Cu Be2 Co Ni

Common names: Beryllium Copper
Beryllium Bronze

A copper alloy containing beryllium and small amounts of cobalt, nickel and/or iron, that can be strengthened by heat treatment. Material solution heat treated at high temperature has a soft supersaturated alpha-phase structure, and subsequent precipitation hardening at lower temperature precipitates a finely dispersed beryllium-rich phase in the matrix. In this condition, the alloy exhibits fair conductivity and still higher strength and hardness than Cu Be1.7 Co Ni. Cold working, performed before precipitation hardening, can further improve strength and hardness. The most commonly used wrought forms are plate, strip, rod and wire.

COMPOSITION (weight %)

Be	1.8–2.1
Co+Ni	0.20–0.60
Co+Ni+Fe	0.20–0.60
Cu	rem.

1 SOME TYPICAL USES

Electrical

Springs, contacts and connectors; circuit-breaker parts; fuse clips; contact pads; plugs for high-frequency connectors.

Mechanical

Springs; pressure-responsive elements, including diaphragms, flexible bellows and tubes of Bourdon pressure gauges; numerous components of industrial and aircraft instruments; non-sparking safety tools; watch and clock parts; crinkle washers; resistance-welding electrodes and ancillary equipment, including flash-welding dies; components for cryogenic equipment; wear-resistant parts, including guides, bushings, bearings and cams; chains and other components for non-magnetic applications.

2 PHYSICAL PROPERTIES

The "solution heat treated" and "precipitation hardened" conditions referred to in this section relate to material with or without cold work. When no specific condition is quoted, the value shown is applicable to material in all conditions of heat treatment and working.

		Metric Units	English Units
2.1	Density at 20 °C *68 °F* (solution heat treated or precipitation hardened)	8.25 g/cm³	0.300 lb/in³
2.2	Melting range	865–985 °C	1 590–1 805 °F
2.3	Coefficient of thermal expansion (linear) at:		
	—246 to 25 °C *—411 to 77 °F*	0.000 013 per °C	0.000 007 per °F
	— 76 to 25 °C *—105 to 77 °F*	0.000 015 ,, ,,	0.000 008 ,, ,,
	20 to 100 °C *68 to 212 °F*	0.000 017 ,, ,,	0.000 009 ,, ,,
	20 to 200 °C *68 to 392 °F*	0.000 017 ,, ,,	0.000 009 ,, ,,
	20 to 300 °C *68 to 572 °F*	0.000 018 ,, ,,	0.000 010 ,, ,,
2.4	Specific heat (thermal capacity) at:		
	20 °C *68 °F*	0.10 cal/g °C	0.10 Btu/lb °F
2.5	Thermal conductivity at:		
	—269 °C *—452 °F* (precipitation hardened)	~0.004 5 cal cm/cm² s °C	~1.1 Btu ft/ft² h °F
	—263 °C *—441 °F* (,, ,,)	~0.012 ,,	~2.8 ,,
	—253 °C *—423 °F* (,, ,,)	~0.026 ,,	~6.2 ,,
	—193 °C *—315 °F* (,, ,,)	~0.089 ,,	~21 ,,
	20 °C *68 °F* (solution heat treated)	~0.20 ,,	~48 ,,
	20 °C *68 °F* (precipitation hardened)	0.25–0.30 ,,	60–73 ,,
	200 °C *392 °F* (,, ,,)	0.30–0.35 ,,	73–85 ,,
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (solution heat treated)	~10 m/ohm mm²	~17 % IACS
	20 °C *68 °F* (precipitation hardened)	12–17 ,,	20–30 ,, ,,
	200 °C *392 °F* (,, ,,)	9–13 ,,	15–22 ,, ,,
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (solution heat treated)	~0.10 ohm mm²/m ~10 microhm cm	~61 ohms (circ mil/ft) ~4.0 microhm in
	20 °C *68 °F* (precipitation hardened)	0.086–0.057 ohm mm²/m 8.6–5.7 microhm cm	52–35 ohms (circ mil/ft) 3.4–2.3 microhm in
	200 °C *392 °F* (,, ,,)	0.11–0.078 ohm mm²/m 11–7.8 microhm cm	69–47 ohms (circ mil/ft) 4.5–3.1 microhm in
2.8	Temperature coefficient of electrical resistance at:		
	20 °C *68 °F* (solution heat treated) applicable over range from 0 to 100 °C *32 to 212 °F*	~0.001 0 per °C (17% IACS)	~0.000 6 per °F (17% IACS)
	20 °C *68 °F* (precipitation hardened) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 8 ,, ,, (20 ,, ,,) 0.001 2 ,, ,, (30 ,, ,,)	0.000 4 ,, ,, (20 ,, ,,) 0.000 7 ,, ,, (30 ,, ,,)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*:		
	solution heat treated	12 500 kg/mm²	17 800 000 lb/in²
	precipitation hardened	13 500 kg/mm²	19 200 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*:		
	solution heat treated	4 600 kg/mm²	6 600 000 lb/in²
	precipitation hardened	5 000 kg/mm²	7 100 000 lb/in²

