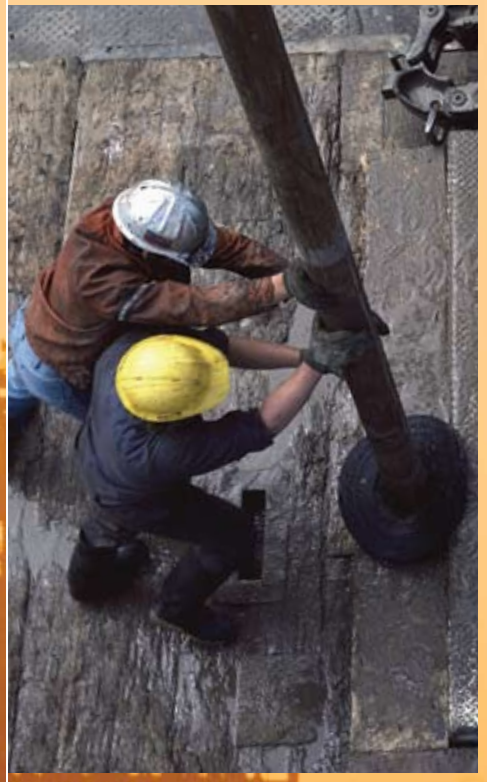
MATERION

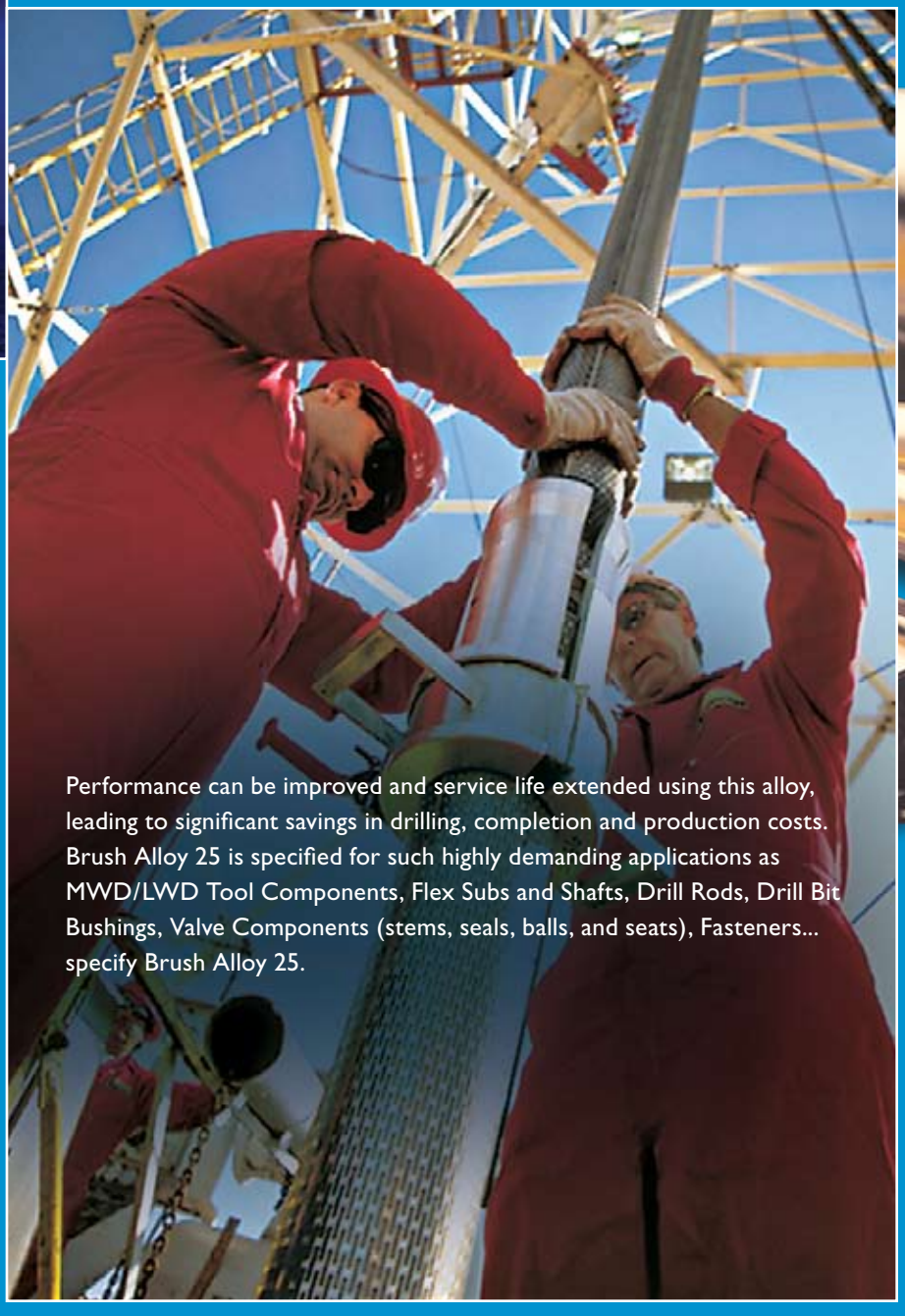


BRUSH PERFORMANCE ALLOYS

ENGINEERED MATERIALS FOR TOUGH ENVIRONMENTS

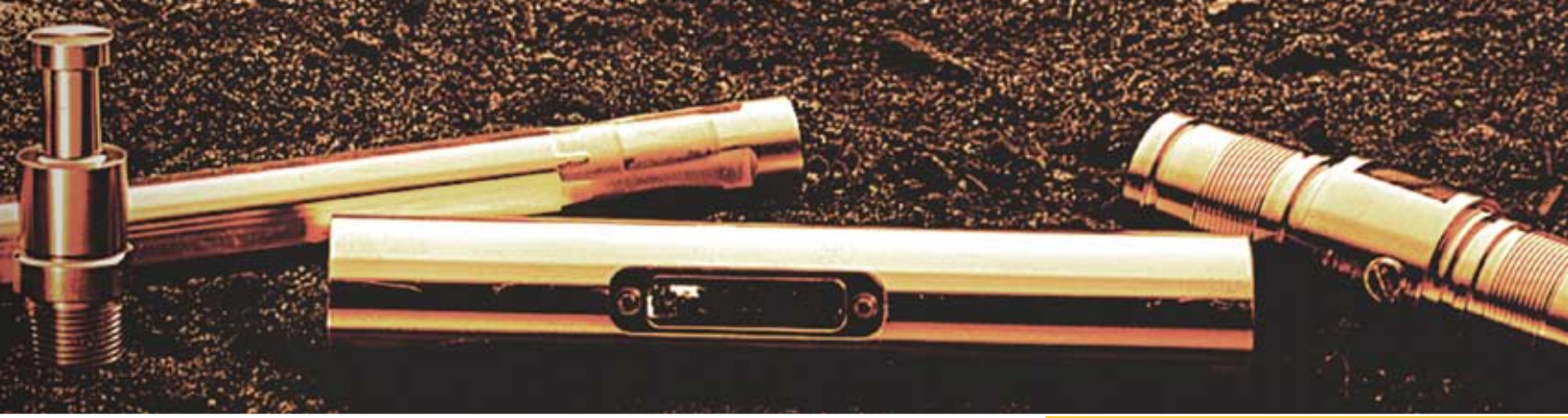
BRUSH ALLOY 25

A DEFINITE ADVANTAGE FOR THE OIL AND GAS INDUSTRY



UNIQUE PROPERTY COMBINATIONS OF BRUSH ALLOY 25 MAKE IT THE MATERIAL OF CHOICE IN NATURAL RESOURCE EXPLORATION, DRILLING, COMPLETION AND PRODUCTION EQUIPMENT.

