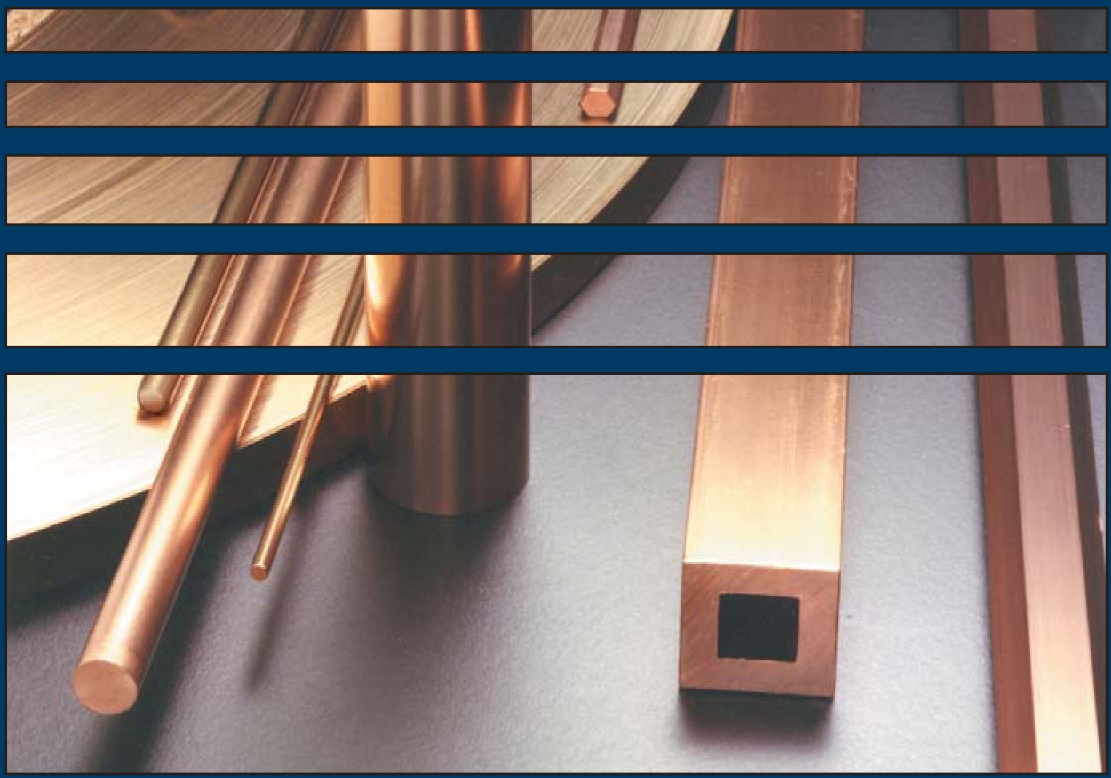
Guide to Copper Beryllium



Aleaciones de Berilio S.L.

Buen Suceso 13 - 28008 Madrid - tel. 915 488 187 - fax 915 489 307

paco_aguirre@aleacionesdeberilio.com

BRUSH WELLMAN
ENGINEERED MATERIALS

strip

rod

wire

bar

tube

plate

Guide to Copper Beryllium

Brush Wellman is the leading worldwide supplier of High Performance Copper Alloys, including Copper Beryllium. We provide manufacturing excellence in the form of high reliability products and services to satisfy our customers' most demanding applications. We provide these services in a culture of local support and global teamwork.

Content

Alloy Guide

The copper beryllium alloys commonly supplied in wrought product form are highlighted in this section. Wrought products are those in which final shape is achieved by working rather than by casting. Cast alloys are described in separate Brush Wellman publications.

Although the alloys in this guide are foremost in the line that has established Brush Wellman's worldwide reputation for quality, they are not the only possibilities. We welcome the opportunity to work with you in selecting or developing an alloy to make your application succeed.

Wrought Alloys

Brush Wellman manufactures copper beryllium in several distinct compositions. These fall into two categories: alloys selected for high strength (Alloys 25, 190, 290, M25 and 165) and alloys selected for high conductivity (Alloys 3, 10, 174 and Brush 60®). Alloy 390™ combines both attributes, high strength and high conductivity.

Brush Alloy 25 is the most commonly specified copper beryllium and is available in the wrought forms listed on page 5. In its age hardened condition, Alloy 25 attains the highest strength and hardness of any commercial copper base alloy. The ultimate tensile strength can exceed 200 ksi, while the hardness approaches Rockwell C45. Also, in the fully aged condition, the electrical conductivity is a minimum of 22% IACS (International Annealed Copper Standard). Alloy 25 also exhibits exceptional resistance to stress relaxation at elevated temperatures.

Brush Alloy 190 is a mill hardened strip product. In other words, the strip is age hardened to a specified strength level as part of the manufacturing process at Brush Wellman prior to shipment. This alloy is similar to Alloy 25 in chemical composition. Alloy 190 is supplied with tensile strength up to 190 ksi and Rockwell hardness to C42. Cost effectiveness is realized by elimination of age hardening and cleaning of stamped parts.

Brushform® 290 is a mill hardened strip product that is similar in strength properties and composition to Alloy 190 but exhibits improved formability. Component reliability and fabrication considerations may require a high strength material with good formability. The improved strength/formability relationship of Brushform® 290 makes it a cost effective alternative to conventional mill hardened product for such applications.

Brush Alloy M25 offers the strength properties of Alloy 25 with the added benefit of being “free machining”. Alloy M25 rod and wire contain a small amount of lead to provide an alloy tailored for automatic machining operations. Lead promotes formation of finely divided chips thus extending cutting tool life.

Brush Alloy 165 contains less beryllium than Alloy 25 and has slightly lower strength. It is less expensive than Alloy 25 and may be substituted when strength is less demanding. Alloy 165 is available in wrought product forms in annealed and aged tempers.

Brush Alloys 3 and 10 combine moderate yield strength, up to 140 ksi, with electrical and thermal conductivity from 45 to 60 percent of pure copper. Alloys 3 and 10 are available in wrought product forms and can be supplied fully hardened. Hardened products are identified by the temper designation AT or HT, and have good formability.

Chemical Composition (weight percent)

Brush Alloy	Copper Alloy UNS Number	Beryllium	Cobalt	Nickel	Cobalt + Nickel	Cobalt + Nickel + Iron	Lead	Copper
25 **190** **290**	C17200	1.80-2.00	_	_	0.20 min	0.6 max	0.02 max	Balance
M25	C17300	1.80-2.00	_	_	0.20 min	0.6 max	0.20-0.6	Balance
165	C17000	1.60-1.79	_	_	0.20 min.	0.6 max	_	Balance
3	C17510	0.2-0.6	_	1.4-2.2	_	_	_	Balance
10	C17500	0.4-0.7	2.4-2.7	_	_	_	_	Balance
60	C17460	0.15-0.50	_	1.0-1.4	_	_	_	Balance
174	C17410	0.15-0.50	0.35-0.60	_	_	_	_	Balance
390	C17460	0.15-0.50	_	1.0-1.4	_	_	_	Balance

Note: Copper plus additions equal 99.5% minimum.

Brush 60® and Brush Alloy 174 offer users the opportunity to upgrade component performance over bronzes and brasses, particularly where conductivity and stress relaxation resistance are design considerations. Both are supplied with a yield strength up to 125 ksi, superior to other copper alloys such as phosphor bronze, silicon bronze, aluminum brasses and the copper-nickel-tin alloys. Furthermore, they offer up to fivefold better electrical conductivity than those alloys, and exhibit better stress relaxation resistance. Brush 60® offers an excellent combination of elastic modulus, strength, formability and conductivity. Both are available as mill hardened strip.

Alloy 390™ combines the best attributes of the two separate families of commercial copper beryllium alloys – the strength of the "high strength" Alloy 25 with the conductivity of "high conductivity" Alloys 3 and 174. In addition to the combination of high strength and conductivity, Alloy 390™ has excellent stress relaxation resistance at elevated temperatures. In applications where durability is important, its excellent fatigue strength extends product life and improves product quality. Alloy 390™ is available as prehardened strip.

Wrought Products

Wrought copper beryllium is available from Brush Wellman in a variety of product forms. The following paragraphs define the products most commonly specified by copper beryllium users.

Strip is flat-rolled product, other than flat wire, 0.188 inch or less in thickness, and supplied in coil form.

Wire is a solid section other than strip, furnished in coils or on spools or reels. Wire may be furnished straightened and cut to length, in which case it is classified as rod.

Flat wire is 0.188 inch or less in thickness and 1-1/4 inch or less in width. This designation includes square wire 0.188 inch or less in thickness. In all cases surfaces are rolled or drawn without having been slit, sheared or sawed. Flat wire is furnished in straight lengths or on spools or reels.

Rod is a round, hexagonal or octagonal solid section furnished in straight lengths. Rod is supplied in random or specific lengths.

Bar is a solid rectangular or square section thicker than 3/ 16 inch and up to and including 12 inches wide. Bar is an extruded product. If cut from plate it is called rolled bar. Edges are either sharp, rounded, or have some other simple shape.

Plate is flat-rolled product thicker than 0.188 inch and over 12 inches wide.

Tube is a seamless hollow product with round or other cross section. Tube is normally extruded or drawn, and is supplied in random or specific length.

Extruded shape is a solid section other than round, hexagonal, octagonal, or rectangular. Shapes are

Standard Product Forms

Form	Brush Alloy			
	25, 3	165	10, M25	190, 290 390, 174 60
Cold Rolled				
Strip	✓	–	–	✓
Flat Wire	✓	–	–	–
Rectangular Bar	✓	–	–	–
Square Bar	✓	–	–	–
Plate	✓	–	–	–
Cold Drawn				
Rod	✓	✓	✓	–
Bar	✓	✓	✓	–
Tube	✓	–	–	–
Wire	✓	–	✓	–
Shapes	✓	–	✓	–
Hot Worked				
Rod	✓	✓	–	–
Bar	✓	✓	–	–
Plate	✓	✓	–	–
Tube	✓	✓	–	–
Special Shapes				
Turned Rod	✓	✓	–	–
Billets	✓	✓	–	–
Forgings	✓	✓	–	–
Extrusions	✓	✓	–	–

produced to the user's specification and are supplied in straight lengths.

Forgings, made from cast billet, are supplied in forms ranging from simple geometric configurations to near-net shapes according to user specifications.

Custom fabricated parts are supplied to customer drawings as finished or semi-finished parts. Such products are fabricated from basic product forms (rod, extrusions, plate, etc.) by processes such as ring rolling, forging, welding and machining.

Physical Properties

Copper beryllium's physical and mechanical properties differ considerably from those of other copper alloys because of the nature and action of the alloying elements, principally beryllium. Varying the beryllium content from about 0.15 to 2.0 weight percent produces a variety of alloys with differing physical properties. Typical values of some of these properties are presented in the table on this page.

Whether a high strength or a high conductivity alloy, some physical properties remain similar. For example, the elastic modulus of the high strength alloys is 19 million psi; for the high conductivity alloys, 20 million psi. Poisson's ratio is 0.3 for all compositions and product forms.

A physical property that differs significantly between alloy families is thermal conductivity, which ranges from about 60 Btu/(ft•hr•F) for high strength alloys to 140 Btu/(ft•hr•F) for the high conductivity grades. The thermal and electrical conductivities of copper beryllium promote its use in applications requiring heat dissipation and current carrying capacity. Electrical conductivity is listed with mechanical properties in the Product Guide section of this book.

The thermal expansion coefficient of copper beryllium is independent of alloy content over the temperature range in which these alloys are used. The thermal expansion of copper beryllium closely matches that of steels including the stainless grades. This insures that copper beryllium and steel are compatible in the same assembly.

Specific heat of copper beryllium rises with temperature. For Alloys 25, M25 and 165, it is 0.086 Btu/(lb•F) at room temperature, and 0.097 Btu/(lb•F) at 200 F. For Alloys 3, 10, 174, Brush 60® and 390™ it rises from 0.080 to 0.091 Btu/(lb•F) over the same temperature range.

Magnetic permeability is very close to unity, meaning that the alloys are nearly perfectly transparent to slowly varying magnetic fields.

Copper beryllium high strength alloys are less dense than conventional specialty coppers, often providing more pieces per pound of input material. Copper beryllium also has an elastic modulus 10 to 20 percent higher than other specialty copper alloys. Strength, resilience, and elastic properties make copper beryllium the alloy of choice.

Typical Physical Properties

Brush Alloy	Density lb/cu.in.	Elastic Modulus 10^6 psi	Thermal Expansion Coefficient in/in/°F, 70°F to 400°F	Thermal Conductivity Btu/(ft•hr•°F)	Melting Temp. °F
25, 190, 290 M25	0.302	19	9.7×10^{-6}	60	1600-1800
165	0.304	19	9.7×10^{-6}	60	1600-1800
3	0.319	20	9.8×10^{-6}	140	1900-1980
10	0.319	20	9.8×10^{-6}	115	1850-1930
60	0.318	20	9.8×10^{-6}	128	1880-1960
174	0.318	20	9.8×10^{-6}	135	1880-1960
390	0.318	20	9.8×10^{-6}	128	1880-1960

Note: Tabulated properties apply to age hardened products. Before age hardening the density is: 0.298 lb/cu.in. for Alloys 25, M25 and 165; 0.316 lb/cu.in. for Alloys 3 and 10

Product Guide

Brush Wellman copper beryllium wrought products are recognized worldwide for unequalled quality and reliability among high performance copper base alloys. The products are stocked in a wide range of sizes and shapes. Moreover, because copper beryllium performs well in most metalworking and joining processes, special configurations can be produced economically.

Mechanical and electrical properties are presented in this section (English units are standard – metric equivalents are available on request). These properties aid design by guiding size and temper selection but the tabulations do not limit your choice. A narrower range or a property outside the range are frequently requested. We often produce to user specifications and we welcome the challenge of a special product.

Strip

Brush Wellman copper beryllium strip is used across a broad spectrum of applications. For example, a formed spring is often the active element in a signal or current directing device. In a connector, a copper beryllium contact regulates insertion force to encourage contact wiping action, provides a high normal force to minimize contact resistance, and maintains withdrawal force to ensure conducting path integrity.

This accomplishment often requires an intricate stamped contact that combines flexing and stiffening members in the same part. Among the many copper beryllium tempers described on this and following pages, there is one with compliance and formability to meet requirements of nearly any contact spring design.

Specifications

Brush Alloy	UNS Number	Strip
25	C17200	ASTM B 194 QQ-C-533 AMS 4530, 4532 SAE J 461, 463
190	C17200	ASTM B 194
290	C17200	ASTM B 194
3	C17510	ASTM B 534 MIL-C-81021 RWMA Class 3
174	C17410	ASTM B 768
Brush 60®	C17460	ASTM B 768

ASTM American Society for Testing and Materials
QQ Federal Specification
MIL Military Specification
SAE Society of Automotive Engineers
AMS Aerospace materials Specification (Published by SAE)
RWMA Resistance Welder Manufacturer's Association
Note: Unless otherwise specified, material will be produced to ASTM specification.

Other benefits of copper beryllium strip include the following:

- In many tempers, strength and forming characteristics do not vary with direction (isotropic). Deep drawn bellows or disc diaphragms for pneumatic controls depend on nondirectional properties both in manufacture and in service.
- Shielding strips that ground electromagnetic interference have demanding forming requirements, but also require strength and endurance.
- Relay contacts and switch parts must resist the action of repeatedly applied loads, sometimes at moderately elevated temperature, and therefore must have high fatigue strength.
- High hardness is a benefit in insulation displacement connectors that must cut through conductor wire insulation to make reliable contact.

Thickness is critical in spring design, strongly influencing force-deflection characteristics. For this reason Brush Wellman guarantees strip thickness to be uniform within tolerance limits shown in the adjoining table. Width of the slit strip is held to ±0.003 inch in all widths up to 3.5 inches.

