NGK BERYLCO

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Beryllium Copper Alloys

Technical Guide

Security • Reliability • Performance

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Beryllium

Although the main ore of beryllium, beryl, from the Greek ‘bērullos’ was already known 5000 years before Christ and appreciated as a gemstone, its industrial exploitation really began until 1941.

The discovery of beryllium has been attributed to Louis-Nicolas Vauquelin (F) in 1798 at the request of the mineralogist Hauy, trying to find possible chemical similarity between beryl and emerald. It was in 1828 that Friedrich Whöhler (D) and Antoine Bussy (F) isolated the metal. Vauquelin conferred to this new identified element the name glucinium based on the Greek 'glikys', by reference to the sweet taste of some of its compounds. The name beryllium was officially given to this element in 1957.

Beryllium (Be) is a mineral extracted from the ground mainly in an oxide state. A bivalent element, beryllium is a steel grey metal that can be mostly found in the minerals, the most important of which are beryl ($Be_3Al_2Si_6O_{18}$), also called emerald and aquamarine according to its color, and chrysoberyl (Al_2BeO_4). Pure beryllium is obtained by reduction of beryl or by electrolysis of beryllium chloride.

Beryllium is the fourth element on the periodic table. Beryllium metal has excellent thermal conductivity, transparent to X-ray and is nonmagnetic. Beryllium is a light element (density 1.85 g/cm^3), which melts at 1300°C and has a very high Young's modulus. The physical properties of beryllium make an item for various applications in high end products. As metallic material, its uses are relatively limited to aerospace and nuclear industries as well as defense applications.

Age-hardening copper based-alloys

The most interesting property of beryllium, which has been instrumental in the development of industrial alloys, is its ability as an addition to cause precipitation hardening in other metals, in particular nickel, aluminum and especially copper. These two alloys owe their development to the fact that the beryllium nickel or copper, can cause hardening of the alloy structural precipitation annealing treatment at low temperature.

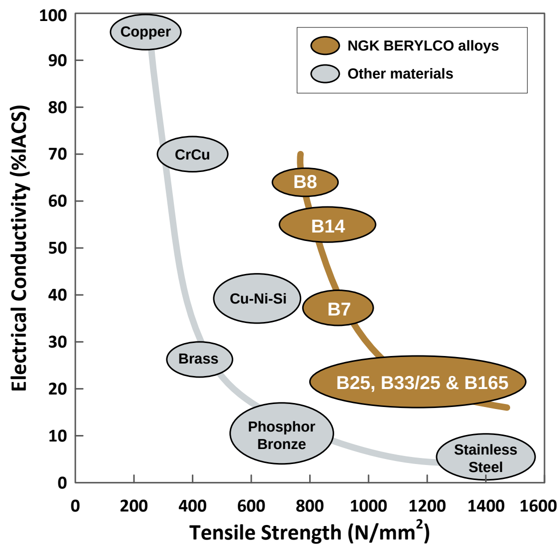
The copper beryllium alloys are produced from a master alloy of copper and beryllium, containing approximately 4 % of beryllium. The manufacturing process is as follows:

1) Chemical treatment of the ore (beryl), a double aluminium beryllium silicate, to produce a beryllium oxide.

2) Reduction of the beryllium oxide with carbon by calcining in an electric arc furnace in the presence of copper.

Copper-beryllium alloys are mainly based on copper with a beryllium addition. High strength beryllium copper alloys contain 0.4 to 2% of beryllium with about 0.3 to 2.7% of other alloying elements such as nickel, cobalt, iron or lead. The high mechanical strength is achieved by precipitation hardening or age hardening.

High Strength and Electrical Conductivity



The Berylco alloys combine a range of properties particularly suited and ideal to meet the exacting requirements of many applications in the automotive, electronic, medical, telecommunication, Oil&Gas, aeronautical, watch, electro-chemical industries, etc.

Very high mechanical properties and improved electrical conductivity can be obtained by means of a simple thermal treatment which produces a structural precipitation hardening. This is the fundamental property of copper beryllium alloys:

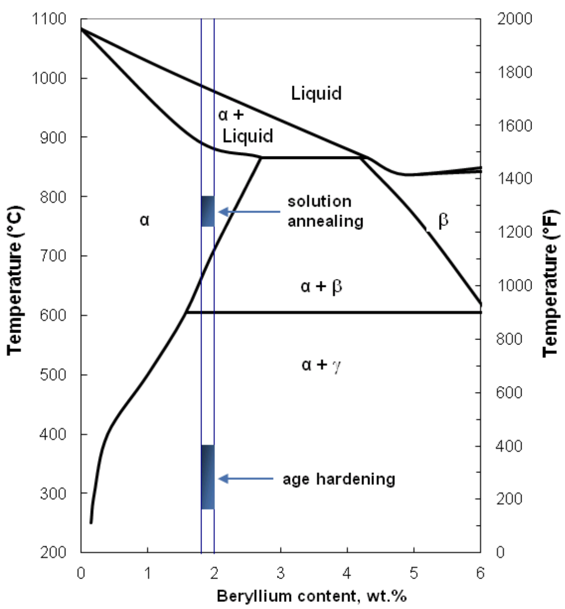
- The alloys can be supplied in tempers which allow plastic deformation almost equivalent to copper. After forming deep-drawn parts, or parts with complex bends, they can be heat treated to obtain very high mechanical properties
- They have very high tensile strength, up to 1500 N/mm^2.
- They exhibit an outstanding fatigue strength and excellent resistance to fatigue in reverse bending and vibrations.
- Hardness as high as 400 Vickers or Brinell, possibly greater, can be obtained.
- They have excellent wear resistance.
- They present complete resistance to anelastic behaviour under elastic deformation.
- They can operate over a wide range of temperatures, particularly very low cryogenic temperatures, but also at elevated temperatures which are above those normally acceptable for the common copper alloys.

Because they are copper base alloys:

- Beryllium Copper exhibit a high electrical conductivity ranges from 22 to 70% IACS depending on the alloys and temper.
- They are non-magnetic
- They have excellent corrosion resistance and are ideal for use in marine and industrial environments.
- They have good machinability.
- They are non-sparking.
- They have a high fluidity and good castability.

Heat treatment and phase diagram of Cu-Be

The binary phase diagram allows a better understanding of the mechanism of heat treatments. It shows the condition of the alloy as a function of the temperature and the beryllium content.



The solubility of beryllium in copper increases with increasing temperature, from practically zero at room temperature to more than 2% by weight at temperatures above 800°C. This zone is represented at the left of the diagram where the alloy is in solid solution (phase α), a face centred cubic structure like copper.

For the typical alloy CuBe1.9 (1.8 to 2% of beryllium) the alloy is in the α phase between 720°C and 860°C. For industrial purposes the solution heat treatment is done between 750° and 800°C. By rapidly cooling the metal after the solution heat treatment, using a water quench for example, the super-saturated solution can be maintained at room temperature. This operation is always done by the supplier.

In this condition the copper beryllium is workable and ready for the structural precipitation hardening which imparts the interesting properties to this alloy. This structural hardening is produced when the alloy tries to return to its equilibrium conditions $\alpha + \gamma$. Since the structure which is not in equilibrium can remain in the super-saturated condition at room temperature indefinitely, the metal must be heated to accelerate the transformation.

The γ phase is a beryllium-rich phase (1 atom in 2), body centered cubic. The formation of this γ phase causes a reduction of the beryllium content in the α matrix, which in turn improves the electrical and thermal conductivity. At the same time it produces a contraction of the material which amounts to a non-uniform linear shrinkage of about 0.2 % average.

The structural hardening is the result of the precipitation of the γ phase which passes trough several intermediary phases. The maximum of hardness for the alloy is produced by these intermediary phases. The precipitation hardening is generally done at temperatures between 300° and 400°C for 15 min to 4 hours at temperature, depending on the type of furnace used and the properties desired.

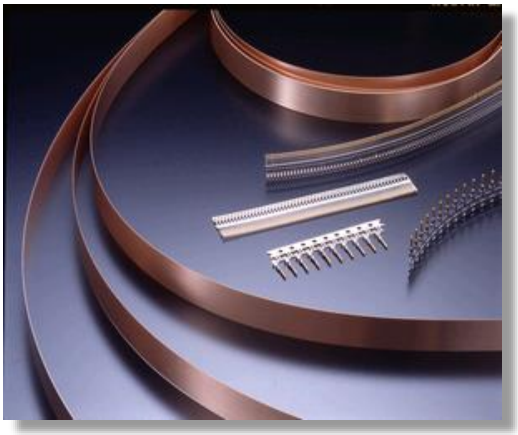
The maximum mechanical properties are obtained by treatment at 310-330°C for a period of 2 to 3 hours at temperature, depending on the initial temper of the metal.

The high conductivity alloys (nickel beryllide in copper) have a range from 0.15 to 0.7 weight percent beryllium. In these alloys most of the beryllium is partitioned to beryllide intermetallics. Coarse beryllides formed during solidication limit grain growth during annealing, while fine beryllides formed during precipitation hardening improve the 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 in this alloy family results in high resistance to creep and stress relaxation.

Delivery temper

Copper-beryllium properties are determined in part by chemical composition, but cold work and age hardening are also important. The choice of temper depends primarily on the degree of deformation or the machining which the semi-finished product has to undergo, since the final properties of the part depend much more on the precipitation heat treatment than the cold deformation after the solution heat treatment.



Temper designations are defined in the current standards but some lessprecise term such as 'quarter hard' and 'half hard' are also recognised by suppliers and users.

Copper beryllium in the solution annealed condition is desingated by a suffix letter 'A', for example alloy B25 A. this is the softest condition in which the alloy can be obtained.

Suffix letter 'H' for 'Hard' denotes an alloy that has been hardened by cold working, such as by rolling or drawing, for example B25 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, such as B25 HT. Copper beryllium bearing a 'M' for 'Mill Hardened' suffix has received proprietary mill processing, for example B25 HM, and guaranteees properties within a specific range.

As far as strip products are concerned one should chose the hardest temper possible which will still permit the deformation necessary for forming the part to be manufactured:

- The annealed (A) temper is recommended for deep drawing applications. When planning this operation it is preferable to specify for deep drawing application at the time of order.
- The 1/4 H temper is recommended for all applications where severe forming without drawing is planned.
- The 1/2 H temper still permits severe but limited deformation, but the H temper should be reserved for parts which are practically flat.

The mill hardened tempers offer the advantage of not requiring any heat treatment by the user. However, it must be remembered that the metal in this condition already has the properties required for the finished part and that they must be compatible with the requirements for the forming of the part. The choice of the mill hardened quality must therefore be a compromise between the characteristics desired for the application and the suitability for forming.

For rod and wire products the most suitable temper is 'cold worked', and in particular the free machining alloy 33/25. This alloy has a machinability index of about 60 %, while the standard Berylco 25 has an index of about 20 %.

Applications

The Berylco alloys combine a range of properties that make them essential materials and ideal for producing parts with high precision and the most varied complex shapes used in many fields and applications such as:

- Connectors in the electronic industries (computers, telecommunications, aerospace, automotive, etc.)
- Contact springs in the electromechanical, appliance, and automotive industries
- Instrument components (diaphragms, bellows, etc.)
- Springs and flexible parts
- Friction and wear parts
- Non-magnetic and non-sparking special tools
- Plastic injection molds, etc.

Demands for cost, quality, comfort, miniaturisation, safety, environmental protection, dimensional tolerances requirements, blemish-free forming surface conditions, and high general performance, are constantly increasing in all these fields and result in new and future great technical challenges requiring suitable high-performance alloys such as copper beryllium.

Security – Reliability – Performance	
High strength Hardness	Mecanical parts ; splined shafts, cams, gears, bearings and bearing cages requiring good wear resistance.
High yield strength	Clips, washers, springs, diaphragms, bellows, gimbal suspension, requiring good fatigue resistance.
High fatigue resistance	Contacts, connectors, relays, switches, all springs subjected to prolonged vibration.
Galling resistance Abrasion resistance	Shells, molds and parts for injection, bearings, valves, etc.
Stress relaxation resistance	Automotive applications, aeronautics, space and cryogenic.
Electrical & thermal conductivity Nonmagnetic	Watchmaking, electronic and electrical applications, instrumentation, welding equipments.
Corrosion resistance Formability	Industrial environments (especially petrochemicals), corrosive and marine environment, etc.
Nonsparking	Safety tools and applications in explosive and harsh environment.

Copper-beryllium

NGK Berylco is specialised in the manufacture of copper-beryllium alloys. These alloys fall into two distinct categories such as **high strength** (B25, B33/25 and B165) and **high conductivity** (B14, B7 and B8). Alloy B14 combines both attributes high strength and high conductivity. Many of our alloys are available in both heat treatable and mill-hardened (pre-heat treated) conditions.

Berylco 25

Alloy B25, containing less than 2% of beryllium, can achieve the highest strength (1500 MPa) and hardness of any commercial copper based alloy in the age hardened condition. In the annealed and low cold-rolled condition, it has an excellent bending formability. Alloy B25 is also delivered in the pre-heat treated (mill-hardened) condition. The strip is age hardened to a specific strength level as part of the manufacturing process prior to shipment. Cost effectiviness is made by elimination of the need for age hardening and cleaning of the stamped parts, as well as avoiding any part distortion. Alloy B25 exhibits some unique combination of properties of mechanical and electrical properties, associated to an excellent formability depending on the tempers. B25 also exhibits exceptional high fatigue life and resistance to stress relaxation at elevated temperatures.

Berylco 165

Alloy B165 exhibits nearly similar mechanical and electrical properties to B25. It contains less beryllium than B25 and is especially used in the humid field. It offers a good strength and is well recommendend for marine applications.

Berylco 33/25

Alloy B33/25 achieves the strength properties of B25 after age hardening with the added benefits of being free machining. Small amount of lead addition promotes formation of finely divided chips and extends cutting tool life, which improve the machinability. Alloy B33/25 rod and wire is suitable for automatic machining operations. In the hardened condition after machining, B33/25 offers a high resistance to fatigue, an excellent resistance to thermal relaxation and a unique combination of strength and conductivity. It can be locally annealed to allow crimping after hardening and is easily coated with a galvanic layer.

Berylco 14

Alloy B14 contains low beryllium content and can be supplied fully hardened. After special mill-hardened process, the B14 S offers an excellent formability with electrical and thermal conductivity from 45 to 65% of pure copper (typical value: 55% IACS). Delivered in the hardened condition, the B14 S combines excellent stress relaxation resistance at elevated temperature and high mechanical resistance up to 950MPa. No subsequent heat treatment of the stamped parts is required, which reduces production costs and avoids deformation of the finished parts. This alloy offer users the opportunity to upgrade component performance over bronzes and brasses that no other copper alloy about this price range can reach.

Berylco 7

Alloy B7 contains less beryllium and is availableas mill-hardened condition. No further age-hardening is required. It combines the best attributes of both the high strength and high conductivity commercial copper beryllium alloy families. In addition to its high strength and conductivity, B7 has excellent formability, stress resistance at elevated temperature which still exceptional for such grade. This alloy is specially recommended for high batches.

Berylco 8

This alloy is the result of the most recent development of NGK group. Alloy B8 is a copper alloy containing some nickel and about 0.4% of beryllium. B8 strip is supplied in the mill-hardened condition, which somewhat limits its formability but avoids further heat-treatment of the final parts. Amongst the copper-beryllium family, B8 offers the highest electrical conductivity of Berylco alloys (> 60% IACS). Combining a very high thermal electrical conductivity and good mechanical strength, it is used in all applications requiring good crimp and mechanical properties at elevated temperature.

Physical properties

Designation and chemical composition (%)

Alloy designation					Composition (weight percent) in %							
	NGK Berylco	ISO/EN Symbole	ISO/EN Number	UNS (ASTM)	Beryllium (Be)	Cobalt (Co)	Nickel (Ni)	Nickel (Ni) + Cobalt (Co)	Cobalt (Co) + Nickel (Ni) + Iron (Fe)	Lead (Pb)	Aluminium (Al)	Copper (Cu) + additions
High Strength	**B25**	CuBe2	CW101C	C17200	1.8-2.0	0.3 max.	-	-	0.6 max	-	-	99.5 mini
	B33/25	CuBe2Pb	CW102C	C17300	1.8-2.0	0.3 max.	-	-	0.6 max	0.2 mini.	-	99.5 mini
	B165	CuBe1.7	CW100C	C17000	1.6-1.8	0.3 max.	-	-	0.6 max	-	-	99.5 mini
High conductivity	**B14**	CuNi2Be	CW110C	C17510	0.2-0.6	-	1.8-2.5	-	-	-	-	99.5 mini
	B8	CuNi2Be	CW110C	C17510	0.2-0.6	-	1.4-2.2	-	-	-	-	99.5 mini
	B7	CuNi2Be	CW110C	C17530	0.2-0.4	-		1.8-2.5	-	-	0.6 maxi.	99.5 mini

Physical properties

Physical properties after pricipitation hardening			B25 B33/25	B165	B14	B 8	B7
Melting point	(°C)		865-980	890-1000	1030-1070	1005-1070	1050-1085
Density	(g/cm³)	at 20°C	8,26	8.35	8,75	8,75	8,71
Specific heat	(Cal/(g.°C))	at 20°C	0,1	0,1	0,1	0,1	0,1
Coefficient of linear expansion	($x10^{-6}$/°C)	at 20° to 200°C	17,3	17,5	18	17,6	17,6
Electrical resistivity ρ (maxi)	(10^{-8}Ω.m)	at 20°C	7,9	7,8	3,8	3,1	5,4
Thermal conductivity	(W/m.K)	at 20°C	84-130	90-135	167-260	167-260	148-194
Electrical conductivity	(% IACS)	at 20°C	25	25	50	63	38
Modulus of elasticity	(N/mm^2)		130 000	128 000	132 000	132 000	127 000
Modulus of rigidity	(N/mm^2)		50 000	49 000	52 000	52 000	49 000
Poisson's ratio			0,3	0,3	0,3	0,3	0,3
Magnetic permeability	μ (μ=1+4πk)		1.000042	1.000042	1.000031	1.000031	1.000027
Fatigue resistance	(N/mm^2)	at 10^8 cycles	≥ 300	≥ 300	≥ 240	≥ 240	≥ 250

References Specifications

Authority		Strip	Rod and Wire
EN	Comité Européen de Normalisation	1652, 1654	12163, 12164, 12165, 12166, 12167
ASTM	American Society for Testing & Materials	B194, B534	B196, B197, B442
CDA	Copper Development Association	C17200, C17000, C17510, C17530	C17200, C17300, C17510
AMS	Aerospace Materials Specification	4530, 4532	4533, 4534, 4650, 4651, 4725
SAE	Society of Automotive Engineers	J461, J463	J461, J463
JIS	Japanese Industrial Standard	H3130 C1720 P.R, H3130 C1751 P.R	H3270 C1720 B.W
AFNOR(1)	Association Française de Normalisation	A51.109*	A51.114*, A51.414*, NFL14.709
DIN(1)	Deutsches Institut fur Normung	17666*, 17670*, 1777*	17666*, 17672*
QQ(2)	US Federal Specification	QQ-C-533	QQ-C-530
BS(1)	British Standard	BS 2870*	BS 2873*

- Specifications replaced by EN (1) or ASTM (2) specifications. Withdrawn and superseded specifications are listed for reference only, and are not used for purchasing.
- Please contact NGK Berylco to determine the appropriate replacement specification.