Performance can be improved and service life extended using this alloy, leading to significant savings in drilling, completion and production costs. Brush Alloy 25 is specified for such highly demanding applications as MWD/LWD Tool Components, Flex Subs and Shafts, Drill Rods, Drill Bit Bushings, Valve Components (stems, seals, balls, and seats), Fasteners... specify Brush Alloy 25.



BRUSH ALLOY 25 OFFERS HIGH STRENGTH AND EXCELLENT CORROSION RESISTANCE IN COMBINATION WITH...

- Fatigue Strength
- Galling Resistance
- Magnetic Transparency
- Resiliency
- High Hardness

SPECIFICATIONS AND STANDARDS

Brush Alloy 25 conforms to many industry specifications and standards including:

ASTM B 196, B 251, B 643

NACE MRO 175/ ISO 15156

BRUSH ALLOY 25 FOR INNOVATIVE DESIGN

BRUSH ALLOY 25 OFFERS DESIGN FLEXIBILITY.

Because the alloy is age-hardenable, it can be produced in a wide range of strengths. Property combinations within this range can be tailored to the individual application requirements.

Figure 1: Mechanical and Electrical Properties of Brush Alloy 25 Rod, Bar and Tube for Standard Tempers

Temper	Ultimate Tensile Strength		Yield Strength 0.2% Offset		Elongation	Rockwell Hardness	Electrical Conductivity	
	ksi	MPa	ksi	MPa	%	B or C Scale	% IACS	MS/m
A (TB00)	60-85	414-586	20-35	138-241	20-60	B45-B85	15-19	9-11
H (TD04)	85-130	586-896	75-105	517-724	8-30	B88-B103	15-19	9-11
AT (TF00)	165-200	1138-1379	130-175	896-1207	3-10	C36-C42	22-28	9-11
HT (TH04)	175-225	1207-1551	145-200	1000-1379	2-9	C39-C45	22-28	9-11
DST (TF00)•	120-140 min.	827-965 min.	90-110 min.	621-758 min.	12-13 min.	C26 min.	22-28	9-11

Design property combinations available upon request.
* Refer to Figure 9 on page 8

Figure 2: Brush Alloy 25 Chemical Composition (weight percent)

Copper Alloy UNS Number	Beryllium	Cobalt + Nickel	Cobalt + Nickel + Iron	Copper
C17200	1.80-2.00	0.20 min.	0.60 max.	Balance

Figure 3: Physical Properties of Age Hardened Brush Alloy 25

Density		Elastic Modulus		Thermal Expansion Coefficient		Thermal Conductivity		Poisson's Ratio	Melting Temperature	
lb/in^3	g/cm^3	10^6 psi	10^3 MPa	in/in/°F (70F to 400F)	m/m/°C (20C to 200C)	BTU/ (ft•hr•°F)	Watt/ (m•°C)		°F	°C
0.302	8.36	19	13.1	9.7×10^{-6}	17×10^{-6}	60	105	0.30	1600-1800	871-982

AGE HARDENING

Age hardening response depends on time, temperature and amount of cold work because strengthening is governed by precipitate size and distribution. For ease of heat treatment, a time-temperature combination is designated to produce maximum strength. For Brush Alloy 25, this combination is in the range of 3 hours at 600-675F.

