x 10^{-6} length/length/°C
	77 to 212°F (25 to 100°C) Condition H 900	5.78 x 10^{-6} in/in/°F	10.40 x 10^{-6} length/length/°C
	77 to 392°F (25 to 200°C) Condition H 900	6.17 x 10^{-6} in/in/°F	11.10 x 10^{-6} length/length/°C
	77 to 572°F (25 to 300°C) Condition H 900	6.33 x 10^{-6} in/in/°F	11.40 x 10^{-6} length/length/°C
	77 to 752°F (25 to 400°C) Condition H 900	6.50 x 10^{-6} in/in/°F	11.70 x 10^{-6} length/length/°C
	77 to 932°F (25 to 500°C) Condition H 900	6.67 x 10^{-6} in/in/°F	12.00 x 10^{-6} length/length/°C
	77 to 1112°F (25 to 600°C) Condition H 900	6.22 x 10^{-6} in/in/°F	11.20 x 10^{-6} length/length/°C
	77 to 212°F (25 to 100°C) Condition H 1000	5.89 x 10^{-6} in/in/°F	10.60 x 10^{-6} length/length/°C
	77 to 392°F (25 to 200°C) Condition H 1000	6.17 x 10^{-6} in/in/°F	11.10 x 10^{-6} length/length/°C
	77 to 572°F (25 to 300°C) Condition H 1000	6.39 x 10^{-6} in/in/°F	11.50 x 10^{-6} length/length/ °C
	77 to 752°F (25 to 400°C) Condition H 1000	6.50 x 10^{-6} in/in/°F	11.70 x 10^{-6} length/length/°C

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Physical properties

PROPERTY	At or From	English Units	Metric Units
MEAN COEFFICIENT OF THERMAL EXPANSION (CTE)	77 to 932°F (25 to 500°C) Condition H 1000	6.67×10^{-6} in/in/°F	12.00×10^{-6} length/length/°C
	77 to 1112°F (25 to 600°C) Condition H 1000	6.78×10^{-6} in/in/°F	12.20×10^{-6} length/length/°C
	77 to 212°F (25 to 100°C) Condition H 1100	6.28×10^{-6} in/in/°F	11.30×10^{-6} length/length/°C
	77 to 392°F (25 to 200°C) Condition H 1100	6.67×10^{-6} in/in/°F	12.00×10^{-6} length/length/°C
	77 to 572°F (25 to 300°C) Condition H 1100	6.89×10^{-6} in/in/°F	12.40×10^{-6} length/length/°C
	77 to 752°F (25 to 400°C) Condition H 1100	7.06×10^{-6} in/in/°F	12.70×10^{-6} length/length/°C
	77 to 932°F (25 to 500°C) Condition H 1100	7.17×10^{-6} in/in/°F	12.90×10^{-6} length/length/°C
	77 to 1112°F (25 to 600°C) Condition H 1100	7.28×10^{-6} in/in/°F	13.10×10^{-6} length/length/°C
THERMAL CONDUCTIVITY	73°F (23°C) Annealed/CT	97.6 Btu-in/hr/ft^2/°F	14.06 W/m·K
	212°F (100°C) Annealed/CT	108.6 Btu-in/hr/ft^2/°F	15.65 W/m·K
	392°F (200°C) Annealed/CT	122.9 Btu-in/hr/ft^2/°F	17.71 W/m·K
	572°F (300°C) Annealed/CT	134.4 Btu-in/hr/ft^2/°F	19.37 W/m·K
	752°F (400°C) Annealed/CT	148.7 Btu-in/hr/ft^2/°F	21.43 W/m·K
	932°F (500°C) Annealed/CT	165.5 Btu-in/hr/ft^2/°F	23.85 W/m·K
	1112°F (600°C) Annealed/CT	178.7 Btu-in/hr/ft^2/°F	25.76 W/m·K
	73°F (23°C) Condition H 900	103.0 Btu-in/hr/ft^2/°F	14.85 W/m·K
	212°F (100°C) Condition H 900	117.2 Btu-in/hr/ft^2/°F	16.89 W/m·K
	392°F (200°C) Condition H 900	133.3 Btu-in/hr/ft^2/°F	19.21 W/m·K
	572°F (300°C) Condition H 900	145.5 Btu-in/hr/ft^2/°F	20.97 W/m·K
	752°F (400°C) Condition H 900	156.0 Btu-in/hr/ft^2/°F	22.49 W/m·K
	932°F (500°C) Condition H 900	170.1 Btu-in/hr/ft^2/°F	24.52 W/m·K