N.B.: The values given in Section 2, which have been appropriately rounded in view of the composition range involved, are based on selected literature references; the melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted.

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 10); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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3 FABRICATION PROPERTIES

The information given in this table is for general guidance only, since many factors influence fabrication techniques. The values shown are approximate only, since those used in practice are dependent upon form and size of metal, equipment available, techniques adopted and properties required in the material.

For further information on heat treatment and the related properties of this alloy, see General Data Sheet No. 4.

		Metric Units	English Units
3.1	Casting temperature range [(a)]	1 030–1 100 °C	1 885–2 010 °F
3.2	Heat treatment conditions		
3.2.1	Solution heat treatment		
3.2.1.1	Temperature range	760– 800 °C	1 400–1 470 °F
3.2.1.2	Time at temperature	60–15 min.	
3.2.1.3	Type of furnace	Muffle	
3.2.1.4	Cooling	Water quench	
3.2.2	Interstage annealing temperature range	650– 750 °C	1 200–1 380 °F
3.2.3	Precipitation hardening		
3.2.3.1	Temperature range	310– 360 °C	590– 680 °F
3.2.3.2	Time at temperature	3 – 0.5 h	
3.2.3.3	Type of furnace	Muffle or salt bath	
3.2.3.4	Cooling	Air	
3.3	Hot working temperature range	625– 800 °C	1 155–1 470 °F
3.4	Hot formability	Good	
3.5	Cold formability		
	Solution heat treated	Good	
	Precipitation hardened	Limited	
3.6	Cold reduction		
	Solution heat treated	40% max.	
	Precipitation hardened	10% max.	
3.7	Machinability:	See General Data Sheet No. 2	
	Machinability rating (free-cutting brass = 100)		
	Solution heat treated and cold worked	30%	
	Precipitation hardened	20%	
3.8	Joining methods: [(a)] [(b)]	See General Data Sheet No. 3.3	
	Soldering	Good	
	Brazing	Good	
	Oxy-acetylene welding	Not recommended	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Good	
	Coated metal-arc welding	Fair	
	Resistance welding: spot	Good	
	seam	Fair	
	butt	Fair	

(a) Adequate fume extraction must be ensured during melting, casting and welding to avoid risk of toxicity from beryllium oxide.

(b) These processes, involving the application of heat, are generally restricted to solution-heat-treated material, but soldering must be carried out after precipitation hardening to avoid melting of the joint.

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition [(a)]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	Br Be	—	266.51	266.51	266.51	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Be2 Co Ni	252 of. 68	—	—	—	259 of. 70	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	CuBe2	17 666	1780 17 670	17 672	17 677 17 682	17 671	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	BeCu P2 BeCu R2 BeCu B2 BeCu W2	—	H 3801	H 3802	H 3803	—	—	—
Netherlands	N or NEN [(b)]	Cu-Be2 Co Ni	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States [(c)]	ASTM	No. 172	—	B 194	B 196	B 197	—	—	—
International Organisation for Standardization	ISO	Cu Be2 Co Ni	R 1187	—	—	—	—	—	—

(a) Applicable when the chemical composition is not given in the specifications for wrought forms.
(b) Older specifications bear prefix N; for new specifications the NEN prefix is used.
(c) In the United States, bar and flat wire are covered under the Plate-Sheet-Strip column.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

Tensile properties	see tables 5.1.1/3.1/3.2
Hardness	,, ,, 5.1.1/3.1/3.2
Shear strength	,, ,, 5.1.1/3.1/3.2
Modulus of elasticity (tension)	see 2.9
Modulus of rigidity (torsion)	,, 2.10

5.2 Mechanical properties at low temperature

Tensile properties	see tables 5.2.1.1/2
Impact properties	,, ,, 5.2.1.1/2

5.3 Mechanical properties at elevated temperature

Short-time tensile properties	see table 5.3.1
Creep properties	see tables 5.3.2.1/2

5.4 Fatigue properties

Fatigue strength at room temperature	see tables 5.4.1.1/2

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE [(a)]

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

This table is representative of practice in many European countries. For American practice, see table 5.1.3.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.