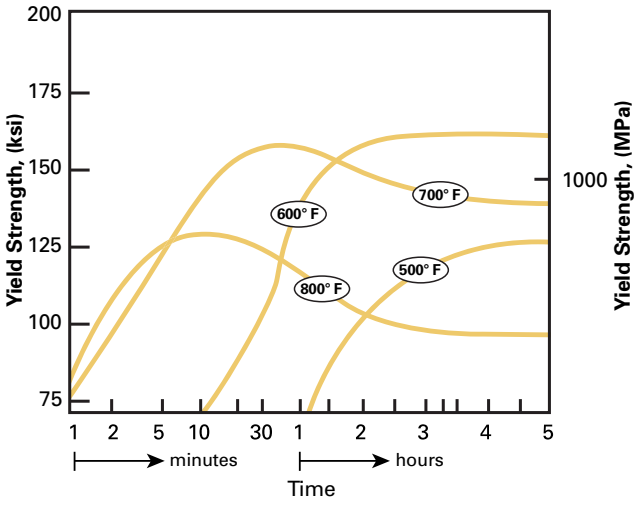
Aging at times shorter than required to achieve peak strength is known as underaging. Toughness, fatigue strength and, in some cases, corrosion resistance, benefit from an underaged microstructure. Overaging involves heating for a time longer than needed to achieve peak strength. Electrical and thermal conductivities and dimensional stability are maximized by overaging. Altering the aging temperature can also achieve similar results.

TEMPER DESIGNATIONS

Copper beryllium properties are determined, in part, by composition. However, cold work and age hardening are also important. The combined effect of noncompositional factors is defined as the alloy's temper.

Temper designations are defined in ASTM B601. Copper beryllium in the Annealed condition is designated by a suffix letter "A", for example 25 A. Suffix letter "H" denotes an alloy has been Hardened by cold working. The suffix "T" following an "A" or "H" designates an alloy which has been given a standard heat treatment, for example 25 AT or 25 HT.

Figure 4: Brush Alloy 25 Age Hardenability

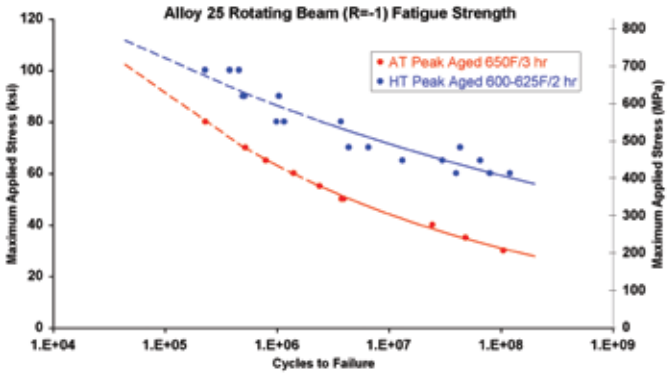


BRUSH ALLOY 25 FOR PERFORMANCE EXCELLENCE

FATIGUE PERFORMANCE

Brush Alloy 25 has a long history of success in downhole components subject to cyclic loading. It resists fatigue failure with high static strength, toughness and an ability to diffuse strain by work hardening.

Figure 5: Rotating Beam Fatigue Strength for High Strength Brush Alloy 25 >140 ksi (965 MPa) 0.2% Offset Yield Strength



CRYOGENIC BEHAVIOR

Brush Alloy 25 is used in liquefied gases and at sub-zero temperatures since strength, ductility and toughness are maintained in cryogenic conditions. Unlike many high strength steels, Brush Alloy 25 has no ductile to brittle transition temperature.

CORROSION RESISTANCE

Brush Alloy 25 has excellent corrosion resistance. In marine environments, its performance is unsurpassed. Components have seen more than thirty years of service without evidence of fouling or detrimental corrosion. This low sea water corrosion rate makes Brush Alloy 25 an ideal material choice for subsea components.

Additionally, Brush Alloy 25 is not susceptible to sulfide or chloride stress corrosion cracking, resists carbon dioxide and is effectively immune to hydrogen embrittlement. In sour environments, it is used where exposure is intermittent.