Standard products forms

NGK wrought copper beryllium are available in a variety of product forms and sizes, to meet demand from most industrial sectors. The most standard products are:

- **Strip** is flat-rolled product of maximum thickness 1.5mm and supplied in coil form.
- **Rod** is generally round section furnished in straight lengths, extruded or drawn ranging from diameter 1.4 to 65 mm. They are supplied in random or specific length.
- **Wire** furnished in coils or on spools or reels.
- **Plate** is flat-rolled product thicker than 1mm and over 200mm wide.
- **Tube** is a seamless hollow with round section supplied in random or specific manufacturing length.

Standard products forms	NGK Berylco Designation					
	B25	B33/25	B165	B14	B8	B7
Strip	✓	-	✓	✓	✓	✓
Rod	✓	✓	-	✓	-	-
Wire	✓	✓	-	✓	-	-
Plate	✓	-	-	✓	-	-
Tube	✓	-	-	✓	-	-

Strip and plate

NGK Berylco manufactures copper beryllium strips and plates primarily intended to be drawn and then stamped into small contacts used in a wide range of industrial applications such as connectors electrical contacts, membranes, spring elements, electromagnetic shielding, etc.. A copper-beryllium contact blade naturally has a spring back effect and can also be, due to its good conductivity, the active component of a electrical conductor device.

Contact made of copper beryllium settles insertion force in a connector, providing sufficient force to minimize contact resistance and maintaining the extraction force necessary to ensure the integrity of the conductingcircuit. This often requires a stamped contact part that combines rigidity and flexibility altogether. This is the major characteristics of copper beryllium alloys.

The NGK alloys offer the guarantee of high manufacturing performance. Strips are characterised by their fine tolerances such as chemical composition, dimensional accuracy and mechanical properties. They can be surface treated (nickel, gold, silver, tin, etc.) that increases conductivity so as to ensure a good contact point or improving the electromagnetic surfaces compatibility.

Berylco Strip – high resistance alloys

Mechanical and Electrical Properties										
Alloy	Temper		TS (N/mm²)	YS 0.2 (N/mm²)	Elongation A50 mini (%)	Hardness (HV)	Electrical Conductivity (% IACS)	Heat Treatment	Formability R/t at 90° bending	
									Long.	Trans.
B25	Age hardenable									
	A	TB00	410 - 540	190 - 380	35	90 - 150	15 - 19	---	0,0	0,0
	1/4H	TD02	510 - 610	400 - 560	15	130 - 190	15 - 19	---	0,0	0,0
	1/2H	TD03	590 - 690	510 - 660	8	180 - 220	15 - 19	---	1,0	2,0
	H	TD04	690 - 830	650 - 800	2	215 - 270	15 - 19	---	2,0	5,0
	Age hardened									
	AT	TF00	1130 - 1350	960 - 1210	3	350 - 410	21 - 28	3h at 315°C	--	--
	1/4HT	TH01	1210 - 1400	1020 - 1280	3	360 - 430	21 - 28	2h at 315°C	--	--
	1/2HT	TH02	1260 - 1450	1090 - 1350	1	370 - 440	21 - 28	2h at 315°C	--	--
	HT	TH04	1310 - 1520	1130 - 1420	1	380 - 450	21 - 28	2h at 315°C	--	--
	Mill hardened (standard)									
	1/4HM	TM01	750 - 870	550 - 760	15	235 - 280	19 - 28	M	1,3	1,8
	1/2HM	TM02	830 - 960	650 - 850	12	260 - 310	19 - 28	M	1,5	2,0
	HM	TM04	930 - 1080	750 - 980	9	290 - 350	19 - 28	M	2,3	2,5
	SHM	TM05	1030 - 1150	860 - 1020	9	310 - 360	19 - 28	M	2,5	3,0
	XHM	TM06	1100 - 1250	930 - 1180	4	345 - 395	19 - 28	M	3,0	4,0
	XHMS	TM08	1200 - 1320	1030 - 1230	3	365 - 420	19 - 28	M	4,0	6,0
	Mill hardened Type B (high formability)									
	1/2HMB		830 - 930	660 - 860	12	255 - 310	17 - 26	M	0,0	0,0
	HMB		930 - 1030	760 - 930	9	280 - 340	17 - 26	M	1,0	1,0
	XHMB		1070 - 1210	930 - 1170	6	330 - 390	17 - 26	M	2,0	2,0
	Mill hardened Type S (very high formability)									
	HM-TypeS		960 - 1040	790 - 940	9	285 - 370	17 - 26	M	0,5	0,5
	XHM-TypeS		1060 - 1220	930 - 1070	6	315 - 395	17 - 26	M	1,0	1,0
B165	Age hardenable									
	A	TB00	410 - 530	190 - 380	35	90 - 150	15 - 19	---	0,0	0,0
	1/4H	TD02	510 - 610	400 - 560	15	130 - 190	15 - 19	---	0,0	0,0
	1/2H	TD03	580 - 690	500 - 660	8	180 - 220	15 - 19	---	1,8	2,0
	H	TD04	680 - 830	620 - 800	2	210 - 270	15 - 19	---	3,5	5,0
	Age hardened									
	AT	TF00	1030 - 1260	890 - 1140	3	330 - 380	21 - 28	3h at 315°C	--	--
	1/4HT	TH01	1100 - 1320	930 - 1170	3	340 - 390	21 - 28	2h at 315°C	--	--
	1/2HT	TH02	1170 - 1380	1030 - 1250	1	360 - 410	21 - 28	2h at 315°C	--	--
	HT	TH04	1240 - 1450	1060 - 1300	1	370 - 440	21 - 28	2h at 315°C	--	--
	Mill hardened (standard)									
	AM	TM00	690 - 800	480 - 660	16	210 - 250	19 - 28	M	1,0	1,2
	1/4HM	TM01	750 - 870	550 - 760	15	235 - 280	19 - 28	M	1,8	2,0
	1/2HM	TM02	830 - 960	650 - 850	12	260 - 310	19 - 28	M	2,0	2,2
	HM	TM04	930 - 1070	750 - 980	9	285 - 340	19 - 28	M	2,3	2,5
	SHM	TM05	1020 - 1150	850 - 1020	9	300 - 360	19 - 28	M	2,5	3,0
	XHM	TM06	1100 - 1250	930 - 1170	4	335 - 385	19 - 28	M	3,0	5,0

Note

- Strip Properties – Values are applicable to thickness 0.1mm and over.
- M – "Mill Hardened" M indicates that the metal has been submitted to a treatment facility designed especially to give characteristics falling within a guaranteed range specific properties.
- Formability – The formability R/t ratio allows a bending radius at 90° without cracking in the direction of rolling (longitudinal and transverse bending ways), for the various tempers. Typical R/t values are applicable for strip of 0.25mm thick or less.

R = radius of bending ; t = thickness of the strip

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Berylco Strip – High conductivity alloys

Mechanical and Electrical Properties										
Alloy	Temper		TS (N/mm²)	YS 0.2 (N/mm²)	Elongation A50 mini (%)	Hardness (HV)	Electrical Conductivity (% IACS)	Heat Treatment	Formability R/t at 90° bending	
									Long.	Trans.
B14	Age hardenable									
	A	TB00	250 - 380	140 - 300	20	60 - 130	22 - 25	---	0,0	0,0
	1/2H	TD03	410 - 530	340 - 480	5	125 - 160	22 - 25	---	1,5	2,0
	H	TD04	480 - 600	370 - 560	2	140 - 185	22 - 25	---	2,0	3,0
	Age hardened									
	AT	TF00	680 - 870	550 - 690	8	190 - 250	≥ 45	3h at 480°C	--	--
	1/2HT	TH02	750 - 900	650 - 850	5	215 - 265	≥ 45	2h at 480°C	1,5	2,0
	HT	TH04	750 - 950	670 - 900	5	220 - 270	≥ 45	2h at 480°C	2,0	2,0
	Mill hardened (high formability)									
	S780		780 - 930	680 - 850	12	220 - 270	≥ 48	M	0,3	0,3
	S880		880 - 1020	780 - 950	10	250 - 310	≥ 48	M	0,7	0,7
B8	Mill hardened (standard)									
	HT	TH04	700 - 870	600 - 780	5	210 - 260	≥ 60	M	1,0	1,0
B7	Mill hardened (standard)									
	1/2HT	TH02	670 - 800	550 - 760	10	195 - 250	≥ 38	M	0,0	0,0
	HT	TH04	765 - 900	685 - 830	8	220 - 275	≥ 33	M	0,5	1,0
	EHT		870 - 1000	750 - 930	4	250 - 310	≥ 30	M	1,0	1,5

Note

- Strip Properties – Values are applicable to thickness 0.1mm and over.
- M – "Mill Hardened" M indicates that the metal has been submitted to a treatment facility designed especially to give characteristics falling within a guaranteed range specific properties.
- Formability – The formability R/t ratio allows a bending radius at 90° without cracking in the direction of rolling (longitudinal and transverse bending ways), for the various tempers. Typical R/t values are applicable for strip of 0.25mm thick or less. R = radius of bending ; t = thickness of the strip

Manufacturing tolerances

thickness

Temper	Mini (all alloys)	Maxi		
		B25	B165	B14
A	0.06	2.00	0.90	1.20
1/4 H	0.055	2.00	0.90	1.00
1/2 H	0.05	2.00	0.80	0.90
H	0.05	1.60	0.60	0.70
Mill hardened	0.05	0.40*	0.40*	0.40*

* for higher values please contact us..

Widths

Thickness	Mini (all alloys)		Maxi**					
			B25		B165		B14	
	temper	hardened	temper	hardened	temper	hardened	temper	hardened
0.05 to 0.099	3***	4	150	150	150	150	150	150
0.10 to 0.199	3	4	400	170	170	170	400	170
0.20 to 0.299	3	4	430	220	220	220	430	215
0.30 to 0.399	4	4	430	220	220	220	430	215
0.40 to 0.499	5	6	430		220		430	
0.50 to 0.799	6	8	430		220		430	
0.80 to 0.999	8	12	220		220			
1.00 to 1.199	10		220		220			
1.20 to 1.5*	12		220		220			

* for thickness above 1.5mm please consult us.
** for wider widths, please consult us (Long delivery).
*** we can slit small dimensions, up to 0.5mm width. For these special cases please consult us..

Strip dimensional tolerances

Thickness tolerances (mm)		
Thickness	Standard	Precision
< 0.099	± 0.004	± 0.0025
0.10 - 0.149	± 0.005	± 0.0035
0.15 - 0.199	± 0.006	± 0.004
0.20 - 0.249	± 0.007	± 0.005
0.25 - 0.299	± 0.008	± 0.006
0.30 - 0.399	± 0.009	± 0.007
0.40 - 0.499	± 0.010	± 0.008
0.50 - 0.599	± 0.013	± 0.009
0.60 - 0.799	± 0.015	± 0.010
0.80 - 0.999	± 0.030	On demand
1.00 - 1.199	± 0.035	On demand
1.20 - 1.499	± 0.045	On demand
1.50 - 2.000	± 0.050	On demand

➡ If supplied A temper, only standard tolerances are possible.

Width tolerances (mm)				
Thickness	Width	from 3 to 49.9	from 50 to 100	> 100
≤ 0.80 mm	standard	± 0.08	± 0.10	± 0.15
	precision	± 0.05	± 0.06	± 0.10
> 0.80 mm	standard	± 0.10	± 0.15	± 0.20

Camber tolerances max. / 1m (mm)	
Ratio : Width / Thickness (mm)	Straightness tolerances fo (mm)
8 to 15	8
15.1 to 30	6
30.1 to 60	4
60.1 to 120	3
> 120	2

➡ If the measurement is made over a length l1 other than 1 m, the value for f1 is established by the formula: $f_1 = fo \times l_1^2$ (l_1 is in mm).

Plate dimensional tolerances

Thickness tolerances (mm)			Length	Width
Thickness(1,2)	Tolerance		1200 maxi	200 maxi
	B25	B14		
0.90 – 1.19	± 0.035	± 0.035	+5/-0	+2/-0
1.20 – 1.49	± 0.045	± 0.045	+5/-0	+2/-0
1.50 – 2.00	± 0.050	± 0.050	+5/-0	+2/-0
2.01– 3.00	± 0.100	± 0.065	+5/-0	+2/-0
3.01 – 5.00	± 0.150	± 0.085	+5/-0	+2/-0
5.01 – 6.00	± 0.180	± 0.100	+5/-0	+2/-0

(1) Fot a specific temper, please consult us.
(2) For thicker plate, please contact us and read chapter 'Special Prodcuts - Mold and Plate for the plastic industry'.

Special request

The released tables can be used as a guide for the user to choose the alloy temper to achieve optimum characteristics before forming. The values shown are not static and, particularly for mill-hardened products, and depending on your special request, our NGK team can explore options for improving formability while maintaining the desired mechanical performance. For these special analyzes, NGK Berylco offers the services of its engineers and technicians.

B25 and B165 temper A (Annealed): NGK can provide in this soft temper a special quality for deep drawing. If this is a planned operation, please specify when ordering.

Packaging

NGK Berylco can provide transverse winding strips, converting redundant strip in coil into a useable product, packed in coils of very long lengths – Contact us

UTS	:	Ultimate tensile strength
YS 0.2	:	Yield strenght at 0.2% elongation
A50%	:	Remnant elongation, after failure
HV	:	Hardness Vickers

Rod, Bar and Tube

Rod and bar range on their cold drawn or extruded shape is extensive. Tubes are available in a wide range of diameter/wall thickness combinations such as ultra-thin tube walls to large size forged tubes. Tubes and bars can be delivered to the age-hardened condition. Rod, bar and tubes are primarily found in the annealed (A) and precipitation hardened (AT), as well as cold drawn (H) and precipitation hardened (HT).

Typical applications are precise turned machining components for high performance connectors, bushing and bearings for aircraft landing gear and pivoting members, long-life tricone drilling bit bushings, pressure housings for precision magnetometers, core pins and other inserts for plastic injection, rugged resistance welding gun components, die inserts for resistance welding, antigalling wear plates, guide rails and bus bars, machined threaded fasteners, and various strong instruments tubes such as bourdon and pitot types.

Mechanical and Electrical Properties									
Alloy	Temper		Diameter (mm)	TS (N/mm²)	YS 0.2 (N/mm²)	Elongation A50 mini (%)	Hardness (HV)	Electrical Conductivity (% IACS)	Heat Treatment
B25 & B33/25	Age hardenable								
	A	TB00	All dimensions	420 - 600	170 - 270	35	90 - 150	15 - 19	---
	H	TD04	Ø ≤ 25 mm	620 - 900	550 - 800	3	200 - 250	15 - 19	---
	H	TD04	Ø > 25 mm	600 - 800	500 - 750	5	180 - 240	15 - 19	---
	Age hardened								
	AT	TF00	All dimensions	1150 - 1350	1000 - 1250	3	360 - 410	21 - 28	3h at 315°C
	HT	TH04	Ø ≤ 25 mm	1300 - 1500	1150 - 1400	1	390 - 440	21 - 28	2h at 315°C
	HT	TH04	Ø > 25 mm	1200 - 1500	1050 - 1400	2	380 - 430	21 - 28	2h at 315°C
B14	Age hardened								
	AT	TF00	All dimensions	650 - 800	500 - 670	10	190 - 250	48 - 60	3h at 480°C
	HT	TH04	All dimensions	740 - 900	640 - 800	8	210 - 270	48 - 60	2h at 480°C

Manufacturing tolerances

Alloy B25, B33/25 and B14 are normally produced as cold drawn round bars in diameter range Ø1.4 to 65 mm (no age-hardening).
NGK range of products is extensive. We also manufacture (contact us):

- Round rods range from Ø < 1.4 mm or Ø > 70mm.
- Profile bars ⬡, □, ⬡, plane, cold draw or hot worked and some out of limits diameters.
- Mill-hardened rods.
- Tubes range from Ø > 70mm. Contact us for inside diameters.

■ Length

Length / Diameters			
Berylco 25		Berylco 33/25	
Ø (mm)	± (mm)	Ø (mm)	± (mm)
< 25,4	3 m ± 100mm	≤ 3.0	3 m ± 10mm
25,5 – 45.0	2 m mini	3,1 - 18	3 m ± 50mm
45,1 - 50,8	1,5 m mini	18,1 - 25	3 m ± 100mm
50,9 - 60.0	1 m mini	25,1 - 40	2 m mini
> 60	On demand		

➡ Remarks: For the Berylco 33/25, *CuBe2Pb*, rods are pointed and chamfered up to Ø16 mm before shipment.
➡ Rods can be delivered centerless ground.
➡ Contact us

Semi-finished Berylco products

■ Dimensional tolerances

Dimensional tolerances			
Berylco 25 (age hardenable)		Berylco 33/25 (age hardenable)	
Ø (mm)	± (mm)	Ø (mm)	± (mm)
1,4 - 3.0	h9 : +0, -0,025	0,9 - 2,3	h8 : +0, - 0.014
3,1 - 6.0	h9 : +0, -0,030	2.4 - 3.0	h8 : +0, - 0.014
6,1 - 10.0	h9 : +0, -0,036	3.1 - 6.0	h8 : +0, - 0.018
10,1 - 18.0	h10 : +0, -0,070	6.1 - 10.0	h8 : +0, - 0.022
18,1 - 25.0	h10 : +0, -0,084	10.1 - 13.0	h8 : +0, - 0.027
25,1 - 30.0	h11 : +0, -0,130	13.1 - 18.0	h9 : +0, - 0.043
30,1 - 50.0	h11 : +0, -0,160	18.1 - 25.4	h9 : +0, - 0.052
50,1 - 60.0	h11 : +0, -0,190	25.5 - 30.0	h10 : +0, - 0.084
		30.1 - 40.0	h10 : +0, - 0.100

➡ NGK Berylco can also supply some profile rods (square, rectangular and hexagonal) cold drawn or hot worked, and some non-standard sizes.