For a given temper, individual elongation values may show some variation above or below the typical values indicated.

The mechanical properties of this alloy are largely dependent upon heat treatment conditions. For further information, see General Data Sheet No. 4.

Form	Temper	Tensile Strength kg/mm²	Proof Stress 0.2% offset kg/mm²	Elongation		Hardness		Shear Strength kg/mm²	Typical Size Related to Properties Shown [(b)]
				%	gauge length	Brinell	Vickers		
Plate Strip	Solution Heat Treated	51	23	50	$5.65\sqrt{S_o}$	105	110	—	0.2–5 mm thick
	Solution Heat Treated and Cold Worked to Typical Tempers	55	40	30	$5.65\sqrt{S_o}$	135	140	39	0.2–5 mm thick
		58	50	22	50 mm	160	170	40	0.2–3 mm thick
		63	56	15	50 mm	185	195	41	"
		70	64	8	50 mm	210	220	48	0.2–1 mm thick
		77	71	5	50 mm	220	230	—	"
	Precipitation Hardened after Solution Heat Treatment	125	110	6	$5.65\sqrt{S_o}$	370	390	—	0.2–5 mm thick
		127	110	3	50 mm	375	395	—	0.2–3 mm thick
	Precipitation Hardened after Cold Working to Typical Tempers	134	117	2	50 mm	385	405	—	0.2–3 mm thick
		138	123	1	50 mm	395	415	—	0.2–1 mm thick
		142	127	—	—	410	430	—	"
Strip	Mill Hardened to Typical Tempers	75	60	20	50 mm	240	255	36	0.2–5 mm thick
		82	68	17	50 mm	260	275	43	"
		90	76	14	50 mm	285	300	47	0.2–3 mm thick
		102	88	11	50 mm	315	330	51	"
		120	105	7	50 mm	340	360	56	0.2–1 mm thick
		126	110	6	50 mm	360	380	58	"
Rod [(c)]	Solution Heat Treated	50	18	45	$5.65\sqrt{S_o}$	100	105	—	2–50 mm diam. or equivalent area
	Solution Heat Treated and Cold Worked to Typical Tempers	55	40	30	$5.65\sqrt{S_o}$	135	140	—	25–50 mm diam. or equivalent area
		65	58	15	$5.65\sqrt{S_o}$	185	195	—	5 to 25 mm diam. or equivalent area
	Precipitation Hardened after Solution Heat Treatment	125	110	5	$5.65\sqrt{S_o}$	365	385	—	2–50 mm diam. or equivalent area
	Precipitation Hardened after Cold Working to Typical Tempers	130	112	3	$5.65\sqrt{S_o}$	375	395	—	25–50 mm diam. or equivalent area
		135	117	2	$5.65\sqrt{S_o}$	385	405	—	5 to 25 mm diam. or equivalent area
Wire	Solution Heat Treated	49	18	40	100 mm	—	—	—	—
	Solution Heat Treated and Cold Drawn to Typical Tempers	72	66	5	100 mm	—	—	—	2–5 mm diam.
		85	78	3	100 mm	—	—	—	1–2 mm diam.
		100	90	2	100 mm	—	—	—	up to 1 mm diam.
	Precipitation Hardened after Solution Heat Treatment	125	110	3	100 mm	—	—	—	—
	Precipitation Hardened after Cold Drawing to Typical Tempers	135	120	—	—	—	—	—	2–3 mm diam.
		140	125	—	—	—	—	—	1–2 mm diam.
		145	130	—	—	—	—	—	up to 1 mm diam.

(a) It will be noted that tables 5.1.1 and 5.1.3, giving typical tensile properties and hardness values in Metric and American units, respectively, are not directly comparable. This is because the properties quoted reflect to some extent the metalworking techniques, specification practices and testing procedures in the countries concerned, and in view of the different sizes of products referred to in these tables. Individual manufacturers of semi-fabricated products can, however, normally meet the requirements of any national standard.