Brush Alloy 25 meets the requirements of NACE Standard MRO 175/ ISO 15156

Figure 6: Resistance to Chloride Stress Corrosion Cracking

Temperature, °F (°C)	300 (150)	311 (155)	300 (150)
Applied Stress (percent of 0.2% yield strength) ksi (MPa)	100 (689)	100 (689)	100 (689)
Oxygen Content (parts per million in saturating gas)	1	1	5000
pH	8	3	7
Chloride Concentration (weight percent) **sodium** **potassium** **magnesium**	 3 10 0	 0 0 42	 0 6 25
Test Duration (hours)	720	1000	1000
Test Result	no cracking	no cracking	no cracking

GALLING RESISTANCE

Brush Alloy 25 has superior galling resistance. This is one of the primary reasons that Brush Alloy 25 is selected for equipment where the service conditions include high loading and relative motion between metal components.

Brush Alloy 25 resists galling to many other alloys and resists galling to other Brush Alloy 25 components.

Figure 7: Galling Resistance Comparison to Specific Alloys

Alloy 1 vs. Alloy 2		Threshold Galling Stress	
		ksi	MPa
Brush Alloy 25 (145, 1000)	Brush Alloy 25 (145, 1000)	100+	689+
Brush Alloy 25 (145, 1000)	17-4PH (146, 1007)	90+	621+
Brush Alloy 25 (145, 1000)	MP35N (145, 1000)	75+	517+
Brush Alloy 25 (145, 1000)	Nitronic 50 (79, 545)	60+	414+
Brush Alloy 25 (145, 1000)	Monel K500 (115, 793)	50+	345+
Brush Alloy 25 (145, 1000)	Gall Tough (65, 448)	50+	345+
Brush Alloy 25 (145, 1000)	Ti-6Al-4V (142, 979)	7.5[1]	52[1]
Nitronic 50 (79, 545)	Nitronic 50 (79, 545)	2	14
Monel K500 (115, 793)	Monel K500 (115, 793)	<10	<69
Ti-6Al-4V (142, 979)	Ti-6Al-4V (142, 979)	<2.5	<17

[1]Alloy 1 galled to Alloy 2
- Test Method per ASTM G98
- Values shown are unlubricated threshold galling stress (ksi, MPa) for button and block galling test.
- Values given as 50+ indicate the samples did not gall.
- Number in parentheses following alloy designations are 0.2% offset Yield Strength (ksi, MPa)
- Other alloy comparisons available.

ELEVATED TEMPERATURE STRENGTH

Brush Alloy 25 demonstrates excellent stability of tensile properties from cryogenic temperatures through 500F, despite long exposure. When tested at conventional strain rates, tensile properties retain room temperature values through 500F.

BRUSH ALLOY 25 FOR PRECISION TUBING

WHEN YOU CAN'T RISK THE CHANCE OF MAGNETIC HOT SPOTS

Brush Alloy 25 HT Precision Tubing is an ideal material for downhole instrument and battery housings. Its unique combination of high strength, ductily, magnetic transparency and corrosion resistance provides the tool designer with a material that will provide years of performance under severe drilling conditions.

A key aspect of instrument housing design is the ability to withstand downhole pressures. Equations in API Bulletin #5C3 relate the yield strength of the material (Yp), the outside diameter of the tube (D) and the wall thickness (t) to the amount of pressure (Pyp) a tube can withstand before collapsing.

$$Pyp = 2Yp\left(\frac{(D/t) - 1}{(D/t)^2}\right)$$

The ability to age harden Brush Alloy 25 HT to various strength and ductility combinations offers a wide variety of design possibilities which are ideally suited to withstand downhole collapse pressure. The available strength and elongation combinations for Brush Alloy 25 HT Precision Tubing are shown to the right.

Figure 8: Minimum Strength and Elongation for Brush Alloy 25 HT Precision Tubing

Yield Strength 0.2% Offset		Elongation %
ksi	MPa	
150	1034	5
140	965	6
130	896	8
120	827	10
110	759	12

Brush Alloy 25 HT Precision Tubing is manufactured to tight tolerances and is available from stock.

MAGNETIC PROPERTIES

Brush Alloy 25 is non-magnetic. Magnetic permeability is near unity meaning that the alloy is nearly perfectly transparent to slowly varying magnetic fields. Localized deformation or surface abrasion will not cause magnetic "hot spots" and the material will not become magnetized by machining.