➡ Round rod cold drawn in

* For heat treated rods, please consult us.

■ Shape tolerances

Shape tolerance (circularity to products with a circular section), defined as the difference between the largest and the smallest dimension, measured on a same cross section of a rod or wire, is equal to half tolerance on diameter or flat.

Wire

Wire is one of the most versatile copper beryllium product forms with no other product having extremely diverse range of applications:
Coil springs, miniature machined electronic sockets, spring loaded test probes, cold headed fasteners, long travel coil springs, fatigue resistant and lightweight stranded cable, bandoliered connector contacts, braided shielding cloth, corrosion and biofouling resistant marine wire and wire mesh structures and eyeglass frames.

Mechanical and Electrical Properties									
Alloy	Temper		Diameter (mm)	TS (N/mm²)	YS 0.2 (N/mm²)	Elongation A50 mini (%)	Hardness (HV)	Electrical Conductivity (% IACS)	Heat Treatment
B25 & B33/25	■ Age hardenable								
	A	TB00	Ø ≥ 0.30	390 - 540	140 - 250	35	---	---	---
	1/2H	TD03	Ø ≥ 0.10	550 - 780	470 - 750	10	---	---	---
	H	TD04	Ø ≥ 0.10	750 - 1140	610 - 960	2	---	---	---
	■ Age hardened								
	AT	TF00	Ø ≥ 0.30	1130 - 1300	980 - 1200	3	---	> 22	3h at 315°C
	1/2HT	TH02	Ø ≥ 0.10	1200 - 1450	1100 - 1350	2	---	> 22	2h at 315°C
	HT	TH03	Ø ≥ 0.10	1270 - 1550	1200 - 1460	1	---	> 22	2h at 315°C

Manufacturing tolerances

■ Dimensional tolerances

Diameter (mm)	0.10 - 0.25	0.26 - 0.30	0.31 - 0.50	0.51 - 2.00	2.10 - 3.50	3.60 - 4.50	4.60 - 9.50
Standard tolerances (mm)	± 0.005	± 0.008	± 0.010	± 0.020	± 0.030	± 0.040	± 0.050
Precision tolerances (mm)	On demand	On demand	± 0.005	± 0.010	± 0.015	± 0.020	± 0.030

Before aging	Ø : from 0.20 to 0.50 mm	Depending on temper (contact us)
	Ø : from 0.50 to 9.50 mm	All tempers
	Ø : from 9.50 to 12.0 mm	Depending on temper (contact us)

Square or rectangular wire can also be supplied.

Special products

In addition to the strip, wire and rod semi-finished products, NGK Berylco include a large variety of wrought products such as foundry alloys (casting ingots, master alloys to 4%), Chill-Vents, forged rods, plates, tubes, Microtubes, profiles, safety tools, etc.

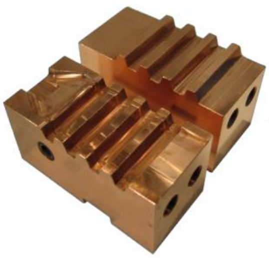
Foundry alloys

Copper beryllium foundry alloys (casting ingots and master alloy to 4%) are primarily used to cast any parts of any shapes, in various types of moulds (rods, complex shapes, etc.). Master alloys can control composition in production of commercial beryllium-containing alloys in many base metal systems and as an example, to protect against oxidation and melt ignition in magnesium.

Casting ingots are used in shell, permanent molds, investment, sand, centrifugal and pressure casting. Berylliums in copper increases melt, fluidity and cleanliness while providing a heat treatable casting. Replication of mold detail in cast parts is excellent and copper-beryllium, because of its excellent mechanical and thermal resistance, increases durability and good thermal regulation molds.

Chill-Vent

The patented C-Block Chill-Vent is specially designed & made by NGK. Event & Simplification: Chill-Vents are often used in association with permanent moulds for die casting light metals such as aluminium and magnesium. Only one alloy, beryllium copper, can provide both the hardness and thermal conductive properties required for use as a chill vent in aluminium and/or magnesium die-casting. NGK Chill-Vent provides solutions to the following die casting problems :



- Reduces gas hole defects due to poor gas flow
- Prevents eruption of aluminium from dies
- Eliminates aluminium/vent reactions
- Eliminates need for external air ventilation equipment
- Simplifies die design to reduce mold size
- Simplifies ventilation control in vacuum systems

Overall reduction of production costs are achieved through drastically minimizing the causes of casting rejections and metal losses normally associated with "flashing". C-Block is available in various combinations and configurations for both non-vacuum and vacuum die casting systems. NGK R&D department can help you to realise and produce the Chill-Vents required to your needs.

Safety Tool

The Berylco Safety tools have some unique properties:

- Nonsparking
- High Strength
- Nonmagnetic
- Corrosion Resistant

Non-sparking Berylco Safety Tools provide excellent protection against fires and explosions in environments where flammable solvents, fuels, materials, gasses and residues are present. While many nonferrous alloys meet non-sparking standards, only beryllium copper has the superior strength and hardness not found in safety tools made from aluminium, bronze and brass.

The nonmagnetic and corrosion-resistant properties of our tools are well suited for industrial and high technology applications. Whenever the safety of your workers or plant is a concern, Berylco Safety Tools deliver the durability, performance and value you expect from the industry leader.

Mold and Plate for the plastic industry

Berylco Plus, Supra and Ultra products are designed with one goal in mind. Improved profit through improved performance. Plate products are available in three grades from two alloy systems:

- Berylco Plus - higher conductivity, lower hardness beryllium copper alloy (alloy C17510).
- Berylco Supra - medium conductivity, medium hardness beryllium copper alloy (alloy C17200).
- Berylco Ultra - lower conductivity, higher hardness beryllium copper alloy (alloy C17200).

Berylco products are recognised as excellent mould alloys for the plastic industry as injection moulds and tooling for blow moulds. They are known to produce superior quality plastic parts with minimum total production costs over other competing mould materials. This is due to its optimum combination of hardness, wear resistance, thermal fatigue, and thermal conductivity.

Plate and Rod tolerances

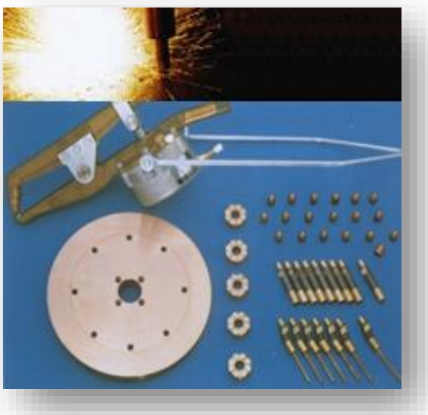
	Thickness (mm)	Tolerance (mm)	Max. width (mm)	Max. length (mm)
Plate	20 – 300	+1 / 0	500	2000
Rod	20 – 300	-	-	2000

*Other thickness can be made available as required.

RWMA Electrode

Because of high strength and high conductivity, BeCu Alloys are suitable for resistance welding equipment such as electrodes, shanks, etc.

- Berylco 14 (C17510) - RWMA Group A class 3
- Berylco 25 (C17200) - RWMA Group A class 4



Manual and automated welding equipment continues to respond to the highly competitive assembly needs of industry today. High stresses and massive current flow at rapid cycles calls for materials with something extra. Extra strength, extra conductivity, extra endurance, extra reliability. Unplanned downtime is the most expensive operating consequence of choosing materials poorly.

MicroTuBe

MicroTuBe benefits from all the Beryllium Copper alloys natural advantages and is designed to last longer:

- High-Precision tubes
- Good oxidation resistance
- Non-magnetic & non-sparking
- Smooth internal and external surface
- High degree of roundness

NGK high strength MicroTubes are available in comprehensive size range (Øext 0.1 to 3mm). Main applications are heat transfer tube, Micro precision tube for contact probe, coaxial semi-rigid cable, RFI antenna, Terminals, etc

Dam Block

NGK Berylco Dam Block benefits natural advantages of copper beryllium alloys for the continuous copper bar casting machine. NGK specifically developed alloy C17510 to optimize the life cycle of Dam Blocks in relation to particular stresses continuous copper casting machines and operations. Compared to conventional copper, the NGK Dam Blocks possible to obtain a longer and improve the thermal conductivity lifecycle.

NGK Berylco can provide Dam Blocks for all types of installation based projects and dimensions requested.

Alloys properties comparison

Alloy		temper	UTS (N/mm²)	$YS_{0.2}$ (N/mm²)	A% in 50mm	hardness (HV)	fatigue strength	modulus of elasticity (GPa)	electrical conduct. (% IACS)	density (g/cm³)
Steel Inox	X10CrNi18-8	spring	1800	- -	- -	500	- -	195	2.5	7.9
Nickel Beryllium	NiBe2	**1/2 HT**	**1700**	**1400**	**9**	**500**	**660 (1)**	**200**	**7.5**	**8.4**
Cuivre Beryllium	CuBe2	**1/2 HT**	**1350**	**1200**	**1.5**	**390**	**300**	**128**	**22**	**8.3**
Copper-Nickel	CuNi20Mn20	1/2 HT	1250	1200	0.5	390	300	157	3	8.3
Copper-Nickel	CuNi15Sn8	spring	1240	1170	3	370	- -	127	8	8.9
Steel Inox	Z10CN18.09	H	1200	1050	20	- -	- -	196	2.5	7.9
Cuivre Beryllium	CuBe1.7	**1/2 HT**	**1190**	**1020**	**1.5**	**360**	**280**	**128**	**22**	**8.3**
Copper Titane	CuTi4	1/2 HT	1160	1120	4	350	290	130	15	8.6
Steel Carbon	XC75	spring	1150	1100	8	400	- -	210	10	7.85
Copper-Nickel	CuNi8Sn5	spring	1000	930	6	335	- -	124	15	8.3
Cuivre-Beryllium	CuNi2Be	**S880**	**960**	**880**	**12**	**270**	**270**	**131**	**55**	**8.7**
Brass	CuZn22Al3.5	extra spring	900	800	2	250	255	117	17	8.2
Cuivre- Beryllium	CuCo2Be	**1/2 HT**	**820**	**750**	**5**	**240**	**250**	**131**	**50**	**8.7**
Bronze	CuSn9P	spring	820	800	0.5	250	- -	108	12	8.8
Maillechort	CuZn27Ni18	spring	800	670	2	210	220	126	5	8.7
Bronze	CuSn8	spring	800	750	2	235	220	110	12	8.8
Copper-Silicon	CuNi3Si	spring	800	655	5	240	- -	130	45	8.8
Bronze	CuSn6P	spring	770	740	1	235	215	118	13	8.8
Inconel 600	NiCr16Fe7	H	730	630	- -	- -	- -	217	1.7	8.5
Bronze	CuSn5	spring	720	620	2	215	210	112	14	8.9
Bronze	Cu Sn2Zn9	spring	680	- -	- -	215	- -	126	20	8.8
Copper-Nickel	CuNi9Sn2	spring	680	640	0.5	205	- -	122	11	8.9
Copper-Nickel	CuNi44Mn1	H	680	600	3	180	- -	150	3.5	8.9
Copper-Iron	Fe1.5CoSn	extra spring	680	660	- -	- -	200	121	50	- -
Copper-Nickel	CuNi2Si	TH4	670	620	6	210	245	130	40	8.9
Brass	CuZn36Pb2	extra spring	660	610	3	190	- -	109	26	- -
Brass	CuZn9.5Sn2	spring	645	620	2	215	- -	126	28	8.8
Brass	CuZn30	spring	600	480	3	180	160	112	28	8.5
Brass	CuZn10	extra spring	540	480	1	165	152	112	44	8.8
Copper Cadmium	Cd0.8Sn0.6	extra spring	530	480	1.5	180	- -	119	60	- -
	CuFe2P	F 50	500	430	5	150	- -	123	75	8.80

(1) For 10^7 cycles in AT temper

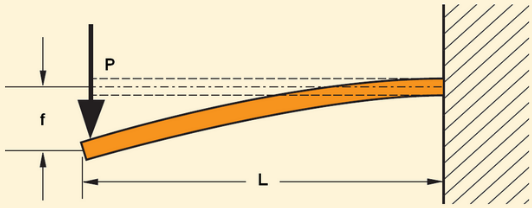
Spring Characteristics

In general, the most important properties of a spring, whatever its application, are the elastic properties of the materials such as the elastic limit, the modulus of elasticity, the fatigue strength or retention of properties with time.

- The table shown on the opposite page exihbits the mechanical and electrical properties of various spring alloys.
- Below are shown the equations to be used for the calculation of flat springs in two types of configuration:

■ Simple flat spring of rectangular cross-section, clamped at one end with a load in the other end:

$$f = \frac{4PL^3}{E\ell e^3} \qquad \sigma = \frac{6PL}{\ell e^2} \qquad \sigma = \frac{3fEe}{2L^2}$$



f = Deflection (mm)
E = Modulus of elasticity (N/mm²)
e = Thickness (mm)
P = Load (N)
L = Length (mm)
ℓ = Width (mm)
σ = Stress (N/mm²)

■ Simple flat spring of rectangular cross-section, supported at both ends and loaded in the centre:

$$f = \frac{PL^3}{4E\ell e^3} \qquad \sigma = \frac{3PL}{2\ell e^2} \qquad \sigma = \frac{6fEe}{L^2}$$

The deflection is:

- Inversely proportional to the Modulus of Elasticity.
- Inversely proportional to the cube of the thickness.

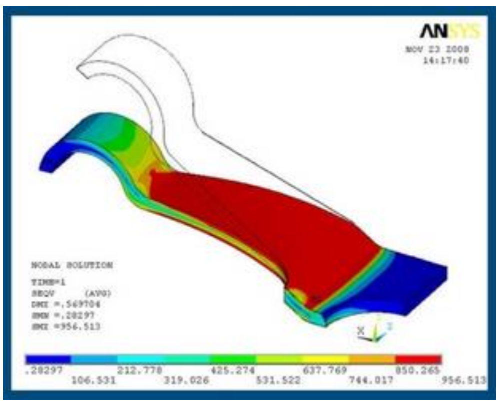
The stress is:

- Inversely proportional to the square of the thickness.
- Directly proportional to the Modulus of elasticity and the deflection.

When comparing two flat springs of steel and copper beryllium, having the same dimensions, a given load will produce almost twice the defection in the copper beryllium spring. The low modulus of elasticity combined with a high elastic limit make copper beryllium an ideal material for diaphragms and bellows.

Alloy	$YS_{0.2}$ (N/mm²)	Modulus E (GPa)	Ratio
Cu Be 1.9	1120	127	8.81
Steel XC 75	1100	210	5.23
Bronze CuSn8	750	110	6.81
CuNi3Si	650	130	5

When comparing copper beryllium with phosphor bronze under the same conditions, the deflection will be almost identical because of a similar modulus. However, the allowable stress for the copper beryllium will be much higher because of the higher yield strength. This means that the copper beryllium spring can exert a higher contact force. These exceptional spring characteristics for a copper base alloy can be particularly useful when trying to miniaturise spring contacts, relays, or connectors.



Berylco alloys ratio of yield strength to Young's modulus E is greater than that of steel and phosphor bronze, which means that a greater contact force and deflection can be achieved.

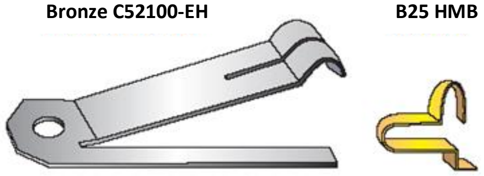
Spring properties and Miniaturisation

Demand for maximum performance of the materials is increased due to the more compact assembly and the miniaturisation of electrical components.

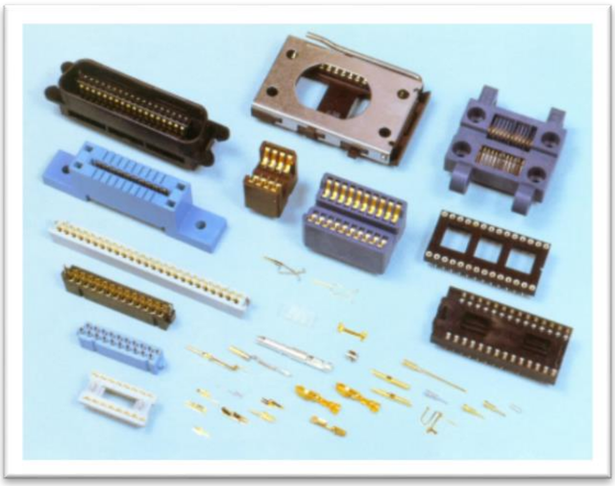
Due to the excellent properties of copper beryllium spring, it is possible to miniaturize the entire spring contact originally made from phosphor bronze and cupronickel while maintaining equal or higher strength. This leads to reduce the whole part, the surrounding raw materials (metal, plastic, resin, coating, etc.), and the total product cost.

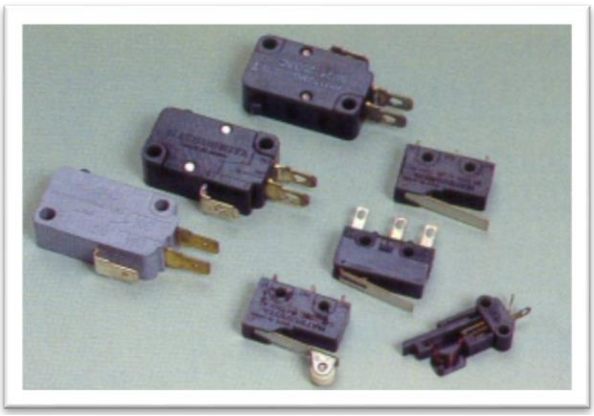
Beryllium copper contributes greatly to the miniaturization and improvements in our everyday products. It enables a design evolution, offering more complex shapes to smaller thickness, while maintaining high mechanical properties and conductivity.

It is essential for the power connectors (Board to Board), switches, sensors and relays automotive components, aeronautic instruments and connectors, telecommunications, home appliances, etc.



Alloy	Weight of the part (g)	Ratio
B25 HMB	1.14	0.14
Bronze C52100-EH	1	0.12





Stress relaxation

The general trend towards miniaturisation and achieving higher intensities and temperatures led to consider the resistance to stress relaxation as an element of prime importance.

Copper beryllium and all material are subject to stress relaxation over time which is exacerbated by the temperature. This relaxation is much lower than most other copper-based alloys, especially brass or phosphor bronze, but it is important enough to need to take this into account in some applications.