(b) It is possible to obtain sizes outside the ranges given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.

(c) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.1.2 Typical Tensile Properties and Hardness Values—SI and English Units

Tensile properties and hardness values in SI and English units are omitted from this data sheet, since alloys within the composition range concerned are not normally produced by British manufacturers.

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American Standards. For practice in European countries, see table 5.1.1.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.

For a given temper, individual elongation values may show some variation above or below the typical values indicated.

The mechanical properties of this alloy are largely dependent upon heat treatment conditions. For further information, see General Data Sheet No. 4.

5.1.3.1. Solution-Heat-Treated Material

Form	Temper	Tensile Strength psi	Yield Strength 0.2% offset psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [(a)]
				%	gauge length	F	B	30 T		
Flat Products (Plate, Strip, Bar and Flat Wire)	Solution Heat Treated	70 000	36 000	55	2 in.	93	61	56	51 000	0.032 in. thick
		69 000	32 000	35	2 in.	94	62	62	50 000	0.040 in. thick
		62 000	26 000	35	2 in.	93	60	61	45 000	0.060 in. thick
	Solution Heat Treated and Cold Worked									
	Quarter Hard	83 000	82 000	30	2 in.	—	87	76	61 000	0.032 in. thick
	Half Hard	96 000	91 000	15	2 in.	—	95	80	72 000	,,
	Hard	115 000	107 000	5	2 in.	—	100	82	82 000	,,
	Half Hard	93 000	82 000	5	2 in.	—	92	78	68 000	0.040 in. thick
	Hard	110 000	104 000	2	2 in.	—	100	82	78 000	,,
Rod [(b)]	Solution Heat Treated	72 000	38 000	35	2 in.	95	65	62	53 000	1 in. diam.
	Solution Heat Treated and Cold Worked									
	Half Hard	110 000	90 000	15	2 in.	—	95	—	78 000	up to 1 in. diam.
	Half Hard	100 000	85 000	15	2 in.	—	95	—	72 000	over 1 in. diam.
Wire	Solution Heat Treated	70 000	—	30	10 in.	—	—	—	—	0.040 in. diam.
	Solution Heat Treated and Cold Worked									
		150 000	—	—	—	—	—	—	—	0.051–0.075 in. diam.
	Hard Drawn	130 000	—	—	—	—	—	—	—	0.075–0.100 in. diam.
		120 000	—	—	—	—	—	—	—	0.10–0.114 in. diam.

5.1.3.2 Precipitation-Hardened Material

Form	Temper	Tensile Strength psi	Yield Strength 0.2% offset psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [(a)]
				%	gauge length	G	C	30 N		
Flat Products (Plate, Strip, Bar and Flat Wire)	Precipitation Hardened after Solution Heat Treatment	178 000	146 000	10	2 in.	—	38	58	116 000	0.021 in. thick
		189 000	173 000	5	2 in.	—	41	62	121 000	0.032 in. thick
		175 000	130 000	5	2 in.	—	37	56	115 000	0.040 in. thick
		175 000	120 000	6	2 in.	102	37	56	115 000	0.470 in. thick
	Precipitation Hardened ftaer Cold Working									
	Quarter Hard	191 000	171 000	5	2 in.	—	40	61	122 000	0.032 in. thick
	Half Hard	204 000	183 000	3	2 in.	—	42	63	126 000	,,
	Hard	210 000	189 000	2	2 in.	—	43	64	129 000	,,
	Half Hard	195 000	140 000	3	2 in.	—	41	62	123 000	0.040 in. thick
	Hard	200 000	150 000	2	2 in.	—	42	63	125 000	,,
	Hard	190 000	140 000	2	2 in.	—	41	62	121 000	0.050 in. thick
	Half Hard	191 000	165 000	3	2 in.	—	40	61	122 000	0.078 in. thick
	Half Hard	173 000	100 000	5	2 in.	102	37	56	114 000	0.470 in. thick
	Hard	193 000	120 000	2	2 in.	105	41	62	123 000	,,
Rod [(b)]	Precipitation Hardened after Solution Heat Treatment	187 000	94 000	5	2 in.	96	32	52	120 000	0.50 in. diam.
	Precipitation Hardened after Cold Working									
	Half Hard	200 000	135 000	3	2 in.	—	40	61	125 000	up to 1 in. diam.
	Hard	190 000	140 000	1	2 in.	—	41	62	121 000	1 in. diam
	Half Hard	185 000	170 000	3	2 in.	—	40	61	120 000	over 1 in. diam.
Wire	Precipitation Hardened after Solution Heat Treatment	175 000	100 000	5	2 in.	—	—	—	—	—
	Precipitation Hardened after Cold Working									
	Hard Drawn	215 000	200 000	1	10 in.	—	—	—	—	0.040 in. diam.

