

# WROUGHT

## WROUGHT WEAR-RESISTANT ALLOYS



# Wrought Wear-Resistant Alloys

## Plate, Sheet, and Bar

Kennametal Stellite is a global provider of solutions to wear, heat, and corrosion problems and is a world-class manufacturer of Cobalt bricked alloy-based materials and components.

### Industries Served

Wrought Stellite 6B materials and components, and Stellite 6K knife and scraper components are found in many industries, including:

- **Aerospace**
- **Oil & Gas**
- **Power Generation**
- **Food**
- **Pulp and Paper**
- **Glass**
- **Other Processing Industries**



# Stellite™ 6B and 6K

Stellite™ alloys are available in many different grades (chemical compositions) and several different processes or methods of manufacture. These different processes include casting, powder metal, hardfaced deposit, and wrought. For wrought grades Stellite™ 6B and Stellite™ 6K, the wrought or hot forging method of production leads to improvements of the resulting material in regards to:

- **Mechanical Properties**
- **Toughness**
- **Wear Resistance**
- **Corrosion Resistance**

## Stellite™ 6B

When it comes to tough, wear-resistant materials with “guaranteed” mechanical properties, Stellite™ 6B is in a class by itself. Unlike many other materials that sacrifice toughness for wear resistance, Stellite™ 6B offers both. The key is the extensive hot working processing of the material which transforms a brittle, wear-resistant ingot into tough, wear-resistant Stellite™ 6B. With its excellent wear characteristics, hot hardness, good corrosion resistance, and superior mechanical properties, Stellite™ 6B has been the material-of-choice for the most demanding wear applications.

Whether your application involves high-impact pulp agitators, critical directional drilling tools, or aerospace components, Stellite™ 6B can offer superior wear resistance and the mechanical properties needed to withstand the toughest of applications. Stellite™ 6B meets the requirements of Aerospace Material Specification AMS 5894. All Stellite™ 6B products are accompanied by full material certifications and are DFARS compliant. When it comes to your equipment, don't settle for anything less, use genuine Stellite™ 6B.

Stellite™ 6B is stocked in standard mill forms of flat stock ranging from 0.031" to 1.0" thick and round bar ranging from 0.312" through 6.0" diameter. Special sizing is available on request. Ask about our finish machined Stellite™ 6B components capability.

## Stellite™ 6K

Stellite™ 6K has similar properties to Stellite™ 6B, but is slightly harder and less ductile. Stellite™ 6K is excellent for cutting or scraping applications such as knives or scraper blades. Stellite™ 6K is a custom-rolled material and can be produced to a gauge and sheet size uniquely suited to your application.

Stellite™ 6K is available in flat stock ranging from 0.045" to 0.375" thick. Ask about our finish machined Stellite™ 6K components capability.

# Stellite™ 6B and 6K

## Resist Seizing and Galling

Stellite™ 6B is resistant to the effects of seizing or galling. In many cases, its low coefficient of friction allows sliding contact with other metals without damage by metal pick-up. Stellite™ 6B has been used in equipment where no lubricants were used because of the nature of the product being handled. Sleeves made of Stellite™ 6B move smoothly, with a minimum of resistance, even when operating in contact with other metal parts. They have been useful in inaccessible areas where efficient lubrication is impossible. Sleeves and bushings have resisted seizing even when lubricants were diluted by gasoline, cleaning fluids, and other liquids that wash out an oil film. They have operated at peak efficiency even when lubricants decomposed under heat or were destroyed by abrasive particles.

## Resist Erosive Wear

Parts made of Stellite™ 6B have a long service life, even under constant erosive conditions. This material has outstanding resistance to cavitation-erosion. The wrought structure results in improved abrasion wear resistance comparable to much harder cast materials. Stellite™ 6B used for steam turbine erosion shields has protected the blades of turbines for over 30 years of continuous service.

## Excellent Hot Hardness

Stellite™ 6B and retains high hardness, even at red heat. Once cooled back to room temperature, it recovers its full original hardness.

## Good Impact and Thermal Shock Resistance

Stellite™ 6B combines wear and corrosion resistance with good impact strength and resistance to thermal shock. The toughness of the wrought alloy depicted by its Charpy impact energy goes up almost four fold compared to the cast version.

## Resist Heat and Oxidation

High temperatures have little effect on the hardness, toughness, and dimensional stability of these alloys. They are highly resistant to atmospheric oxidation at ordinary temperatures, and have good resistance to oxidation at elevated temperatures.