The material must remain stable during operation, especially when it is under stress for extended periods. An electrical contact spring must retain its properties in service, and it is therefore important to know the relaxation characteristics of the material to be used.

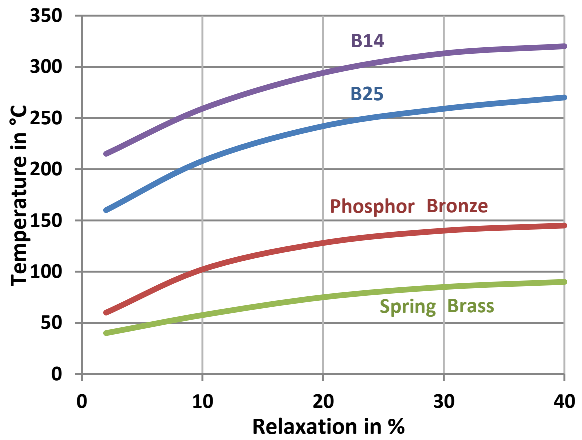
Materials with too low strength resistance lose its contact force. In time this may lead to increased contact resistance, a greater thermal heating that may eventually cause rupture.

The following table shows values for comparable percentage relaxation after 1000 hours.

With electronic components generally being tested at 150°C it will be noticed that the alloys B25 and B14 remain absolutely stable under stress at this temperature for long periods.

Since the properties of these alloys are obtained by structural precipitation hardening at temperatures of 320 and 480°C respectively the electrical springs are in a stable condition and retain their characteristics in service.

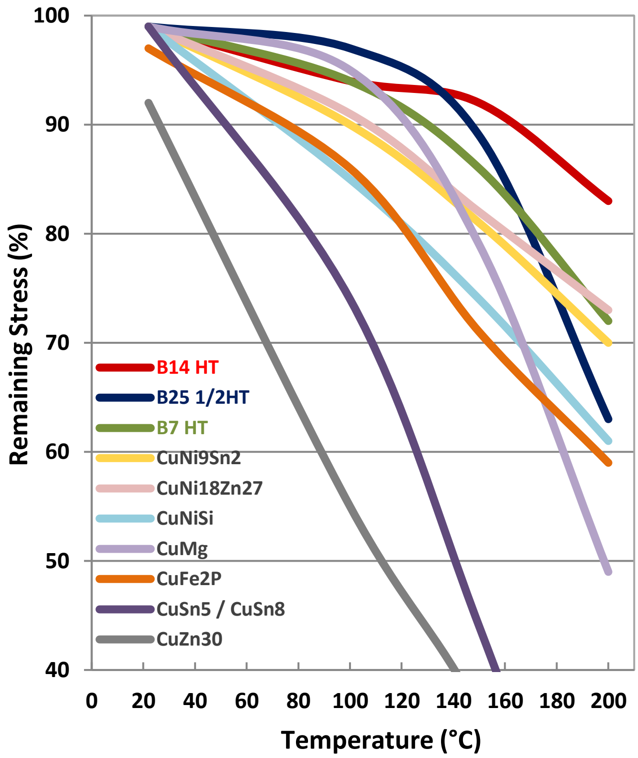
Relaxation of various alloys at elevated temperatures under 350 MPa stress



Initial stress 50% of yield strength			
Alloy	Room temperature	100°C	150°C
Brass 70/30	7	45	64
Bronze CuSn5	1	26	56
Bronze CuSn8	2	25	55
Berylco 25 XHM	0	3	11
Berylco 25 1/4 HT	0	4	12
Berylco 14 AT	2	5	10
Berylco 14 HT	0	6	8

Copper beryllium alloy is widely used for applications of conductive springs because it has an excellent combination of properties: strength, fatigue resistance, electrical conductivity and corrosion resistance. The demand for high performance materials has increased because of the more compact assembly and the miniaturisation of electrical components operating at higher temperatures.

Sress relaxation of various alloys at temperatures range from 0 to 200°C (1000h)



Initial stress 75% of $YS_{0.2}$
Bad way (thickness ~0.2mm)

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Fatigue Strength

Fatigue strength is defined as the maximum stress that can be applied for a defined number of cycles without failure. This resistance to cyclic stress is one of the remarkable characteristics of beryllium copper. These constraints are generated by cantilever bending, axial loading, or rotational bending. Copper-beryllium alloys are resistant to fatigue failure due to their high static strength, toughness as well as their ability to increase strength by cold hardening.

Copper Beryllium fatigue curves are illustrated by the graphs as shown below. The ratio of the minimum to maximum stress is called the stress ratio 'R'. This ratio R defines the test conditions. Spring contacts deflected in a single direction (R=0) display a higher a higher fatigue strength than those flexed in reverse bending (R=-1). Standard tests measure fatigue behaviour on flat or round beams.

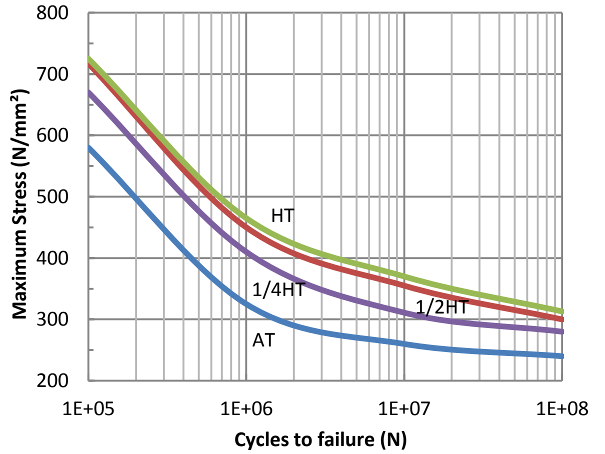
The fatigue strength for cold worked and precipitation hardened Berylco 25 is approximately:

- 420 N/mm^2 at 10^6 cycles
- 300 N/mm^2 at 10^8 cycles
- Strip products: The fatigue resistance is not much changed by the heat treatment. However, the most hardened and tempered to maximum hardness grades are more sensitive to surface defects and internal stresses, although the fatigue limit is slightly higher. In longitudinal bending for flat plates of 1.5mm thick, the soft-annealed and hardened temper, a fatigue limit at 10^8 cycles 300 N/mm^2 can be used.
- On wrought products: In rotating bending test at 10^8 cycles, a fatigue limit of 270 N/mm^2 was recorded on annealed and hardened extruded semi-products. The quality of the surface naturally affects the fatigue characteristics. Some metal tests made on half-hard or hard temper after age-hardening, the increase of the fatigue limit by pickling is about 15 N/mm^2 as well as by polishing or buffing.

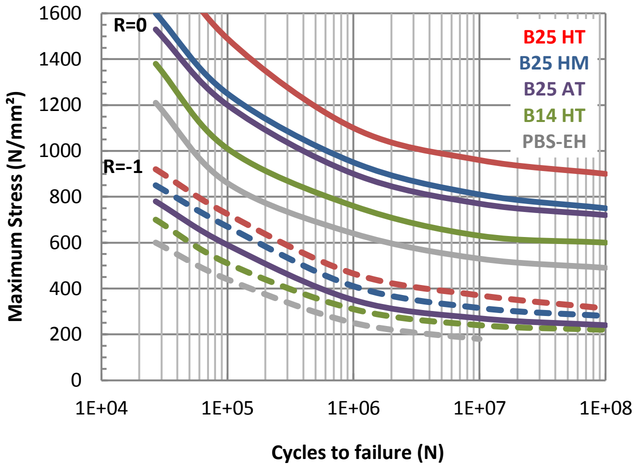
This limit is higher for copper-based alloys, which explains the interest of Berylco 25 as strips and wire for manufacturing electrical and electronic connectors, contact springs and any products subject to cyclic stress environment. They are also used for making heavier components such as aircraft landing gear bushings, rollers in rolling-element bearings and anti-galling thread or downhole equipment used in oil drilling techniques.

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

Fatigue strength under reverse bending



Berylco 25 – After precipitation hardening (320-340°C) based on the ASTM publication N°367



Elevated temperatures strength

Over-ageing occurs at elevated temperatures and produces a softening effect on high strength alloys. Beryllium-copper Berylco 25 demonstrates good stability of tensile properties from cryogenic temperatures up to about 200-250°C despite long exposure. Exposure to intermittent operation temperatures of 300°C or even higher can be applied. The high conductivity beryllium copper alloys (B14 and B8) retain strength through 350-400°C. The hardness of these alloys leads to their use in moulds components for plastic injection as well as welding electrodes.

Elevated temperature properties of Berylco 25							
		annealed-aged			annealed-cold worked-aged		
Temperature	Time at temp.	UTS (N/mm²)	YS0.2 (N/mm²)	A%	UTS (N/mm²)	YS0.2 (N/mm²)	A%
20°C	- -	1265	1065	6.8	1325	1275	2
250°C	500h	1260	1005	3.9	1325	1080	2
300°C	500h	1020	750	3	1040	770	3

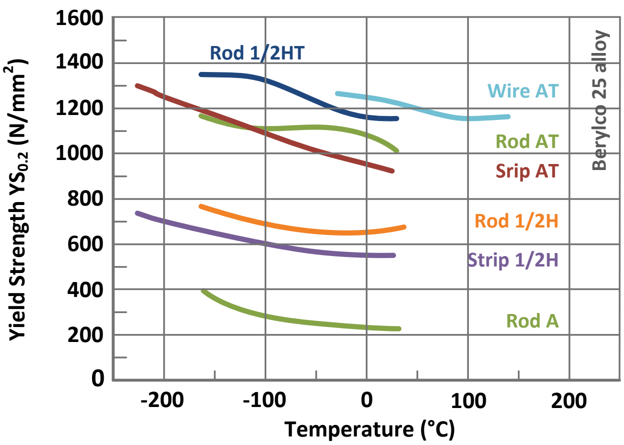

Welding electrodes RWMA

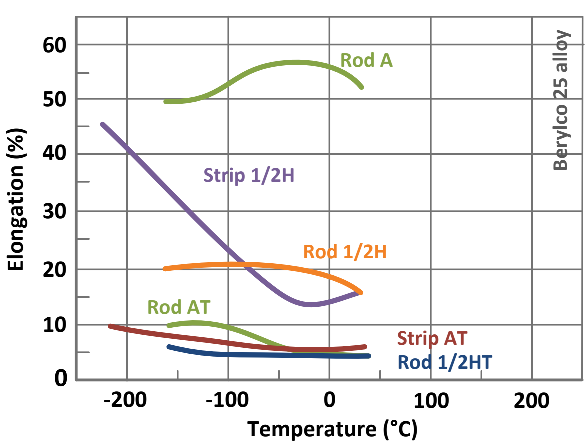
Cryogenic properties

Like many copper base alloys the copper beryllium is a cryogenic alloy which does not exhibit tendency to fracture at low temperatures but rather improvement of properties. It is used in liquid hydrogen and liquid oxygen due to its ability to maintain strength and toughness in cryogenic conditions. Beryllium-copper alloys exhibit no ductile to brittle transition temperature and strength (and ductility) tend to increase as temperature drops.

Cryogenic temperatures properties of Berylco 25					
Solution annealed and precipitation hardened	Temperature in °C				
	20°C	– 50°C	– 100°C	– 150°C	– 200°C
UTS (N/mm²)	1340	1360	1380	1400	1490
YS $_{0.2}$ (N/mm²)	980	1060	1080	1110	1170
A% on25mm (%)	5	6	8	9	9
Young Modulus E (N/mm²)	123000	125000	131000	131000	134000
Charpy Impact (N/mm²)	5.5	6.9	6.9	8.3	9.6

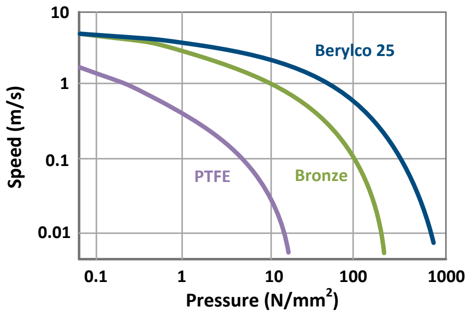

Satellite applications





Wear resistance

The coefficient of friction of non-lubricated copper beryllium shows little difference from that of other copper base alloys. It decreases slightly with increasing hardness. Its excellent galling resistance is due to its high hardness, its ability to self-lubrication, the presence of a film surface and its high thermal conductivity.



With lubrication, the friction coefficient of beryllium copper is significantly reduced (0.02 - 0.06) and wear resistance remains low even under high stress (500 MPa) that can not be achieved by any other copper alloys.

They are used for the production of heavy-duty components. For example, they are used as bearing and bushing such as aircraft landing gears and some heavy equipment in mining drilling techniques.

Wear tests against heat treated steel, using various copper base alloys under the same conditions, have produced the following values for the coefficient of friction:

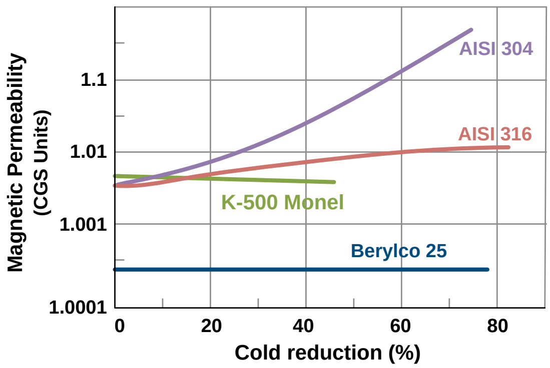
■ Silicon bronze	0.71
■ Phosphor bronze	0.67
■ Aluminium bronze	0.66
■ Copper	0.51
■ Copper beryllium (annealed & cold-worked)	0.40 – 0.53
■ Copper beryllium (annealed & aged)	0.44 – 0.54
■ Manganese bronze	0.26

Magnetic Properties

At constant nickel-addition, increasing additions of iron will bring alloy B25 from diamagnetism to paramagnetic. In this case, the value of the susceptibility depends of the beryllium solution-heat-treatment temperature and decreases when the temperature increases.

The as shown graph illustrates this phenomenon, these results show that it is possible for some applications to have a beryllium copper with very low magnetic susceptibility.

Berylco 25 alloy has magnetic permeability between 0.997 and 1.003 at field strength of 1000 gauss. A permeability of unity represents perfect transparency to slowly carrying magnetic fields. This property is unaffected by hardening or cold working in contrast to other nonmagnetic alloys that can become magnetically activated during machining or forming operations. Combined with high strength, fracture toughness and accurate dimensional stability, these properties lead to excellent service in magnetic instrument housings, magnetic support structures, measuring equipments and other various products.



Electrical conductivity

Definition

The electrical conductivity of the alloys C is expressed in % IACS (International Annealed Copper Standard). A 1m long wire of annealed copper weighing 1g has a conductivity of 100% and a resistivity ρ_{20} of $1{,}7241 \times 10^{-8}$ Ω.m (or conductivity of 58,0 MS/m) at 20°C. The formula for converting resistivity to conductivity is a follows:

$$C\ (\%IACS) = \frac{1.7241}{\rho_{20}} \times 100$$

with ρ_{20} (µΩ • cm) alloy electrical resistivity at 20°C.

Berylco 25 & 165	
■ before ageing	15 to 18 % IACS
■ after standard ageing	22 to 23 % IACS
■ mill hardened	20 to 28 % IACS*

Berylco 14 & 8	
■ before ageing	22 to 25 % IACS
■ after standard ageing	45 to 48 % IACS
■ mill hardened	45 to 65 % IACS*

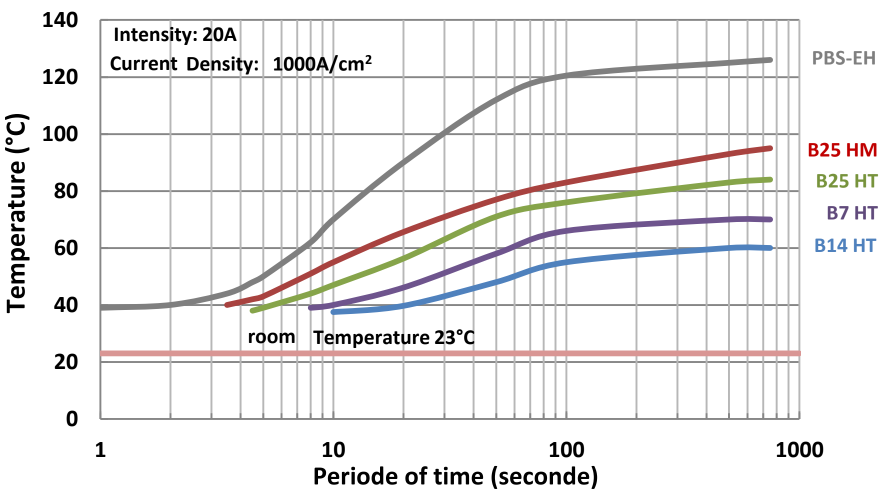
* Depending on temper

Heat generation

A beryllium copper spring is often the active element of a current conducting device. Copper beryllium contact within a connector sets the insertion force and provides sufficient force to minimize the contact resistance. It also maintains the extraction force necessary to ensure the integrity of the conductor circuit while maintaining the current passage through the contact spring.

Thermal and electrical conductivities of copper-beryllium favor the use of these alloys for applications requiring excellent heat dissipation and good conduction capacity of high current up to 30A. For example, at 20A, they heat half a phosphor bronze and remain practically stable for long periods of time. The choice of a less resistant alloy may cause premature aging of the parts and cause failure of the product.

Metal internal heat generated by its resistivity may cause stress relaxation in service. The selection of high conductive material over time is essential for switches, sensors and relays in automotive, aerospace and automation components. Demand for maximum performance of the materials is increased due to the more compact assembly and the miniaturisation of electrical components operating at higher intensities.