(a) It is possible to obtain sizes different from those given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.

(b) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

5.2.1.1 Solution-Heat-Treated Material

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Sheet [1] 3 mm 0.125 in.	Solution Heat Treated and Cold Worked 21%	27	80	63.5	40	90 000	56.2 [a]	15	2 in.	—	—	—
		—77	—108	67	42.5	95 000	61.2 [a]	20	2 in.	—	—	—
		—197	—323	82.5	52	117 000	70.3 [a]	37	2 in.	—	—	—
		—253	—424	96.5	61	137 000	75.9 [a]	45	2 in.	—	—	—
Rod [2] 14 mm diam. 0.560 in. diam.	Solution Heat Treated	27	80	51.5	33	73 400	24.0 [a]	52	1 in.	74	28.5 [b]	103 [b]
		—59	—75	52	33	74 300	27.0 [a]	55	1 in.	75	26.3 [b]	95 [b]
		—129	—200	59.5	37.5	84 300	32.0 [a]	51	1 in.	75	23.0 [b]	83 [b]
		—184	—300	69	43.5	97 800	40.2 [a]	50	1 in.	68	20.2 [b]	73 [b]
	Solution Heat Treated and Cold Worked	27	80	72.5	46	103 000	68.9 [a]	16	1 in.	57	8.3 [b]	30 [b]
		—59	—75	76.5	48.5	109 000	68.5 [a]	20	1 in.	—	8.3 [b]	30 [b]
		—129	—200	82.5	52	117 000	73.1 [a]	21	1 in.	49	8.6 [b]	31 [b]
		—184	—300	81	51.5	115 000	77.3 [a]	20	1 in.	50	7.5 [b]	27 [b]
Rod [4] 16 mm diam. 0.625 in. diam.	Solution Heat Treated	20	68	51	32.5	72 500	27.4 [a]	46.5	2 in.	58.5	18.8 [f]	54.5 [f]
		—41	—42	52.5	33.5	75 000	31.3 [a]	46.5	2 in.	59	23.5 [f]	68 [f]
	Solution Heat Treated and Cold Worked	20	68	79.5	50.5	113 000	78.0 [a]	11	2 in.	42.5	8.0 [f]	46.5 [f]
		—41	—42	83.5	53	118 500	78.7 [a]	11.5	2 in.	41.5	8.8 [f]	51 [f]
Rod [3] 19 mm diam. 0.75 in. diam.	Solution Heat Treated	20	68	49	31	69 900	19.3 [a]	62.6	$4.52\sqrt{S_o}$	79.6	28.3 [c]	102.5 [c]
		—78	—108	52.5	33.5	74 900	24.4 [a]	69.0	$4.52\sqrt{S_o}$	79.0	27.2 [c]	98.5 [c]
		—197	—323	69.5	44	99 000	34.7 [a]	69.8	$4.52\sqrt{S_o}$	72.8	24.0 [c]	86.5 [c]
		—253	—423	82.5	52.5	117 200	40.9 [a]	69.0	$4.52\sqrt{S_o}$	69.8	—	—
	Solution Heat Treated and Cold Worked	20	68	71.5	45.5	101 800	68.0 [a]	19.2	$4.52\sqrt{S_o}$	68.0	10.4 [c]	37.5 [c]
		—78	—108	76	48.5	108 400	70.4 [a]	22.9	$4.52\sqrt{S_o}$	69.8	11.0 [c]	40.0 [c]
		—197	—323	92.5	59	131 900	83.5 [a]	31.0	$4.52\sqrt{S_o}$	66.0	9.5 [c]	34.5 [c]
		—253	—423	108	68.5	153 800	83.7 [a]	31.4	$4.52\sqrt{S_o}$	60.0	—	—

(continued on opposite page)