Strip curvature, either edgewise (camber), or in the plane of the strip (coilset or crossbow) also is carefully controlled. In press working, excellent strip shape aids proper feed, particularly with progressive dies.

Tolerance
(inches)

Strip Thickness over	Strip Thickness incl.	Brush Wellman Standard Tolerance (plus or minus)
0.0020	0.0040	0.00015
0.0040	0.0060	0.00020
0.0060	0.0090	0.00025
0.0090	0.0130	0.00030
0.0130	0.0260	0.00040
0.0260	0.0370	0.00060
0.0370	0.0500	0.00080
0.0500	0.0750	0.0010

Note: Tolerances apply to rolled and mill hardened strip.

Temper Designations

Copper beryllium properties are determined in part by composition, but cold work and age hardening are also important. The combined effect of non-compositional factors is defined in the alloy's "temper." When alloy number and temper are specified on a drawing or order, for example Brush Alloy 3 AT, the user is assured of a specific set of properties.

Temper designations are defined in the specification ASTM B 601, "Standard Practice for Temper Designations for Copper and Copper Alloys." Less precise terms such as "quarter hard" and "half hard" are also recognized by suppliers and users. The relationship between these terms and the ASTM nomenclature is given in the table on this page.

Copper beryllium in the solution annealed condition is designated by a suffix letter " A " , for example Alloy 25 A. This is the softest condition in which the alloy can be obtained. Suffix letter "H" denotes an alloy that has been hardened by cold working, such as by rolling or drawing, for example Alloy 25 H. The suffix letter "T" following an "A" or "H" designates an alloy which has been given a standard heat treatment, and as a result has "peak" properties, for example Alloy 25 HT.

Copper beryllium bearing an "M" suffix has received proprietary mill processing, for example Alloy 190 HM, and guarantees properties within a specific range.

Alloy 3 is available in the fully aged condition. The products are designated AT for annealed and precipitation treated; and HT for annealed, cold rolled, and precipitation treated. Brush 60® and Alloy 174 are provided only in the cold rolled, precipitation treated condition.

Temper Designations

Brush Designation	ASTM Designation	Description	Cold Rolled Thickness Reduction in Percent
A	TB00	Solution Annealed	0
1/4 H	TD01	Quarter Hard	11
1/2 H	TD02	Half Hard	21
3/4 H	TD03	Three-Quarter Hard	29
H	TD04	Hard	37
AT	TF00	The suffix "T" added to temper designations indicates that the material has been age hardened by the standard heat treatment.	
1/4 HT	TH01		
1/2 HT	TH02		
3/4 HT	TH03		
HT	TH04		
AM	TM00	Mill hardened to specific property ranges, no further heat treatment is required.	
1/4 HM	TM01		
1/2 HM	TM02		
HM	TM04		
SHM	TM05		
XHM	TM06		
XHMS	TM08		
HTR	–	Mill hardened to provide properties not available by standard age hardening. Alloy 3 only.	
HTC	–		

Mechanical and Electrical Properties of Copper Beryllium Strip

Alloy	Temper (note 2)	Tensile Strength (ksi)	Yield Strength 0.2% offset (ksi)	Elongation Percent (note 3)	Fatigue Strength (ksi) R = -1, 10^8 cycles	HARDNESS (see note 4)		
						Diamond Pyramid	Rockwell	
							B or C	Superficial	Electrical Conductivity (% IACS)
25 C17200	**A** Dead Soft (TB00)[1]	60-76	28-36	35-65	30-35	90-144	B45-78	30T46-67	15-19
	A Planished (TB00)[1]	60-78	30-55	35-60	30-35	90-144	B45-78	30T46-67	15-19
	1/4 H (TD01)	75-88	60-80	20-45	31-36	121-185	B68-90	30T62-75	15-19
	1/2 H (TD02)	85-100	75-95	12-30	32-38	176-216	B88-96	30T74-79	15-19
	H (TD04)	100-120	90-115	2-18	35-39	216-287	B96-102	30T79-83	15-19
	AT (TF00)[5]	165-195	140-175	3-15	40-45	353-413	C36-42	30N56-62	22-28
	1/4 HT (TH01)[6]	175-205	150-185	3-10	40-45	353-424	C36-43	30N56-63	22-28
	1/2 HT (TH02)[6]	185-215	160-195	1-8	42-47	373-435	C38-44	30N58-63	22-28
	HT (TH04)[6]	190-220	165-205	1-6	45-50	373-446	C38-45	30N58-65	22-28
190 C17200	**AM** (TM00)	100-110	70-95	16-30	40-45	210-251	B95-C23	30N37-44	17-28
	1/4 HM (TM01)	110-120	80-110	15-25	41-47	230-271	C20-26	30N41-47	17-28
	1/2 HM (TM02)	120-135	95-125	12-22	42-48	250-301	C23-30	30N44-51	17-28
	HM (TM04)	135-150	110-135	9-20	45-52	285-343	C28-35	30N48-55	17-28
	SHM (TM05)	150-160	125-140	9-18	47-55	309-363	C31-37	30N52-56	17-28
	XHM (TM06)	155-175	135-170	4-15	50-57	317-378	C32-38	30N52-58	17-28
	XHMS (TM08)	175-190	150-180	3-12	50-60	325-413	C33-42	30N53-62	17-28

Brushform® 290 C17200	**TM00**	100 min	75-95	19-35	40-45	225-309	B98-C31	30T81-30N52	17-26
	TM02	120 min	95-115	14-30	42-48	255-339	C25-34	30N46-54	17-26
	TM04	140 min	115-135	9-25	44-50	285-369	C28-38	30N48-58	17-26
	TM06	155 min	135-155	6-13	47-57	317-393	C32-40	30N52-60	17-26
	TM08	175 min	155-175	3-15	50-60	345-429	C35-43	30N55-62	17-26
Brush 60® C17460	**3/4 HT** (TH03)	115-135	95-115	11 min	46-47	_	_	_	50 min
	HT (TH04)	120-140	105-125	10 min	42-45	_	_	_	50 min
174 C17410	**1/2 HT** (TH02)	95-115	80-100	10-20	40-45	180-230	B89-98	30T75-82	50 min
	HT (TH04)	110-130	100-120	7-17	40-45	210-278	B95-102	30T79-30N48	45-60
3 C17510	**AT** (TF00)	100-130	80-100	10-25	38-44	195-275	B92-100	30T77-82	45-60
	HT (TH04)	110-135	95-120	8-20	42-47	216-287	B95-102	30T79-83	48-60
Alloy 390™ C17460	**HT**	135-153	138-158	1 min.	35-40	_	_	_	44 min.

NOTES:
1. Annealed strip is available dead soft or planished. Dead soft offers maximum deep drawing capability, but planished strip often is preferred for precision stamping.
2. ASTM alphanumeric code for product tempers in parentheses.
3. Elongation applies to strip 0.004 inch and thicker.
4. Diamond pyramid hardness numbers are a direct conversion from the Rockwell hardness scale.
5. Age 3 hrs at 600°F (315 C).
6. Age 2 hrs at 600°F (315 C).

Forming

The accompanying table is a guide to temper selection based on forming requirements. The R/t ratios in the table indicate the allowable punch radius (R) for a 90 degree bend as a function of strip thickness (t). Low R/t implies high formability.

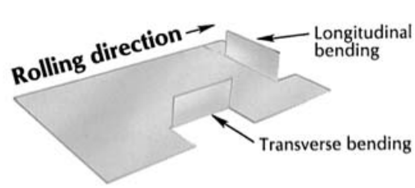
Annealed strip has excellent formability with both longitudinal and transverse bends posing no forming problems. Certain mill hardened tempers also have low directionality. Because of this isotropy, special consideration does not have to be given to the manner in which parts are stamped relative to the rolling direction. In many instances

Formability

Formability Rating	Specific Formability	Alloy and Heat-treatable Temper	R/t Ratio for 90° Bend Direction of Bend		Alloy and Mill Hardened Temper	R/T Ratio for 90° Bend Director of Bend	
			L	T		L	T
Excellent	Used for deep drawn and severely cupped or formed parts	25A	0	0			
Excellent	As formable as the annealed temper but easier to blank	25 1/4H	0	0	290 TM00 290 TM02	0 0	0 0
Very Good	Used for moderately drawn or cupped parts.	25 1/2H	0.5	1.0	190 AM 174 1/2 HT 190 1/4 HM 60 3/4 HT 3 AT 290 TM04	0 0.5 0.5 0.7 1.0 1.0	0 0.5 0.5 0.7 1.0 1.0
Good	Formable to a 90° bend around a radius less than 3 times the stock thickness	25H	1.0	2.9	190 1/2 HM 60 HT 390HT(<0.004") 3 HT 190 HM 290 TM06	0.5 1.5 2.0 2.0 2.0 2.5	1.0 1.5 2.0 2.0 2.0 2.0
Moderate	Suitable for light drawing; used for springs				174 HT 190 SHM 290 TM08 390HT(>0.004") 190 XHM	1.2 2.8 3.5 3.5 4.0	5.0 3.2 3.0 3.5 5.0
Limited	For essentially flat parts; forming requires very generous punch radius				190 XHMS	5.0	10.0

Note: Formability ratios are valid for strip up to 0.050 inch thick. Strip less than 0.010 inch thick will form somewhat better than shown. Values reflect the smallest punch radius that forms a strip sample into a 90° "vee"-shaped die without failure.

R = punch radius   t = stock thickness



this will permit nesting of parts to allow efficient material utilization.

The tooling requirements for stamping and drawing copper beryllium are the same as those required for any copper base alloy with similar hardness. Tools should be kept sharp, with punch to die clearances of about 5% of the stock thickness (or 2-1/2% per side). This practice will minimize edge burr formation during blanking or shearing. Burrs should be removed prior to age hardening since they can be the source of fatigue failure in highly stressed parts. Draft angles should be about 1/2 degree per side greater than those used for phosphor bronze or brass to preclude copper beryllium buildup on the punches, which could change die clearances. Lubricants can prolong die life, but those containing sulfur may cause staining and a possible embrittlement of copper beryllium.

Springback becomes more pronounced as temper and strength increase. Springback can be controlled by overforming bends to achieve required angles. For a given punch radius, springback decreases with increasing strip thickness.

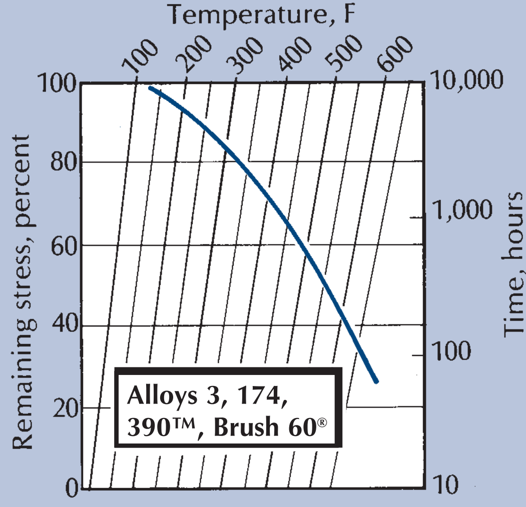
Stress Relaxation Resistance

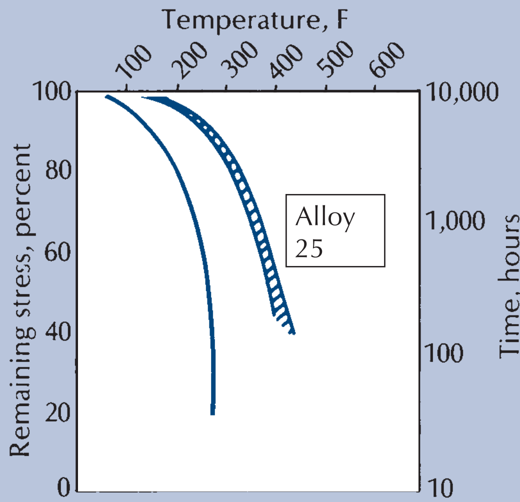
Copper beryllium alloys are often chosen because of their inherent resistance to stress relaxation. Miniaturization in computer hardware, automotive interconnections and aerospace systems has accented the importance of high thermal stability. Today, many electronic contacts and other spring elements must remain stable longer while operating at higher temperatures than ever before.

Stress relaxation is commonly evaluated on samples cut from strip and subjected to constant elastic bending strain at moderately elevated temperature. In one common method, a sample is secured in a fixture and deflected as a cantilever beam to an initial stress that is a predetermined fraction of the alloy's 0.2 percent yield strength, typically 75 percent. The fixture and deflected sample are exposed to high temperature for extended time, usually up to 1,000 hours. Stress relaxation causes permanent set. The ratio of permanent set to initial deflection defines the degree of loss of initial bending stress caused by relaxation.

The stress relaxation behavior of several alloys is displayed in the figures on this page. In these figures, the percentage of bending stress remaining after exposure is related to temperature and time by a Larson-Miller technique. This method allows extrapolation over a range of time and temperature.

Stress Relaxation Resistance





Stress Relaxation Resistance

1. Select the accumulated exposure time along the right hand axis.
2. Extend a horizontal line from this point to the exposure temperature line (the diagonal lines that are identified at top).
3. Draw a vertical line from the time-temperature intersection point to the stress relaxation curve.
4. Draw a horizontal line from this intersection to the remaining stress axis to determine the percentage of stress remaining after exposure.

Wire

Wire is one of the most versatile copper beryllium product forms with no other product having applications based on as many diverse attributes. Applications of round wire include:

- Miniature machined electronic sockets
- Long travel coil springs
- Cold headed fasteners
- Spring loaded test probes
- Lightweight, fatigue resistant stranded cable
- Bandoliered connector contacts
- Braided shielding cloth
- Corrosion and biofouling resistant marine wire and wire mesh structures
- Eyeglass frames

Specifications

Brush Alloy	UNS Number	Wire
25	C17200	ASTM B 197 QQ-C-530 AMS 4725 SAE J 461, 463
M25	C17300	ASTM B 197 QQ-C-530
3	C17510	*
10	C17500	*

ASTM American Society for Testing and Materials
QQ Federal Specification
SAE Society of Automotive Engineers
AMS Aerospace Materials Specification (Published by SAE)
Note: Unless otherwise specified, material will be produced to ASTM specification.
*Product available, specifications being prepared

Wire that is straightened and cut to length is called rod.

Wire is available with cross sections other than round. "Shaped" wire plays an important role in specialized applications. For example, flat wire is used in retractable antennas and telecommunication cables. Flat wire can also be used in place of narrow slit strip. Although there is a width to thickness ratio above which flat wire is impractical, many times a savings is realized. Flat wire eliminates a slitting burr.

Square wire is used in electronic contacts especially where wire wrapping requires sharp corners for reliable contact. Occasionally square or rectangular wire requires a beveled corner for orientation. These and other less common shape requirements can be met with copper beryllium wire.

Brush Wellman supplies wire in diameters from 0.500 inch down to 0.050 inch with tolerances shown in the table on this page. Finer wire can be supplied either by special order from Brush Wellman or from anyone of a number of copper beryllium wire redrawers.

Wire is supplied annealed (A), or in quarter hard (1/4H), half hard (1/2H), or full hard (H) tempers. In special cases however, prehardened (also called "pretempered") wire is available. This product offers versatility in strength and durability for products with mild to somewhat stringent forming requirements.

Tolerance
(inches)

Wire Diameter		Brush Wellman Standard Tolerance (plus or minus)	
over	**incl.**	**Cold Drawn**	**Annealed**
0.0500 -	0.0800	0.0003	0.001
0.0800 -	0.1250	0.0004	0.002
0.1250 -	0.2500	0.0006	0.002
0.2500 -	0.3125	0.0007	0.002
0.3125 -	0.4060	0.0010	0.002
0.4060 -	0.500	0.0010	0.002

Note: Out of Round tolerance is half the diameter tolerance.