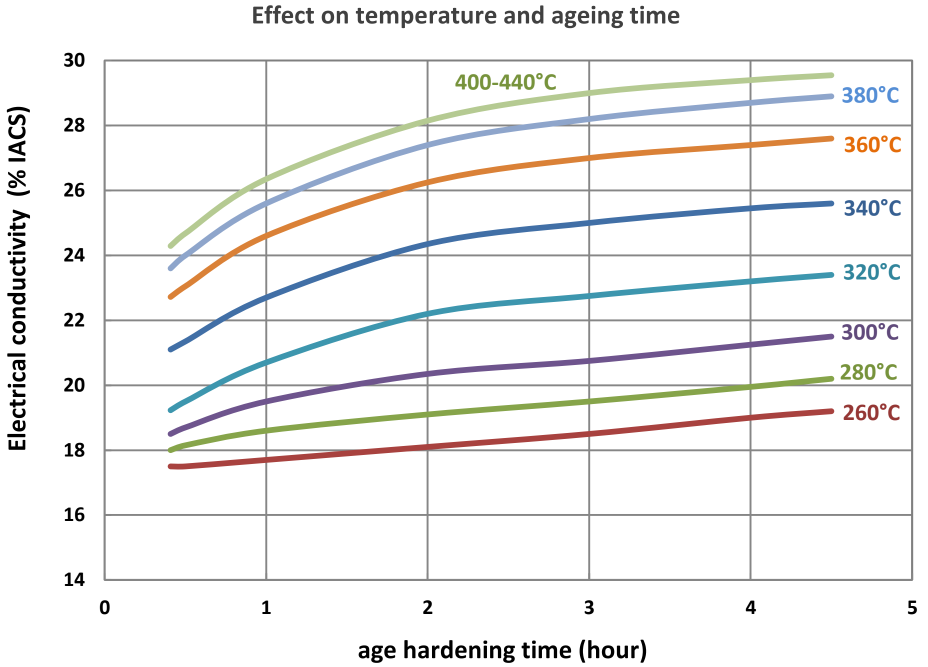


Heat resistance to a passing current of 20A and heat dissipation of copper-beryllium alloys.
(Sample dimension : 0,2 x 10 x 75 mm)

Conductivity of Berylco 25

The electrical conductivity of B25 after precipitation hardening is 22 to 28 % IACS (at 20°C = 7 to 8.5 µΩcm). Although this is only one quarter of the conductivity of pure copper it is superior to the other high strength copper alloys.

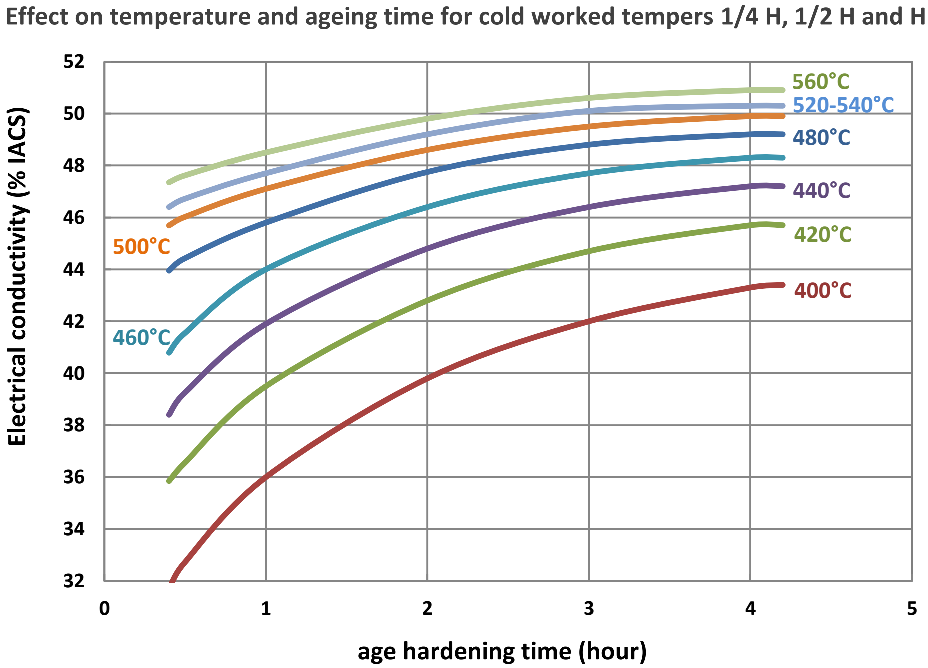
Copper-Beryllium – Alloy Berylco 25
Electrical conductivity in %IACS



Conductivity of Berylco 14

The B14 (Copper-Nickel-Beryllium) exhibits a good conductivity which exceeds 45 % IACS (at 20°C = 3.6 µΩcm). For special tempers it can reach up to 60 % IACS (at 20°C = 2.9 µΩcm). The B8 achieves 65 %IACS.

Copper-Beryllium – Alloy Berylco 14
Electrical conductivity in %IACS



Corrosion resistance

Generally speaking the corrosion resistance of copper beryllium is similar to that of other copper based alloys with high copper content.

Copper beryllium has good resistance to **atmospheric corrosion**. Although it may tarnish, especially in humid atmospheres, this does not influence the mechanical properties. Gaseous non-anhydrous halogens will accelerate the corrosion. Similarly, humid ammonia is corrosive.

In water, whether sweet water or salt water, the resistance is excellent, and the properties are practically not affected. In salt fog or mist the resistance to corrosion is better than that of coper or phosphor bronze.

Galvanic corrosion

Copper beryllium is practically not affected by galvanic corrosion. As a noble metal with a high potential it is not attacked by the metals most commonly used in industry, such as steel and aluminium.
If the exposed surface of the copper beryllium is large in relation to these metals the latter could be subject to galvanic attack.

The table below gives a rating for certain metals and common alloys in salt water, based on their respective potentials.
The metals and alloys which are anodic with respect to copper beryllium can be corroded in its presence, while copper beryllium can be corroded in the presence of cathodic metals and alloys.

Galvanic rating in salt water (extract from "metals handbook")	
Anodic	
1. Magnesium and alloys	9. Lead an tin
2. Zinc and galvanised steel	10. Bi-phased brass (Muntz – Naval)
3. Aluminium and alloys	11. Nickel and activated inconel
4. Cadmium	12. Copper and alloys 70/30 –85/15 brass, admiralty brass, cupro-nickel, copper beryllium, etc,
5. Aluminium alloys containing copper	
6. Soft steel, forged or cast	13. Passivated nickel and inconel
7. Activated Chrome steel	14. Monel and titanium
8. Activated stainless steel 18/8	15. Passivated chrome steel and stainless steel
	16. Precious metals and graphite
Cathodic	

The **industrial environment** generally has little corrosive influence on copper beryllium except in certain chemical industries where it is exposed to oxidising acids or ammonia and in the rubber industry where it is corroded by the sulphur.

Copper beryllium does not stand up well in the presence of liquid metals. Its corrosion resistance in the presence of molten metals such as lead, tin, bismuth cadmium, and aluminium are considered as poor. Nevertheless experience has shown that in the die casting industry the use of copper beryllium in contact with molten alloys of zinc and especially aluminium causes minimal amounts of corrosion.

The copper beryllium alloys re not subject to **stress corrosion**, or “season cracking” like certain brasses. They have excellent resistance to corrosion fatigue and are not subject to **hydrogen embrittlement**.

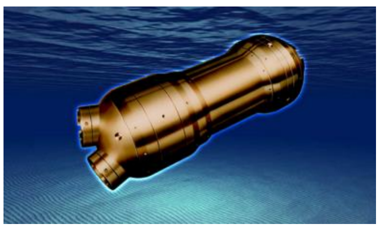
Corrosion resistance of copper beryllium in the presence of various products and atmospheres

E : Excellent	No problem under normal operating condictions
G : Good	Slight corrosion, not serious under normal operating conditions
L : Limited	Can be used with the possibility of considerable corrosion
P : Poor	Use is not recommended

Acetic acid	(acid) diluted	E
Acetic acid	(acid) > 2.5%	G
Acetic acid	(anhydrous)	G
Acetone		E
Acetylene		P
Alcohols		E
Alchydes		E
Alumina		E
Aluminium	(chloride)	L
Aluminium	(hydroxide)	E
Aluminium	(sulphate)	G
Aluminium molten		L
Alum		G
Ammoniac wet		P
Ammoniac dry		E
Ammonium	(chloride)	P
Ammonium	(hydroxide)	P
Ammonium	(nitrate)	P
Ammonium	(sulphate)	L
Amyl	(acetate)	E
Amyl	(alcohol)	E
Anilin		L
Anilin	(paint)	L
Silver	(sels)	P
Asphalt		E
Atmospheres	industrial	E
Atmospheres	marine	E
Atmospheres	rural	E
Nitrogen		E
Barium	(carbonate)	E
Barium	(chloride)	G
Barium	(hydroxide)	E
Barium	(sulphate)	E
Barium	(sulfide)	P
Benzene		E
Benzine		E
Benzoic	(acid)	E
Benzol		E
Beets	(sugar syrop)	E
Beer		E
Bismuth molten		P
Borax		E
Boric	(acid)	E
Bordeaux mixture		E
Bromide dry		L
Brome sec		E
Butane		E
Butyric	(acid)	G
Butyric	(alcohol)	E
Cadmium molten		P
Cofee		E
Calcium	(bisulphate)	G
Calcium	(bisulphide)	G
Calcium	(chloride)	G
Calcium	(hydroxide)	G
Calcium	(hypochloride)	L
Cane	(sugar syrop)	E
Carbone	(tetrachloride wet)	G
Carbone	(tetrachloride dry)	E
Carbonic gas (dry orwet))		E
Ketones		E
Lime		E
Lime	(chloride)	L
Lime	(sulfide)	P
Chloride acetic	(acid)	L
Chlorine wet		L
Chlorine dry		E
Hydrochloric	(acid) diluted	L
Hydrochloric	(acid) > 5%	P
Chloroform dry		E
Chromic	(acid)	P
Cider		E
Citrus	(acid)	E
Cotton	(oil)	E
Creosote		G
Copper	(chloride)	L
Copper	(nitrate)	L
Copper	(sulphate)	G
Cyanide	(acid)	P
condensate water		E
Salt water		G
Mineral water		L
Oxygenated water	(diluted)	L
Oxygenated water	> 10%	G
Drinking water		P
Stale water		E
Gasoline		G
Tin molten		E
Ethers		E
Ethylene	(acetate)	E
Ethylene	(chloride)	G
Ethylene	(glycol)	E
Ethylene	(alcool)	E
Ferric	(chloride)	G
Ferric	(sulphate)	G
Ferric	(chloride)	P
Ferric	(sulphate)	P
Fluoric wet		L
Fluoric dry		E
Hydrofluoric	(acid)	L
Fluorsilicic	(acid)	G
Formaldehyde		E
Formic		G
Freon		E
Fruits	(juice)	G
Fuel		E
Furfural		E
Gallium molten		P
Gas natural		E
Gelatine		E
Glucose		E
Glycerine		E
Tar		E
Hydrobromic	(acid)	L
Hydrocarbons		E
Hydrogen		E
Hydrogen sulphide, wet		M
Hydrogen sulphide dry		E
Indium molten		P
Kerosene		E
Lactic	(acid)	G
Milk		E
Lacquers		E
Flax	(oil)	G
Lithium molten		P
Magnesium	(chloride)	G
Magnesium	(hydroxyde)	E
Magnesium		E
Corn	(oil)	E
Molasses		E
Mercury and salts		P
Methyl	(chloride), dry	E
Wetting	(agents)	E
Nickel	(chloride)	L
Nickel	(sulphate)	L
Oleic	(acid)	G
Oxalic	(acid)	G
Oxygen		E
Palmitic	(acid)	G
Paraffin		E
Phenol		L
Phosphor		E
Phosphorous	(acid)	L
Picric	(acid)	P
Lead molten		P
Oxalic		G
Potassium	(bichromate)	P
Potassium	(carbonate)	G
Potassium	(chloride)	G
Potassium	(cyanide)	p
Potassium	(sulphate)	E
Potassium molten		G
Propane		E
Resin		E
Castor	(oil)	E
Brine		G
Soap	(solutions)	E
Sodium	(bicarbonate)	E
Sodium	(bichromate)	P
Sodium	(bisulphate)	G
Sodium	(carbonate)	E
Sodium	(chloride)	G
Sodium	(chromate)	E
Sodium	(cyanide)	P
Sodium	(hypochlorite)	L
Sodium	(nitrate)	G
Sodium	(peroxide)	L
Sodium	(phosphate)	E
Sodium	(silicate)	E
Sodium		E
Sodium		M
Sodium	(thiosulphate)	P
Sodium molten		G
Solvent for lacquer		E
Soda		G
Sulphur wet		L
Sulphur dry		G
Sulphur molten		P
Sulphur	(chloride) wet	P
Sulphur	(chloride) dry	E
Stearic	(acid)	E
Sugar	(solution)	E
Sulphurous	(acid)	G
Sulphurous	(anhydride) wet	G
Sulphurous		E
Sulphuric		G
Sulphuric	(acid) concentrated, cold	G
Sulphuric	(acid) 40- 80%	L
Sulphuric	(anhydride) dry	E
Tannic	(acid)	E
Tartaric	(acid)	E
Turpentine		E
Thallium molten		P
Toluene		E
Trichloracetic	(acid)	G
Trichlorethylene		G
Trichlorethylene	dry	E
Steam		E
Varnish		E
Vinegar		G
Whisky		E
Zinc	(chloride)	L
Zinc	(sulphate)	E
Zinc molten		L

Undersea Communication Equipment

The signal cables for submarine telecommunication optical fiber becomes lower the more advance signal. In order to avoid this loss of signal repeaters (signal boosters) are placed at intervals of 40 to 100km. Owing to its properties of corrosion resistance to salt water and very high mechanical resistance (up to 8000 m depth), beryllium copper B165 alloy is mainly used as a fastening element which allows establish and ensure intercontinental connection to terrestrial communication networks.



Stamping and Forming

Stamping

Beryllium copper in the cold-worked condition exhibits sharper cuts and less burrs than in the ageing temper. A clearance between punch and die of 5-10 % of the material thickness should be used. If solution annealed material has to be used the clearance should be reduced to 5-6 % to avoid excessive wear of the tooling. If the strip has been stored for an extended period of time in a potentially oxidising atmosphere, like high humidity, it should be pickled prior to stamping.

When stamping copper beryllium the tool life of the cutting tools is about the same as for phosphor bronze. The choice of material for the tooling depends on the number of parts to be produced. Heat treated steels with 12 % chromium are suitable for normal manufacturing. Carbide tooling can be used where delicate parts with superior finish are to be produced, or where a high degree of dimensional precision is required for large series. In all cases the tooling must be kept sharp. Use of lubricants, such as soluble oil emulsion or mineral oil, reduces the tool wear.

Drawing

Depending on the depth of the draw dead soft up to half hard (1/2H) material can be used. The table below gives some data for allowable depth of draw for copper beryllium based on ERICHSEN deep drawing test.

For very deep draws only dead soft material can be used (A temper). Where excessive depths are required, it may be necessary to include an intermediate solution heat treatment between successive drawing operations since the copper beryllium has a tendency to work harden more rapidly than other copper base alloys. The solution heat treatment consists of a solution anneal followed by a rapid quench. This operation requires an accurate furnace which can maintain the temperature between 770 and 790°C. It is important not to exceed the maximum temperature or, above all, the time in the furnace (3 to 10 minutes depending on thickness) in order to avoid grain growth in the areas where the cold work of the preceding operation was less than the critical cold work. The part must then be pickled before the following operation.

Double acting presses are preferable since they can clamp the periphery of the blank during the entire operation, thus eliminating the possibility of folds, particularly in thin material. The design of the punch and die does not present any problems. However, the tooling must be stronger than that normally used for the drawing of brass since the forces required are considerably larger. The clearance between punch and die should be between 5 and 10 % of the metal thickness.

Carbide and chrome tooling imparts better polish and improved appearance to the finished part. The choice of lubricant is also important. In many cases more or less heavy soap paste (depending on the degree of deformation) has given good results. When mineral oils are used it is important to carefully clean the parts immediately following the stamping operation in order to avoid spotting.

Berylco 25 – Allowable depth of draw

temper / thickness	dead soft (A)	1/4 hard (1/4 H)	1/2 hard (1/2 H)	4/4 hard (H)
0.2mm	10mm	6mm	4.5mm	3mm
0.3mm	11mm	7mm	5.5mm	4mm
0.5mm	12mm	8mm	6.5mm	5mm

Forming and bending

In forming and bending the most important considerations are the minimum bending radius and the spring back.

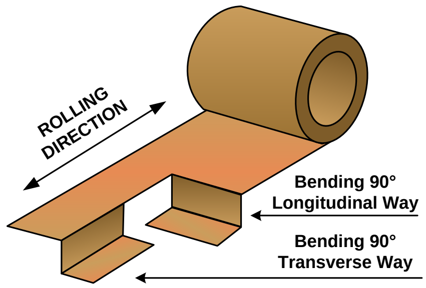
■ Bending radius

The level of formability is a guide to define a temper selection based on forming requirement. The bending radius (R) allowed without craking depends on the temper of the metals as well as the direction of the bend in relation to the direction of rolling (longitudinal or transversal way). The radii are expressed as a function of the strip thickness (t) and are based on 90° bends by the formability ratio R/t.

The table below shows the minimum bending radius allowable for strip of 1 mm thickness or less and for the various tempers.

Annealed strip has excellent formability with both longitudinal and transverse bends posing no forming problems. Certain mill-hardened tempers also exhibit low formability directionnality difference. 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 cases, this will permit efficient and best conditions of utilisation of the metal.

By adhering to the values given in the table one can normally avoid cracking, but in some cases it may be necessary to increase the radii in order to avoid orange peel. They should be increased when a more important angle is desired.

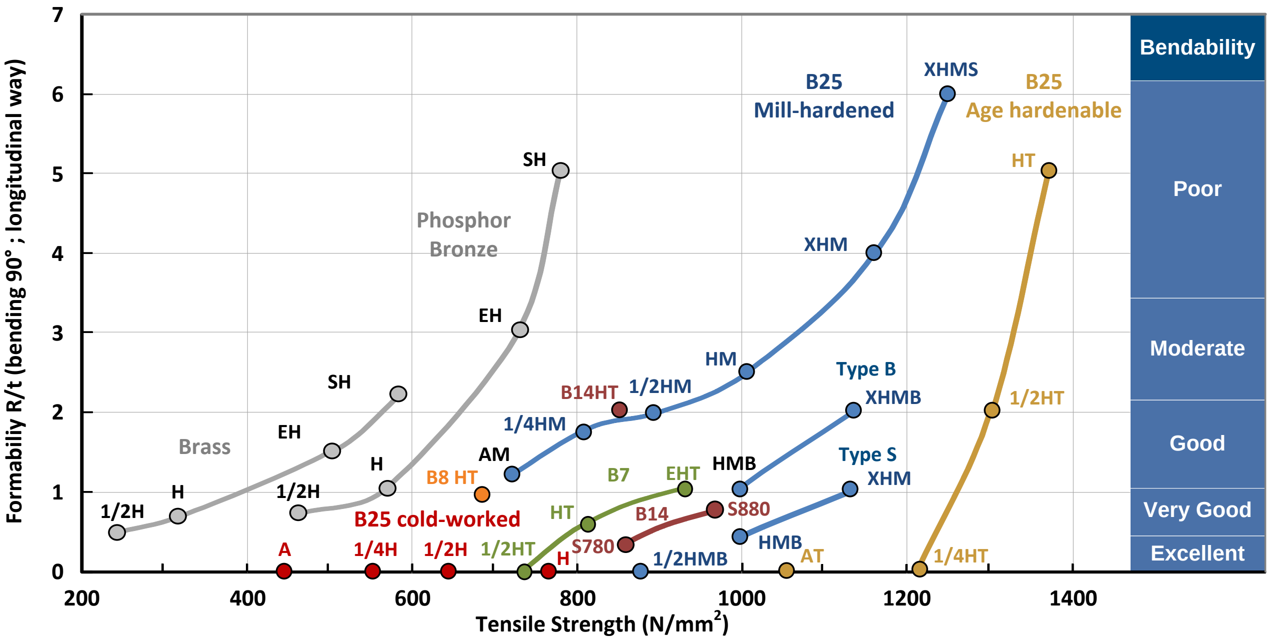


R = bending radius ; t = strip thickness.