5.2.1.2 Precipitation-Hardened Material

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress		Elongation		Reduction of Area	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	%	gauge length	%	kg m/cm²	ft lb
Sheet [5] **1 mm 0.040 in.**	Precipitation Hardened	24	75	112.5	71.5	**160 000**	**93.5** [a]	—	**4.5**	[g]	—	—	—
		—253	—423	153.5	97.5	**218 000**	**134** [a]	—	**9.8**	[g]	—	—	—
Strip [6] **1.5 mm 0.062 in.**	Precipitation Hardened	27	80	128.5	81.5	**183 000**	—	**75.9** [e]	**3.5**	[g]	—	—	—
		—73	—100	134.5	85.5	**191 000**	—	**74.9** [e]	**5.0**	[g]	—	—	—
	Precipitation Hardened after Cold Working 37%	27	80	133	84.5	**189 000**	—	**68.7** [e]	**3.0**	[g]	—	—	—
		—73	—100	136.5	86.5	**194 000**	—	**75.8** [e]	**3.2**	[g]	—	—	—
Rod [5] **13 mm diam. 0.50 in. diam.**	Precipitation Hardened	24	75	—	—	—	—	—	—	—	—	[d]	**5.5**
		—196	—320	—	—	—	—	—	—	—	—	[d]	**4.7**
		—253	—423	—	—	—	—	—	—	—	—	[d]	**5.0**
Rod [2] **14 mm diam. 0.560 in. diam.**	Precipitation Hardened	27	80	132	83.5	**187 600**	**102** [a]	—	**6**	1 in.	**7**	1.3 [b]	**4.8** [b]
		—59	—75	133	84.5	**189 000**	**113** [a]	—	**6.5**	1 in.	**10**	1.5 [b]	**5.3** [b]
		—129	—200	138	87.5	**196 000**	**115** [a]	—	**9.5**	1 in.	**13**	1.6 [b]	**5.8** [b]
		—184	—300	149	94.5	**212 000**	**120** [a]	—	**9.5**	1 in.	**14**	1.9 [b]	**6.8** [b]
	Precipitation Hardened after Cold Working	27	80	136	86.5	**193 500**	**119** [a]	—	**4**	1 in.	**12**	1.4 [b]	**5.0** [b]
		—59	—75	138	87.5	**196 000**	**126** [a]	—	**4.5**	1 in.	**13**	1.4 [b]	**5.0** [b]
		—129	—200	143.5	91	**204 000**	**136** [a]	—	**4.5**	1 in.	**14**	1·5 [b]	**5.5** [b]
		—184	—300	151.5	96	**215 500**	**139** [a]	—	**5.5**	1 in.	**10**	2.0 [b]	**7.3** [b]
Rod [4] **16 mm diam. 0.625 in. diam.**	Precipitation Hardened after Cold Working	20	68	141.5	90	**201 500**	**120** [a]	—	**3**	2 in.	**6**	0.34 [f]	**2** [f]
		—41	—42	151	96	**215 000**	**124** [a]	—	**2.5**	2 in.	**4**	0.69 [f]	**4** [f]
Rod [7] **19 mm diam. 0.75 in. diam.**	Precipitation Hardened [h]	26	78	128	81.5	**182 000**	**105** [a]	—	**9.0**	1 in.	**12.0**	—	—
		26	78	125	79.5	**178 000**	**104** [a]	—	**10.0**	1 in.	**12.0**	—	—
		—76	—104	129	82	**183 600**	**112** [a]	—	**9.0**	1 in.	**14.5**	—	—
		—76	—104	126	80	**179 200**	**110** [a]	—	**9.0**	1 in.	**15.0**	—	—
		—196	—320	146	93	**208 000**	**134** [a] [i]	—	**12.0**	1 in.	**20.0**	—	—
		—196	—320	140.5	89.5	**200 000**	**127** [a] [i]	—	**16.0**	1 in.	**24.5**	—	—

(a) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.

(b) Charpy Keyhole-notch specimen; cross-sectional area at the notch 0.5 cm².

(c) Charpy U-notch specimen; cross-sectional area at the notch 0.5 cm².

(d) Cross-sectional area of the specimen at the notch not reported in original document, therefore impossible to give conversions into kg m/cm².

(e) This value was originally reported in psi; in this table it is given in ton/in² to 3 significant figures.

(f) Izod standard specimen; cross-sectional area at the notch 0.8 cm².

(g) Gauge length not stated in original document.

(h) 8 hours at 850 °F (*454* °C) and air cooled.

(i) Quoted as "yield point" in original document, but offset strain not defined.

