JACQUET

ALLOY K500 DATA SHEET

UNS N05500

GENERAL PROPERTIES

//// **Alloy K500** (UNS designation N04400) is an age-hardenable nickel-copper alloy which combines the high corrosion resistance of **Alloy 400** with greater strength and hardness. The increased hardness is achieved by the additions of aluminum and titanium to its chemistry and by subsequent heat treating to achieve final desired properties.

//// **Alloy K500** offers outstanding corrosion resistance to many naturally occurring and chemical environments. It's high nickel content gives it excellent resistance to chloride-ion stress corrosion cracking. After heat treating, **Alloy K500** offers mechanical properties in the range of 2 to 3 times greater than **Alloy 400**. It retains its high tensile properties up to around 1 200 °F (650 °C) and remains non-magnetic down to -210 °F (-135 °C).

APPLICATIONS

////MARINE INDUSTRY

//// Fasteners ;

//// Springs ;

//// Chains ;

//// Valve Components.

////CHEMICAL INDUSTRY

//// Pumps ;

//// Shafts ;

//// Impellers ;

//// Valve Components.

////PULP AND PAPER INDUSTRY

//// Doctors Blades ;

//// Scrapers.

////OIL AND GAS PRODUCTION

//// Drill Collars ;

//// Pump Shafts ;

//// Impellers ;

//// Non=magnetic Housings ;

//// Safety Lifts ;

//// Valves ;

//// Sensors.

STANDARDS

Product form	Specifications						
	ASTM	ASME	AMS	Military	BS	DIN	Luftfahrt-WL
Rod and Bar	**B**865	**Code Case** 1192	4676	**QQ-N-**286	3076**NA**18	17752	**Blatt**1
Wire	–	–	–	**QQ-N-**286	3075**NA**18	17753	**Blatt**2
Forgings	–	–	–	**QQ-N-**286	–	17754	–

ALLOY K500

CHEMICAL COMPOSITION (%)

C	Mn	S	Si	Cu	Ni + Co	Fe	Al	Ti
0.25 max	1.50 max	0.01 max	0.50 max	27.0→33.0	15.5 max	8.00 max	0.10	0.35→0.85

MECHANICAL PROPERTIES

Product form and condition	Ultimate Tensile Strength		Yield Strength 0.2 % Offset		Elongation	Hardness	
	ksi	MPa	ksi	MPa	% in 2"	Brinell	Rockwell
Rod & Bar, HF	90→155	621→1069	40→110	276→758	45→20	140→315	75B→35C
Rod & Bar, HF/Aged	140→190	965→1310	100→150	690→1034	30→20	265→346	27→38C
Rod & Bar, HF/Annealed	90→110	621→758	40→60	276→414	45→25	140→185	75→90B
Rod & Bar, HF/Ann/Aged	130→165	896→1138	85→120	586→827	35→20	250→315	24→35C
Rod & Bar, CD/CD	100→140	690→965	70→125	483→862	35→13	175→260	88B→26C
Rod & Bar, CD/Aged	135→185	931→1276	95→160	655→1103	30→15	255→370	25→41C
Rod & Bar, CD/Annealed	90→110	621→758	40→60	276→414	50→25	140→185	75→90B
Rod & Bar, CD/Ann/Aged	130→190	896→1310	85→120	586→827	30→20	250→315	24→35C
Wire, CD/Annealed	80→110	552→758	35→65	241→448	40→20	–	–
Wire, CD/Ann/Aged	120→150	827→1034	90→110	621→758	30→15	–	–
Wire, CD/Sprg temp	145→190	1000→1310	130→180	896→1241	5→2	–	–
Wire, CD/Sprg temp/Aged	160→200	1103→1379	140→190	965→1310	8→3	–	–

////EFFECT OF AGE HARDENING

Round Bar Condition	Thermal Treatment	Tensile	Yield Strength 0.2 % Offset	Elongation	Hardness	
		ksi	ksi	% in 2"	Rockwell	Brinell
Hot Rolled	Room Temperature	97.5	40.5	44	82B	169
Hot Rolled	16 hrs at 1080 °F	147	92	28	–	270
Hot Rolled	16 hrs at 1080 °F + 1 month at 800 °F	161.5	109	26	–	310
Hot Rolled	16 hrs at 1080 °F + 1 month at 800 °F	165	112	25	–	307
Hot Rolled	16 hrs at 1080 °F + 1 month at 800 °F	162.3	109.2	25.5	–	310
Hot Rolled	2 hrs at 1100 °F	132	82	36	17	–
Hot Rolled	4 hrs at 1100 °F	136	86	34	20	–
Hot Rolled	8 hrs at 1100 °F	142	90	33	22	–

SHORT TIME ELEVATED TEMPERATURE MECHANICAL PROPERTIES

In the hot rolled and aged condition.