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Physical properties

PROPERTY	At or From	English Units	Metric Units
THERMAL CONDUCTIVITY	1112°F (600°C) Condition H 900	182.6 Btu-in/hr/ft²/°F	26.32 W/m·K
	73°F (23°C) Condition H 1000	109.8 Btu-in/hr/ft²/°F	15.83 W/m·K
	212°F (100°C) Condition H 1000	125.0 Btu-in/hr/ft²/°F	18.01 W/m·K
	392°F (200°C) Condition H 1000	140.5 Btu-in/hr/ft²/°F	20.25 W/m·K
	572°F (300°C) Condition H 1000	150.6 Btu-in/hr/ft²/°F	21.71 W/m·K
	752°F (400°C) Condition H 1000	163.4 Btu-in/hr/ft²/°F	23.55 W/m·K
	932°F (500°C) Condition H 1000	177.5 Btu-in/hr/ft²/°F	25.58 W/m·K
	1112°F (600°C) Condition H 1000	191.6 Btu-in/hr/ft²/°F	27.61 W/m·K
	73°F (23°C) Condition H 1050	109.6 Btu-in/hr/ft²/°F	15.80 W/m·K
	212°F (100°C) Condition H 1050	125.5 Btu-in/hr/ft²/°F	18.09 W/m·K
	392°F (200°C) Condition H 1050	141.7 Btu-in/hr/ft²/°F	20.42 W/m·K
	572°F (300°C) Condition H 1050	152.6 Btu-in/hr/ft²/°F	21.99 W/m·K
	752°F (400°C) Condition H 1050	163.1 Bt u-in/hr/ft²/°F	23.51 W/m·K
	932°F (500°C) Condition H 1050	175.5 Btu-in/hr/ft²/°F	25.29 W/m·K
	1112°F (600°C) Condition H 1050	186.7 Btu-in/hr/ft²/°F	26.91 W/m·K
MODULUS OF ELASTICITY (E)	Condition H 1000	28.8 x 10^3 ksi	—
	Condition H 1100	28.4 x 10^3 ksi	—
ELECTRICAL RESISTIVITY (RT)	70°F, Annealed/CT	569 ohm-cir-mil/ft	946 microhm·mm
	70°F, Condition H 900	496 ohm-cir-mil/ft	824 microhm·mm
	70°F, Condition H 1000	494 ohm-cir-mil/ft	822 microhm·mm
	70°F, Condition H 1100	464 ohm-cir-mil/ft	772 microhm·mm

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Magnetic properties

DC MAGNETIC PROPERTIES

CONDITION	COERCIVITY, Hc	SATURATION INDUCTION, Bs	SATURATION FLUX DENSITY
	Oe	kG	G
Annealed/CT	25.5	13.4	13400.0
Condition H 900	23.3	13.8	13800.0
Condition H 950	24.0	13.6	13600.0
Condition H 1000	28.1	13.3	13300.0
Condition H 1050	34.2	12.4	12400.0
Condition H 1100	53.0	10.1	10100.0

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Typical mechanical properties

EFFECTS OF -65°F (-54°C) TEST TEMPERATURE ON LONGITUDINAL MECHANICAL PROPERTIES

4.25 IN. DIAMETER BAR

CONDITION	TEST TEMPERATURE		0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 4D	REDUCTION OF AREA
	°F	°C	ksi	MPa	ksi	MPa	%	%
H 950	73	23	242	1669	256	1765	13	62
	-65	-54	258	1779	272	1875	12	53
H 975	73	23	235	1620	247	1703	13	61
	-65	-54	249	1717	261	1800	14	58
H 1000	73	23	219	1510	231	1593	15	63
	-65	-54	233	1606	245	1689	15	63
H 1050	73	23	201	1386	215	1482	17	66
	-65	-54	210	1448	231	1593	18	63