BRUSH ALLOY 25 FOR DAMAGE TOLERANCE

FUNCTIONALITY AND RELIABILITY

A special grade of copper beryllium has been developed for improved damage tolerance in demanding end-use oilfield products. Brush Alloy 25 Drill String Temper (DST) provides a unique combination of high strength and high ductility. Engineers choose Brush Alloy 25 DST to optimize resiliency, eliminate mechanical damage in the field and provide the best performance at the lowest total cost of ownership. Brush Alloy 25 DST solves the challenges of natural resource development and production.

Figure 9: Mechanical Properties for Brush Alloy 25 DST

Rod & Tubing Outside Diameter	Minimum Tensile Strength ASTM E8		Minimum Yield Strength 0.2% Offset		Minimum Elongation
Inches	ksi	MPa	ksi	MPa	%
< 7	140	965	110	759	12
7 - 11	135	931	100	698	13
>11	120	927	90	621	13

Figure 10: Plane Strain Fracture Toughness of Brush Alloy 25 AT

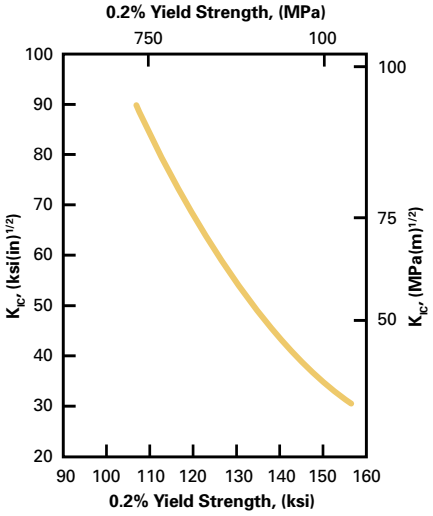
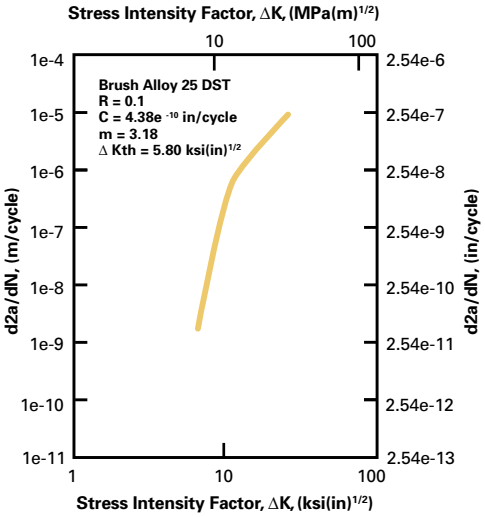


Figure 11: Fatigue Crack Propagation Resistance of Brush Alloy 25 DST 110 ksi (965 MPa) 0.2% Offset Yield Strength



FRACTURE TOUGHNESS AND FATIGUE CRACK PROPAGATION

Brush Alloy 25 DST offers the highest fracture toughness and resistance to crack propagation of any precipitation strengthened copper alloy. These property attributes provide the designer considerable flexibility to engineer damage tolerant and inspectable components using Brush Alloy 25 DST.

BRUSH ALLOY 25 FOR **REDUCED MANUFACTURING COSTS**

MACHINABILITY

Brush Alloy 25 can be machined using conventional methods. Because of easy chip removal, machinability of Brush Alloy 25 is better than that of other high performance alloys. Since machinability rates are much higher, production is more efficient and manufacturing costs are reduced.

The material can also be electrical discharge machined, photo-chemically etched, welded and brazed.