–		Ultimate Tensile Strength		Yield Strength 0.2% Offset	
°F	°C	ksi	MPa	ksi	MPa
70	21	–	1100	–	690
200	93	151	–	97	–
212	100	–	1040	–	670
392	200	–	1020	–	640
400	204	148	–	93	–
572	300	–	980	–	620
600	316	139	–	90	–
752	400	–	890	–	600
800	427	125	–	87	–
932	500	–	750	–	570
1000	538	102	–	80	–
1112	600	–	620	–	490
1200	649	80	–	64	–

PHYSICAL PROPERTIES

Density

0.305 **lb/in^3**

8.44 **g/cm^3**

Magnetic Permeability

75 **°F,** 200 **oersted** 1.002

Specific Heat

0.100 **Btu/lb-°F**

419 **J/kg-°K**

Curie Temperature

-150 **°F**

-65 **°C**

Melting Range

°F = 2400→2460

°C = 1315→1350

THERMAL PROPERTIES

Temperature		Mean Linear Expansion		Thermal Conductivity		Specific Heat		Electric Resistivity	
°F	°C	in/in/°F x 10^{-6}	µm/m.°C	Btu-in/h/ft²/°F	J/kg.°C	Btu/lb/°F	J/kg.°C	Ω-circ mil/ft	µΩ.m
−320	−200	6.2	11.2	–	–	–	–	330.8[d]	0.550
−250	−157	6.5	11.7	86	12.3	0.071	297.3	–	–
−200	−130	6.8	12.2	92	13.1	0.077	322.4	–	–
−100	−70	7.2	13.0	103	14.7	0.087	364.3	–	–
70	21	–	–	121	17.2	0.100	418.7	370	0.615
200	100	7.6	13.7	136	19.4	0.107	448.0	372	0.618
400	200	8.1	14.6	156	22.2	0.114	477.3	378	0.628
600	300	8.3	14.9	178	25.4	0.117	489.9	385	0.640
800	400	8.5	15.3	198	28.2	0.120	502.4	390	0.648
1000	500	8.7	15.7	220	31.4	0.125	523.4	393	0.653
1200	600	9.1	16.4	240	34.2	0.132	552.7	396	0.658
1400	700	9.3	16.7	262	37.3	0.141	590.3	400	0.665
1600	800	9.6	17.3	282	40.2	0.157	657.3	408	0.678
1800	900	–	–	302[e]	43.1	0.186[e]	778.7	418	0.695

[a] Between 70 °F (21 °C) and temperature shown. Age-hardened material.

[b] Material was in the annealed condition prior to test

[c] Electrical resistivity is markedly influenced by thermal history because of the age-hardening characteristics of the alloy. The data shown reperesent values measured on a decreasing temperature on material in an equivalent to annealed condition with a small amount of age hardening.

[d] Resistivity of sample from this test tested at room temperature: 355.5 Ω/circ mil/ft.

[e] Extrapolated

ALLOY K500

//// One of the useful characteristics of **Alloy K500** is that it is virtually nonmagnetic, even at very low temperatures. The alloy can, however, form a magnetic layer on the surface of the material during processing. The aluminum and copper may be selectively oxidized during heating, leaving a magnetic nickel-rich film on the outside of the piece. This effect is particularly noticeable on thin wire or on strip where there is a high ratio of surface to weight. The magnetic film can be removed by pickling or bright dipping in acid and the nonmagnetic properties of the material will be restored. The combination of low magnetic permeability, high strength, and good corrosion resistance has been used to advantage in a number of applications, notably oil-well surveying equipment and electronic components.