As far as possible the bending radii in a given part should be homogeneous, and one should chose the hardest temper which will still allow the deformations necessary for the manufacture of the part. This will also reduce the deformation during heat treatment. Low R/t ratio indicates high formability.

Banding radius (R) for 90° bends (thickness (t) ≤ 0.5 mm)
Minimum radius as function of thickness

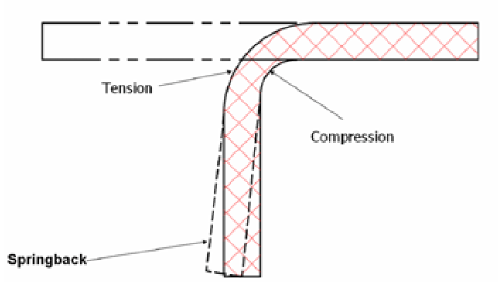
Bending direction	B25		B165			Bending direction	B14	
temper	Long.	Trans.	Long.	Trans.		Etats	Long.	Trans.
■ Age hardenable								
A	0	0	0	0		A	0	0
1/4 H	0	0	0	0		1/2 H	1,5t	2t
1/2 H	1t	2t	2t	3t		H	2t	3t
H	2t	5t	4t	6t				
■ Mill-hardened (standard)								
1/4 HM	1,3t	1,8t	1.5t	2t		AT	2t	3t
1/2 HM	1,5t	2t	2t	3t		1/2 HT	3t	4t
HM	2,3t	2,5t	4t	6t		HT	2t	2t
SHM	2,5t	3t						
XHM	3t	4t	6t					
XHMS	4t	6t						
■ Mill-hardened (high formability)								
1/2 HMB	0	0				S780	0,3t	0,3t
HMB	1t	1t				S880	0,7t	0,7t
XHMB	2t	2t						
HM-TypeS	0.5t	0.5t						
XHM-Type S	1t	1t						



Bendability of copper-beryllium alloys at various tempers.

■ Spring back

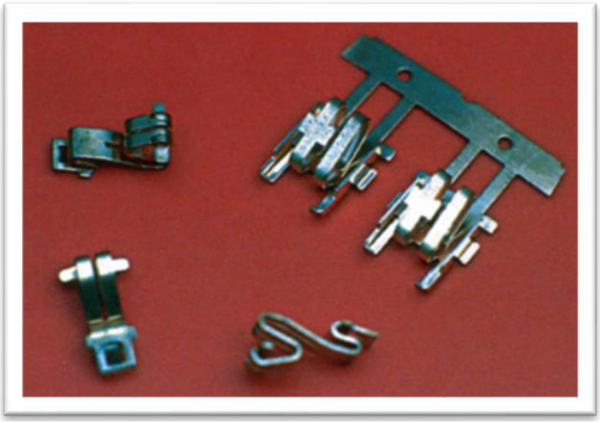
The spring back is a function of the modulus of elasticity of the material and its yield strength. It can be partially controlled by the design of the tooling, and by adjusting the press to coin the bend more or less severely.



For a given thickness the amount of spring back increases with increasing yield strength and increasing bending radius. Therefore it is not unusual under normal manufacturing conditions to find variations in the same products when they originated from different manufacturing lots.

When precise angular tolerances (less than 2°) must be maintained we recommend precipitation hardening in fixtures. See the chapter on 'Thermal Treatment'.

Under favourable conditions the fixture helps to maintain angular tolerance of +/-1/2° ; at the same time it permits the use of less complicated tooling since the effect of spring back does not have to be controlled so accurately.



C17200 mill-hardened parts with complex shape

Heat Treatment

Introduction

For the user the advantages of working with copper beryllium are its easy fabrication (by machining or forming) and the simplicity of obtaining the desired final properties by a low temperature heat treatment. This makes copper beryllium the most flexible of all copper base alloys.

For most other copper based alloys, parts must be manufactured from metal which already has the final properties of the finished part. This can make the fabrication difficult, if not impossible, due to the reduced elongation and formability issues resulting from the higher mechanical properties.

Copper beryllium can be supplied in the form of strip, rod, bar, wire or tubing as cold worked product. These shapes are produced either by rolling or drawing.

The heat treatment for copper beryllium is done in two stages:

1 – The solution annealing consists of heating the metal, followed by rapid quenching. This softening process is almost always performed by the supplier and is not recommended to be undertaken by the user.
2 – The structural ageing or precipitation hardening treatment is usually carried out by the user.

Choice of temper condition

NGK Berylco can supply any coper-beryllium alloys in the following tempers listed below in increasing order of hardness:

- Annealed (A)
- 1/4 Hard (1/4 H)
- 1/2 Hard (1/2 H)
- 4/4 Hard (H)
- Mill Hardened

The mill hardened tempers will not be covered here since they have already been subjected to age-hardening at the plant prior to dispatch to customers. Mill-hardened metal is particularly used for parts which do not necessitate high formability and to avoid distortion during age-hardening treatment.

The choice of the supplied temper is determined by the degree of cold deformation required for the part, the basic rule being: **select the hardest temper which will still permit the manufacturing process of the part**.

Heat treatment furnace

Soft annealed material (A temper) should be used only for deep drawing operations. As regards other conditions, users are referred to our General Information Sheet describing applications in terms of bending which are possible with the various “as-supplied” conditions.

In the rare instances where fabrication requires an excessive degree of deformation, it may be necessary to re-soften the metal by a second solution annealing treatment (heating and quenching) in order to continue the cold working operations. Our technical department will be pleased to advise you in connection with specific applications.

Age hardening of copper-beryllium alloys

Forming and/or machining is followed by precipitation hardening (or age hardening) to obtain the desired final properties for the application of the part concerned.

These properties are determined by the initial condition of the metal as supplied, as well as by the duration and temperature of the heat treatment. Since the first of these factors is conditioned by the shape of the part to be obtained, it is possible to vary the other two factors to obtain various permutations in terms of tensile strength, yield strength, ductility, electrical conductivity, hardness, and impact resistance. Hence, precipitation treatment time and temperature will be determined by the particular application in consideration.

In order to ensure that full advantage is taken of the properties of available from beryllium-copper alloys which can be obtained by experimenting with treatment time and temperature, preliminary tests should preferably be conducted, particularly where high temperatures and short treatment time are envisaged.

The curves presented at the end of this booklet illustrate the effects of precipitation treatment. Tensile strength, yield strength and hardness increase with treatment time and temperature up to a maximum peaks value, after which they decline. The opposite occurs in the case of elongation values. The higher the temperature of treatment, the faster the rate of change occured. However, over a certain temperature range, the curve tends to flatten out and no great change will be observed over a period of several hours treatment. Conductivity increases with precipitation treatment time and temperature.

Precipitation treatment time and temperature

Alloys Berylco 25, 165 and 33/25 can be age hardened over a range of temperatures extending from 260 and 440°C. Maximum hardness values, which are not always necessarily desirable, are obtained by treating the alloy for 2 to 3 hours at 310-340°C, depending on the initial metal condition.

In the case of alloy B165, maximum hardness values are obtained by using temperatures of some 10-15°C higher than B25.

Two types of graph are shown for alloys B25 and B33/25:

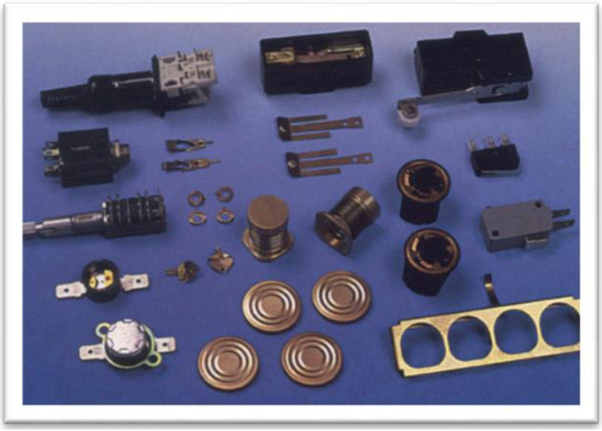
1) Curves for a given treatment time (3 hours) showing the mechanical properties obtained as the treatment temperatures are varied.

These curves clearly show the effects of the precipitation treatment:

- The region prior to the maximum is referred as the under-aged region.
- The region after the maximum is referred as the over-aged region.
- The spread of mechanical properties due to differences in condition prior to treatment is less in the over-aged than in the under-aged region. This is an initial pointer to the choice of treatment designed to obtain finished items with the smallest possible deviation in properties..

2) Curves illustrating the effect of treatment at various temperatures. It should be noted that:

- Where treatment temperature is less than 300°C, precipitation is a slow process, so that a long time will be required to obtain properties near to the maximum.
- However, where the treatment temperature is higher than 350°C, the rate of precipitation is accelerated and hardening is obtained within a very short time.
- The curves exhibit a steep slope at the start of the precipitation treatment and then flatten out or fall off (at temperatures above 340°C). However, the curve does not slope steeply in the over-aged region, thus leaving some latitude as regards treatment time.



In practice, when maximum hardness is not a requirement, it will be preferable to employ over-ageing, which will reduce the dispersion of final properties. Again, it will be seen that for a treatment time of 3 hours, most of the curves exhibit only a slight slope or a pseudo-plateau, so that **over-ageing with extended treatment time is preferable**.

However, considerations of productivity may frequently call for a reduction in treatment time. Here again, it will be preferable to employ over-aging, using the highest temperature consistent with the desired final properties, since under-ageing combined with short treatment time can give uncertain results owing to the steep slope of the curve in this region.

Finally, it should be kept in mind that the temperatures employed may lead to a differential expansion and that the precipitation process causes beryllium-copper alloys to shrink slightly (about 1-3mm per m).

Where it is desired to obtain high-precision parts, and to minimize inevitable distortion which occurs during the precipitation treatment process, under-ageing at comparatively low temperatures and for long periods should be employed. Alternatively, a jig should be used to prohibit movement during the treatment.

The considerations outlined above can best be illustrated by an example:

Starting with metal in the 1/2 hard condition, it is desired to obtain a 0.2 % yield strength value of about 1000-1100 N/mm². Assuming a treatment time of 3 hours, over-aging will occur at a temperature of approximately 370°C and under-ageing at approximately 260°C. Normally, the treatment used will be 3 hours at 370° C. However, if distortion is suspected and a jig cannot be used, treatment of 3 hours at 260°C will be carried out. Again, if a high rate of production is sought and very accurate equipment is available, treatment at 400°C for only 30 minutes could be employed; in which case, preliminary tests will be required for accurate determination of a suitable treatment temperature and time.

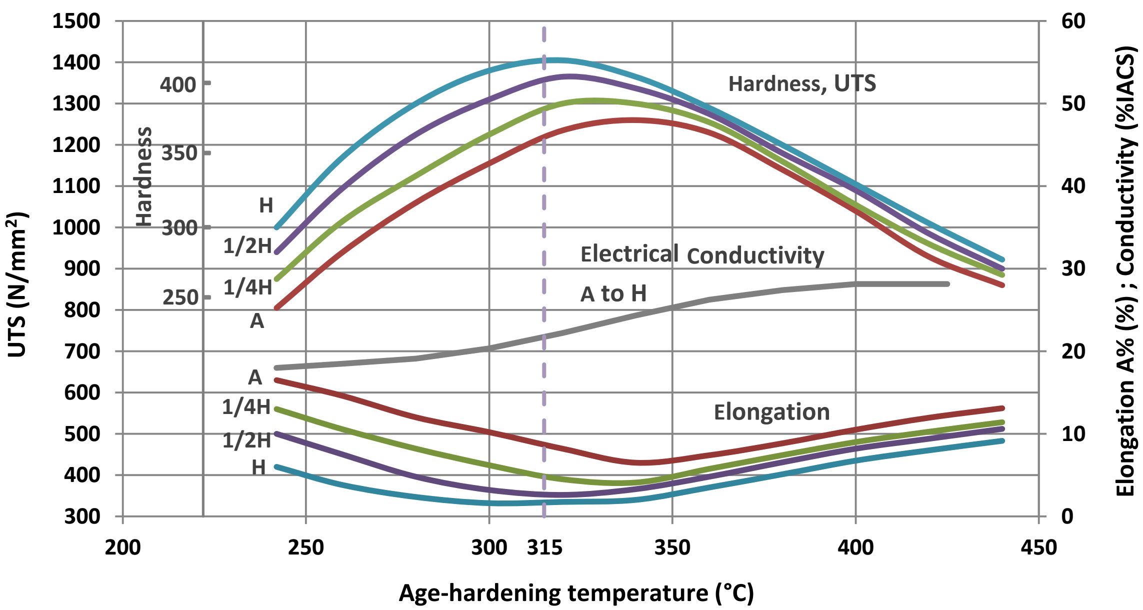
Precipitation treatment effects

The various graphs shown in this booklet illustrate the effect of precipitation treatment on the properties listed below:

- Ultimate tensile strength (UTS)
- 0.2% yield strength (YS 0.2%)
- Elongation (%) on a 50mm gauge length
- Vickers hardness (HV or VPN)
- Fatigue life
- Electrical conductivity

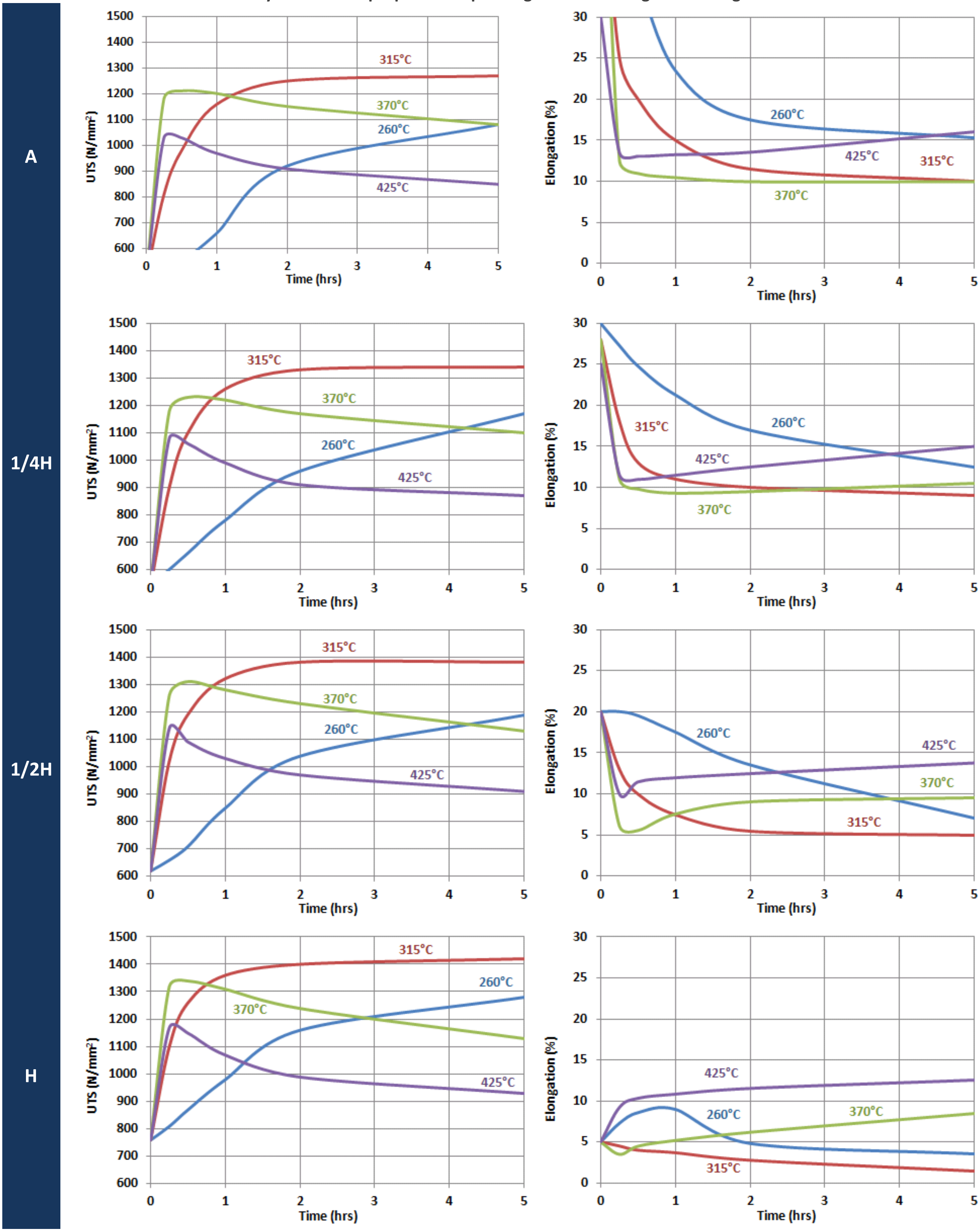
These graphs are only a guide to the effects of precipitation treatment and should not be taken as indicating precise treatment times and temperature required to yield particular properties.

The fatigue life curves are extrapolated from the data given in ASTM N°367. Longevity will depend on a variety of factors such as the shape of the item, stamping defects, surface condition, etc.