Mechanical and Electrical Properties of Copper Beryllium Wire

Alloy	Temper (*)	Heat Treatment	Wire Diameter inch	Tensile Strength ksi	Yield Strength 0.2% offset ksi	Elongation percent	Electrical Conductivity percent IACS
25 C17200 and M25 C17300	**A** (TB00)	–	0.050-0.500	58-78	20-30	30-60	15-19
	1/4 H (TD01)	–	0.050-0.500	90-115	75-105	3-25	15-19
	1/2 H (TD02)	–	0.050-0.500	110-135	90-125	2-15	15-19
	3/4 H (TD03)	–	0.050-0.080	130-155	115-150	2-8	15-19
	H (TD04)	–	0.050-0.080	140-165	130-160	1-6	15-19
	AT (TF00)	3 hr 600-625F	0.050-0.500	160-200	145-180	3 min	22-28
	1/4 HT (TH01)	2 hr 600-625F	0.050-0.500	175-210	165-200	2 min	22-28
	1/2 HT (TH02)	1-1/2hr 600-625F	0.050-0.500	185-215	170-210	2 min	22-28
	3/4 HT (TH03)	1 hr 600-625F	0.050-0.080	190-230	175-220	2 min	22-28
	HT (TH04)	1 hr 600-625F	0.050-0.080	195-230	180-220	1 min	22-28
3 C17510 and 10 C17500	**A** (TB00)	–	0.050-0.500	35-55	10-30	20-60	20-30
	H (TD04)	–	0.050-0.500	65-80	55-75	2-20	20-30
	AT (TF00)	3 hr 900-925F	0.050-0.500	100-130	80-110	10 min	45-60
	HT (TH04)	2 hr 900-925F	0.050-0.500	110-140	95-125	10 min	48-60

*ASTM alphanumeric code for product tempers.

Rod, Bar and Tube

Lengths from one inch to thirty feet; sections from 3/8 inch to more than 9 inches; precision and versatility from cold drawing and extrusion; simplicity of age hardening; strength, corrosion resistance, machinability...these are just a few of the useful features that make rod, bar, and tube unique.

Rod is supplied in straight lengths for machining or forming into finished components by the user. Forming is done before age hardening, machining usually after hardening. Typical applications include:

- Low maintenance bearings and bushings
- Rugged resistance welding gun structural components
- Core pins and other inserts for plastic injection molding and metal die casting

Bar also is produced in straight lengths, but has a cross section other than round. Square, rectangular and hexagonal are, the most common.

Specifications

Brush Alloy	UNS Number	Rod, Bar and Tube
25	C17200	ASTM B 196, 251, 643 QQ-C-530 MIL-C-21657 SAE J 461, 463 AMS 4533, 4534, 4535, AMS 4650, 4651 RWMA Class 4
M25	C17300	ASTM B 196 QQ-C-530 MIL-C-21657
165	C17000	ASTM B 196 SAE J 461, 463 RWMA Class 4
3	C17510	ASTM B 441, 937 SAE J 461, 463 RWMA Class 3
10	C17500	ASTM B 441, 937 SAE J 461, 463 RWMA Class 3

ASTM American Society for Testing and Materials
QQ Federal Specification
MIL Military Specification
SAE Society of Automotive Engineers
AMS Aerospace Materials Specification (Published by SAE)
RWMA Resistance Welder Manufacturer's Association
Note: Unless otherwise specified, material will be produced to ASTM specification.

Applications include:

- Antigalling wear plates
- Guide rails and bus bars
- Machined threaded fasteners
- Die inserts for resistance welding

Tube comes in a wide range of diameter/wall thickness combinations. These range from the ultra thin wall configurations produced by tube redrawing specialists, to light wall cold drawn tube, to heavy wall hot worked product. Typical applications are:

- High deflection, strong instrument tubes such as bourdon and pitot types (redrawn tube)
- Bearings for aircraft landing gear and pivoting members
- Long life tri-cone drilling bit bushings
- Pressure housings for precision magnetometers and other instruments

An important use of rod, bar and tube is in products for resistance welding applications. Copper beryllium fills the needs of this industry by providing hardness and electrical conductivity for precision in structural components and durability in electrodes. Ease of fabrication in bending and machining also contributes to cost effective resistance welding.

Rod, bar and tube are available in the hardened condition. Annealed and precipitation hardened (AT), and annealed, cold drawn and precipitation hardened (HT) tempers are available as shown in the table on page 17.

Tolerance
(inches)

Product	Dimension over	Dimension incl.	Brush Wellman Standard Tolerance plus or minus
Cold Drawn	0.375	0.500	0.002
Round Rod	0.500	1.00	0.003
(diameter)	1.00	2.00	0.004
	2.00	3.00	0.2% of size
Cold Drawn	0.150	0.500	0.004
Hex Rod	0.500	1.00	0.005
(diameter)	1.00	2.00	0.006
	2.00	3.00	0.4% of size
As extruded	0.750	1.25	0.020
Round Rod	1.25	2.50	0.030
(diameter)	2.50	6.00	0.060

Mechanical and Electrical Properties of Copper Beryllium Rod, Bar and Tube

Alloy	Temper (*)	Heat Treatment	Outside Diameter or Distance Between Parallel Surfaces inch	Tensile Strength ksi	Yield Strength 0.2% offset ksi	Elongation percent	Hardness Rockwell B or C Scale	Electrical Conductivity percent IACS
25 C17200 and M25 C17300	**A** (TB00)		all sizes	60-85	20-35	20-60	B45-85	15-19
	H (TD04)		up to ⅜	90-130	75-105	8-30	B88-103	15-19
			over ⅜ to 1	90-125	75-105	8-30	B88-102	15-19
			over 1 to 3	85-120	75-105	8-20	B88-101	15-19
	AT (TF00)	3 hr 600°F-625°F	up to 3	165-200	145-175	4-10	C36-42	22-28
			over 3	165-200	130-175	3-10	C36-42	22-28
	HT (TH04)	2-3 hr 600°F-625°F	up to ⅜	185-225	160-200	2-9	C39-45	22-28
			over ⅜ to 1	180-220	155-195	2-9	C38-44	22-28
			over 1 to 3	175-215	145-190	4-9	C37-44	22-28
165 C17000	**A** (TB00)		all sizes	60-85	20-35	20-60	B45-85	15-19
	H (TD04)		up to ⅜	90-130	75-105	8-30	B92-103	15-19
			over ⅜ to 1	90-125	75-105	8-30	B91-102	15-19
			over 1 to 3	85-120	75-105	8-20	B88-101	15-19
	AT (TF00)	3 hr 600°F-625°F	up to 3	150-190	125-155	4-10	C32-39	22-28
			over 3	150-190	125-155	3-10	C32-39	22-28
	HT (TH04)	2-3 hr 600°F-625°F	up to ⅜	170-210	145-185	2-5	C35-41	22-28
			over ⅜ to 1	170-210	145-185	2-5	C35-41	22-28
			over 1 to 3	165-200	135-175	4-9	C34-39	22-28
3 C17510 and 10 C17500	**A** (TB00)		all sizes	35-55	10-30	20-35	B20-50	20-30
	H (TD04)		up to 3	65-80	50-75	10-15	B60-80	20-30
	AT (TF00)	3 hr 900°F	all sizes	100-130	80-100	10-25	B92-100	45-60
	HT (TH04)	2 hr 900°F	up to 3	110-140	95-125	5-25	B95-102	48-60

*ASTM alphanumeric code for product tempers.

Plate and Rolled Bar

Plate and rolled bar are made with exacting attention to detail. Plate is a straight length of flat rolled product thicker than 0.188 inches and wider than 12 inches. Rolled bar is a rectangular or square section that is abrasively cut or sawed from plate.

Solution annealed (A), cold rolled (H), and age hardened tempers (AT and HT) are available. Temper selection depends on the application and the method of component fabrication. For example, with Alloy 25 the annealed temper is the preferred selection when small holes are to be drilled; age hardening to the desired hardness is performed after drilling. Heat treated alloys are selected when heavier cuts using more rigid tooling can be made.

If the "A" or "H" temper is selected, parts are usually machined oversize to accommodate the slight dimensional change that occurs during hardening. The parts are then finish machined.

These flat rolled products are noted for dimensional stability both in precision machining and in service. Thermal management devices of various types are common applications. Thermal conductivity, fatigue resistance, and excellent machinability are key features contributing to cost effective use.

Examples of plate and rolled bar applications are:

- Heat tolerant molds for plastic injection systems
- Structural components in electrical resistance welding
- Galling resistant wear plates and rub strips
- Metal die casting, plastic blow molding, and injection molding inserts
- Water cooled chill plates for computer memory devices
- Damage resistance, nonsparking tools

Specifications

Brush Alloy	UNS Number	Plate and Rolled Bar
25	C17200	ASTM B 194 QQ-C-530 SAE J 461, 463 AMS 4530, 4533, 4534 AMS 4650, 4651 RWMA Class 4
165	C17000	ASTM B 534 SAE J 461, 463 RWMA Class 4
3	C17510	ASTM B 534 SAE J 461, 463 RWMA Class 3
10	C17500	ASTM B 534 SAE J 461, 463 RWMA Class 3

ASTM American Society for Testing and Materials
QQ Federal Specification
MIL Military Specification
SAE Society of Automotive Engineers
AMS Aerospace Materials Specification (Published by SAE)
RWMA Resistance Welder Manufacturer's Association
Note: Unless otherwise specified, material will be produced to ASTM specification.

Tolerance
(inches)

Thickness		Brush Wellman Standard Tolerance	
over	incl.	plus	minus
0.188	0.205	0.010	0
0.205	0.300	0.012	0
0.300	0.500	0.015	0
0.500	0.750	0.019	0
0.750	1.00	0.023	0
1.00	1.50	0.028	0
1.50	3.0	0.033	0

Note: Tolerances are for widths up to 24 inches. Specific width tolerance is plus or minus 1/16 inch.

Mechanical and Electrical Properties of Copper Beryllium Plate and Rolled Bar

Alloy	Temper (*)	Heat Treatment	Thickness inch	Tensile Strength ksi	Yield Strength 0.2% offset ksi	Elongation percent	Hardness Rockwell B or C Scale	Electrical Conductivity percent IACS
25 C17200	**A** (TB00)		all sizes	60-85	20-35	20-60	B45-85	15-19
	H (TD04)		up to ⅜	90-130	75-105	8-20	B91-103	15-19
			over ⅜ to 1	90-125	75-105	8-20	B90-102	15-19
			over 1 to 2	85-120	75-105	8-20	B88-102	15-19
			over 2 to 3	85-120	75-105	8-20	B88-102	15-19
	AT (TF00)	3 hr 625°F	all sizes	165-200	140-175	3-10	C36-41	22-28
	HT (TH04)	2 hr 625°F	up to ⅜	180-215	160-200	1-5	C38-45	22-28
			over ⅜ to 1	180-220	155-200	1-5	C38-44	22-28
			over 1 to 2	175-215	150-200	2-5	C37-43	22-28
			over 2 to 3	165-200	130-180	2-5	C36-42	22-28
165 C17000	**A** (TB00)		all sizes	60-85	20-35	20-60	B45-85	15-19
	H (TD04)		up to ⅜	90-130	75-105	8-20	B92-103	15-19
			over ⅜ to 1	90-125	75-105	8-20	B91-102	15-19
			over 1 to 2	85-120	75-105	8-20	B88-101	15-19
			over 2 to 3	85-120	75-105	8-20	B88-101	15-19
	AT (TF00)	3 hr 625°F	all sizes	150-190	130-155	3-10	C33-39	22-28
	HT (TH04)	2 hr 625°F	up to ⅜	170-210	135-165	2-5	C35-41	22-28
			over ⅜ to 1	170-210	135-165	2-5	C35-41	22-28
			over 1 to 2	165-200	135-165	2-5	C34-39	22-28
			over 2 to 3	160-190	125-165	2-5	C34-38	22-28
3 C17510 and 10 C17500	**A** (TB00)		all sizes	35-55	25-45	20-35	B20-45	20-30
	H (TD04)		up to 3	70-85	55-80	2-8	B78-88	20-30
	AT (TF00)	3 hr 900°F	all sizes	100-130	80-100	8-20	B92-100	45-60
	HT (TH04)	2 hr 900°F	up to 3	110-140	100-120	5-15	B95-102	48-60

*ASTM alphanumeric code for product tempers.

Forgings and Extrusions

The ease with which copper beryllium can be worked allows fabrication of large, near-net shape components by forging and extrusion.

Forging extends the size range available in copper beryllium components. Processes include rotary forging, ring rolling, roll forging, swaging, cold heading, and various open and closed die techniques. Forgings include:

- Disc shaped resistance seam welding electrodes (open die forging)
- Generator rings (ring forged)
- Aerospace and hydrospace components
- Gears and power transmission couplings

Extrusions find application in continuous long lengths, where economy is achieved by near-net shape techniques; in short lengths where near-net shape processing is combined with high production rate; and in back extruded parts where relatively large diameter hollows can be produced economically. Extrusions include:

- Wear resistant guide rails for computer peripheral equipment
- Heat and fatigue resistant mold segments for continuous casting equipment
- Abrasion and galling resistant dies and die inserts for resistance flash welding
- Corrosion resistant, antigalling cylinders for under-sea cable communication system repeater housings

Specifications

Brush Alloy	UNS Number	Forgings and Extrusions
25	C17200	ASTM B 570 QQ-C-530 SAE J 461, 463 AMS 4650 RWMA Class 4
165	C17000	ASTM B 570 SAE J 461, 463 RWMA Class 4
3	C17510	RWMA Class 3
10	C17500	SAE J 461, 463 RWMA Class 3

ASTM American Society for Testing and Materials
QQ Federal Specification
SAE Society of Automotive Engineers
AMS Aerospace Materials Specification (Published by SAE)
RWMA Resistance Welder Manufacturer's Association
Note: Unless otherwise specified, material will be produced to ASTM specification.

Mechanical and Electrical Properties of Copper Beryllium Forgings and Extrusions

Alloy	Temper (*)	Heat Treatment	Tensile Strength ksi	Yield Strength 0.2% offset ksi	Elongation percent	Hardness Rockwell B or C Scale	Electrical Conductivity percent IACS
25 C17200	**A** (TB00)		60-85	20-40	35-60	B45-85	15-19
	AT (TF00)	3 hr 625°F	165-200	130-175	3-10	C36-42	22-28
165 C17000	**A** (TB00)		60-85	20-40	35-60	B45-85	15-19
	AT (TF00)	3 hr 650°F	150-190	120-155	3-10	C32-39	22-28
3 C17510 and 10 C17500	**A** (TB00)		35-55	20-40	20-35	B20-50	20-35
	AT (TF00)	3 hr 900°F	100-120	80-100	10-25	B92-100	45-60

*ASTM alphanumeric code for product tempers.

Drill String Products

A special temper of copper beryllium has been developed to meet the specific needs of oil and gas well drilling. Components for this demanding environment serve as part of the drill string's bottomhole assembly and enclose sensitive magnetic measuring instrumentation. These tubular components must be transparent to magnetic fields, must resist corrosion, must be strong enough to withstand the stress of tightly torqued threaded connections, and tough enough to withstand the rotating and bending abuse of downhole service.

A copper beryllium grade called **Brush Alloy 25 Drill String Temper** meets these requirements. In addition, it is noted for its ability to minimize galling in threaded tool joints. The "thread saver sub", for example, eliminates galled threads in the drill string bottomhole assembly and prolongs the life of adjoining components.

Drill String Temper is not susceptible to chloride stress corrosion cracking as the table on this page shows. It resists carbon dioxide and it is effectively immune to hydrogen embrittlement. In sour environments it is used for drilling and well logging where exposure is intermittent and inhibitors are used.