N.B.:—Original values are printed in **bold type**; other values are converted.

—All converted values for impact strength are to be taken as indicative only; the impact energy has been converted from ft lb into kg m/cm² taking into account the actual cross-sectional area of the specimen at the notch.

—Data not available: yield strength, 0.5% extension under load.

—Further data can be obtained from the following papers:

—Johnson, H. L. and Brooks, H. E. Impact Strength of Various Metals at Temperatures Down to 20° Absolute. Ohio State Univ., ASTIA Rept. No. AD67 (1952). (Includes Charpy impact tests from RT to —269°C on 2.05% Be alloy as square rolled rod).

—Brechna, H. Materials in Electromagnets and Their Properties. Proc. 2nd Internat. Conf. on Magnet Technology, Oxford, England (1967). Rutherford Lab. (1967), pp. 305-329 (Table 4 includes tensile data at 78 and 293 K for precipitation-hardened alloy containing 2% Be).

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% Offset kg/mm² [a]	Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi		
Strip [8] [9] 0.5 mm 0.02 in	Precipitation Hardened	20	68	130	82.5	**185 000**	**106**	**7**
		93	200	137	87	**195 000**	**109**	**8**
		149	300	126.5	80.5	**180 000**	**102**	**9**
		204	400	124.5	79	**177 000**	**98.4**	**7**
		260	500	121	77	**172 000**	**102**	**5**
		316	600	93.5	59.5	**133 000**	**86.5**	**6**
		371	700	69	43.5	**98 000**	**59.1**	**5**
		427	800	38.5	24.5	**55 000**	**29.5**	**15**
		482	900	23	14.5	**33 000**	**19.1**	**20**
		538	1 000	16	10.5	**23 000**	**12.1**	**43**
		621	1 150	7	4.5	**10 000**	**3.52**	**36**
	Precipitation Hardened after Cold Working 37%	20	68	147.5	93.5	**210 000**	**134**	**5**
		93	200	147.5	93.5	**210 000**	**132**	**4**
		149	300	144	91.5	**205 000**	**127**	**3**
		204	400	139	88.5	**198 000**	**123**	**2**
		260	500	131.5	83.5	**187 000**	**108**	**3**
		316	600	104	66	**148 000**	**92.1**	**5**
		371	700	67.5	43	**96 000**	**54.8**	**7**
		427	800	33.5	21.5	**48 000**	**25.3**	**13**
		482	900	17.5	11	**25 000**	**13.4**	**32**
		538	1 000	10	6	**14 000**	**5.62**	**60**
		621	1 150	6.5	4	**9 000**	**3.52**	**100**

(a) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.

N.B.:—Original values are printed in **bold type**; other values are converted.
—Data on short-time tensile properties at elevated temperatures are available only for precipitation-hardened material.
—Data not available:
Proof Stress, 0.1% offset; yield strength, 0.5% extension under load.
—Further data can be obtained from the paper in which the above results were originally reported, namely:
■Wikle K. G. and Sarle, N. P. Properties of Hardened Copper-Beryllium Strip After Exposures to Elevated Temperatures. Proc. ASTM, Vol. 61 (1961), pp. 988-1007. (provides elevated-temperature tensile data as three-dimensional property-time-temperature plots for exposure and testing temperatures up to 1 150 °F and exposure times up to 120 h).

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension % [a]	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Wire [10] 0.9 mm diam. 0.035 in. diam.	Precipitation Hardened after Cold Drawing 50%	40	104	116.0	73.7	**165 000** [b]	**531.4**	**0.945**	**0.060 8**	**0.007 92**
				123.0	78.1	**175 000** [b]	**213**	**0.887**	**0.050 2**	**0.008 33**
				130.1	82.6	**185 000** [b]	**265**	**1.125**	**0.131 1**	**0.026 25**
		90	194	56.2	35.7	**80 000** [c]	**504**	**0.386 6**	**0.002 94**	**0.002 5**
				116.0	73.7	**165 000** [b]	**504.5**	**0.852**	**0.013 6**	**0.022 9**
				130.1	82.6	**185 000** [b]	**504.5**	**1.026**	**0.058 37**	**0.018 3**

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate x Duration).
(b) Material which has an average grain size of 0.040 mm as solution heat treated.
(c) Material which has an average grain size of 0.005 mm as solution heat treated.