////MAGNETIC CHARACTERISTICS

Condition	Tensile	Permeability	Curie Temperature, °F, for permeability of			
	psi	70 °F, 200 oersted	1.01	1.02	1.05	1.10
Annealed & Quenched	92 500	1.0011	−210	−210	–	–
Annealed & Age-hardened	151 000	1.0018	−153	−178	−202	−210
Cold Drawn 20 %	137 000	1.0011	−210	–	–	–
Cold Drawn 20 % & Age-hardened	186 050	1.0019	−130	−150	−182	−210
Cold Drawn 50 %	151 250	1.0010	−210	–	–	–
Cold Drawn 50 % & Age-hardened	198 000	1.0019	−130	−150	−182	−210

MACHINING //

//// Heavy machining of **Alloy K500** is best accomplished when the material is in the annealed condition or in the hot-worked and quenched condition. Age-hardened material, however, can be finished-machined to close tolerances and fine finished. The recommended practice therefore, is to machine slightly oversize, age-harden, then finish to size. During aging, a slight permanent contraction (about 0.0002 in/in) takes place, but little warpage occurs because of the low temperatures and slow cooling rates involved.

////TURNING AND BORING DATA

Condition	Operation	Tooling													
		High Speed (T15, M33, etc.)				Carbide					Other				
		Speed		Feed		Speed		Feed		Grade	Speed		Feed		Grade
		sfm	m/min	ipr	mm/rev	sfm	m/min	ipr	mm/rev		sfm	m/min	ipr	mm/rev	
Annealed	Finishing	35	10	0.008	0.20	225	69	0.008	0.20	C-6	700	213	0.006	0.15	Ceramic
Annealed	Finishing	–	–	–	–	130	40	–	–	C-2/C-3	–	–	–	–	–
Annealed	Roughing	25	8	0.030	0.76	175	53	0.020	0.51	C-6	800	244	0.008	0.20	Ceramic
Cold Drawn	Finishing	60	18	0.005	0.13	425	130	0.004	0.10	C-2	125	38	0.008	0.20	Cast Alloy
Cold Drawn	Finishing	–	–	–	–	–	–	–	–	–	600	183	0.006	0.15	Ceramic
Cold Drawn	Roughing	50	15	0.010	0.25	375	114	0.008	0.20	C-2	500	152	0.014	0.36	Ceramic
Ann & Aged	Finishing	20	6	0.005	0.13	130	40	0.005	0.13	C-2	600→1600	183→488	0.006	0.15	Ceramic
Ann & Aged	Roughing	15	5	0.010	0.25	75	23	0.008	0.20	C-2	250→1000	78→305	0.010	0.25	Ceramic
Cold Drawn & Aged	Finishing	18	5	0.004	0.10	110	34	0.005	0.13	C-2	400→1300	122→396	0.004	0.10	Ceramic
Cold Drawn & Aged	Roughing	12	4	0.008	0.20	70	21	0.007	0.18	C-2	300→700	91→213	0.008	0.20	Ceramic