EFFECTS OF -65°F (-54°C) TEST TEMPERATURE ON LONGITUDINAL MECHANICAL PROPERTIES

4.25 IN. DIAMETER BAR

CONDITION	TEST TEMPERATURE		NOTCH TENSILE STRENGTH[1]		NTS/UTS	CHARPY V-NOTCH IMPACT	HARDNESS[2]	FRACTURE TOUGHNESS[3] (K_{IC})
	°F	°C	ksi	MPa		FT-LBS	HRC	ksi√in
H 950	73	23	372	2565	1.5	22	49.5	95
	-65	-54	240	1655	0.9	6	49.5	53
H 975	73	23	372	2565	1.5	27	48.0	109
	-65	-54	305	2103	1.2	8	48.0	74
H 1000	73	23	357	2461	1.5	41	47.5	129
	-65	-54	363	2503	1.5	15	47.5	87
H 1050	73	23	330	2275	1.5	52	45.5	139
	-65	-54	343	2365	1.5	28	45.5	110

[1] *K_t = 10.*
[2] *Hardness measurements made at room temperature on fractured CVN specimens.*
[3] *1-1/4 in.-thick compact tension specimens.*

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EFFECTS OF EXPOSURE AT ELEVATED TEMPERATURES ON ROOM TEMPERATURE MECHANICAL PROPERTIES[1]

THERMAL STABILITY, 10 IN. DIAMETER BAR

CONDITION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONG. IN 4D	REDUCTION OF AREA	NOTCH TENSILE STRENGTH[2]		CHARPY V-NOTCH IMPACT		HARDNESS
	ksi	MPa	ksi	MPa	%	%	ksi	MPa	FT-LBS	J	HRC
H 1025	214	1475	227	1565	15	67	353	2434	36	49	47
H 1025 + 600°F (316°C) 1000 hrs, AC	217	1496	230	1586	15	68	353	2434	32	43	47
H 1025 + 700°F (371°C) 1000 hrs, AC	224	1544	235	1620	15	68	349	2406	23	31	48
H 1025 + 800°F (427°C) 1000 hrs, AC	231	1593	244	1682	14	63	344	2372	13	18	49
H 1025 + 900°F (482°C) 1000 hrs, AC	219	1510	232	1600	16	66	331	2282	25	34	48
H 1050	205	1413	220	1517	17	66	336	2317	43	58	46
H 1050 + 600°F (316°C) 1000 hrs, AC	205	1413	220	1517	17	68	337	2324	39	53	46
H 1050 + 700°F (371°C) 1000 hrs, AC	210	1448	225	1551	17	66	338	2330	28	38	47
H 1050 + 800°F (427°C) 1000 hrs, AC	221	1524	234	1613	15	60	334	2303	18	24	48
H 1050 + 900°F (482°C) 1000 hrs, AC	206	1420	221	1524	17	65	322	2220	30	41	46.5

[1] *All longitudinal properties.*

[2] *Notch tensile strength with K_t = 10.*

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EFFECTS OF EXPOSURE AT ELEVATED TEMPERATURES ON ROOM TEMPERATURE MECHANICAL PROPERTIES[1]