Brush Alloy 25 has low magnetic permeability (between 0.997 and 1.003) that does not change under severe service or handling, is easily machined, and resists thread damage without the need for special coatings or treatments.

Brush Alloy 25 meets all requirements of **American Petroleum Institute Spec 7** for drill collars and rotary substitutes. Mechanical properties and results of performance tests are in the accompanying tables. Examples of drill string applications are:

- Nonmagnetic drill collars
- Measurement while drilling components
- Instrument housings
- Threaded saver subs
- Drill rod for coring tools in mining or hydrocarbon drilling and exploration
- Mud motor flexible drive shafts
- Cross over subs

Resistance to Chloride Stress Corrosion Cracking

Temperature°F	300	311	300
Applied stress (percent of 0.2% yield strength)	100	100	100
Oxygen content (parts per million in saturating gas)	1*	1	5000*
pH	8	3	7
Chloride concentration (weight percent)			
sodium	3	0	0
potassium	10	0	6
magnesium	0	42	25
Test duration, hours	720	1000	1000
Test result	no cracking	no cracking	no cracking

*Total pressure 1000 psi

Mechanical Properties for Copper Beryllium Drill String Subs and Collars

Drill Collar Outside Dia. inches	Minimum Tensile Strength ksi	Minimum Yield Strength 0.2% offset ksi	Minimum Elongation percent
up to 7	140	110	12
7 - 11	135	100	13
over 11	120	90	13

Note: Tensile tests per ASTM E 8
Yield strength by 0.2% offset method.

Resistance to Galling in Threaded Joint

Couple (pin/box)	Onset of Galling Failure (percent of API Minimum Torque)	
	Lubricated	Nonlubricated
Stainless/Stainless[1]	130	< 100
Alloy25/Stainless[2]	NF at 180	–
Alloy25/Stainless[1]	NF at 200	200
Alloy25/AISI 4140[2]	NF at 205	–
Alloy25/Alloy25[1]	NF at 200	NF at 200

[1]API NC-38
[2]API 6-5/8 REG

NF – No Failure

Other Products and Services

In addition to the copper beryllium products detailed in this book, Brush Wellman offers a full line of cast and wrought products and a range of special customer services. A few are described on this page, but the number far exceeds those listed. Brush is always willing to work with users to find a product or service that makes an application succeed.

Master Alloys

Common **master alloys** include 4% beryllium copper, 5% beryllium aluminum, and 6% beryllium nickel. Supplied as ingot or shot, master alloy is a melt additive used for one or more of the following purposes: to deoxidize or desulfurize copper and nickel; to harden copper, nickel, and aluminum; to improve cleanliness, fluidity, and corrosion resistance in aluminum; to minimize loss of oxidizable elements such as magnesium in aluminum; to protect against oxidation and melt ignition in magnesium; and to control composition in production of commercial beryllium-containing alloys in many base metal systems.

Casting Ingot

Copper beryllium **casting ingot** is available in high conductivity and high strength compositions for casting without additions. Investment, shell, permanent mold, sand, centrifugal and pressure casting are a few of the methods used. Beryllium in copper increases melt fluidity and cleanliness while providing a heat treatable casting. Replication of mold detail in cast parts is excellent.

moldMAX® and PROtherm®

moldMAX® and PROtherm® are available in a selection of plate thickness and rod diameters. These heat treated materials are used as mold components in the manufacture of plastic parts.

Nickel Beryllium

For applications requiring high strength for service at temperatures up to 700 F, Brush Wellman produces nickel beryllium Alloy 360. The fully aged alloy is capable of tensile strength approaching 300 ksi.

Manufacturing Services

For copper beryllium requirements beyond those described in the Product Guide, our manufacturing facilities and service centers are prepared to meet your special needs. Examples include the following:

- Traverse winding
- Tension leveling of cold rolled strip
- Near net shape sawing of billet, plate and rod
- Shearing no specific length
- Tin or solder coating

Custom Fabrication

Custom Fabrication offers the user an alternative to inhouse fabrication of copper beryllium parts. Brush Wellman's manufacturing capability often provides an economical route to a custom input blank for the user's finish machining process. An experienced Brush Wellman team, after completing a producibility analysis of the customer's drawings and specifications can offer guidelines to producing a quality product cost effectively and on time.

Certified Suppliers

In response to a need beyond internal capabilities, Brush Wellman can refer the user to a supplier with demonstrated expertise in manufacturing copper beryllium products with specialized equipment and technology. Examples include the following:

- Fine wire drawing
- Thin foil rolling
- Thin wall tube redrawing
- Multigage strip contouring
- Prototype blanking and forming
- Photochemical machining
- Fixture age hardening
- Joining
- Inlay cladding
- Solder striping
- Electron beam welding
- Zone annealing
- Electroplating

Contact a Brush representative to explore opportunities.

Engineering Guide

Topics related to designing and working with copper beryllium are highlighted in this section. The emphasis is on alloy and product performance in fabrication and service environments. When more detail is needed, information is available in separate Brush Wellman publications.

Heat Treating Fundamentals

An awareness of the ways that composition, cold work, and thermal processes interact to synthesize properties and microstructure is useful in designing and working with copper beryllium. Small beryllium additions to copper, activated by mechanical and thermal processing, result in strength exceeding that of most copper base alloys and many hardened steels. Furthermore, controlled mechanical working and specific thermal processing allow properties to be tailored to meet a broad range of requirements. These fundamental effects are explored on the following pages.

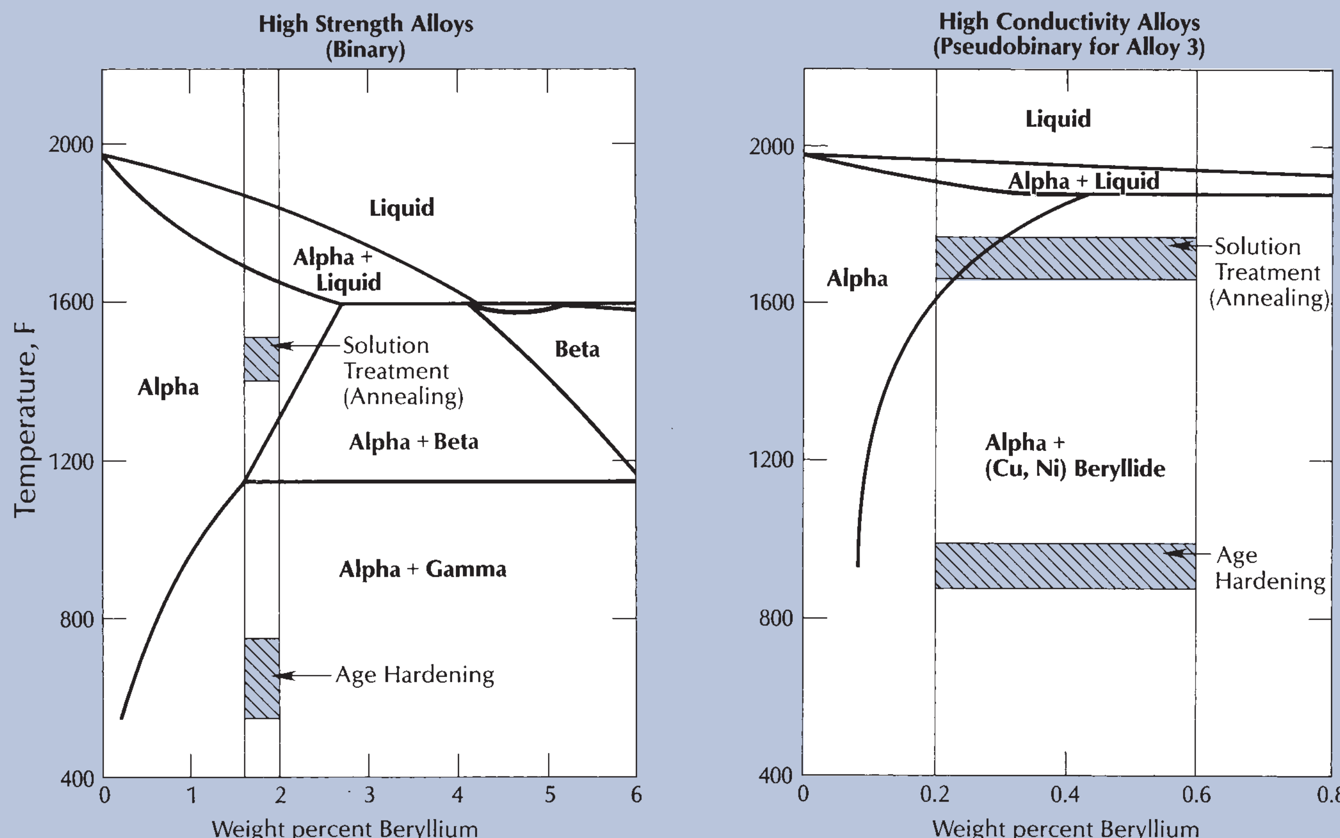
Phase Diagrams

A binary equilibrium phase diagram approximating the behavior of **high strength alloys** is shown below. Since these alloys contain up to 0.6 weight percent total cobalt and nickel in addition to beryllium, the binary phase diagram is not rigorously appropriate but it helps in describing alloy behavior.

At concentrations of 1.6 to 2.0 weight percent beryllium, a beryllium rich constituent known as gamma phase is present below 1100 F. This phase forms as a result of the limited solid solubility of beryllium. In these alloys it is the primary contributor to precipitation hardening.

The binary diagram shows that heating above 1300 F causes beryllium to dissolve in the alpha solid solution phase. A rapid quench to room temperature maintains beryllium in solid solution. This process, called solution annealing, makes the alloy soft and ductile, helps regulate grain size, and prepares the alloy for age hardening. Since it is performed as part of the manufacturing process, most users do not anneal copper beryllium.

Beryllium in Copper



Heating the supersaturated solid solution to 600 F and holding for 2 to 3 hours causes precipitation of the strengthening phase and hardens the alloy.

The binary phase diagram shows that at 1590 F the solubility limit is 2.7 percent (the cobalt addition reduces this to about 2.3). At room temperature, less than 0.25 percent beryllium is soluble. This difference in solubility is the driving force for hardening; few other copper alloys compare. There are three reasons for adding cobalt to high strength alloys. First, and most important, this addition promotes fine grain size by limiting grain growth during solution annealing. Second, cobalt makes precipitation hardening less time sensitive. Third, it increases maximum strength slightly.

A pseudobinary phase diagram (nickel beryllide in copper) for Alloy 3, a typical high conductivity alloy, is shown at the right on page 24. Altogether, the high conductivity alloys span the range from 0.15 to 0.7 weight percent beryllium. However, in these alloys most of the beryllium is partitioned to beryllide intermetallics. Coarse beryllides formed during solidification limit grain growth during annealing, while fine beryllides formed during precipitation hardening impart strength.

The temperature ranges for solution annealing, and for age hardening are higher for these alloys than for the high strength alloys. The stability of the strengthening phase at elevated temperature results in high resistance to creep and stress relaxation in this alloy family.

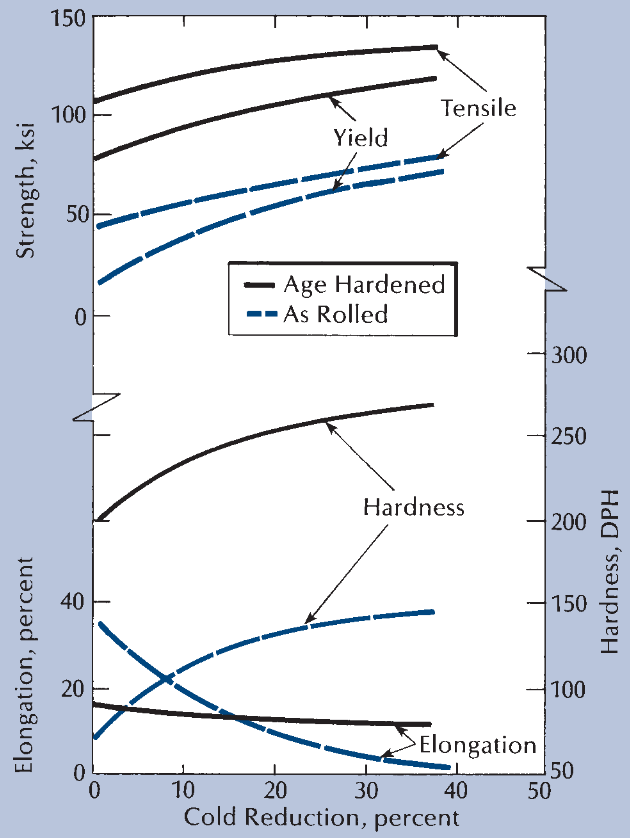
Cold Work Response

Cold work in an age hardening alloy denotes plastic deformation at a temperature below the onset of precipitation. A metalworking process changes the dimensions of a workpiece, typically in two directions, with rolling, drawing, bending, and upsetting being prime examples of cold working operations. In contrast to hot working, cold work elongates grains in the working direction, and deformation effects accumulate.

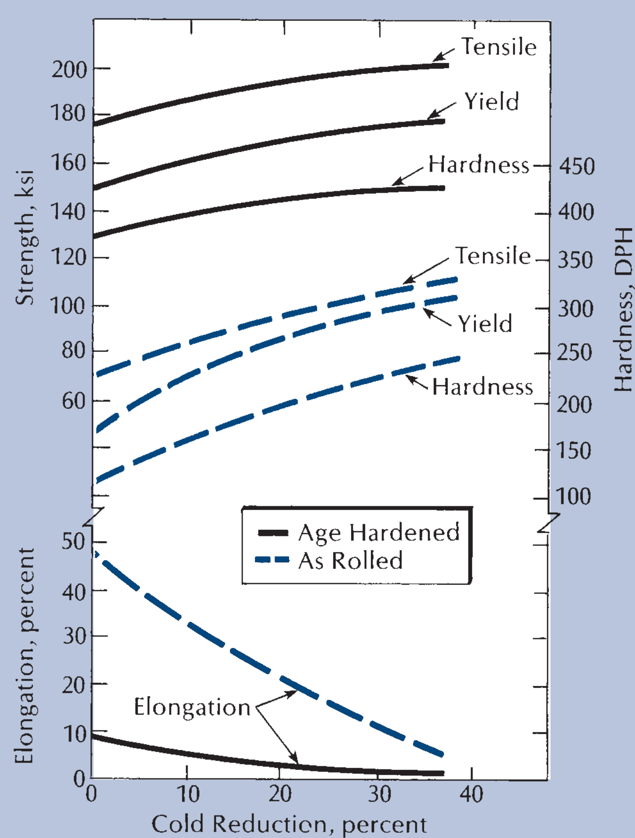
Cold work increases strength and hardness of copper beryllium as shown in the figures on this page. A reduction in ductility, measured by elongation, accompanies this increase in strength.

The strengthening effects of cold work are especially important in age hardened products (see figures). Cold work increases the number of precipitation sites and thereby accelerates age hardening. However, elongation declines as cold work increases, but at a much lower rate than in the unaged product.

Alloy 3



Alloy 25



During processing of mill products, cold working produces excellent dimensional precision and shape. Annealing of cold worked copper beryllium under closely controlled conditions causes grain refinement and reduces property directionality. Incorporating a well engineered schedule of cold work and annealing cycles into our mill process ensures a product with precise dimensions and a well controlled microstructure.

Age Hardening

Age hardening response depends on time, temperature, and amount of cold work because strengthening is governed by precipitate size and distribution. For each alloy there is a temperature-time combination that is designated as standard practice because it produces maximum strength.

Departures from standard practice, either higher or lower temperatures for example, may be used to meet requirements that permit less than maximum strength or hardness. A temperature higher than standard causes more rapid precipitation and thus faster strengthening, while a lower temperature results in a slower strengthening rate.