////COMPARISON OF TOOL MATERIALS

Tool Material	Tool Characteristics	Machining Condition	Alleaned 180–250 BHN		Alleaned 250–375 BHN	
			Roughing	Finishing	Roughing	Finishing
HSS	Steel with carbides. Good strength and toughness. Poor heat resistance for small tools, interrupted cuts and low rigidity applications	DOC	0.22 (6.35 mm)	0.06 (1.52 mm)	0.25 (6.35 mm)	0.06 (1.52 mm)
		ipr	0.010	0.005	0.008	0.004
		mm/rev	0.25	0.13	0.20	0.10
		sfm	15	20	12	18
		m/in	5	6	4	5
Carbide	Cobalt binder containing W, Ti and Ta carbides Combine good toughness and good high temperature resistance For general purpose use on machines of limited power.	DOC	0.25 (6.35 mm)	0.06 (1.52 mm)	0.02 (0.51 mm)	0.04 (1.02 mm)
		ipr	0.015	0.007	0.008	0.005
		mm/rev	0.36	0.18	0.20	0.13
		sfm	100	130	70	105
		m/in	30	40	21	32
Coated Carbide	Combine tough carbide base and wear resistant coatings. Improved tool life compared to basic carbide grades. Improved productivity compared to uncoated carbide	DOC	0.25 (6.35 mm)	0.06 (1.53 mm)	0.02 (0.51 mm)	0.04 (1.02 mm)
		ipr	0.010	0.005	0.008	0.005
		mm/rev	0.25	0.18	0.20	0.13
		sfm	120	150	80	115
		m/in	244	46	183	35
Silicon Aluminum nitride (Slalon)	Hot pressed monolithic silicon aluminium oxynitride. Excellent toughness and thermal resistance. Excellent overall performance	DOC	0.25 (6.35 mm)	0.06 (1.53 mm)	0.10 (2.54 mm)	0.02 (0.51 mm)
		ipr	0.010	0.007	0.008	0.005
		mm/rev	0.25	0.18	0.20	0.13
		sfm	800	1000	600	800
		m/in	244	395	183	32
Whisker rein forced alumina (Re-alumina)	Aluminium oxide with silicon whiskers. Best combination of edge strength, shock and thermal resistance. Excellent overall performance in roughing and finishing.	DOC	0.25 (6.35 mm)	0.06 (1.53 mm)	0.02 (0.51 mm)	0.02 (0.51 mm)
		ipr	0.008	0.006	0.007	0.004
		mm/rev	0.20	0.15	0.18	0.10
		sfm	1000	1600	700	1300
		m/in	305	488	213	396
Cermet	Composite titanium barbide and titanium nitrate. Excellent abrasion and crater resistance, poor toughness.	DOC	0.25 (6.35 mm)	0.06 (1.52 mm)	0.02 (0.51 mm)	0.02 (0.51 mm)
		ipr	0.006	0.005	–	0.003
		mm/rev	0.15	0.13	–	0.08
		sfm	250	600	–	400
		m/in	76	183	–	122
Composite Alumina	Cold or hot pressed aluminia and titanium carbide. Hot pressed grades have high edge strength. Primarily for machining materials over 35 Rc in hardness.	DOC	0.25 (6.35 mm)	0.06 (1.53 mm)	0.02 (0.51 mm)	0.02 (0.51 mm)
		ipr	0.014	0.005	0.010	0.004
		mm/rev	0.36	0.13	0.25	0.10
		sfm	700	1000	500	700
		m/in	213	395	152	213
Cubic Boron (CBN)	Composite of cubic boron nitride in a metal binder. Combines highest hardness with excellent toughness. Primarily for machining materials over 45 Rc in hardness.	DOC	0.25 (6.35 mm)	0.06 (1.52 mm)	0.02 (0.51 mm)	0.02 (0.51 mm)
		ipr	0.014	0.006	0.008	0.004
		mm/rev	0.36	0.15	0.20	0.10
		sfm	500	800	300	500
		m/in	152	244	91	152

////DRILLING DATA

Condition	Drill Diameter		Surface speed		Feed*	
	in	mm	sfm	m/min	lpr	mm/rev
Not Aged	0.1250→ 0.1875	3.2→4.8	25→35	8→11	0.002→0.004	0.05→0.10
Aged Hardened	0.500→0.6875	13→17	8→10	2→3	0.006→0.010	0.15→0.25

use smaller value for smaller drills in the range

////TAPPING AND THREADING

Condition	HSS Tapping surface speed		Thread Engagement	HSS single point to die Threading Surface Speed	
	lpr	mm/rev	%	sfm	m/min
Not Aged	10→15	3→5	55	12→18	3.7→5.5
Aged Hardened	5→10	1.5→3	50	3.0→3.5	0.9→1.1

////MILLING DATA

Condition	Tool Material	Face and side							
		Roughing				Finishing			
		Feed		Speed		Feed		Speed	
		in/tooth	mm/tooth	sfm	m/min	in/tooth	mm/tooth	sfm	m/min
Annealed or Cold Drawn	**M**-2, 42, **T**-10, **C**-6	0.003→0.006	0.08→0.15	20→35	6→11	0.004→0.006	0.01→0.15	65→75	20→23
Hot Fin or Cold Drawn & Aged	**M**-2, 10, **T**-15, **C**-2	0.003→0.005	0.08→0.13	5→20	2→6	0.008→0.012	0.20→0.30	65→70	120→21
		End and Slot							
Annealed or Cold Drawn	**M**-2, 42, **T**-10, **C**-6	0.001→0.003	0.03→0.08	15→25	5→8	0.001→0.004	0.03→0.10	55→95	17→29
Hot Fin or Cold Drawn & Aged	**M**-2, 10, **T**-15, **C**-2	0.001→0.003	0.03→0.08	5→15	2→5	0.001→0.004	0.03→0.10	165→110	20→34