THERMAL STABILITY, 4.50 x 1.50 IN. FORGED BAR

CONDITION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONG. IN 4D	REDUCTION OF AREA	NOTCH TENSILE STRENGTH[2]		CHARPY V-NOTCH IMPACT		HARDNESS
	ksi	MPa	ksi	MPa	%	%	ksi	MPa	FT-LBS	J	HRC
H 950	239	1648	255	1758	14	62	367	2530	20	27	49
H 950 + 600°F (316°C) 1000 hrs, AC	242	1669	259	1786	16	59	354	2441	12	16	49.5
H 950 + 700°F (371°C) 1000 hrs, AC	250	1724	268	1848	14	56	285	1965	11	15	51
H 950 + 800°F (427°C) 1000 hrs, AC	253	1744	272	1875	13	54	271	1868	9	12	51.5
H 950 + 900°F (482°C) 1000 hrs, AC	211	1455	223	1538	19	67	332	2289	34	46	46
H 1000	218	1503	231	1593	16	66	355	2448	38	52	47
H 1000 + 600°F (316°C) 1000 hrs, AC	219	1510	232	1600	18	65	354	2441	30	41	47
H 1000 + 700°F (371°C) 1000 hrs, AC	226	1558	240	1655	16	65	350	2413	25	34	47.5
H 1000 + 800°F (427°C) 1000 hrs, AC	229	1579	245	1689	15	62	347	2392	18	24	48
H 1000 + 900°F (482°C) 1000 hrs, AC	210	1448	222	1531	20	66	327	2255	32	43	46

[1] All longitudinal properties.

[2] Notch tensile strength with $K_t = 10$.

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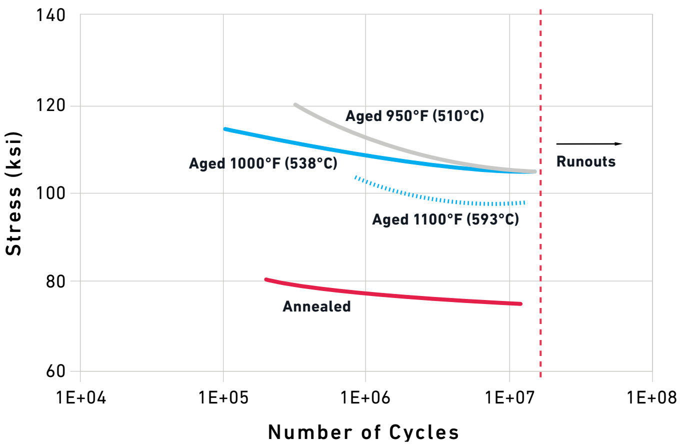
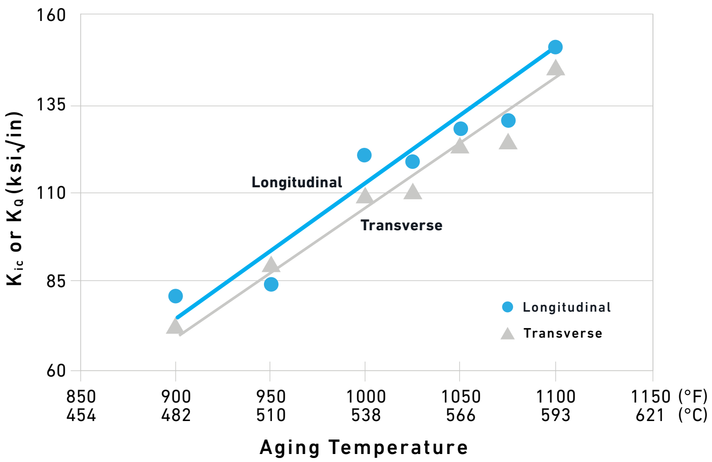
FATIGUE STRENGTH

Effects of aging temperature on the smooth rotating beam fatigue (R.R. Moore) strength of Custom 465 are shown below. Data were developed from longitudinal specimens obtained from 4.5 x 1.5 in. forged bar. Specimens surviving at least 17 million cycles at 10 thousand cycles/minute were defined as "Runouts."



FRACTURE TOUGHNESS

The fracture toughness, or resistance to rapid crack growth, of Custom 465 is influenced by aging temperature and, to a lesser extent, by orientation. The effects of aging temperature (4 hrs, AC) are illustrated below for longitudinal (L-T) and transverse (T-L) compact tension specimens obtained from 4.5 x 1.5 in. forged bar. Because the specimen size was limited by the section size (i.e., 1.5 in. thick), data for aging temperatures of 1050–1100°F (566–593°C) are K_Q values rather than K_{ic}.