## Corrosion Resistance

In addition to wear-resistance, Stellite™ 6B has good resistance to a variety of corrosive media. This combination of properties makes Stellite™ 6B particularly useful in such applications as food handling machinery, chemical equipment, and others where both wear and corrosion resistance are necessary.

## Heat Treatment

Wrought forms of Stellite™ 6B and Stellite™ 6K are supplied in the solution heat-treated condition unless otherwise specified. The standard heat treatment is at 2250°F (1232°C) followed by air cooling.

## Available Forms

Stellite™ 6B and Stellite™ 6K are available in sheets, plates, and fabricated shapes. Stellite™ 6B is also available as round bar stock. Kennametal Stellite has the capability to provide components made of these materials to your exact specifications. For more information, contact us about our in-house machine shop capabilities.

### Available Forms

PRODUCT	STELLITE™ 6B	STELLITE™ 6K
Round Bar	0.312 to 6.0 inch diameter	Not available in Bar Stock
Flatstock	Thickness = 0.031 – 1.0 inches Sheet Size = up to 36" x 96"	Thickness = 0.045 – 0.375 inches Sheet Size = custom rolled sizes
Fully Machined Components	•	•

## Certified Mechanical Properties

Covers Stellite™ 6B in the form of sheet and plate up to 1" thick and round bar up to 3.5" diameter.

### Minimum Properties of Wrought Stellite™ 6B

PROPERTY	VALUE
Tensile Strength	130 ksi (896 MPa) MIN
Yield Strength at 0.2% offset	70 ksi (483 MPa) MIN
Elongation in 4D	5% MIN
Reduction in Area	7% MIN
Hardness	33–43 HRC

## Properties Data

The properties listed in this booklet are typical or average values based on laboratory tests conducted by the manufacturer. They are indicative only of the results obtained in such tests and should not be considered as guaranteed maximums or minimums. Materials must be tested under actual service conditions to determine their suitability for a particular purpose. All data represent the average of four or less tests unless otherwise noted. The secondary units (metric) used in this booklet are those of the SI system.

### Chemical Composition, Percent

PRODUCT	Co	Ni	Si	Fe	Mn	Cr	Mo	W	C
Stellite™ 6B	Bal.	3.00*	2.00*	3.00*	2.00*	28.00 – 32.00	1.50*	3.50 – 5.50	0.90 – 1.40
Stellite™ 6K	Bal.	3.00*	2.00*	3.00*	2.00*	28.00 – 32.00	1.50*	3.50 – 5.50	1.40 – 1.90

\* Maximum

### Average Physical Properties

PHYSICAL PROPERTIES	TEMP., °C	METRIC UNITS STELLITE™		TEMP., °F	BRITISH UNITS STELLITE™	
		6B	6K		6B	6K
Hardness Limits Typical	22	33 – 43 RC 36 – 40 RC	40 – 42* RC 43 – 47 RC	72	33 – 43 RC 36 – 40 RC	40 – 42* 43 – 47
Density	22	8387	Kg/m <sup>3</sup> 8387	72	0.303	lb/in <sup>3</sup> 0.303
Melting Range	—	1265 – 1354°C		—	2310 – 2470°F	
Electrical Resistivity	22	0.91	microhm-m —	72	36	microhm-m —
Thermal Conductivity	22	0.147	watt-cm/sq. cm.°C —	72	103	Btu-in/sq.ft.hr.-°F — (546 ohms per cir. mil. ft.)
Mean Coefficient of Thermal Expansion	0 – 100	13.9	x 10 <sup>-6</sup> /m/m.K 13.8	32 – 212	7.7	microinches/in.-°F 7.7
	0 – 200	14.1	13.8	32 – 392	7.8	7.7
	0 – 300	14.5	13.8	32 – 572	8.0	7.7
	0 – 400	14.7	13.8	32 – 752	8.2	7.7
	0 – 500	15.0	13.8	32 – 932	8.3	7.7
	0 – 600	15.3	14.0	32 – 1112	8.5	7.8
	0 – 700	15.8	14.2	32 – 1292	8.8	7.9
	0 – 800	16.3	14.5	32 – 1472	9.1	8.1
	0 – 900	16.9	14.9	32 – 1652	9.4	8.3
	0 – 1000	17.4	15.5	32 – 1832	9.7	8.6
Electrical Conductivity Compared to Copper, percent	22	1.90	—	72	1.90	—
Specific Heat (calculated)	Room	J/kg•K 423	Room —	72	0.101	Btu/lb.-°F —
Magnetic Permeability at 200 Oersteds (15,900 A/m)	22	<1.2	<1.2	72	<1.2	<1.2
Reflecting Power, percent	—	57 – 70	—	—	57 – 70	—