Properties of B25 and B33/25 alloys after age-hardening at various temperatures (retention time: 2 hours)

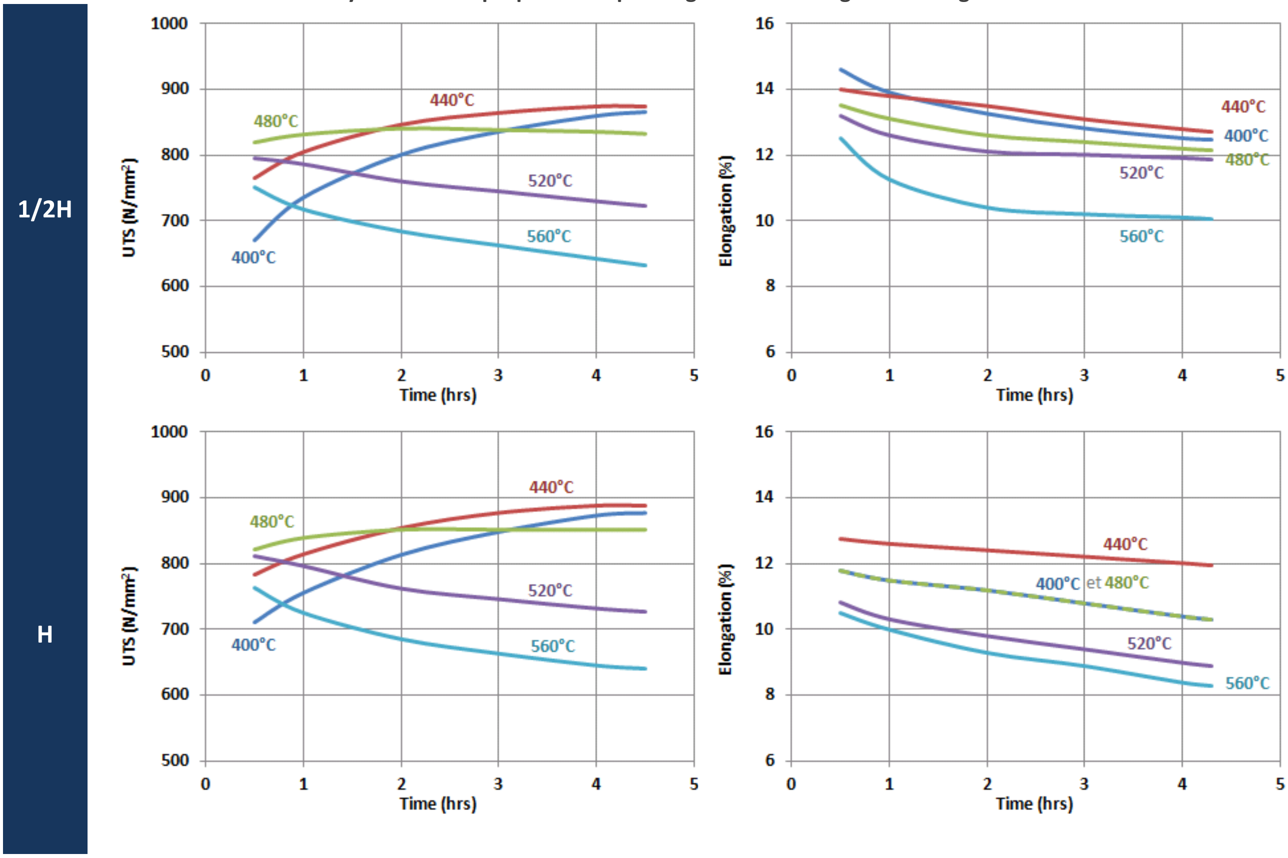
B25 alloy mechanical properties depending on time and age hardening time



High conductivity alloys age-hardening

The high conductivity alloys Berylco 14, 7 and 8 reach their maximum hardness values when heat treated at about 460-480°C for 2 to 3 hours, depending on the temper. Since these alloys can be readily fabricated after precipitation hardening NGK Berylco supply them in the aged condition. If they cannot be manufactured in the aged condition because of formability problems they must be precipitation hardened after forming in a controlled atmosphere (reducing). A hat treatment in air will cause intergranular oxidation which cannot possibly be removed by any known pickling process.

B14 alloy mechanical properties depending on time and age hardening time



Heat treatment jig

In special cases, precipitation treatment may have to be carried out on parts held in formers or jigs while undergoing treatment. This is only necessary where dimensions have to be held to within very close tolerances. The preferred treatment will normally be over-ageing and extended treatment time.

If the mass of the jig used is very high as compared to that of the parts to be treated, a thermocouple should be employed to measure the actual temperature of the furnace containing the parts being treated.

Where high dimensional accuracy is required in the case of very small parts, it is not usually practicable to use jigs. In this case, the age-hardening treatment can be carried out in a bed of inert powdered material, such as sand. This will generally support the parts sufficiently to prevent the amount of distortion which can occur.

Precipitation treatment furnaces

The use of air circulation furnaces is recommended. Controlled atmosphere systems can be used to obtain bright surface treated products, but care should be taken to avoid any contamination of the atmosphere by chlorine products. Salt bath furnaces, which exhibit the advantage of rapid and uniform heating, give good results over the entire temperature range used for precipitation treatment of beryllium-copper. They can be beneficial, where the treatment time is short and where a precise means of controlling temperature is required.

Commercially available salt mixtures with melting points in a range 135-220°C are normally used. Nitrate-based salts dissolve readily in hot water, but require the observance of certain precautions as specified by the suppliers.

Air or controlled atmosphere furnaces which do not provide circulation can only be used for quite long treatment times of about 3 hours. The use of vacuum furnaces is not recommended because of the low rate of heat exchange obtained with this type of furnace.

Since the rate of cooling is not critical, parts leaving the treatment furnace can be quenched in cold water, thus simplifying handling and setting a definite limit to the treatment time employed.

Cleaning –pickling and brightening

Where the precipitation treatment is not carried out in a controlled atmosphere and it is desired to obtain a clean surface and bright finish after heat treatment, a number of precautions and finishing operations will be required.

All parts to be treated should be absolutely free of grease. Should this not be the case, parts should be carefully degreased.

Parts should be pickled after heat treatment. A simple method consists of immersing the parts in a 20-30 % sulphuric acid bath used at 80-90°C. The parts should be pickled for 15-30 minutes, depending on the degree of oxidation (or until the dark film on the surface has been removed). The pickling operation should be followed by rinsing in cold water.

Pickling may be followed by brightening. However, when brightening treatment is to be employed, extra care has to be taken with pickling, otherwise dull or pitted areas may persist after brightening. The maximum permissible pickling time can be determined by noting the subsequent results obtained on brightening.
A variety of brightening processes exist, some of which merely restore the original color of the metal, two examples are:

- Immersion in a cold 15-30 % nitric acid and water solution. The parts should be withdrawn as soon as gas bubbles appear..
- Immersion for 30-45 seconds in a cold 2.5 % (in volume) sulphuric acid solution to which has been added 50-60 g/litre of sodium bichromate.

In both the above cases, the brightening stage should be followed by thorough rinsing in cold water and drying.

Other brightening baths, such as “White” baths (sulphuric/nitric acid mixtures at various concentrations) give better results, but require some skill and experience in their operation in view of the possible rate of attack on the metal.

The bichromate bath is not recommended where brightening is to be followed by electroplating.

Machining

Copper beryllium alloys can be machined at any conditions. The machining properties of the copper beryllium alloys depend largely on their composition and temper.

The accompanying table gives machinability ratings compared to free-machining brass, which is rated 100. Based on this comparison a material with an index of 50 should be machined at a speed of approximately half of that used for a material rated 100 in order to obtain the same tool life.

These values can only be used as a guide since the machinability depends on a number of factors such as the type of machine, type of tool used, experience of the operator, rigidity of the support, etc.

For copper beryllium, however, there are a number of points which must be kept in mind:

- This alloy work hardens very rapidly and each cut must penetrate below the surface which has been work hardened by the preceding cut; for practical purposes a depth of 0.2 mm is considered a minimum.

- Copper beryllium is a precipitation hardening alloy and extended heating during machining can start the hardening effect. It is therefore important to keep the part cooled during machining.
- The oxide of beryllium is very abrasive. Therefore, when machining parts which have been oxidised the tool should always penetrate into the metal in order to avoid scraping of the surface oxide.
- Copper beryllium shrinks during precipitation hardening; 0.6 % by volume, 0.2 % linear, on the average. For parts requiring close machining tolerances this must be kept in mind, and the final machining should be done after precipitation hardening.
- Finally, for the pressure of the tooling and the rigidity of the support it must be kept in mind that the yield strength of copper beryllium is only 60 % that of steel.

Machinability ratings of Berylco alloys with respect to soft copper and other copper based alloys

Alloy	Composition	Machinability index (%)
Groupe 1 – Free machining alloys		
Free machining brass	Cu – 35Zn – 3Pb	100
Brass with 0.2% Pb	Cu – 33Zn – 2Pb	90
Leaded copper	Cu – 1Pb	80
Nickel silver with lead	Cu – 42Zn – 10Ni – 2Pb	80
Brass with 1% Pb	Cu – 34Zn – 1Pb	70
Brass with 0.5% Pb	Cu – 34.5Zn – 0.5Pb	60
Berylco 33/25 (A ; H)	Cu – 1.9Be – 0.25Co – 0.3Pb	60
Groupe 2 – Alloys with average machinability		
Aluminium bronze - silicon	Cu – 7Al – 2Si	60
Muntz metal	Cu – 40Zn	40
Berylco 14 (AT ; HT)	- - -	40
Hot worked Berylco alloys	- - -	30
Cast Berylco alloys (C and A tempers)	- - -	30
BrassTombac	Cu – 15Zn	30
Brass	Cu – 35Zn	30
Groupe 3 – Alloys with poor machinability		
Copper "touch pitch"	Cu	20
Phosphor bronze	Cu – 5Zn	20
Aluminium bronze	Cu – 7Al – 2Fe	20
Copper-Nickel	Cu – 30Ni	20
Nickel-Silver	Cu – 18Ni – 17Zn	20
Berylco alloys 25 et 165 (AT ; HT)	- - -	20

Materials for tooling

The copper beryllium alloys can be machined with high speed steel or carbide tools. The type of material recommended in the USA are the high speed steels M1, M2; T1 and T2 (AISI specs). For carbide tooling the type C2 is recommended. In Europe K20 and K30 are usually used. In general carbide tooling is reserved for long runs where high dimensional precision is required.

Cutting fluids

Cutting fluids produce a better surface finish, better tool life, and higher cutting speeds ; but one of their most important functions is the heat removal. Since this is their main function the soluble oil emulsions give the best results because of their excellent cooling properties. Depending on the type of machining to be performed they can have a concentration of between 1.5 and 10 % in water. Since they contain sulfur they many cause spotting of the parts, and it is advisable to remove the oil with hot water after machining.

Aisi	AFNOR	DIN	C	Cr	Mo	W	V
M1	Z85 DCWV 08-04-02-02	1-33-46	0.8	4.0	8.5	1.5	1.0
M2	Z85 WDCV 06-05-04-02	1-33-42	0.85	4.0	5.0	6.25	2.0
T1	Z80WCV 18-04-01	1-33-55	0.7	4.0	- -	18.0	1.0
T2	Z85WCV 18-04-02	1-32-55	0.85	4.0	- -	18.0	2.0

Aisi	AFNOR-DIN	TiC + TaC	Co	WC
C2	K20	2.0	6.0	92.0
	K30	1.0	9.0	90.0
	K40	0.0	12.0	88.0

For delicate operations it may be necessary to use a lubricant with a higher penetration and a more tenacious film. In these cases a lubricant with a mineral oil base should be used. Oils having low viscosity offer good penetration and their cooling properties are sufficient for delicate operations. Mineral oil base cutting oils with additions of 3 to 7 % lard oil give the best machining conditions for copper beryllium.

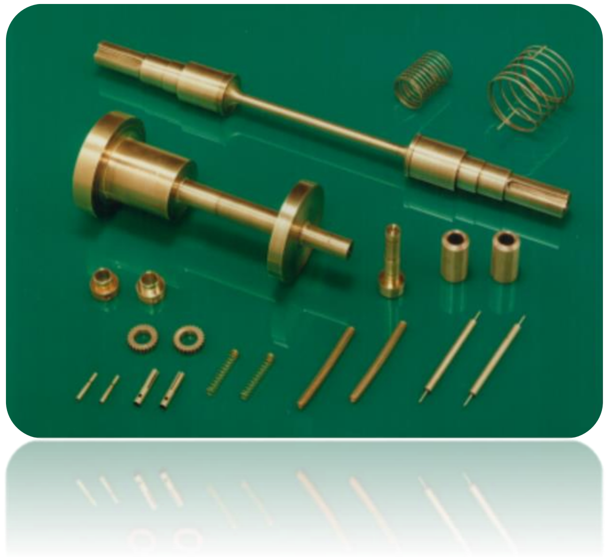
However, for the most difficult machining operations the sulfur containing oils offer the best combination of lubricity, penetration, and surface finish. The high surface resistance of these oils is of particular interest for operations where significant pressures and high speeds are required. When using sulfur containing oils the parts must be cleaned as soon as possible after machining to avoid spotting.

Turning of copper beryllium

Copper beryllium alloys can be turned on any type of equipment, either with high speed steel or carbide tools. The choice depends on the amount of machining to be accomplished.

Cutting speeds can go up to approximately 30 to 70 m/minute depending on the type of tooling and its geometry. When turning free machining alloys containing lead with carbide tooling the cutting speeds can go up to 200 m/minute (or higher). When the machining has to be done dry the speeds should be reduced. Relatively thick oil emulsions and mineral oils with lard oil additions can be used in most turning operations.

Chip removal can be a problem, especially when working with the softer tempers, which produce long, tenacious chips. In many cases this problem can be resolved by the use of chip breakers.



Alloy **Berylco 33/25** in any temper provides improved chip control due to a carefully controlled addition of lead. This alloy is well suited to automatic machining operations as the lead in the alloy reduces tool wear, eliminates clogging chips and produced small and short chips.

Drilling of copper beryllium

Copper beryllium alloys can by drilled in any temper with standard high speed commercial drills. For large volume production it is advisable to use drills which are specially designed.

Helical drills with a helix angle of 26-30° and a lip angle of 115-130° usually give satisfactory results. The advance can vary between 0.02 and 0.2 mm per turn and the cutting speed between 15 and 20 m per minute.

When drilling cast parts after they have been heat treated (AT) a reinforcement of the principal cutting edges and a more rigid support are recommended. This can be accomplished by using specially sharpened short drills.

In order to obtain satisfactory results the cutting and advance speeds should be constant, and cutting fluid should be used abundantly. It is very important that the tool cut constantly in order to avoid glazing of the bottom of the hole by friction which would produce rapid work hardening in copper beryllium.

Repeated insertions of the drill after momentary interruption can cause problems and particular care should be taken to extract the chips when the drill is withdrawn. This should be done regularly performing deep drilling.

Reaming of copper beryllium

When a part has to be reamed, either to obtain better dimensional precision, or better surface finish, the reamer should be mounted in a floating support in order to obtain better centring in the hole.

Standard reamers of high speed steel with right handed helix are most suitable for copper beryllium. Carbide tipped reamers should be used only for large volume production.

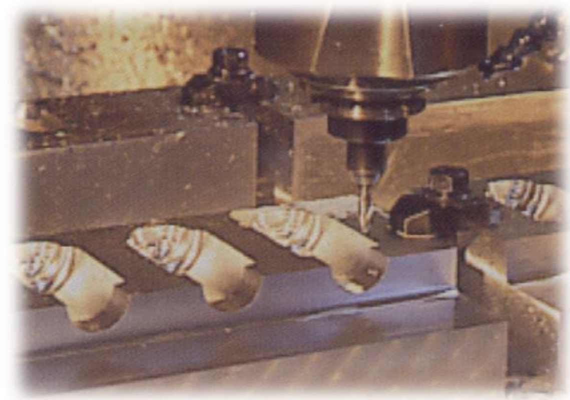
Allowing 0.12 to 0.15mm of the radius for removal will avoid overheating of the surface and permit penetration of the layer which has been cold worked by the drilling operation. Use of a cutting fluid is recommended.

Tapping of copper beryllium

Tapping and threading are the most delicate operations for copper beryllium. Nevertheless, the copper beryllium alloys can be taped relatively easily in the age hardenable tempers with taps normally used for copper.

The cutting speeds should be relatively slow, especially for the hardened tempers. If the are 25 to 30 m/min. for the softest alloys they should be limited to 2 to 3 m/min. for the high strength alloys which have been heat treated for maximum hardness.

The uses of cutting fluids are recommended for all tapping or tread cutting operations. Since the cutting speeds are usually too low to produce a significant rise in temperature the cutting fluid should be selected for its lubricating properties. A thick mineral oil with sulphur chloride compounds or fatty oil products are recommended. Immediate rinsing in mineral spirits reduces the risk of spotting on the parts.



Milling of copper beryllium

Milling of copper beryllium alloys does not present any special problems. High speed steel or carbide tipped tooling can be used. It is recommended that the cutting angle (or relief angle) be 10° for both, cylindrical cutters or face cutters. The milling operations can be facilitated by the use of cutting fluids.

Sawing of copper beryllium

Generally, copper beryllium alloys can be sawed relatively easily, except in the very soft or very hard tempers.

Thus, sawing of high strength alloys in the precipitation hardened condition is not recommended, except for mill hardened material with a hardness of less than 300 Vickers.

Similarly, it is better to avoid sawing of the high strength or high conductivity alloys in the annealed (A) condition. In this condition the metal is gummy and tends to clog the teeth of the saw.

For reciprocating saws high speed steel blades are generally used for the copper base alloys. The blades have a regular pitch, large teeth and good clearances to allow evacuation of the chips. With hand saws a relatively slow cadence should be used (less than 50 strokes per minute), and sufficient pressure should be applied so that the teeth are always cutting.

Similarly, for band saws, which are generally used in foundries to cut off risers, special attention should be paid to maintain sufficient advance pressure so that the teeth are always cutting.

Circular saws usually have integral high speed steel teeth or inserted teeth. The best results are obtained with saws where the alternate teeth are slightly higher by some tenths of a millimetre, and are bevelled on both sides.

Whenever possible the use of a cutting fluid, like soluble oil diluted at the rate of 4 % in water, is recommended.

Grinding of copper beryllium

Since copper beryllium can be readily ground in any condition, the parts are usually finish ground after precipitation hardening. However, if rough grinding operations are to be performed, such as debarring, they should generally be done before precipitation hardening.

Using speeds which are too low will cause rapid wear of the grinding wheel, while speeds which are too high can "burn" the part or load the grinding wheel with metal.

Use of a cutting fluid is recommended. Wet grinding prolongs the life of the grinding wheel and produces a better surface finish. Soluble oil emulsions of 1.5 to 3 % are adequate.