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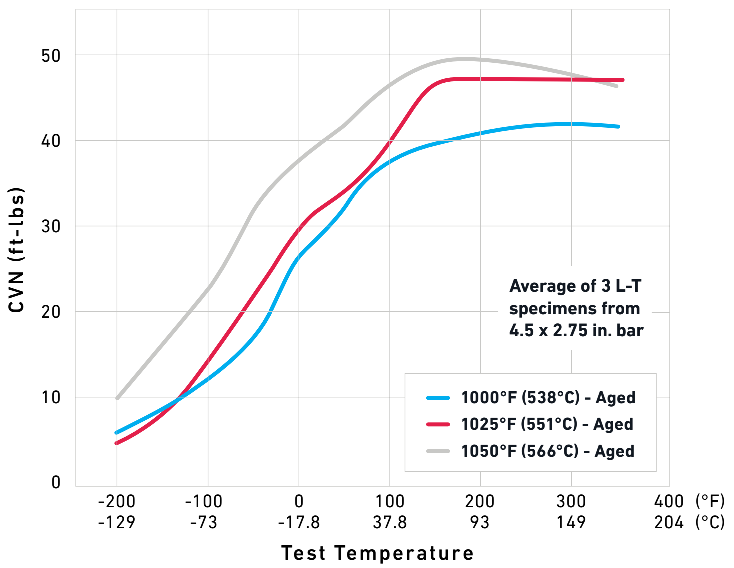
IMPACT PROPERTIES

Effects of aging temperature and test temperatures on the Charpy V-notch impact energy of Custom 465 forged bar are illustrated below.



DOUBLE-RESTRAINED SHEAR STRENGTH AT ROOM TEMPERATURE

CONDITION[1]	ULTIMATE TENSILE STRENGTH		SHEAR STRENGTH	
	ksi	MPa	ksi	MPa
Annealed	146	1007	90	621
Annealed + 950°F (510°C) age	253	1744	154	1062
Annealed + 1000°F (538°C) age	232	1600	141	972
Annealed + 1050°F (566°C) age	219	1510	133	917
Annealed + 1100°F (593°C) age	195	1344	124	855
Annealed + 32% cold drawn	160	1103	96	662
32% Cold drawn + 950°F (510°C) age	280	1931	169	1165
32% Cold drawn + 1000°F (538°C) age	255	1758	159	1096
32% Cold drawn + 1025°F (552°C) age	246	1696	154	1062
71% Cold drawn + 950°F (510°C) age	288	1986	166	1145

[1] *Aged at indicated temperature, 4 hours, AC.*

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SHORT-TERM ELEVATED-TEMPERATURE LONGITUDINAL TENSILE PROPERTIES

2.00 IN. DIAMETER BAR

CONDITION	TEST TEMPERATURE		0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 4D	REDUCTION OF AREA
	°F	°C	ksi	MPa	ksi	MPa	%	%
H 1000	73	23	226	1558	235	1620	14	66
	500	260	191	1317	202	1393	14	67
	600	316	187	1289	199	1372	14	68
	700	371	183	1262	190	1310	15	69
	800	427	172	1186	178	1227	16	70

TYPICAL ROOM TEMPERATURE MECHANICAL PROPERTIES

3 TO 9 IN. ROUND

CONDITION	ORIENTATION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONG. IN 4D	REDUCTION OF AREA
		ksi	MPa	ksi	MPa	%	%
H 950	Long.	240	1655	256	1765	12	57
	Trans.	239	1648	256	1765	11	49
H 1000	Long.	217	1496	231	1593	14	63
	Trans.	218	1503	232	1600	13	57

3 TO 9 IN. ROUND

CONDITION	ORIENTATION	NOTCH TENSILE STRENGTH[1]		NTS/UTS	CHARPY V-NOTCH IMPACT	HARDNESS
		ksi	MPa		FT-LBS	HRC
H 950	Long.	359	2475	1.40	16	49.5
	Trans.	346	2386	1.35	13	49.5
H 1000	Long.	352	2427	1.52	35	47.5
	Trans.	347	2392	1.50	28	47.5