\* Minimum depending on gauge

■ Average Hot Hardness

PRODUCT	TEST TEMP.		BRINELL HARDNESS AT TEMPERATURE, MUTUAL INDENTATION METHOD	
	°F	°C		
Stellite™ 6B	1000	538	226	
	1200	649	203	
	1400	760	167	
	1600	871	102	

■ Average Compressive Strength

PRODUCT	FORM	TEST TEMP.	AVERAGE COMPRESSIVE STRENGTH	
			Ksi	MPa
Stellite™ 6B	1/2-in. (12.7 mm), Plate <sup>1</sup>	Room	347	2392
Stellite™ 6K	Sheet <sup>1</sup>	Room	325	2241

■ Average Modulus of Rupture

PRODUCT	FORM	TEST TEMP.	AVERAGE MODULUS OF RUPTURE	
			Ksi	MPa
Stellite™ 6B	Sheet <sup>1</sup>	Room	338	2360

■ Average Modulus of Elasticity

PRODUCT	FORM	TEST TEMP.	AVERAGE MODULUS OF ELASTICITY	
			psi x 10 <sup>6</sup>	MPa
Stellite™ 6B	Sheet <sup>1</sup>	Room	30.4	210,000
Stellite™ 6B	5/8-in. (15.9 mm), Bar	Room	31.1	214,000

■ Average Izod Impact Strength (un-notched)

PRODUCT	FORM	TEST TEMP.	AVERAGE IZOD IMPACT STRENGTH (UN-NOTCHED)	
			ft. lbs.	J
Stellite™ 6B	1/2-in. (12.7 mm), Plate <sup>1</sup>	Room	62	84

■ Average Charpy Impact Strength

PRODUCT	TEST TEMP.		TYPE OF TEST	AVERAGE CHARPY IMPACT STRENGTH, ft. lbs. (J)			
	°F	°C		Longitudinal		Transverse	
Stellite™ 6B 1/2-in. (12.7 mm), Plate <sup>1</sup>	Room		Un-notched	72	(98)	65	(88)
			notched	6	(8)	—	—
	1000	538	Un-notched	81	(110)	—	—
			notched	15	(20)	—	—
		1250	677	Un-notched	116	(157)	—
				notched	15	(20)	—
		1500	816	Un-notched	126	(171)	—
				notched	15	(20)	—

\* 1 Solution heat-treated at 2250 deg. F (1232 deg. C), air cooled

■ **Average Room Temperature Data – Stellite™ 6B**

FORM	CONDITION	ULTIMATE TENSILE STRENGTH		YIELD STRENGTH AT 0.2% OFFSET		ELONGATION IN 2 in. 50.8 mm, %	HARDNESS ROCKWELL C
		Ksi	MPa	Ksi	MPa		
Sheet, 0.040 in. (1.0 mm), thick	Solution Heat-treated <sup>1</sup>	145.0	1000*	90.1	621*	12*	36*
Sheet, 0.065 in. (1.7 mm), thick	Solution Heat-treated <sup>1</sup>	140.8	971*	86.7	598*	11*	36*
Sheet, 0.125 in. (3.2 mm), thick	Solution Heat-treated <sup>1</sup>	144.7	998*	89.8	619*	11*	37*
Sheet, 0.187 in. (4.8 mm), thick	Solution Heat-treated <sup>1</sup>	144.5	996*	89.3	616*	10*	37*

<sup>1</sup> Solution heat-treated at 2250°F (1232°C), air cooled.

\* Average of 27–31 tests.