For the precipitation hardened tempers corundum wheels are preferred, and for the heat treatable tempers carborundum wheels are preferable. For parting or cut-off operations corundum wheels are recommended for all tempers. An average grain size for the wheel is usually adequate.

Joining

Except for the fact that copper beryllium is a structurally hardening alloy the joining procedures are the same as those for other copper base alloys. The following refers to the alloy Berylco 25, which is the most frequently used, except where the alloy B14 is specified. As for the latter two alloys the procedures are the same, but welding difficulties exist due to their susceptibility for oxidation combined with the necessity for pre-heating to overcome their high thermal conductivity.

Soft soldering

The soft soldering solders have a relatively low melting point, below 250°C. Therefore the soldering can be done after the precipitation hardening without causing a change to the properties of the copper beryllium. However, the metal must be absolutely clean before soldering.

Silver brazing

Silver brazing produces better results as far as strength is concerned. The eutectic copper-silver alloy which melts at 780° C theoretically permits brazing at the solution annealing temperature. But this is a very delicate operation, and the brazing alloys normally used melt between 600 and 650°C. The most typical melt at 625°C and flow at 635°C (with a composition: 50 % Ag, 15.5 % Cu, 16.5 % Zn, and 18 % Cd). Since these temperatures are below the solution annealing temperature the time at temperature must be reduced to a minimum in order to reach the best possible properties after the precipitation hardening.

Resistance welding

Copper beryllium can be spot welded, but welded, and lap welded. Seam welding is more difficult. The best results are obtained when the welding is one in the non-aged condition because of the lower electrical and thermal conductivity. The welding current should be about 50 % higher than that used for mild steel, but the time should be shorter. If copper beryllium is to be joined to another metal special attention must be paid to the choice of the electrodes (shape and material) and to the precise control of the welding conditions.

Arc Welding

Arc welding can be done either by the TIG method, using a tungsten electrode, or by the MIG method, using a consumable electrode. The TIG method is of particular interest since it does not use any flux, the heating effect is limited to a relatively small area, and the inert gas protects the metal from oxidation. The welding problems presented by copper beryllium originate from two peculiarities of this alloy:

- Since copper beryllium is a precipitation hardening alloy, and since the heating during welding destroys the effects of the precipitation heat treatment more or less, it becomes necessary to redo the aging treatment if the optimum properties are desired.
- Beryllium oxide is very refractory and is easily formed. It is therefore absolutely necessary to avoid the presence of oxide or its formation. This is particularly important when working with the alloys B14, which are subject to intergranular corrosion.

Electron beam welding

This type of welding is of special interest for delicate work since the deformations due to the operation are minimised. Since the welding is done under vacuum any oxidation of the materials to be joined is avoided.

The table as-below shows a list of metals and alloys rated in accordance with their weldabilty to copper beryllium as “good”, “acceptable”, or “bad”. This is intended only as a guide since in certain applications and using special procedures some of the materials can give satisfactory results.

Weldability to copper-beryllium		
Good	**Acceptable**	**Bad**
brass70/30	copper	carbon steel
cupro-nickel	brass 85/15	stainless steel
nickel silver	aluminium	magnesium
silicon bronze	nickel	zinc
phosphor bronze	monel	tin

Electrolytic Plating

Fabricators of copper beryllium parts are frequently required to provide parts with plated surfaces. Before plating the metal must have been pickled and must be absolutely clean. This is imperative since the heat treatment generally produces some oxidation of the surface which prevents adhesion of the plating. A sulphuric aced bath after the heat treatment is recommended for the parts to be plated. However, this pickling leaves a reddish deposit on the surface of the metal which must be eliminated by mechanical means, such as tumbling, or chemically, using a 20 % nitric acid solution in water for a very short time to avoid attacking the metal. This pickling must be followed by a thorough rinse and drying.

For electrical contacts which must have low contact resistance, good surface conductivity for high frequency currents, etc. precious metal plating (gold or silver) is usually required. For this type of plating a thin layer of nickel is usually deposited as a diffusion barrier. This deposit should be thin, about 0.5 to 1 micron, especially if the part is subjected to bending in its operation, since the nickel layer is particularly fragile.

Industrial Hygiene

When supplied in solid form, beryllium copper alloys are non-hazardous, because Beryllium (<2%) has been completely dissolved into copper. General handling, stamping, forming, most machining operations, pickling, surface treatment, plating and heat treatment are non-hazardous and do not require any special precautions.
As with other materials industry, beryllium alloys can pose a health risk if the recommended precautions are not followed. If they are subsequently processed in any way which might give rise to airborne dust or fumes, for instance by dry grinding, abrading, electro-discharge machining, melting or welding, then an inhalation hazard could arise.
Inhalation of beryllium oxide and/or beryllium fine particles may cause a chronic respiratory disease (Chronic Beryllium Disease or berylliosis). Any such process requires suitable air extraction and filtration to maintain Be level below 0.6 µg/m^3 of air per working day, value recommended by the Beryllium association BeST (inhalable fraction – 8 hours Time Weighted Average). The use of cutting fluid can also reduce emissions of dust in the atmosphere.
The Occupational Exposure Limit (OEL) currently recommended in France, as in most of the European Member States, is 2 µg/m^3(inhalable – 8 hours TWA).

NGK BERYLCO has developed with the Beryllium association a product stewardship program "Be Responsible" (Be like Beryllium) in order to implement good safety practices at the workplace. Guidances are available in different languages (English, French, German, Italian, Spanish): ***www.berylliumsafety.eu***

For more information concerning the non hazardous use or to request our product safety information sheets (SIS), please contact our environmental department.

European Directives

The NGK Insulators group is recognized as a world leader in the manufacture of beryllium-copper alloys. As such, we have always had a policy to provide our customers with safe and environmentally friendly products, which fully comply with current legislation in order to ensure the sustainability of our services. As a leading manufacturer in Europe, NGK Berylco actively participates in European environmental studies on substances used in our products.

RoHS Compliance

RoHS Directive stands for 'Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment' (EEE). The aim of the RoHS directive (2002/95/CE) is to regulate the use of certain dangerous substances. Since 1st July 2006, all EEE, imported or manufactured in the EU, placed on the EU market should comply with the requirements of this directive. RoHS recast in 2011 (2011/65/CE, RoHS 2) does not include any restriction on beryllium and consequently on the use of copper-beryllium as indicated by our 'RoHS Ready' logo.

REACH Compliance

REACH stands for 'Registration, Evaluation Authorisation and restriction of Chemicals' which enter into force on 1st June 2007. The main REACH objective is to improve the protection of human health and the environment. Even if our copper-beryllium products are considered as being 'articles' under REACH, NGK Berylco registered beryllium in November 2010 (No. 01-2119487146-32-0003). This procedure gave us the opportunity to make new scientific studies which concluded that beryllium metal should be reclassified. The industry is currently working with the European Institutions and Member States to update the current cancer classification as well as to demonstrate that beryllium metal, is like many other metals, safe when used correctly.

Beryllium is not included in the REACH Candidate List (Substances of Very High Concern: SVHC).
In 2016, the BAuA (German Institute of Occupational Health and Safety) published the outcomes of the Risk Management Option Analysis (RMOA) conducted for Beryllium: Beryllium will not be included in the REACH SVHC list and will not be subject to authorization.

Recycling

NGK Berylco, certificated ISO 14001, is consistently monitoring any environmental regulations to ensure the compliance of our products to our customers. A systematic recycling of all waste generation such as metal, working oils, acids, water cooling, etc. is established. We propose also the recovery of the copper beryllium production scraps generated by our customers. Please contact our sales department.

Strip linear density

Strip weights in kg/m for BERYLCO 25 and 165 For strip alloys BERYLCO 14, add 6%								
thickness (mm)	Width in mm							
	5	8	10	12	20	30	40	50
0.04	0.0017	0.0026	0.0033	0.0040	0.0066	0.0099	0.0132	0.0165
0.05	0.0021	0.0033	0.0041	0.0050	0.0083	0.0124	0.0165	0.0207
0.06	0.0025	0.0040	0.0050	0.0059	0.0099	0.0149	0.0193	0.0248
0.07	0.0029	0.0046	0.0058	0.0069	0.0116	0.0173	0.0231	0.0289
0.08	0.0033	0.0053	0.0066	0.0079	0.0132	0.0198	0.0264	0.0330
0.09	0.0037	0.0060	0.0074	0.0089	0.0149	0.0223	0.0297	0.0372
0.10	0.0041	0.0066	0.0083	0.0099	0.0165	0.0248	0.0330	0.0413
0.11	0.0045	0.0073	0.0091	0.0109	0.0182	0.0273	0.0363	0.0454
0.12	0.0050	0.0079	0.0099	0.0119	0.0198	0.0297	0.0397	0.0496
0.13	0.0054	0.0086	0.0107	0.0129	0.0215	0.0322	0.0430	0.0537
0.14	0.0058	0.0093	0.0116	0.0139	0.0231	0.0347	0.0463	0.0578
0.15	0.0062	0.0099	0.0124	0.0149	0.0248	0.0372	0.0496	0.0620
0.16	0.0066	0.0106	0.0132	0.0159	0.0264	0.0396	0.0529	0.0661
0.17	0.0070	0.0112	0.0140	0.0168	0.0281	0.0421	0.0562	0.0702
0.18	0.0074	0.0119	0.0149	0.0178	0.0297	0.0446	0.0595	0.0743
0.19	0.0078	0.0126	0.0157	0.0188	0.0314	0.0471	0.0628	0.0785
0.20	0.0080	0.0132	0.0165	0.0198	0.0330	0.0496	0.0661	0.0826
0.25	0.0108	0.0165	0.0207	0.0248	0.0413	0.0620	0.0826	0.1033
0.30	0.0124	0.0198	0.0248	0.0297	0.0496	0.0743	0.0991	0.1239
0.40	0.0165	0.0264	0.0330	0.0396	0.0661	0.0911	0.1322	0.1652
0.50	0.0207	0.0331	0.0413	0.0496	0.0826	0.1239	0.1652	0.2065
0.60	0.0248	0.0397	0.0496	0.0595	0.0991	0.1487	0.1982	0.2478
0.70	0.0289	0.0463	0.0578	0.0694	0.1156	0.1735	0.2313	0.2891
0.80	0.0330	0.0529	0.0661	0.0793	0.1322	0.1982	0.2643	0.3304
0.90	0.0372	0.0595	0.0743	0.0892	0.1487	0.2230	0.2974	0.3717
1.00	0.0413	0.0661	0.0826	0.0991	0.1652	0.2478	0.3304	0.4130
1.25	0.0516	0.0826	0.1033	0.1239	0.2065	0.3098	0.4130	0.5163
1.50	0.0620	0.0992	0.1239	0.1487	0.2478	0.3717	0.4956	0.6195
1.75	0.0723	0.1157	0.1446	0.1734	0.2891	0.4337	0.5782	0.7228
2.00	0.0826	0.1322	0.1652	0.1982	0.3304	0.4956	0.6608	0.8260
2.50	0.1033	0.1653	0.2065	0.2478	0.4130	0.6195	0.8260	1.0325

Rod linear density

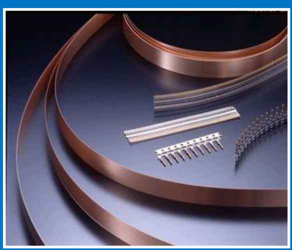
Rod weights in kg/m for BERYLCO 25 et 165 For rod alloys BERYLCO 14, add 6%							
Diameter (mm)	Round (Kg/m)	Square (Kg/m)	Hexagonal (Kg/m)	Diameter (mm)	Round (Kg/m)	Square (Kg/m)	Hexagonal (Kg/m)
0.5	0.0016	0.0021	0.0018	28	5.086	6.476	5.608
1.0	0.0065	0.0083	0.0072	29	5.456	6.947	6.016
1.5	0.0146	0.0186	0.0161	30	5.839	7.434	6.438
2.0	0.0259	0.0330	0.0286	31	6.235	7.938	6.874
2.5	0.0405	0.0516	0.0447	32	6.643	8.458	7.325
3.0	0.0584	0.0743	0.0643	33	7.065	8.995	7.790
3.5	0.0795	0.1012	0.0867	34	7.500	9.549	8.269
4.0	0.1038	0.1322	0.1145	35	7.948	10.12	8.764
4.5	0.1314	0.1673	0.1449	36	8.404	10.70	9.266
5.0	0.1622	0.2065	0.1788	37	8.883	11.31	9.794
6	0.2336	0.2974	0.2575	38	9.370	11.93	10.33
7	0.3179	0.4047	0.3505	39	9.835	12.56	10.88
8	0.4152	0.5286	0.4578	40	10.38	13.22	11.45
9	0.5255	0.6691	0.5794	41	10.91	13.89	12.02
10	0.6487	0.8260	0.7153	42	11.44	14.57	12.61
11	0.7850	0.9995	0.8656	43	11.99	15.27	13.22
12	0.9338	1.189	1.030	44	12.56	15.99	13.84
13	1.096	1.396	1.209	45	13.14	16.73	14.48
14	1.272	1.619	1.402	46	13.73	17.48	15.13
15	1.460	1.859	1.610	47	14.33	18.25	15.80
16	1.661	2.115	1.832	48	14.95	19.03	16.47
17	1.875	2.387	2.067	49	15.57	19.83	17.16
18	2.102	2.676	2.317	50	16.22	20.65	17.87
19	2.342	2.982	2.582	52	17.55	22.34	19.34
20	2.595	3.304	2.861	54	18.92	24.09	20.85
21	2.861	3.643	3.155	56	20.34	25.90	22.42
22	3.140	3.998	3.462	58	21.83	27.79	24.07
23	3.432	4.370	3.784	60	23.36	29.74	25.75
24	3.737	4.758	4.120	62	24.94	31.75	27.50
25	4.055	5.163	4.472	64	26.57	33.83	29.30
26	4.386	5.584	4.836	66	28.26	35.98	31.16
27	4.730	6.022	5.215	70	31.79	40.17	35.05

Hardness – Conversion Table

HV Vickers	HB brinell	Rockwell		Rm (N/mm²)	HV Vickers	HB brinell	Rockwell		Rm (N/mm²)
		HRC	HRB				HRC	HRB	
450	428	45.3		1455	225	214	-		720
440	418	44.5		1420	220	209	-	97	705
430	410	43.6		1385	215	204	-		690
420	400	42.7		1350	210	199	-	95.5	675
410	390	41.8		1320	205	195	-		660
400	380	40.1		1290	200	190	-	94	640
390	371	39.8		1255	195	185	-		625
380	361	28.8		1220	190	181	-	92	610
370	352	27.7		1190	185	176	-		595
360	342	36.6		1155	180	171	-	90	575
350	333	35.5		1125	175	166	-		560
340	323	34.4		1095	170	162	-	87	545
330	314	33.3		1060	165	156	-		530
320	304	32.2		1030	160	152	-	84	510
310	295	31		995	155	147	-		495
300	285	29.8	106.5	965	150	143	-	81	480
295	280	29.2		950	145	136	-		465
290	276	28.5	105.5	930	140	133	-	77	450
285	271	27.8		915	135	128	-		430
280	266	27.1	104.5	900	130	124	-	73	415
275	261	26.4		880	125	119	-		400
270	257	25.6	104.5	865	120	114	-	68	385
265	252	24.8		850	115	109	-		370
260	247	24	103.5	835	110	105	-	63	350
255	242	23.1		820	105	100	-		335
250	236	22.2	102	800	100	95	-	57	320
245	233	21.3		785	95	90	-		305
240	228	20.3	100	770	90	85	-		285
235	223	-		755	85	80	-		270
230	219	-	98.5	740	80	76	-		255

MEMO :

NGK BERYLCO



EUROPE

FRANCE
NGK BERYLCO France
103 Quai Jean Pierre Fougerat, CS 20017,
44220 Couëron, France
Tel : +33 (0)2 40 38 67 50
Fax: +33 (0)2 40 38 09 95

GREAT BRITAIN
NGK BERYLCO UK Ltd
Houston Park, Montford Street,
Salford, M50 2RP, U.K.
Tel: +44 (0)161-745-7162
Fax: +44 (0)161-745-7520

GERMANY
NGK Deutsche BERYLCO GmbH
Westerbachstraße 32
61476 Kronberg Im Taunus, Germany
Tel: +49 (0) 6173 993 400
Fax: +49 (0) 6173 993 401

SPAIN
Massague Rep. Ind. SA
Calle la Ginesta, 6, Apt de Correos 47
08 830 Sant Boi de Llobregat, España
Tel: +34 93 640 0573
Fax: +34 93 630 2865
www.massaguesa.com

ITALY
Tecnicom
Via G. Passeroni, 6
20135 MILANO, Italia
Tel: +39 (0)2 45506240
Fax: +39 (0)2 39304926
Email: tecni_com@tin.it

TURKEY
Promak Pres Otomasyon San.
Perpa Ticaret merkezi B Block K11
No:1987
Okmeydani-34384 Istanbul, Turkiye
Tel: +90 212 320 85 10
Fax: +90 212 320 85 44
Email: makgol@promakmakina.com
www.promakmakina.com

ASIA

JAPAN
NGK INSULATORS Ltd
New Metal Division,
Marunouchi Bldg.25F, 2-4-1, Marunouchi,
Chiyoda-ku, Tokyo, 100-6235, Japan
Tel: +81 (0)3-6213-8913
Fax: +81 (0)3-6213-8973
www.ngk-insulators.com
www.ngk-global.com

CHINA
NGK INSULATORS Ltd
Shanghai Office,
Dawning Centre Tower A Room 1902,
No.500 Hongbaoshi Road,
Shanghai 201103, China
Tel: +86-021-3209-8870
Fax: +86-021-3209-8871
www.ngk-insulators.com

CHINA
NGK INSULATORS Investment Co Ltd
Shenzhen Branch
Room.8, Level.15, Tower 2,
Kerry Plaza, No.1 Zhong Xin Si Road,
Futian District
Shenzhen 518048, China
Tel : +86-755-3304 -3178
www.ngk-insulators.com

AMERICA

USA
NGK METALS Corporation
917 U.S. Highway 11 South,
Sweetwater, TN 37874, USA
Tel: +1 (800) 523-8268
Fax: +1 (877) 645-2328
www.ngkmetals.com

INDIA

INDIA
NGK INSULATORS Ltd
New Delhi Liaison Office,
601, 6th floor, DLF Place, A-4,
District Centre, Saket
New Delhi 110 017, India
Tel: +91-11-4170-4020
www.ngk-insulators.com

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Edition 01/2018