[1] *Notch tensile strength with K_t = 10.*

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STRIP, 0.140 IN.-THICKNESS AND UNDER

CONDITION	ORIENTATION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 2 IN.	HARDNESS
		ksi	MPa	ksi	MPa	%	HRC
Annealed/CT	Long.	105	724	145	1000	7	30
	Trans.	110	758	150	1034	6	—
H 900	Long.	245	1689	260	1793	5	51
	Trans.	250	1724	265	1827	5	—
H 950	Long.	240	1655	250	1724	6	50.5
	Trans.	245	1689	260	1793	5	—
H 1000	Long.	215	1482	225	1551	7	48
	Trans.	220	1517	230	1586	6	—
H 1050	Long.	195	1344	210	1448	8	45.5
	Trans.	200	1379	215	1482	7	—
H 1100	Long.	155	1069	190	1310	10	42
	Trans.	160	1103	195	1344	9	—

WIRE

CONDITION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 4D	REDUCTION OF AREA	HARDNESS
	ksi	MPa	ksi	MPa	%	%	HRC
Annealed/CT	112	772	138	951	20	75	29.5
H 900	247	1703	258	1779	14	51	50
71% Cold drawn	163	1124	174	1200	12	74	38.5
71% Cold drawn + 900°F (482°C) age	293	2020	303	2089	10	57	55

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4.5 x 1.5 IN. AND 4.5 x 2.75 IN. FORGED BARS

CONDITION	ORIENTATION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 4D
		ksi	MPa	ksi	MPa	%
Annealed/CT	Long.	99	683	138	951	20
H 950	Long.	235	1620	254	1751	14
	Trans.	230	1586	250	1724	12
H 1000	Long.	217	1496	231	1593	15
	Trans.	211	1455	227	1565	15
H 1025	Long.	204	1407	218	1503	17
	Trans.	204	1407	218	1503	16
H 1050	Long.	198	1365	215	1482	18
	Trans.	196	1351	213	1469	17
H 1075	Long.	179	1234	203	1400	20
	Trans.	180	1241	202	1393	19
H 1100	Long.	159	1096	190	1310	22
	Trans.	158	1089	190	1310	21
H 1150	Long.	98	676	170	1172	24
	Trans.	104	717	172	1186	22
H 1150M	Long.	77	531	156	1076	25
	Trans.	78	538	159	1096	22

4.5 x 1.5 IN. AND 4.5 x 2.75 IN. FORGED BARS

CONDITION	ORIENTATION	REDUCTION OF AREA	NOTCH TENSILE STRENGTH[1]		NTS/UTS	HARDNESS
		%	ksi	MPa		HRC
Annealed/CT	Long.	80	—	—	—	28
H 950	Long.	63	362	2496	1.43	49
	Trans.	53	355	2448	1.42	—
H 1000	Long.	65	352	2427	1.52	47
	Trans.	61	349	2406	1.54	—
H 1025	Long.	65	343	2365	1.57	46
	Trans.	61	341	2351	1.56	—
H 1050	Long.	67	326	2248	1.52	45
	Trans.	63	324	2234	1.52	—
H 1075	Long.	69	313	2158	1.54	43
	Trans.	67	309	2130	1.53	—
H 1100	Long.	71	280	1931	1.47	40
	Trans.	65	278	1917	1.46	—
H 1150	Long.	72	243	1675	1.43	36
	Trans.	66	241	1662	1.40	—
H 1150M	Long.	72	223	1538	1.43	30
	Trans.	62	221	1524	1.39	—

[1] Notch tensile strength with $K_t = 10$.