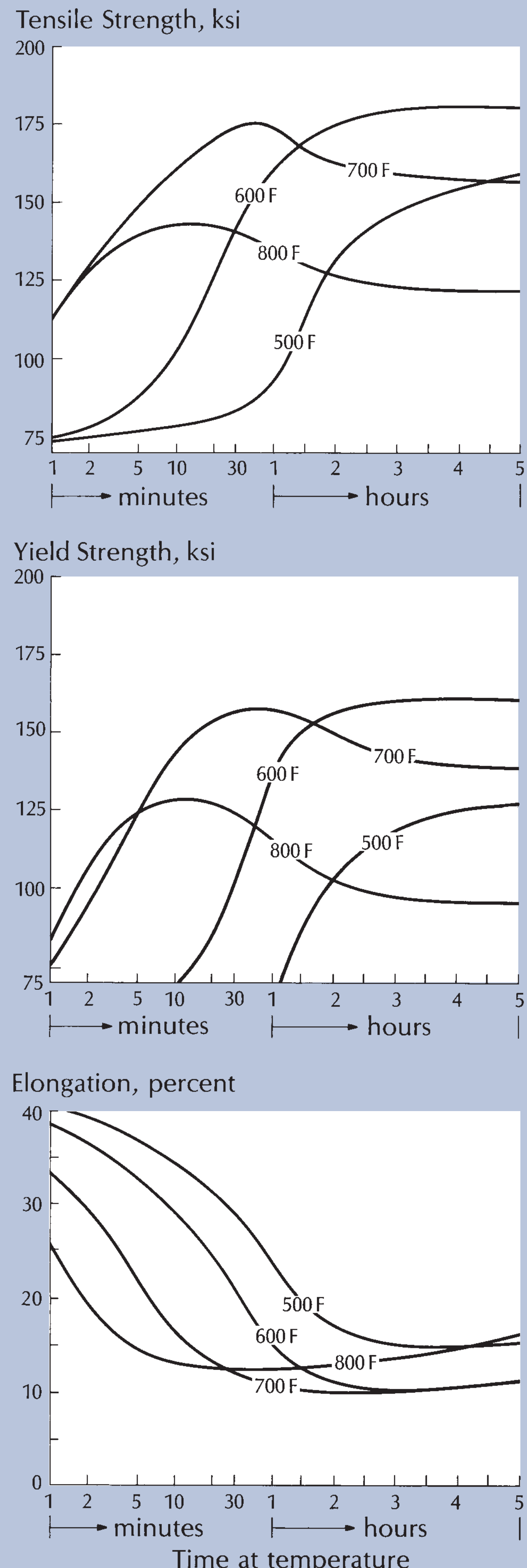
Cessation of aging at times shorter than the time needed to achieve peak strength is known as "underaging". Toughness, fatigue strength and in some cases corrosion resistance, benefit from the underaged microstructure.

"Overaging" involves heating for a time longer than needed to achieve peak strength. This results in precipitate coarsening and consequently in hardness and strength below peak values. Electrical and thermal conductivities, and dimensional stability are maximized by overaging. Caution is required to avoid severe overaging.

Age hardening normally does not require either controlled cooling or a special furnace atmosphere. A protective atmosphere is useful however, especially when it is recirculated to reduce furnace thermal gradients. A low dewpoint atmosphere of 5 percent hydrogen in nitrogen is an example of one that economically aids heat transfer while minimizing post hardening cleaning requirements. Vacuum age hardening is difficult because of the nonuniform nature of radiant heating.

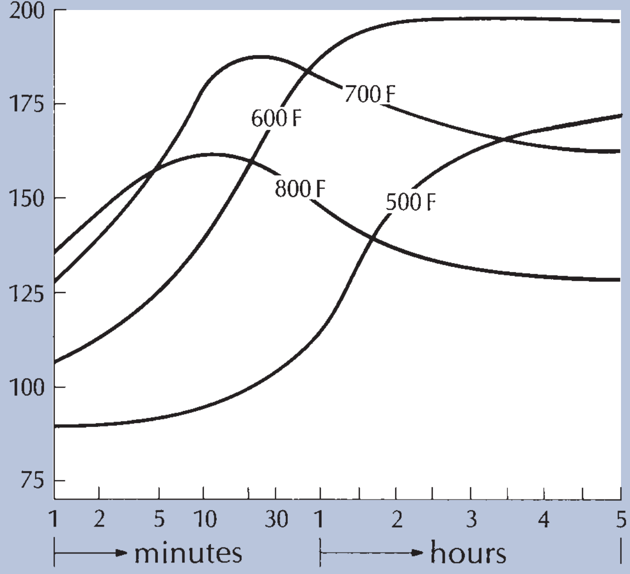
Age hardening increases the density of the high strength alloys slightly as a result of the precipitation reaction. This density change is accompanied by a decrease in linear dimensions of approximately 0.2%. The dimensional change in high conductivity alloys is negligible for most applications.

Alloy 25 A

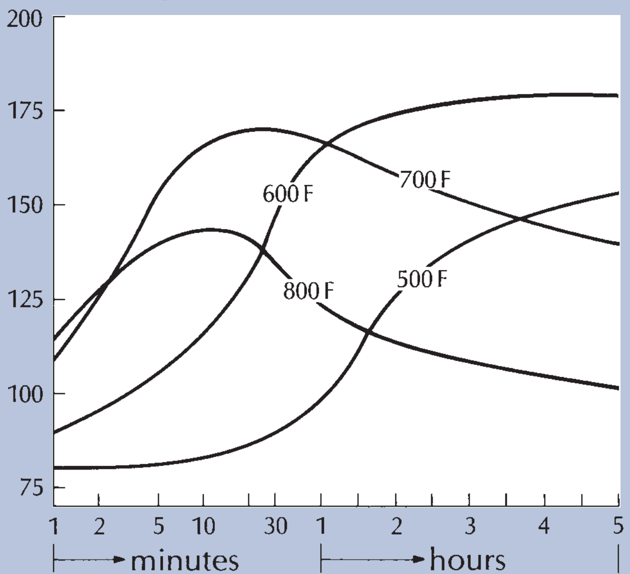


Alloy 25 1/2H

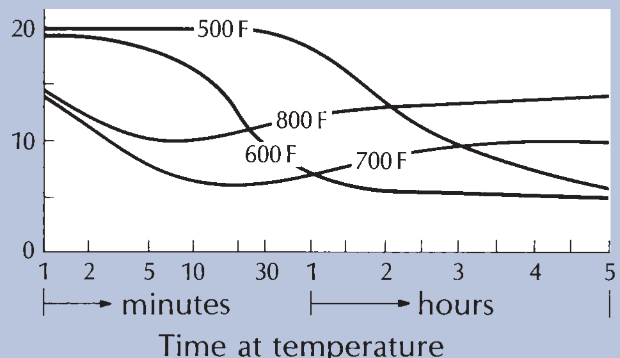
Tensile Strength, ksi



Yield Strength, ksi

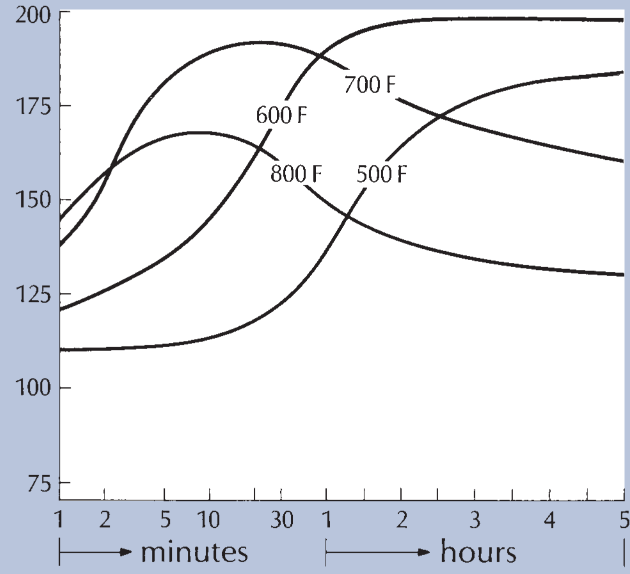


Elongation, percent

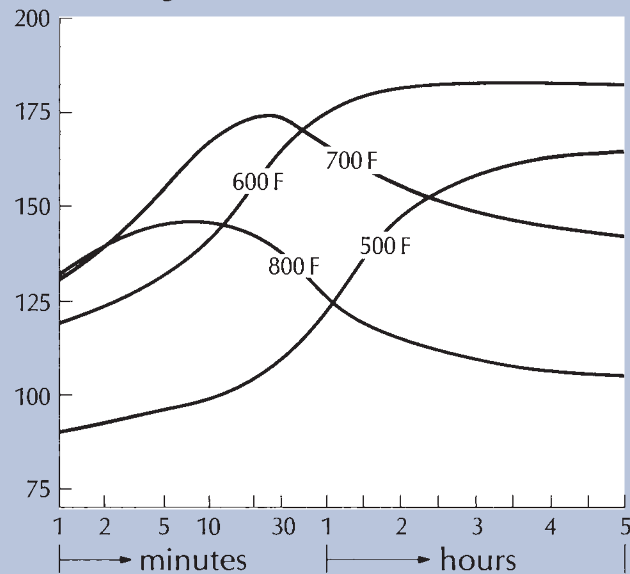


Alloy 25H

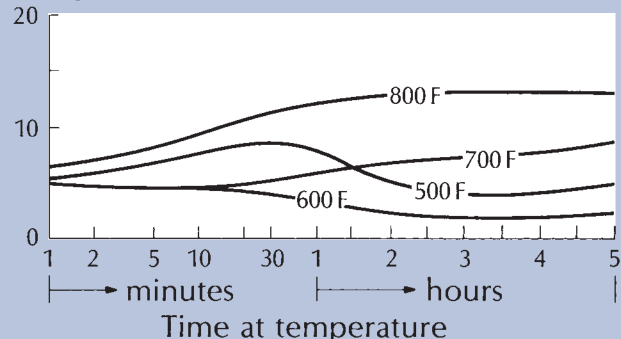
Tensile Strength, ksi



Yield Strength, ksi

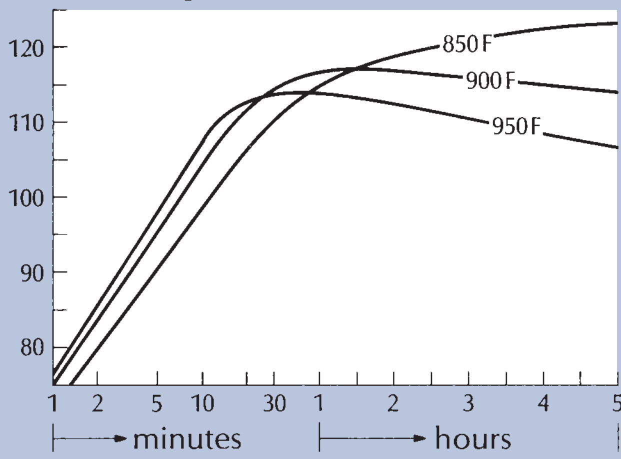


Elongation, percent

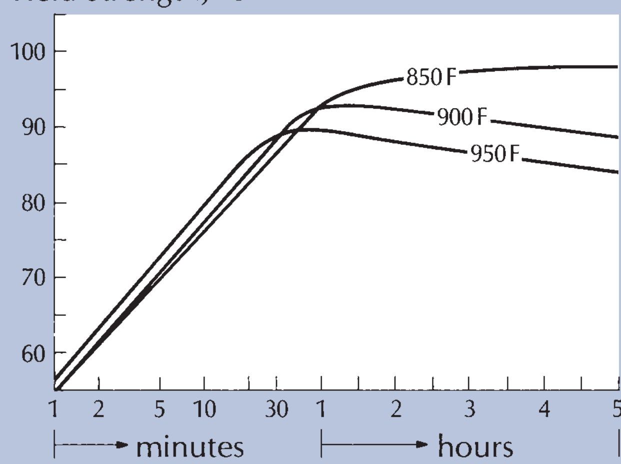


Alloy 3 and 10 A

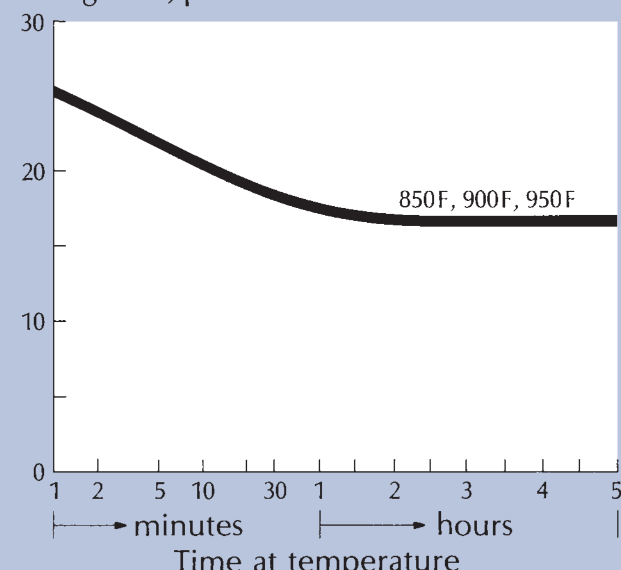
Tensile Strength, ksi



Yield Strength, ksi



Elongation, percent



Fixtures may be used for age hardening to prevent distortion. A salt bath provides the precise control needed for short-time high-temperature aging that results in minimum distortion and the production economies of a short cycle.

Residual stress, which may arise from certain types of deformation after age hardening, may be thermally relieved without loss of hardness. Heating at temperatures of 300 F to 400 F for up to two hours is generally adequate to provide moderate stress relief.

High Strength Alloys

The standard age hardening treatment for Alloy 25 is 600 F for 2 to 3 hours; two hours for cold worked and three hours for annealed products. Representative Alloy 25 age hardening curves at 500 F, 600 F , 700 F and 800 F in the annealed, half hard and full hard conditions are shown in the figures on pages 26 and 27. Several features of these curves are reviewed in the following:

First, age hardening at 600 F - 625 F produces maximum strength for all tempers. Higher temperature achieves peak strength in shorter time, but the peak strength is reduced. Heating at lower temperature increases strength at a slower rate and, although high strength can be achieved, it requires excessive time.

Second, cold work improves the achievable strength levels for all aging temperatures. As the level of cold work increases, the time at temperature to achieve peak strength decreases.

Third, ductility decreases as strength increases. Notice that overaging improves ductility, but there is evidence that toughness is reduced.

In some applications not requiring maximum properties, short time high temperature hardening cycles can be employed. For example, an aging temperature of 700 F produces peak strength in about 30 minutes. The temperature-time conditions, including heat up and cool down rates, are critical to hardening rate and intensity. Consequently, when using a special age hardening method, the temperature-time should be accurately established with sample lots before production begins.

High Conductivity Alloys

The typical age hardening response of Alloys 3 and 10 in the annealed condition is shown on this page. Although the age hardening temperatures are different for these alloys than for Alloy 25, the same trends hold.

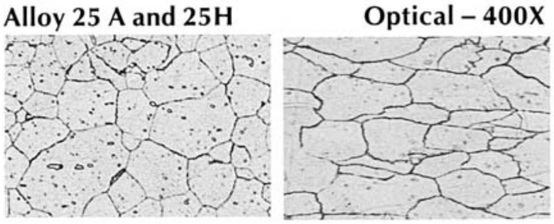
Aging at 850 F produces maximum strength, but 900 F for 2 or 3 hours is commonly recommended because of the general need for high electrical conductivity in these alloys. Increasing aging temperature reduces time to reach peak strength and the achievable strength is decreased. As time increases, elongation falls while strength increases markedly. Beyond two hours the rate of change in ductility becomes negligible.