■ **Average Tensile Data<sup>1</sup>**

PRODUCT	FORM	TEST TEMP.		ULTIMATE TENSILE STRENGTH		YIELD STRENGTH AT 0.2% OFFSET		ELONGATION IN 2 in. 50.8 mm, %
		°F	°C	Ksi	MPa	Ksi	MPa	
Stellite™ 6B	Sheet 0.063 in. (1.6 mm)	Room	Room	146.0	1007	91.6	632	11
		1500	816	73.9	509	45.4	313	17
		1600	871	55.8	385	39.2	270	18
		1800	982	32.6	225	19.8	137	36
		2000	1093	19.5	134	10.9	75	44
		2100	1149	13.3	92	7.7	53	22
	Plate 1/2 in. (12.7 mm)	Room	Room	148.0	1020	88.0	607	7
		1000	538	133.0	917	58.5	403	9
		1250	677	115.0	793	60.6	418	9
	Bar 5/8 in. (15.9 mm)	Room	Room	154.1	1063	92.6	638	17*
		600	316	147.8	1019	74.5	514	30*
		1000	538	129.1	890	67.3	464	28*
		1500	816	75.4	520	46.5	321	28
		1600	871	58.3	402	37.9	261	34*
	Stellite™ 6K	Sheet 0.063 in. (1.6 mm)	Room	Room	176.5	1217	102.7	708
1200			649	146.0	1007	—	—	8
1500			816	70.2	484	44.5	307	17
1800			982	34.1	235	19.3	133	28
2000			1093	17.4	120	8.6	59	53

<sup>1</sup> Solution heat-treated at 2250°F (1232°C), air cooled.

\* Elongation, percent in 1 in. (25.4 mm).

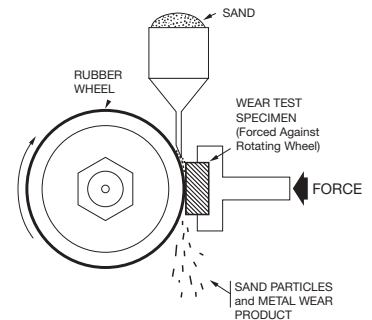
■ **Average Cavitation-Erosion Data**

ALLOY	TEST DURATION, hrs.	WEIGHT LOSS, mg.
Stellite™ 6B	100	42.3
Type 304 Stainless Steel	7	39.9



■ **Average Abrasive Wear Data**

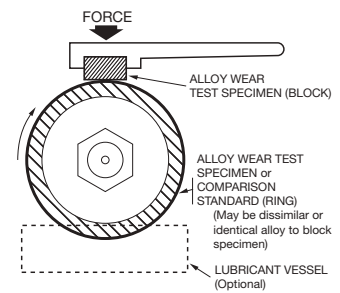
ALLOY	CONDITION	VOLUME LOSS, (mm <sup>3</sup> )	HARDNESS, ROCKWELL	WEAR COEFFICIENT <sup>1</sup>
Stellite™ 6B	Mill annealed	8.2	C-38	0.471 x 10 <sup>-3</sup>
Stellite™ 6K	Mill annealed	13.3	C-46	0.946 x 10 <sup>-3</sup>
Stellite™ 25	Mill annealed 1 hr. at 1600°F (871°C)	53.0	C-24	2.00 x 10 <sup>-3</sup>
1090 Steel	water quenched + 4 min. at 900°F (482°C)	37.2	C-55	8.00 x 10 <sup>-3</sup>
Type 316 Stainless Steel	As received sheet	81.4	B-86	2.0 x 10 <sup>-3</sup>
Type 304 Stainless Steel	As received sheet	102.1	B-92	3.00 x 10 <sup>-3</sup>



**Abrasive Wear Test Unit**  
(Dry Sand)

■ **Average Adhesive Wear Data\***

ALLOY	CONDITION	RING ALLOY	VOLUME LOSS, (mm <sup>3</sup> )	WEAR COEFFICIENT <sup>1</sup>
Stellite™ 6B	Mill annealed	4620 Steel	0.293	3.70 x 10 <sup>-5</sup>
Stellite™ 6K	Mill annealed	4620 Steel	0.561	8.73 x 10 <sup>-5</sup>
Stellite™ 25	Mill annealed 1 hr. at 1600°F (871°C)	4620 Steel	0.285	2.50 x 10 <sup>-5</sup>
1090 Steel	water quenched + 4 min. at 900°F (482°C)	4620 Steel	0.293	6.00 x 10 <sup>-5</sup>



**Adhesive Wear Test Unit**  
(Metal to Metal)

■ **Average Coefficients Of Static Friction For Some Common Materials**

MATERIAL AGAINST	STELLITE™ 6B	CAST IRON	BRONZE	ALUMINIUM	LEAD
Stellite™ 6B	0.119	0.123	0.125	0.138	0.119
Cast Iron	0.123	0.199	0.245	0.213	0.225
Bronze	0.125	0.245	0.231	0.257	0.249
Aluminium	0.138	0.213	0.257	0.213	0.328
Lead	0.119	0.225	0.249	0.328	0.290

Coefficient represents tangent of angle of repose. Tests made on dry surface having better than 120 grit finishes. All values based on averages and are to be used comparatively and not as absolute values.