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> CUSTOM 465

Heat treatment

Solution treatment	Condition A (solution annealed): Heat to 1800°F ± 15°F (982°C ± 8°C), hold one hour at heat and cool rapidly. Sections up to 12 in. can be quenched in a suitable liquid quenchant. Sections over 12 in. should be cooled rapidly in air. For optimum aging response, solution annealing should be followed by refrigerating to -100°F (-73°C), holding eight hours, then warming to room temperature (CT). Subzero cooling should be performed within 24 hours of solution annealing. Custom 465 normally will be supplied from the mill in the solution annealed/cold treated condition (annealed/CT), ready for the one-step hardening treatment. Billet product will be provided in the hot finished condition.
Age	Condition H 900, H 950, H 1000, H 1050, and H 1100: The high-strength levels of Custom 465 are derived from a single age hardening step consisting of heating to a selected temperature between 900/1150°F (482/621°C) and holding for four to eight hours. A water or oil quench is suggested for optimum toughness. Slower cooling methods are not preferred, and are likely to result in reduced toughness. Aging temperature will depend upon the desired combination of strength, toughness, and stress-corrosion cracking resistance. While the alloy does develop maximum strength after a 900°F age, it is not recommended because toughness is significantly degraded compared to aging at higher temperatures. The best combination of properties is obtained after aging at 950°F (510°C) and above and quenching in a suitable liquid, the severity of which should in part be based on the geometry and complexity of the part being aged. Condition H 1150M: While the alloy typically will be machined in the annealed/CT condition, optimum machinability of Custom 465 can be achieved by overaging to the H 1150M condition. Material is heated to 1400°F ± 15°F (760°C ± 8°C) for two hours, air cooled, then reheated to 1150°F ± 15°F (621°C ± 8°C) for four hours and air cooled. If this practice is used, parts must be reannealed at 1800°F (982°C), cold treated at -100°F (-73°C), and aged at a selected temperature.

AVERAGE SIZE CHANGE (CONTRACTION), SOLUTION ANNEALED/CT TO AGED CONDITION

CONDITION	CONTRACTION, IN/IN (M/M)	
	LONGITUDINAL	TRANSVERSE
H 900	.0008	.0007
H 950	.0011	.0010
H 1000	.0014	.0013
H 1050	.0016	.0016
H 1100	.0023	.0023
H 1150M	.0053	.0053

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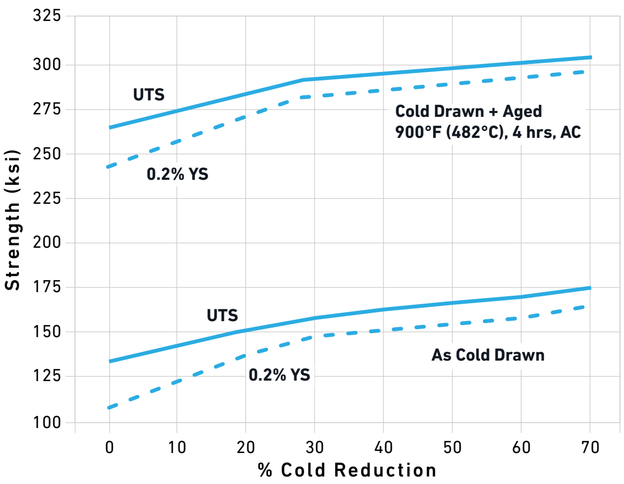
> CUSTOM 465