Microstructures

The combined effects of composition, cold work and thermal treatment are portrayed in the microstructure of copper beryllium.

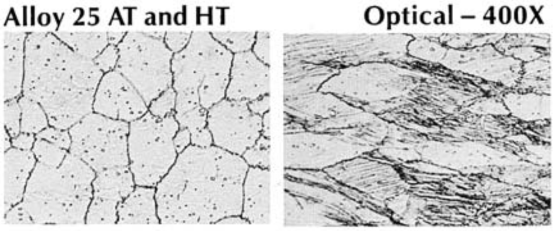
Microstructural features are revealed on a metallographically prepared sample by etching with ammonium persulfate/hydroxide or potassium dichromate. The former etchant delineates grain boundaries in all tempers and displays cold work effects in age hardened material. The latter etchant enhances the contrast of beryllides beyond the as-polished condition. Metallographic examination can thus be tailored to the processing conditions of the material.

Alloy 25 A and 25H **Optical – 400X**



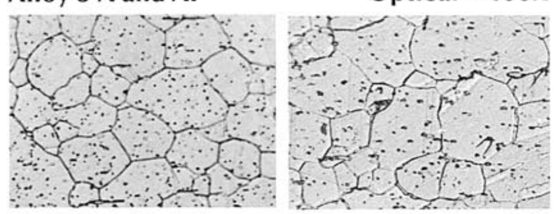
The microstructure of solution annealed Alloy 25 (A temper) reveals an equiaxed grain structure with uniformly dispersed cobalt beryllides. The H temper microstructure for Alloy 25 shows the effect of a cold rolling reduction of 37% of the original thickness on the grain structure. Cold working elongates the grain structure in the working direction.

Alloy 25 AT and HT **Optical – 400X**



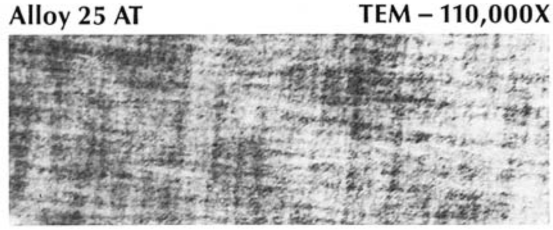
Alloy 25 in the AT temper shows a small amount of grain boundary precipitate in peak-aged product. Cold work plus age hardening produces the highest hardness and strength. The microstructure in the HT condition shows the effect of age hardening on cold worked Alloy 25. Standard age hardening does not change the grain size from that of annealed material. Precipitation of the strengthening gamma phase is not observable at this magnification.

Alloy 3 A and AT **Optical – 400X**



The high conductivity alloys are characterized in the A and AT tempers by equiaxed grains with a fine dispersion of nickel or cobalt rich beryllides. The microstructural features, in this case for Alloy 3, are somewhat more difficult to develop by etching.

Alloy 25 AT **TEM – 110,000X**



A bright field transmission electron micrograph (TEM) of Alloy 25 shows strain fields associated with precipitates. These precipitates are responsible for strengthening. They form initially as Guinier-Preston zones, pass through several stages of increasing tetragonality, ultimately ripening into the equilibrium gamma phase.

Cleaning and Finishing

Copper beryllium displays all the desirable plating and joining characteristics for which the copper alloys are well known. However, because copper beryllium is frequently specified for precision applications, surface cleanliness should be considered a critical factor when articles are to be plated, or joined by soldering, brazing or welding. All foreign substances, including oil, grease, paint, dust, dirt, tarnish and oxide, must be removed before these operations are undertaken. This cannot be emphasized too strongly because most problems related to plating or joining quality can ultimately be traced to improper or inadequate cleaning.

Cleaning

The first step in the preparation of copper beryllium for subsequent plating or joining is the removal of all soils, particularly oils and greases. These are normally present as residual traces of lubricants used during forming or as contaminants from exposure to oil-mist-laden shop atmospheres. Sulfur-bearing lubricants, if not removed quickly, can stain copper beryllium. Surface soils also result from handling; fingerprints and oily work gloves are notorious offenders.

Conventional cleaners, such as organic solvents, and alkaline solutions, are normally adequate for removing oily residues. Normal care should be taken to insure that solution concentrations, temperatures and flow rates are within proper limits and that recirculation or filtration systems are adequately maintained. Vapor degreasing is especially effective for removing oils and greases. Trisodium phosphate and similar alkaline solutions, including the many available proprietary formulations, are likewise satisfactory, and ultrasonic or electrolytic agitation can supplement these media for best results. Cleaning solutions should be thoroughly rinsed from all surfaces. Any questions regarding a cleaner's effectiveness should be resolved by testing on representative copper beryllium samples.

Like all copper alloys, copper beryllium can form a thin surface oxide, or tarnish, when exposed to air . Tarnish formation is accelerated by the presence of moisture and elevated temperature. Oxidation normally results from heat treatment. Even when protective atmospheres are used, the formation of sufficient surface oxides to cause plating or joining problems should be anticipated. Mill-hardened strip however, is thoroughly cleaned and inhibited before delivery.

Surface oxides take two forms: beryllium oxide, present on surfaces exposed to the high temperatures needed for solution annealing; and combinations of beryllium and copper oxides, present on parts after precipitation hardening. The removal of a pure, continuous beryllium oxide will not be considered here since solution annealing is rarely performed by the user. For special cases, such as removal of oxides formed during annealing or welding, contact Brush Wellman for appropriate cleaning procedures.

The surface of copper beryllium can be prepared for plating or joining, or simply restored to its original, lustrous appearance, with the following procedure.

Step 1– Immerse parts in a 120F - 130F aqueous solution of 20-25 volume percent sulfuric acid plus 2-3 volume percent hydrogen peroxide. Immersion time should be that required to remove dark coloration and provide the desired response or appearance.

Step 2 – Rinse thoroughly and dry.

When necessary, parts made from mill hardened material can be readily cleaned by the above method. In all cases care should be taken to avoid excessive immersion time or high acid concentration since these may remove measurable amounts of metal.

Electroplating, Coloring and Polishing

Nickel, gold, silver, tin, chromium, copper, and other metals are commonly electroplated on copper beryllium. Brush Wellman supplies electroplated strip, or can direct an interested user to an experienced supplier for discrete part, electroless, or selective plating. Some frequently used plating pretreatments are as follows.

Alloys other than M25:

Step 1 – Cathodically clean with a hot alkaline solution.

Step 2 – Rinse in cold water.

Step 3 – Immerse for 10-15 seconds in a 120F - 130F aqueous solution of 20-25 volume percent sulfuric acid plus 2-3 volume percent hydrogen peroxide.

Step 4 – Rinse in cold water.

Alloy M25

Step 1 – Cathodically clean with a hot alkaline solution.

Step 2 – Rinse in cold water.

Step 3 – Immerse for 10-15 seconds in a room temperature 10 to 12 volume percent fluoboric acid aqueous solution.

Step 4 – Optionally apply a cyanide copper strike for adhesion as recommended for most copper alloys.

Copper beryllium products can also be colored by all conventional techniques used for copper alloys. Satin black oxide to an artificial patina are examples.

Wet brushing, buffing and electropolishing are used to produce extremely fine surface finishes on copper beryllium. Best electropolishing results are obtained with a nitric acid/ methanol electrolyte at -70F. A phosphoric acid, chromate electrolyte can be used at room temperature, but this may leave certain intermetallic particles in relief. Phosphoric, nitric, and acetic acids can be mixed to produce a chemical polishing solution for use at 160 F .

Joining

Soldering and brazing are important assembly techniques for copper beryllium. As with any precipitation hardening alloy, heating time and temperature during joining must be standardized and controlled.

Welding copper beryllium offers advantages over other structural alloys particularly those depending on cold work for strength. In copper beryllium, a welded joint can retain 90 percent or more of the base metal mechanical properties. Sensitization, surface depletion, and other difficulties associated with welding other alloys are not problems with copper beryllium.

Soldering

Soldering is normally specified when the anticipated service temperature is below about 300 F and electrical and thermal continuity are difficult to insure with a mechanical joint. Soldering lends itself to automation and can be performed by heating with resistance, induction, infrared, or flame. Application techniques include immersion, wave, vapor phase and others. Copper beryllium can be soft soldered after age hardening without detriment to mechanical properties.

Copper beryllium can be soldered with most standard fluxes but flux should never be relied upon as a substitute for a proper cleaning treatment. Activated rosin fluxes (RMA or RA grades) are recommended but these should be removed by hot water rinsing after soldering to prevent corrosion of other components.

It is good practice to join parts as soon after surface preparation as practical. If delays are unavoidable parts should be stored in clean, dry locations free from acidic, sulfurous or ammoniacal fumes. Shelf life can be extended by inhibiting the surface with benzotriazole (BTA), or by precoating with pure tin or tin-lead solder.

Copper beryllium is solderable with all common solder compositions. Alloys containing 60% tin-40% lead (60/40) are generally recommended for electronic assemblies, especially when high speed processes are employed. Hand soldering allows latitude in solder alloy selection and all-purpose 50/50 tin- lead, among others, may be used.

Brazing

Compared with soldering, brazing provides higher strength and superior resistance to thermal exposure at moderately elevated temperatures.

Since brazing is performed at relatively high temperature, it is preferable that parts be brazed before age hardening. With a rapid brazing cycle hardened copper beryllium can be joined effectively. Time at temperature should be the minimum needed to insure braze alloy penetration.

Surface cleanliness is important for achieving sound brazed joints. The surface must be free from all traces of dirt and oil and should be cleaned prior to brazing. A 15 percent to 20 percent nitric acid solution in water, followed by thorough water rinsing works well. Brazing may lightly oxidize exposed surfaces. This oxide can be removed by immersion in 50 percent sodium hydroxide at 265 F, followed by normal acid cleaning.

Furnace, induction and torch brazing are common methods. Braze integrity depends on geometrical factors such as joint design, assembly size, and thermal parameters such as heat input and dissipation rates. Heat sinks may be used to confine heat to the joint area. Small brazed assemblies may permit short time high temperature age hardening to be incorporated into the brazing cycle. However, the brazing cycle must be kept short to avoid overaging. Larger furnace brazed parts require quenching after brazing to permit subsequent age hardening. The brazing temperature should not exceed the solution annealing temperature, 1450 F for high strength alloys and 1600 F for high conductivity alloys.

Welding

Welding is a useful joining process for copper beryllium but careful metallurgical planning is essential. Consideration must be given to joint design, preheat (below age hardening temperature), weld technique, and post welding practice.

Copper beryllium is easily resistance welded by spot or seam welding to itself or other metals. Laser and ultrasonic welding are also performed.

Fusion welding by tungsten arc inert gas (TIC), metal arc inert gas (MIC), plasma-arc, and electron beam are routinely performed on copper beryllium. Post welding thermal hardening treatments are common unless maximum strength in the joint area is not required, as when the joint is made in a low stress area.

Machining

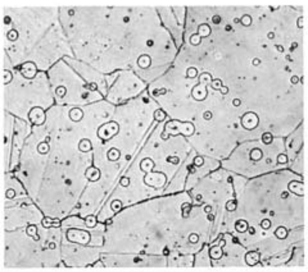
Copper beryllium can be machined at metal removal rates as high or higher than published values for free-cutting copper alloys or stainless steels. This can be done without sacrifice in tool life provided that proper tools and cutting fluids are used. Guidelines for effective metal removal are provided in the table on this page.

Recommended Speeds and Feeds for Machining Brush Wellman Copper Beryllium Alloys

Operation	Cutting Speed, ft/min	Feed, in./rev	Depth of Cut, in.	Tool Material
Alloys 25, M25 and 165				
Turning				
Annealed	1500	0.005-0.010	0.025-0.050	C-2
Drawn, hard	2100	0.005-0.010	0.025-0.050	C-2
Heat treated	900	0.005-0.010	0.025-0.050	C-2
Drilling				
Annealed	200-350	0.002-0.009	–	H.S.S.
Drawn, hard	150-250	0.002-0.009	–	H.S.S.
Heat treated	100-300	0.002-0.009	–	H.S.S.
Tapping				
Annealed	50-100	–	–	H.S.S.
Drawn, hard	30-50	–	–	H.S.S.
Heat treated	10-25	–	–	H.S.S.
Alloys 3 and 10				
Turning	800-1000	0.010-0.025	0.050-0.125	C-2
Drilling	125-600	0.002-0.005	–	H.S.S.
Tapping*	15-150	–	–	H.S.S.

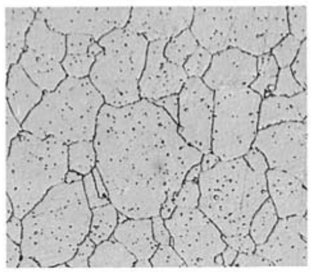
*Cutting speed is very critical when tapping Brush Alloys 3 and 10. Cutting speed should be decreased as size of tap decrease.

Alloy M25 AT



Optical – 400X

Alloy 25 AT



Optical – 400X

High metal removal rates sometimes presents chip removal problems with annealed or cold worked product. Long, stringy, tough chips are difficult to handle. To avoid this difficulty, copper beryllium is usually machined in the age hardened (AT or HT) condition. In addition to improved chip control, age hardening and cleaning after machining are eliminated.

Alternately, Alloy M25 in any temper offers improved chip control due to carefully controlled addition of lead. This alloy is well suited to automatic machining operations, since the lead in the alloy reduces tool wear and eliminates chip clogging.

Photomicrographs of Alloys M25 and 25 are shown above for comparison. The presence of lead in M25 is made visible through special metallographic preparation. The lead is uniformly dispersed and appears as fine particles inside circles which are artifacts of the special etching process. Although the presence of lead limits hot working, it does not affect the response to age hardening, which is identical to that of Alloy 25.

As with many high performance alloys, machining can work harden the surface of a copper beryllium workpiece. Shallow depth of cut or a dull or rubbing tool can accentuate this hardening. For best results, be sure that the tool is sharp and that the feed rate is sufficiently high that each subsequent cut penetrates below the work hardened layer.

Cutting tools should be sharp and have a positive rake angle between 5 and 20 degrees for best performance. The use of chip breakers for chip control during turning is recommended.

The use of a cutting fluid as a coolant and for chip removal is recommended for longer tool life and improved surface finish. Water soluble oils and synthetic emulsions are commonly used coolants. Although the best finishes are obtained from sulfurized oils, these oils will discolor copper beryllium (and other copper alloys). The stain is not harmful, but it should be removed after machining, particularly if the parts will be subsequently age hardened.

Copper beryllium also is commonly machined by other conventional methods such as abrasive machining or grinding using traditional equipment. Selection of grinding wheel, speed, metal removal rate and coolant follows guidelines established by grinding wheel manufacturers and others. Grinding should always be done wet.

Copper beryllium also is machinable by nontraditional methods. Photochemical machining of strip is established technology with chemically resistant masks that were developed specifically for copper alloys. Electrical discharge machining, using either an electrode form or a traveling wire, and electrochemical machining of all product forms are practiced.

Hardness

Although the tensile test is the official verification of mechanical properties, hardness is a useful approximation. Hardness testing is essentially nondestructive, it can be applied to finished components, and the equipment is reasonably portable. The hardness of a miniature contact, a resistance welding electrode, or an aircraft bearing, for example, can be measured with a relatively simple test.

Each hardness test method has a minimum thickness limit to its applicability. A test method must therefore be selected with the gage of the product in mind. The chart on page 34 lists hardness correlations for the test methods most commonly applied to copper beryllium.

A note of caution, however. Hardness values measured using one test method do not always correlate well with those from another. Where hardness is critical, as with stamped and age hardened parts, converted values should be avoided. For example, with a hardness specified as Rockwell C37 minimum, making a Rockwell 15N or 30N test and converting that to Rockwell C is less preferable than making the test on the Rockwell C scale directly. The conversions are useful when hardness is less critical, as it might be with inspection of incoming raw material.