Figure 12: Turning - Single Point Carbide Tool

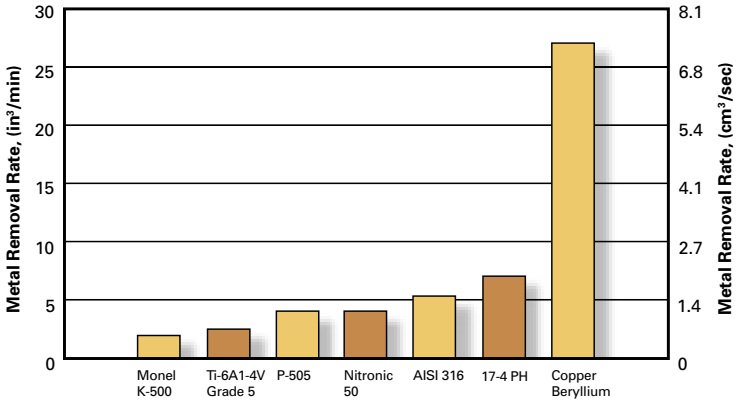
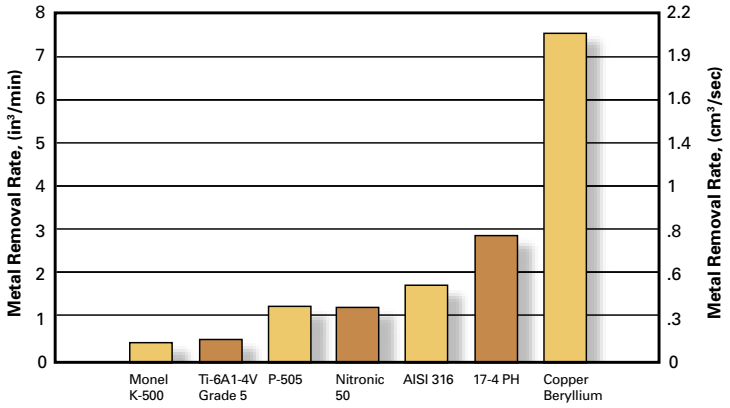
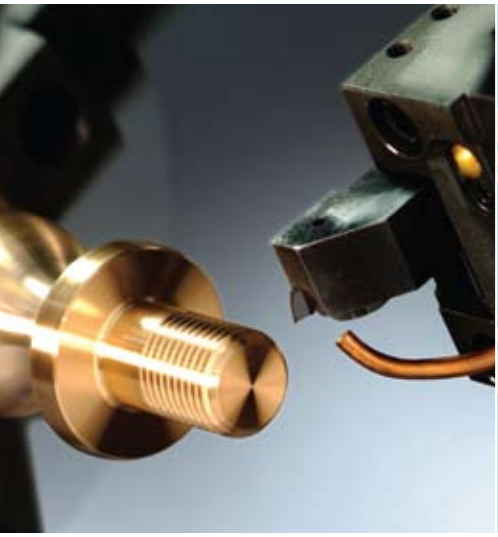
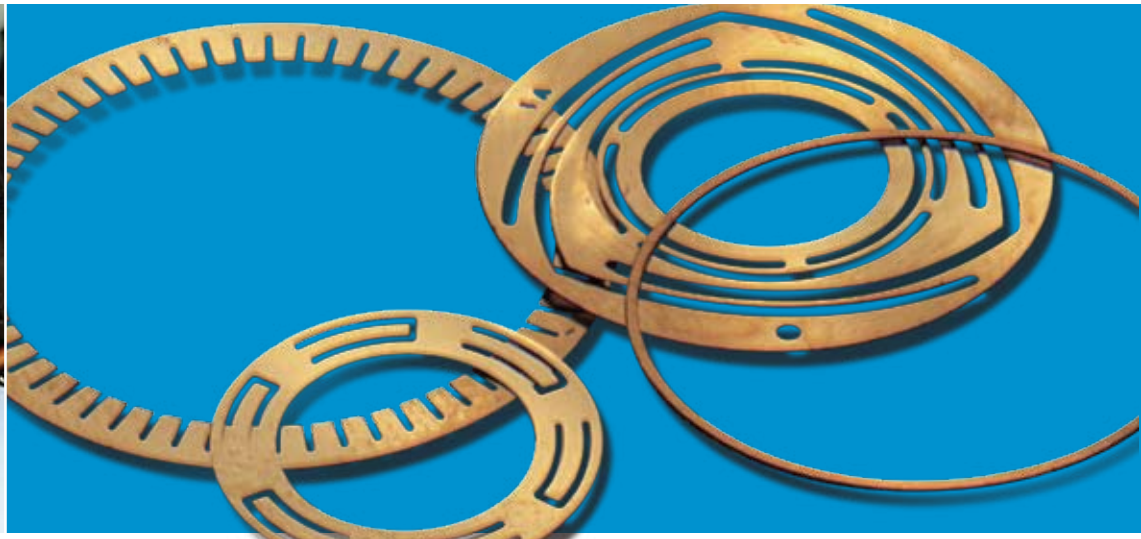
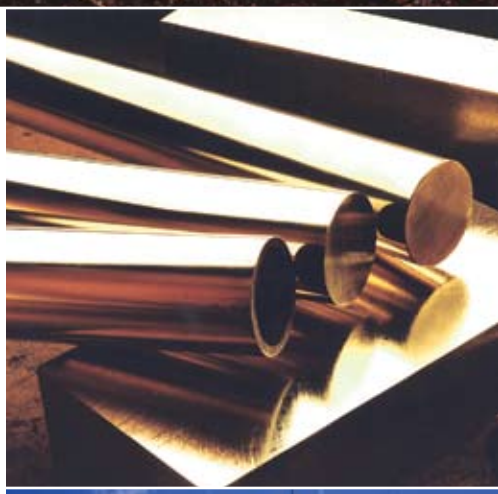