\* Average of two or more tests against a case-hardened SAE 4620 steel ring (Rockwell C-63).

<sup>1</sup> The wear coefficient (K) was calculated using the equation  $V = \frac{KPL}{3h}$   
where: V = Wear volume (mm<sup>3</sup>)  
P = Load (kg)  
L = Sliding distance (mm)  
h = Diamond pyramid hardness

A combination of a low wear coefficient and a high hardness is desirable for good wear resistance.

**■ Average Corrosion Data – Stellite™ 6B\***

FORM	CONCENTRATION, PERCENT BY WEIGHT	TEST TEMP., °F (°C)	AVERAGE PENETRATION RATE PER YEAR**	
			mils	mm
Acetic Acid	10	Boiling	0.08	0.002
Acetic Acid	30	Boiling	0.04	0.001
Acetic Acid	50	Boiling	0.02	<0.001
Acetic Acid	70	Boiling	0.06	<0.002
Acetic Acid	99	Boiling	0.03	<0.001
Chromic Acid	10	150 (66)	95	2.41
Formic Acid	10	Boiling	20	0.51
Formic Acid	30	Boiling	26	0.66
Formic Acid	50	Boiling	47	1.19
Formic Acid	70	Boiling	50	1.27
Formic Acid	88	Boiling	23	0.58
Hydrochloric Acid	2	Room	0.1	<0.003
Hydrochloric Acid	5	Room	63	1.60
Hydrochloric Acid	10	Room	108	2.74
Hydrochloric Acid	20	Room	93	2.36
Hydrochloric Acid	2	150 (66)	0.1	<0.003
Hydrochloric Acid	5	150 (66)	>1000	>25.4
Hydrochloric Acid	10	150 (66)	>1000	>25.4
Hydrochloric Acid	20	150 (66)	>1000	>25.4
Nitric Acid	10	Boiling	0.15	<0.004
Nitric Acid	30	Boiling	6	0.15
Nitric Acid	50	Boiling	>1000	>25.4
Nitric Acid	70	Boiling	>1000	>25.4
Phosphoric Acid	10	Boiling	Nil	Nil
Phosphoric Acid	30	Boiling	2	0.05
Phosphoric Acid	50	Boiling	19	0.48
Phosphoric Acid	70	Boiling	23	0.58
Phosphoric Acid	85	Boiling	611	15.5
Sodium Hydroxide	30	Boiling	13	0.33
Sulfuric Acid	10	Room	0.02	<0.001
Sulfuric Acid	30	Room	Nil	Nil
Sulfuric Acid	50	Room	0.4	0.01
Sulfuric Acid	77	Room	0.7	0.02
Sulfuric Acid	10	150 (66)	0.02	<0.001
Sulfuric Acid	30	150 (66)	0.09	<0.003
Sulfuric Acid	50	150 (66)	>1000	>25.4
Sulfuric Acid	77	150 (66)	176	4.5
Sulfuric Acid	2	Boiling	31	0.79
Sulfuric Acid	5	Boiling	91	2.31
Sulfuric Acid	10	Boiling	157	3.99
Sulfuric Acid	20	Boiling	360	9.14
Sulfuric Acid	50	Boiling	>1000	>25.4
Sulfuric Acid	30	Boiling	>1000	>25.4
Sulfuric Acid	77	Boiling	>1000	>25.4
Ferric Chloride (10 days without crevice)	10	Room	13	0.33***
Ferric Chloride (10 days with crevice bolt)	10	Room	9**	0.23***
Ferric Chloride + Sodium Chloride (10 days)	5 10	Room	18	0.46***
Potassium Permanganate + sodium Chloride (120 hrs)	2 2	194 (90)	8	0.20

\* Determined in laboratory tests. It is recommended that samples be tested under actual plant conditions.

\*\* Corrosion rates for all duplicate samples based on an average of 4–24 hour test periods.

\*\*\* Samples pitted during test.