Diamond Pyramid and Vickers Hardness have the advantage that a continuous set of numbers covers the metallic hardness spectrum. This test allows hardness of products of different gages to be compared directly. An important use of microhardness techniques is in measuring hardness of foils, fine wires, and other products having small dimensions.

Minimium Thickness Requirements for Various Testing Methods

Rockwell Scales	Diamond Pyramid or Vickers	Brinell
B and C - 0.040 in. 30T and 30N - 0.020 in. 15T and 15N - 0.015 in.	0.002 in.	0.125 in.

Hardness Conversion Table

Rockwell			Diamond Pyramid or Vickers	Brinell	Rockwell			Diamond Pyramid or Vickers	Brinell
C	15N	30N		3000 kg	B	15T	30T		500 kg
48	84.5	66.5	485	460	100	93.0	82.0	240	201
47	84.0	66.0	471	448	99	92.5	81.5	234	195
46	83.5	65.0	458	437	98	–	81.0	228	189
45	83.0	64.0	445	426	97	92.0	80.5	222	184
44	82.5	63.0	435	415	96	–	80.0	216	179
43	82.0	62.0	424	404	95	91.5	79.0	210	175
42	81.5	61.5	413	393	94	–	78.5	205	171
41	81.0	60.5	403	382	93	91.0	78.0	200	167
40	80.5	59.5	393	372	92	90.5	77.5	195	163
39	80.0	58.5	383	362	91	–	77.0	190	160
38	79.5	57.5	373	352	90	90.0	76.0	185	157
37	79.0	56.5	363	342	89	89.5	75.5	180	154
36	78.5	56.0	353	332	88	–	75.0	176	151
35	78.0	55.0	343	322	87	89.0	74.5	172	148
34	77.0	54.0	334	313	86	88.5	74.0	169	145
33	76.5	53.0	325	305	85	–	73.5	165	142
32	76.0	52.0	317	297	84	88.0	73.0	162	140
31	75.5	51.5	309	290	83	87.5	72.0	159	137
30	75.0	50.5	301	283	82	–	71.5	156	135
29	74.5	49.5	293	276	81	87.0	71.0	153	133
28	74.0	48.5	285	270	80	86.5	70.0	150	130
27	73.5	47.5	278	265	79	–	69.5	147	128
26	72.5	47.0	271	260	78	86.0	69.0	144	126
25	72.0	46.0	264	255	77	85.5	68.0	141	124
24	71.5	45.0	257	250	76	–	67.5	139	122
23	71.0	44.0	251	245	75	85.0	67.0	137	120
22	70.5	43.0	246	240	74	–	66.0	135	118
21	70.0	42.5	241	235	73	84.5	65.4	132	116
20	69.5	41.5	236	230	72	84.0	65.0	130	114

Fatigue Strength

Copper beryllium strip and wire have a long history of success in the cyclic stress environment of electrical and electronic contact springs. Copper beryllium in heavier sections is also used in components subject to cyclic loading. Examples include aircraft landing gear bushings, copper beryllium races and rollers in rolling-element bearings, and oil and gas well downhole hardware such as anti-galling thread saver subs.

In these applications an outstanding characteristic of copper beryllium is its ability to withstand cyclic stress. Cyclic conditions are produced by cantilever bending, axial loading, and rotational bending.

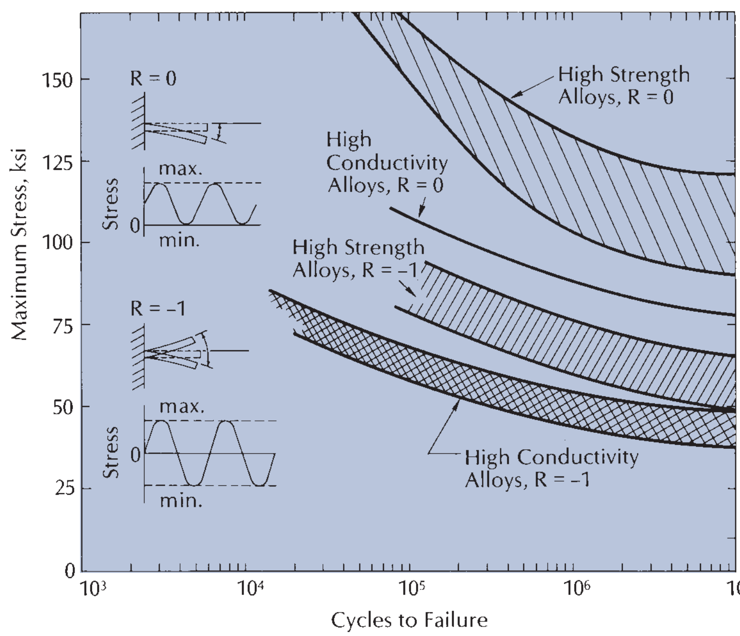
Fatigue strength is defined as the maximum stress that can be endured for a specified number of cycles without failure. Low cycle fatigue strength approaches the static strength. When the number of cycles exceeds one million to ten million, the fatigue strength falls to a fraction of the static strength. Copper beryllium alloys resist fatigue failure with high static strength, toughness, and an ability to diffuse strain by work hardening.

Copper beryllium fatigue curves are provided in the graphs on this page. The ratio of minimum to maximum stress is termed the stress ratio, "R". This term, displayed on the graphs, defines the test conditions. Spring contacts deflected in a single direction (R = 0) display a higher fatigue strength than those flexed in reverse bending (R = -1).

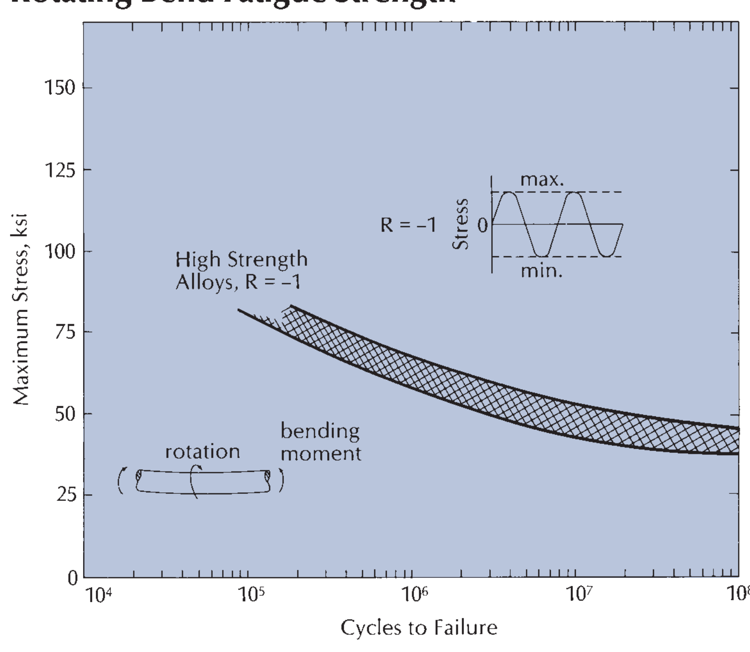
Standard tests measure fatigue behavior of flat springs and round beams. Some spring manufacturers have developed their own tests to suit their particular design requirements. Agreement among testing methods is generally good.

These data serve as a guide, since fatigue performance depends on the surface condition and service stress state. Care should be taken to insure high surface quality, particularly at edges and fillet radii, to take maximum advantage of these important alloys.

Flexure Fatigue Strength



Rotating Bend Fatigue Strength



Corrosion Resistance

Atmospheric Resistance and Shelf Life

In environments encountered during production, storage, and use of electronic or electrical apparatus, copper beryllium alloys exceed the corrosion resistance of most specialty copper alloys.

Resistance to tarnish is critical since many electronic components are soldered after extended storage. Surface inhibition with benzotriazole (BTA) reduces oxide formation and extends shelf life. For optimum solderability, copper beryllium may be coated with tin prior to storage.

Marine Environments

Copper beryllium is well suited for both fresh and salt water because of a low corrosion rate and an inherent resistance to biological fouling. At low velocity, the corrosion rate of copper beryllium in sea water is low and comparable to the cupronickels. High velocity accelerates corrosion of copper beryllium and most copper alloys.

Undersea communication cable housings have seen more than thirty years of undersea service without evidence of fouling or detrimental corrosion. These are made from copper beryllium because of its excellent strength, machinability and resistance to corrosion and fouling.

Processing Environments

Glycols, alcohols, esters, ketones, hydrocarbons and most organic solvents are routinely handled with copper beryllium. The sensitivity of copper beryllium to impurities contained in these liquids is usually greater than sensitivity to the organic itself. For example, traces of sulfides, water, acids, alkalis or salts may accelerate corrosion.

Curing polyvinyl chloride (PVC) and room temperature vulcanized silicone (RTV) plastics can produce fumes, such as HCL and acetic acid, that can corrode copper beryllium and other copper based alloys. However, copper beryllium is used successfully in these applications by limiting the production of these corroding fumes. The curing of other plastics, such as acetal, nylon and polytetrafluoroethylene (PTFE), emits volatiles under similar conditions, but these fumes do not affect copper alloys.

Copper beryllium alloys are compatible with aqueous solutions of most alkali hydroxides, hot or cold. However, many copper alloys, including copper beryllium, are not suitable for handling ammonium hydroxide, which promotes stress corrosion cracking. Copper beryllium alloys should not be in contact with ammonia unless it is dry and oxygen free.

The alloys resist corrosion in cold concentrated sulfuric acid; hot or cold dilute sulfuric acid; hydrofloric acid; or cold dilute hydrochloric acid. However, like other copper alloys, copper beryllium is not recommended for structural components that are exposed to concentrated oxidizing acids such as nitric. Non-oxidizing acids such as hydrochloric and sulfuric are corrosive when they contain oxidizing impurities.

Copper beryllium is immune to stress corrosion cracking caused by chloride ions, unlike stainless steel that can crack in just a few hours under high chloride conditions. This immunity makes copper beryllium ideal for applications in oil well environments. Copper beryllium resists hydrogen embrittlement unlike titanium alloys, steels, and nickel base alloys that are highly susceptible, at comparable strength.

Copper beryllium is susceptible to delayed failure by liquid metal embrittlement by mercury. Strengthening by either cold working or age hardening increases this susceptibility.

Copper Beryllium Service Environments:

- **Industrial** – shelf life sufficient for solderability to 18 months
- **Urban** – sulfidation resistance up to five times that of copper
- **Static Sea Water** – less than 2 mils per year
- **Biofouling** – proven resistance, with more than thirty years exposure
- **Saturated Chlorides** – immune to cracking in sodium, potassium, magnesium and mixed salts
- **Hydrogen** – no effect on ductility or strength after cathodic charging at 90°F for more than 100 hours
- **Organics** – compatible with most solvents, although impurities may cause corrosion
- **Organic Fumes** – resistance should be evaluated case by case
- **Dilute Acids and Alkalis** – may be used with caution
- **Concentrated Oxidizing Acids** – not recommended for use
- **Ammonia** – resistant to attack by anhydrous ammonia, but presence of moisture and oxygen promote stress corrosion cracking
- **Mercury** and other liquid metals - avoid contact
- **Other** – attacked by ferric chloride, ferric sulfide, acid chromates, ammonium hydroxide and mercury compounds

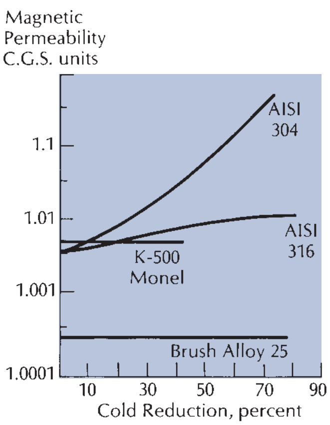
Other Attributes

Copper beryllium often is used because it provides a combination of attributes meeting specific needs of a user's application. Examples include elastic compliance and formability (electronic connector contacts), fatigue strength and electrical conductivity (switch contacts), and hardness and thermal conductivity (resistance welding electrodes).

Copper beryllium has many more useful attributes of which the designer should be aware. Several are highlighted below.

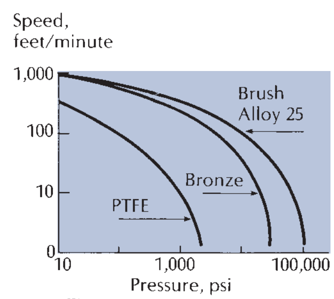
Nonsparking – One of the oldest and best known uses for copper beryllium is in hand tools for industrial processes where a spark is not permissible. A hot, copper rich particle dislodged on impact cools rapidly and does not ignite. In addition to spark resistance, copper beryllium has hardness to provide lasting durability.

Nonmagnetic – Brush Alloy 25 has magnetic permeability between 0.997 and 1.003 at a field strength of 1000 gauss. (A permeability of unity represents perfect transparency to slowly varying magnetic fields.) This property is unaffected by cold work in contrast to other nonmagnetic alloys that can become magnetically "hot" during machining, forming or rigorous service. Combined with high strength, fracture toughness, and precise dimensional stability, these properties lead to excellent service in magnetic instrument housings, magnetic support structures and other systems.



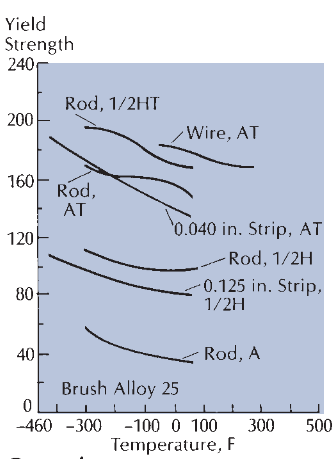
Nonmagnetic

Galling Resistance – Copper beryllium has inherently good wear resistance, allowing contact with other materials with a minimum of friction and surface damage. Threaded joints of copper beryllium mated to itself or to stainless steel are not subject to galling, even under overload conditions.

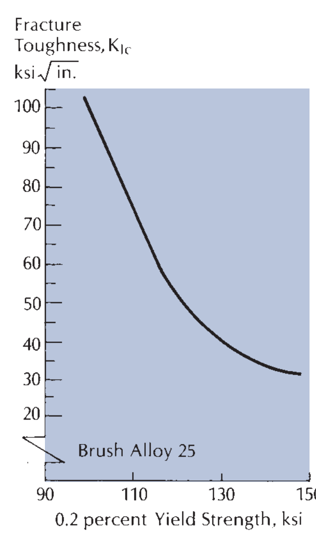


Antigalling

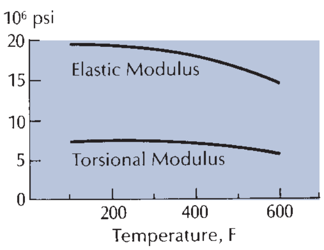
Cryogenic Behavior – Copper beryllium is used in liquid hydrogen and liquid oxygen due to its ability to maintain strength and toughness in cryogenic conditions. Copper beryllium has no ductile to brittle transition temperature, as do many high strength steels.



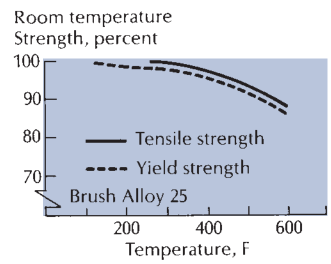
Cryogenics



Toughness



Elevated temperature



Elevated temperature

Elevated Temperature Strength – Copper beryllium Alloy 25 demonstrates good stability of tensile properties from cryogenic temperatures through 500 F despite long exposure. When tested at elevated temperature at conventional strain rates, tensile properties retain essentially room temperature values through 500 F.