Figure 13: Drilling - High Speed Tool Steel Bit









TECHNICAL ASSISTANCE

Detailed information regarding material properties, safe handling, specific applications and fabrication assistance is available from Materion Brush Performance Alloys Customer Technical Service Department in Cleveland, Ohio at 800-375-4205 or email us at brushalloys-techservice@materion.com

QUALITY & ACCREDITATION

We base our quality initiatives on the Lean Six Sigma and Supply Chain Management philosophies of eliminating wasteful activities, reducing variation, improving system performance. Lean Production drives a relentless elimination of "waste" - producing what is needed, when it is needed, in exactly the right quantities, with a minimum amount of resources. Six Sigma is a process-focused data-driven problem solving discipline that drives variation reduction and the elimination of process defects. Supply Chain Management optimizes the material flows to facilitate production from the supply base through internal operations to our customers. To maintain high standards of quality, we provide ongoing training in the quality tools to all employees.

Our production facilities and domestic service centers are certified to ISO 9001:2000 and AS9100-B. The production facilities are also NADCAP accredited for heat treatment. The Quality Management System (QMS) monitors internal and external product performance along with the implementation of the quality system. Overall performance tracking and monthly reviews utilize measurements developed by the management teams at each plant.

Health & Safety – Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material.

For additional information on safe handling practices or technical data on copper beryllium, contact **Materion Brush Performance Alloys, Technical Service Department at 800.375.4205.**

MATERION

ABOUT MATERION

Materion is the new name for Brush Engineered Materials Inc., its Brush Wellman Inc. subsidiary, and all of the company's businesses worldwide. Materion is among the world's premier providers of advanced materials solutions and services. Now under the one Materion brand, we are better aligned to deliver a broader scope of products, services and expertise needed to drive our customers' growth and profitability and become their first choice in a partner. Materion Corporation common stock trades on the New York Stock Exchange under the symbol MTRN.

MATERION BUSINESSES

Advanced Chemicals
Barr Precision Optics & Thin Film Coatings
Brush Beryllium & Composites
Brush Performance Alloys
Ceramics
Electrofusion
Large Area Coatings
Microelectronics & Services
Natural Resources
Technical Materials

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