Workability

Hot working	Custom 465 typically is forged within the temperature range of 1850/2000°F (1010/1093°C), followed by air cooling. Forgings must be solution annealed prior to age hardening.
Cold working	Because of a relatively low annealed yield strength and low work hardening rate, Custom 465 can be readily cold formed by drawing or rolling. Single step aging of cold worked material results in enhanced strengthening response, as illustrated in the following diagram and table. Custom 465 is supplied in the following conditions: 1. Solution annealed, cold treated, cold worked, and ground: This condition is available in diameters up to and including 0.625 in. round. The exact amount of cold work varies by bar diameter but will be a minimum of 60% cold work. 2. Solution annealed, cold treated. In either condition, the material will be manufactured to the maximum hardness associated with industry specifications such as AMS and ASTM. Other conditions are available upon request. Modified cold work ranges may be requested on a custom order basis.
Machinability	Custom 465 can be machined in both the solution-treated and various age-hardened conditions. In Condition A, the alloy gives good tool life and surface finish when machined at speeds 20 to 30% lower than those used for Custom 630 (17Cr-4Ni) or 20 to 30% lower than used for 302 and 304 stainless. The machinability as age-hardened 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 be developed only by solution treating and heat treating at standard hardening temperatures.
Weldability	Custom 465 can be satisfactorily welded by the GTA process using matching filler metal. When the GMA process is employed, Pyromet® X-23 alloy filler metal is suggested to provide high strength and avoid weld-bead cracking associated with this higher-heat-input process. Welds should be fabricated employing the minimum amount of heat-input required to achieve complete penetration. If lower strength can be tolerated, Custom 450® or Custom 630 filler metal may be used. Oxyacetylene welding is not recommended, since carbon pickup in the weld may occur. Preheating is not required to prevent cracking during the welding of this alloy. The material has been welded satisfactorily in the overaged or solution annealed/cold treated condition. Welding in the overaged (H 1150M) condition requires subsequent solution annealing with cold treating and aging. Direct aging of weldments on annealed base metal is possible, but hardness throughout the weld is not uniform. The optimum combination of properties is obtained by solution annealing and cold treating the weldment and then aging.

> CUSTOM 465

EFFECTS OF COLD WORK AND AGING ON YIELD AND ULTIMATE TENSILE STRENGTHS IN WIRE



EFFECTS OF COLD WORK PRIOR TO AGING ON TENSILE AND CHARPY V-NOTCH PROPERTIES

BAR

AGE	C.R.	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONG.	REDUCTION OF AREA	CHARPY V-NOTCH IMPACT
	%	ksi	MPa	ksi	MPa	%	%	FT-LBS
H 950	0	258	1779	267	1841	11.5	63.5	17.5
	60	276	1902	282	1944	11.5	61.5	31
	70	286	1972	293	2020	11	58.5	57
H 1000	0	228	1572	238	1641	13.5	67	44.5
	60	249	1717	257	1772	13	64	52
	70	256	1765	265	1827	12.5	61	55
H 1025	0	220	1517	233	1606	15	68.5	50
	60	236	1627	247	1703	14.5	64.5	54
	70	243	1675	256	1765	14	61.5	53
H 1050	0	204	1407	220	1517	15.5	68.5	52.5
	60	221	1524	236	1627	15	65	53.5
	70	224	1544	241	1661	14.5	62.5	54.5

All longitudinal properties
0% Cold work data taken from bars 1.00–1.25 in. round.
70% Cold work data taken from bar product 0.250–0.637 in. round.
60% Cold work data taken from bar product 0.3125–0.637 in. round.

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> CUSTOM 465

Typical machining speeds and feeds

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

CONDITION	DEPTH OF CUT, IN	MICRO-MELT® POWDER HIGH SPEED TOOLS			CARBIDE TOOLS			
		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		325	425	.005	C-7
Aged	.150	48	.010	M-48, T-15	190	250	.010	C-6
	.025	54	.005		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			MICRO-MELT® POWDER HS 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	.003	.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	MICRO-MELT® POWDER HS 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

DIE THREADING

CONDITION	SPEED, FPM				TOOL MATERIAL
	7 OR LESS	8 TO 15	16 TO 24	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-42, T-15

> CUSTOM 465

MILLING — END PERIPHERAL

CONDITION	DEPTH OF CUT, IN	MICRO-MELT® POWDER HIGH-SPEED TOOLS						CARBIDE TOOLS					
		SPEED, FPM	FEED, IN PER TOOTH — CUTTER DIAMETER, IN				TOOL MATERIAL	SPEED, FPM	FEED, IN PER TOOTH — CUTTER DIAMETER, IN				TOOL MATERIAL
			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

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 — MICRO-MELT® POWDER HIGH-SPEED TOOLS

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

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.

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For additional information, please contact your nearest sales office:

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