■ Average Stress Rupture and Creep Data

PRODUCT	TEST TEMP.,		STRESS		INITIAL ELONGATION %	LIFE, hrs.	TIME IN HOURS FOR TOTAL ELONGATION, % OF			ELONGATION AT RUPTURE, %
	°F	°C	Ksi	MPa			0.5	1.0	2.0	
Stellite™ 6B 0.063 in. (1.6 mm), Sheet <sup>2</sup>	1000	538	60	414	0.70	192.8 <sup>1</sup>	—	—	—	0.8
	1200	649	50	345	0.45	361.4	0.5	113.8	—	3.0
	1400	760	35	241	0.35	59.3	0.4	3.8	16.3	5.1
	1500	816	25	172	0.35	70.6	0.2	4.3	19.9	4.7
	1600	871	19	131	0.10	57.9	0.5	2.2	11.1	4.3
	1700	927	12	83	0.19	104.0	1.8	20.9	89.9	2.6
	1800	982	8	55	0.05	113.4	5.1	22.7	57.6	5.5
	2000	1093	2	14	0.004	116.7	4.4	—	—	13.3

<sup>1</sup> Test discontinued before rupture.

<sup>2</sup> Specimens were solution heat-treated at 2250°F (1232°C) and air cooled prior to testing.

## Fusion Welding

Stellite™ 6B and Stellite™ 6K can be welded by gas tungsten-arc (TIG) with an argon flow of 25 CFH, gas metal-arc (MIG), shielded metal-arc (coated electrode), and oxy-acetylene in this order of preference. The oxy-acetylene method should be used with discretion and care in that Stellite™ will “boil” during welding which may cause porosity. Use a 3x reducing flame to minimize oxidation, penetration, and inter-alloying.

Stellite™ 6B and Stellite™ 6K should be preheated and maintained at 1000°F (358°C) to prevent cracking during welding and then still air cooled. Fixturing, which would chill the weld rapidly, should not be used. Standard weld joints are recommended. Inconel™ 82, 92, or 625 filler metals are recommended for joining Stellite™ 6B to softer materials such as carbon steel or stainless steel, while the harder cobalt-base filler metals such as Stellite™ 6 and Stellite™ 21 are recommended for joining Stellite™ 6B to itself, especially if wear resistance is required in the weld areas. In the latter case, Inconel™ 82, 92, or 625 may be used for root passes and then be overlaid with the harder materials. Gas shielding of the root side of the gas tungsten-arc weldments is not mandatory but is recommended in order to improve weld penetration.

Adequate ventilation is required to control exposure to airborne dust, fumes, and particulate when machining, grinding or welding Stellite™ alloys. MSDS sheets are available.

## Brazing

Stellite™ 6B and Stellite™ 6K are readily joined to other materials by brazing. All forms of surface dirt such as paint, ink, oil, chemical residues, etc., must be removed from the mating parts by etching, solvent scrubbing, degreasing, or other means. In addition, fluxing will be required during torch brazing operations when using silver brazing filler metal to help clean the joint and allow the filler metal to flow more freely over the mating surfaces. Brush joining areas generously with brazing flux prior to heating. When torch or induction brazing, as soon as the brazing filler metal melts, the source of heat should be removed and the parts positioned. The assembly should then be pressed together to squeeze out the excess flux and still air cooled. The parts should not be quenched.

Other brazing filler metals (i.e., gold, palladium, or nickel-based alloys) are satisfactory for joining Stellite™ 6B and Stellite™ 6K. Brazing filler metal selection depends on the service conditions expected.

A close fit of the mating surfaces is recommended. The finished joints will have greater strength if the filler metal is very thin, generally 0.001–0.005" (0.03–0.13 mm) thick.

Brazing with high-temperature filler materials is generally performed in a furnace. Induction and resistance heating with salt-bath and metal-bath dip brazing have limited application. Vacuum furnaces held at less than one micron pressure or controlled atmosphere furnaces, having adequate moisture control at brazing temperatures (less than 60°F (15°C) dew point), produce the most satisfactory results. Controlled atmospheres such as hydrogen or cracked ammonia are suitable for brazing Stellite™ 6B and Stellite™ 6K base materials.

## ***OUR MISSION***

Kennametal delivers productivity to customers seeking peak performance in demanding environments by providing innovative customized and standard wear-resistant solutions, enabled through our advanced materials sciences, application knowledge, and commitment to a sustainable environment.





## **Wrought Wear-Resistant Alloys**

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