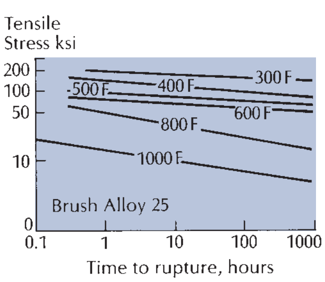
The high conductivity alloys retain strength through about 600 F. The hardness of these alloys leads to their use in welding electrodes and mold components for plastic injection.

Reflectivity – Copper beryllium polishes readily to an optical mirror surface. Because of its color, this surface reflects light efficiently, especially in the infrared spectrum. Reflectivity, machinability and dimensional stability lead to its use in mirrors, particularly where centrifugal or other stresses are present.

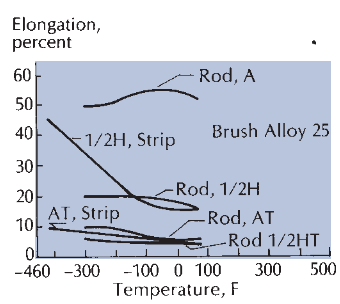
Dimensional Stability – Besides increasing hardness and strength, age hardening can relieve stress in copper beryllium. This results in high dimensional stability during machining or stamping. A conventional stress relief that does not alter strength, and various stabilizing thermal treatments are used.

Special Surface Treatments – Surface modification of copper beryllium creates several unique possibilities. An oxide formed at high temperature greatly increases secondary electron emission. Various technique have been used for local hardening. Laser and electron beam techniques have produced various surface states, ranging from localized solution annealing to glazing. Coatings have been applied for increased emissivity, hardening or appearance.

Appearance – The golden luster of high strength alloys and the coral tinted gold of the high conductivity alloys give copper beryllium an attractive appearance. These alloys are polished and waxed or lacquered for application as decorative components.



Stress rupture



Cryogenics

Your Supplier

Brush Wellman's quality commitment exists throughout our fully vertically integrated corporation. Our commitment extends from the mining of beryllium ore to the manufacture of finished materials including pure beryllium, the oxide ceramic, and numerous alloys on precise and efficient equipment.

This section summarizes a few facts about Brush Wellman, namely; history, corporate profile, mining and manufacturing, distribution, customer service, and quality. Safe handling of beryllium-containing products is addressed in a special section. More information is available for the asking.

This is Brush Wellman Inc.

Company History

Brush Wellman Inc.'s historical roots extend back to 1931 when its predecessor company, The Brush Beryllium Company, was founded in Cleveland, Ohio to commercially develop the beryllium technology of Brush Laboratories. Brush Laboratories was started in 1921 by Charles Brush, Jr. and Dr. C. Baldwin Sawyer, who pioneered work in the extraction of beryllium from ore and the production of beryllium metal, oxide and master alloys.

In the late 1940's, the Atomic Energy Commission (AEC) developed interest in beryllium powder metal technology and became the first significant user of metallic beryllium and beryllium oxide. During the 1950's, commercial applications for beryllium-containing materials grew, particularly copper beryllium. In 1953, Brush Wellman built a small commercial plant at Elmore, Ohio to produce copper beryllium alloys. That facility is now the largest and most advanced facility for beryllium and beryllium-containing alloy production in the world.

In 1958, Brush Wellman purchased Penn Precision Products Company of Reading, Pennsylvania. This acquisition provided Brush Wellman the capability to supply a full range of copper beryllium rolled strip products. The Reading facility now provides world class beryllium- containing strip, rod and wire alloys to meet the demand for these products.

During the 1960's, Brush Wellman acquired extensive mineral rights in the Topaz mountain area of Utah and developed techniques for extracting beryllium from these bertrandite deposits. These ore reserves are sufficient in size to accommodate the global demand for beryllium and beryllium-containing alloys well into the future, and make Brush Wellman the only fully integrated producer of beryllium, beryllium-containing alloys and beryllia ceramic.

Brush Wellman's international organization was established in the 1980's with the formation of Brush Wellman GmbH (Stuttgart, Germany); Brush Wellman Ltd. (Theale, United Kingdom); and Brush Wellman Japan Ltd., (Tokyo, Japan). In 1992, Brush Wellman Singapore (Pte) Ltd. was formed to provide local service and distribution in Southeast Asia. In the 21st Century, additional distribution, service and sales organizations in Hong Kong, China, and Taipei, Taiwan have been established to serve the growing Asian markets.

In May 2000 Brush Wellman Inc. became a wholly-owned subsidiary of a newly created holding company, Brush Engineered Materials Inc. In addition, the foreign subsidiaries became wholly-owned subsidiaries of Brush Engineered Materials Inc.

Corporate Profile

Brush Engineered Materials Inc. (NYSE-BW), with headquarters in Cleveland, Ohio, is the sole parent company of Brush Wellman Inc. Its subsidiaries make the following products:

- **Metallic beryllium** , a lightweight metal possessing unique mechanical and thermal properties. Its specific stiffness is much greater than other engineered structural materials such as aluminum , titanium, and steel. Beryllium Products, including AlBeMet and E-materials, are primarily, but not exclusively, used in the defense and aerospace markets. Brush Wellman's metallic beryllium is produced in Elmore, Ohio. Fabricated components are made at Electrofusion Products in Fremont, California.
- **Beryllium-containing alloys**, including copper beryllium, nickel beryllium and aluminum beryllium, metallurgically tailored to meet specific customer performance requirements. Beryllium alloys are used for demanding applications in computers, telecommunications, automotive electronics, aerospace, oil exploration, undersea and marine environments, and plastic mold tooling.

  Alloy Products are produced at the Elmore, Ohio and Reading, Pennsylvania manufacturing sites. Distribution service centers are operated in Fairfield, New Jersey; Warren, Michigan and Elmhurst, Illinois. Research & Development laboratories are situated in Cleveland, Ohio, Elmore, Ohio and at several other global locations.
- **Beryllia Ceramic (BeO),** a high strength electrical insulator with thermal conductivity greater than many metals. BeO is used in high power electronic circuitry, laser equipment and microelectronics packaging. BeO is produced by the BEM subsidiary, Zentrix Technologies Inc., at facilities in Tucson, Arizona and Newburyport, Massachusetts. Electronic circuits and packages are designed and manufactured at the Zentrix CPT facility in Oceanside, California, using proprietary processes to deposit thick film precious metal circuitry onto ceramic substrates.
- **Other High Performance and Precious Alloys** produced by Brush Engineered Materials' subsidiaries, including the copper-nickel-tin spinodal alloys produced at the Brush Wellman Lorain, Ohio facility. High strength, lubricity, durability, corrosion resistance and thermal conductivity make these copper alloys a premier choice for plastic molding cavities and cores, heavy duty bushings and other severe service applications.

  Brush Engineered Materials subsidiary Technical Materials Inc. (TMI) located in Lincoln, Rhode Island produces inlay/overlay clad, electroplated and other specialty hybrid strip products in a wide range of alloys.

  Brush Engineered Materials subsidiary Williams Advanced Materials Inc. (WAM) located in Buffalo, New York supplies high purity specialized metal products for the electronic industry, including vapor deposition materials, clad and precious preforms, high-temperature braze materials, frame lid assemblies and ultra-fine wire.

Mining and Manufacturing

Brush Wellman begins production of beryllium containing alloys at its Topaz-Spor mining operation in Utah. Here the company operates the only bertrandite producing mine in the free world. Bertrandite ore is mined from open pits, and provides a constant source of ore for Brush Wellman's extraction facility in nearby Delta, UT. At Delta, the bertrandite ore is processed into a fine powder of beryllium hydroxide.

This hydroxide is transported to the Elmore, OH manufacturing plant where alloy production begins.

Elmore

The Elmore, OH plant is the primary thermo-mechanical processing facility for the Alloy Division. Metallurgical and metalworking processes include:

- Reduction of beryllium hydroxide
- Melting and casting
- Hot and cold rolling
- Hot extrusion
- Cold drawing
- Annealing and precipitation heat treating
- Cleaning
- Flattening
- Straightening
- Sawing
- Strip plating
- Machining

The products of Elmore manufacturing are: strip, wire, rod, bar, tube, extruded shapes, custom products, plate, casting ingot, and master alloy. These products are delivered worldwide to service centers for delivery to customers or to the Reading, PA finishing plant for further processing.

Reading

The Alloy Division's Reading, PA facility produces finished gage strip and wire products. A variety of metalworking processes are used:

- Rolling
- Drawing
- Pickling
- Annealing
- Precipitation hardening
- Degreasing
- Slitting and welding
- Traverse winding

Some of the most advanced manufacturing techniques produce a consistent high quality family of products.

Strip is routinely rolled to thicknesses down to 0.002 inch, and wire is drawn to diameters as small as 0.050 inch.

The Reading, PA plant is in close partnership with the Elmore, OH plant. The latter supplies the input stock that the Reading plant turns into finished products. The Alloy Division maintains the highest standards of quality. This dedication to quality is the secret to the success of the Alloy Division and its key to the future.

Product Distribution

Brush Wellman maintains a worldwide network of Service Centers, Independent Distributors and authorized agents. People in this network can answer your inquiry, process your order, and assist with your special requirements. They are responsive to your requests for technical information and have available the complete resources of the Brush Wellman organization.

Brush Wellman Service Centers

There are three North American and four International Brush Wellman Alloy Service Centers. Addresses, telephone and facsimile numbers are listed on the back cover of this book. These service centers:

- Provide local technical and distribution service to customers on all aspects of the use of beryllium-containing alloys, including application engineering, design assistance, safe usage of all the products and alloy selection
- Maintain stock of copper beryllium and other beryllium-containing alloy products in a wide range of alloys, tempers and sizes
- Provide rapid delivery of products slit, cut and packaged to customer requirements throughout the United States, Canada and all international locations
- Provide precision slitting, sawing, leveling, traverse winding and other custom services to meet your exacting requirements
- Work closely with customers to satisfy individual needs for import administration, packaging, labeling and special material properties

Brush Wellman Representative Offices:

- Provide local technical and distribution service to customers on all aspects of the use of beryllium-containing alloys, including application engineering, design assistance and alloy selection
- Ensure that customer requirements are met by the appropriate Brush Wellman company or Brush Wellman Independent Distributor

Independent Distributors

Brush is represented by Independent Distributors in more than 70 locations in the United States, Canada and in most other countries. The Independent Distributors make available many of the same product distribution and technical marketing services of the Brush Wellman Service Centers and provide customers with a local contact for rapid response, including:

- Maintain local stocking programs of alloy products for prompt delivery to their customers
- Have staff that have been trained by Brush Wellman on the latest developments in beryllium-containing alloys, and can provide local language service for local customers
- Provide access to all Brush Wellman resources

Customer Service

Brush Wellman's broad coverage of customer service is offered through:

- Alloy Sales Engineers
- Regional Alloy Service Centers, with customer service personnel
- Sales and Marketing located in Cleveland, Ohio

A written request or a telephone call to any Brush Wellman location will begin the process to satisfy your requirements.

Often the need is for Technical Customer Service. When designing a new part, choosing among available alloys and tempers, interpreting a specification, or weighing component production alternatives, call upon our Technical Service staff in Alloy Marketing.

Brush customer service personnel can draw upon a wide range of Brush Wellman resources. These include:

- Alloy Marketing Technical Staff
- Current technical literature on each product .A technical library with electronic database systems
- Environmental Engineering staff
- Manufacturing and Facilities Engineering personnel
- Custom Fabrication engineering

In addition, Brush people welcome your comments about copper beryllium products, ones you are currently using, and those you would like to see developed in the future. Also, since copper beryllium is a recyclable product, we welcome your inquiries about copper beryllium solid or liquid residuals.

Quality

Brush Wellman is committed to our customers success. Accordingly, we recognize the need to provide high quality products and services as a condition of doing business. The markets we serve include some of the most demanding in the world when it comes to quality of systems, products and services. We have long been recognized for our quality excellence and leadership by these highly demanding markets.

Our quality initiatives are based on the philosophy of defect prevention and reduction in variability. We focus on continuous improvement of our processes and make extensive use of statistical tools.

We believe that continuous improvement requires employee involvement and the use of teams. To maintain high standards of quality, we provide ongoing training in quality skills for all employees.

Accordingly, we have a quality policy that guides the way we function:

We are committed to fulfilling customer needs and expectations through the involvement of all our employees in the continuous improvement of our products and services.

To provide evidence of our quality, we:

- Provide **material certifications** that report test results demonstrating compliance to customer specifications
- On request, we will provide detail of statistical process capability and product quality
- Encourage visits to our operating facilities for the purpose of auditing our quality systems that meet the requirements of **ISO 9002, MIL-I-45208,** and **A2 LA**

Safe Handling

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 Brush Wellman Inc. in Cleveland, Ohio at 800-321-2076.

CORPORATE HEADQUARTERS
BRUSH WELLMAN INC.

17876 St. Clair Avenue
Cleveland, OH 44110 USA
Tel: +(1) 216-486-4200
Fax: +(1) 216-383-6868
Email: sales@brushwellman.com

www.brushwellman.com

Manufacturing Centers

Elmore, Ohio   Reading, Pennsylvania

DOMESTIC SERVICE CENTERS

ILLINOIS
606 Lamont Road
Elmhurst, IL 60126
Toll Free: (800) 323-2438
Local: +(1) 630-832-9650
Fax: +(1) 630-832-9657

NEW JERSEY
180 Passaic Avenue
Fairfield, NJ 07004
Toll Free: (800) 526-2538
Local: +(1) 973-227-2552
Fax: +(1) 973-227-2649

MICHIGAN
27555 College Park Drive
Warren, MI 48093
Toll Free: (800) 521-8800
Local: +(1) 586-772-2700
Fax: +(1) 586-772-2472

INTERNATIONAL SERVICE CENTERS

UNITED KINGDOM & IRELAND
Brush Wellman Limited
Units 4/5 Ely Road
Theale Commercial Estate
Theale Reading
Berkshire, England RG7 4BQ
Tel: +(44) 118-930-3733
Fax: +(44) 118-930-3635

GERMANY
Brush Wellman GmbH
Motorstrasse 34
D-70499 Stuttgart
Germany
Tel: +(49) 711-830-930
Fax: +(49) 711-833-822

JAPAN
Brush Wellman (Japan), Ltd.
Daichi Marusan Building 9
Kanda Jimbocho 3-Chome, Chiyoda-Ku,
Tokyo 101, Japan
Tel: +(81) 3-3230-2961
Fax: +(81) 3-3230-2908

TAIWAN, R.O.C.
Brush International, Inc.
Taiwan Representative Office
11th FL-6, No.188, Section 5,
Nanking East Road,
Taipei, Taiwan, Republic of China
Tel : +(886) 2-2747-8800 x121
Fax : +(886) 2-2747-1485

CHINA / HONG KONG
Brush International, Inc.
Hong Kong Representative Office
Room 604, Blk 1, Enterprise Square
9 Sheung Yuet Road,
Kowloon Bay, Kowloon
Hong Kong
Tel : +(852) 2318-1960 / 1907
Fax : +(852) 2318-1879

REPUBLIC OF KOREA
Brush Wellman (Japan), Ltd.
Korean Representative Office
Room No. 621, Iriom Bldg., 599-1
Yeonsu-2 Dong
Yeonsu-Ku, Incheion City Korea
South Korea
Tel : +(82) 32-811-2171
Fax : +(82) 32-811-2175

SINGAPORE / ASEAN
Brush Wellman (Singapore) Pte Ltd.
110 Paya Lebar Road #02-01
Singapore 409009
Tel : +(65) 6842-4456
Fax : +(65) 6842-6646

CHINA / SHANGHAI
Brush Wellman (Singapore) Pte Ltd.
Shanghai Representative Office
Shanghai Apollo Business Center
1440 Yan An West Road, Room #515
Shanghai, P.R.O.C.
Tel : +(86) 21-6248-1120 x515
Fax : +(86) 21-6248-5875

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ENGINEERED MATERIALS

COPPER & BRASS SERVICENTER ASSOCIATION

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