////BAND SAWING DATA

Condition	Work thickness		Teeth		Surface Speed	
	in	mm	per in.	per mm	sfm	m/min
Not Aged	0.250	6.4	12.0	0.5	75	23
	1	25	10	0.4	50	15
	3	76	8	0.3	50	15
Aged Hardened	0.250	6.4	12.0	0.5	40	12
	1	25	10	0.4	30	9
	3	76	8	0.3	30	9

////LUBRICANTS AND COOLANTS

////In cutting **Alloy K500**, the choice of a cutting fluid is first based on whether cooling or lubrication is the primary consideration. Soluble water-based fluids are used in high metal removal rate turning operations, where heat removal is essential. These fluids are also used in turning with ceramics, but some ceramics cannot withstand thermal shock and require cutting without a cutting fluid. Oils are not recommended for ceramic tooling because of the danger of ignition. In low speed cutting with HSS tools, a sulfur-chlorinated oil that has a viscosity adjusted to the operation is preferred. Normally, a high viscosity provides best tool life, but a lighter fluid will aid in providing chip flushing in small deep holes. When using oil, the high temperatures of cutting may produce a brown sulphur stain. This stain is easily removed with various sodium cyanide or chromic-sulfuric acid cleaning solutions. The stain should be removed before any subsequent thermal treatment including welding, or before use in high temperature applications because the sulfur could cause intergranular attack of the metal surface.

////WORK HARDENING

////The avoidance of work hardening is of fundamental importance to the successful machining of **Alloy K500**. Work hardening occurs when the metal ahead of the cutting tool, especially one that is cutting poorly, is plastically deformed. This hardened layer is very difficult to penetrate in subsequent passes or following operations.

////Techniques that minimize work hardening include the use of sharp cutting edges, positive rake angles, adequate clearance angles, avoidance of dwelling, and machines and setups having sufficient power to keep vibration to a minimum. Feed rate and cutting depth should be set so that in following passes, cutting is done below the previously work hardened layer. For example, in turning, a depth of cut at least 0.015 inch (0.38 mm) is recommended if a following operation is planned, and the feed rate should be .005 inches (0.13 mm) or larger. Vibration can be minimized by using the largest possible tools and holders, and by limiting overhang. Power requirements should be determined whenever possible but a rule of thumb is to operate at only up to about 50 % of a machine's capacity. If, when machining **Alloy K500**, one finds that the material "cannot be cut", the problem usually can be solved by addressing one or more of the above factors related to work hardening.

CORROSION RESISTANCE //

////The corrosion resistance of **Alloy K500** is essentially the same as that of **Alloy 400** with the exception that when the aged condition, **Alloy K500** is vulnerable to stress-corrosion cracking in some environments. **Alloy K500**'s excellent resistance to hydrogen sulfide makes it very effective in sour-gas environments making it an attractive choice in the oil and gas industry. The low corrosion rate of **Alloy K500** in sea water combined with its high strength make it a very good choice for marine service although some pitting may occur in stagnant water, but the rate of pitting slows after the initial attack.

FABRICATING AND HEAT TREATMENT //

////**Alloy K500** can be readily fabricated using standard commercial practices.

////HOT WORKING

////Hot working should be performed in the range of 1 650–2 100 °F (900–1 150 °C). The material should be water quenched after hot working from a temperature no lower than 1 470 °F (800 °C).

////COLD WORKING

////Cold working can be carried out on material in the annealed condition using standard practices although it may require higher power. **Alloy K500** has a work hardening rate similar to that of austenitic stainless steels. With high instances of cold deformation, intermediate anneals may be required.

////HEAT TREATMENT

////Annealing can be carried out at temperatures in the range of 1 560–1 830 °F (850–1 000 °C) on hot finished material and 1 900 °F (1 038 °C) if the material was cold worked.

////WORK HARDENING

////Age hardening of annealed material can be done at 1 080–1 130 °F (580–610 °C) and holding there for 16 hours followed by a furnace cooling rate of 20 °F (12 °C) per hour until the material reaches 900 °F (480 °C) at which time cooling can be continued in the furnace, by air cooling or by quenching.

WELDING //

////**Alloy K500** in the annealed condition may be joined to itself and many other metals by common welding methods. These include GTAW (TIG), plasma arc, GMAW (MIG) and SMAW (MMA). Pulsed arc welding is the preferred technique.

////When welding, the material should be in the annealed condition and be free of scale, grease, paint and markings. After welding and before aging, assemblies should be stress-relieved. Welding in the age-hardened condition is difficult and not recommended.