N.B.:—Original values are printed in **bold type**; other values are converted.
—Data on creep properties are available only for precipitation-hardened material.
—Further data can be obtained from the following paper:
■Bonfield, W. The Temperature Dependence of Microyielding in Polycrystalline Cu 1.9 Wt pct Be. Trans. Met. Soc. AIME, Vol. 242 (1968), pp. 2163-2167 (includes stress/plastic strain curves for solution-heat-treated alloy at —58, —18, and 30°C, and for precipitation-hardened alloy from —58 to 202°C).

5.3.2.2 Stress for Rupture

Form	Temper	Testing Temperature		Stress for Rupture in Time Indicated					
				10 h			100 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
— [8] [a]	Precipitation Hardened	149	300	123.0	78.1	**175 000**	112.5	71.4	**160 000**
		204	400	85.1	54.0	**121 000**	66.8	42.4	**95 000**
		260	500	59.8	37.9	**85 000**	49.2	31.2	**70 000**
		316	600	43.6	27.7	**62 000**	35.2	22.3	**50 000**
		371	700	31.6	20.1	**45 000**	—	—	—
		427	800	25.3	16.1	**36 000**	12.7	8.0	**18 000**

(a) Form not stated in original document.

N.B.:—Original values are printed in **bold type**; other values are converted.
—Data on stress-rupture properties are available only for precipitation-hardened material.
—Data not available:
Stress for rupture in 1 000 h.
—Further data can be obtained from the following paper:
■Sergeant, R. M. Cavity Formation in Copper Alloys. J Inst. Metals, Vol. 96 (1968), pp. 197-201 (stress-rupture properties at 140°C (*284°F*) of precipitation-hardened alloy containing 2.0% Be).

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

5.4.1.1 Solution-Heat-Treated Material

Form	Temper	Number of Cycles × 10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Strip [11] 0.8 mm 0.032 in.	Solution Heat Treated	100	51	23 [a]	32.5	14.5 [a]	72 300	33 000 [a]
	Solution Heat Treated and Cold Worked 21%	100	60	24 [a]	38	15 [a]	85 100	34 000 [a]
	37%	100	80	25.5 [a]	50.5	16 [a]	113 600	36 000 [a]
Strip [12] 0.8 mm 0.032 in.	Solution Heat Treated and Cold Worked 11%	100	58.5	23.5 [a]	37	15 [a]	83 100	33 500 [a]
	21%	100	69	27 [a]	43.5	17 [a]	98 000	38 500 [a]
	37%	100	81	26.5 [a]	51.5	17 [a]	115 000	38 000 [a]
Strip [13] 1 mm 0.040 in.	Solution Heat Treated	1 000	48.5	22.5 [a]	31	14.5 [a]	69 000	32 000 [a]
	Solution Heat Treated and Cold Worked 21%	1 000	65.5	24.5 [a]	41.5	15.5 [a]	93 000	35 000 [a]
	37%	1 000	77.5	26 [a]	49	16.5 [a]	110 000	37 000 [a]

5.4.1.2 Precipitation-Hardened Material

Form	Temper	Number of Cycles × 10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Strip [11] 0.8 mm 0.032 in.	Precipitation Hardened [b]	100	106.5	24.5 [a]	67.5	15.5 [a]	151 300	34 500 [a]
	Precipitation Hardened [c]	100	101.5	28.5 [a]	64.5	18 [a]	144 300	40 400 [a]
	Precipitation Hardened after Cold Working 21% [d]	100	122.5	27.5 [a]	78	17.5 [a]	174 300	39 000 [a]
	21% [e]	100	127	31 [a]	80.5	19.5 [a]	180 400	44 000 [a]
	37% [d]	100	133	27.5 [a]	84.5	17.5 [a]	188 900	38 900 [a]
	37% [e]	100	102.5	36 [a]	65	23 [a]	145 500	51 000 [a]
Strip [12] 0.8 mm 0.032 in.	Precipitation [g] Hardened	100	133	25.5 [a]	84.5	16 [a]	189 100	36 000 [a]
	Precipitation Hardened [i] after Cold Working 11%	100	134.5	27 [a]	85.5	17 [a]	191 200	38 500 [a]
	21%	100	143.5	31 [a]	91	19.5 [a]	203 800	44 000 [a]
	37%	100	147.5	31.5 [a]	93.5	20 [a]	209 900	44 500 [a]
Strip [13] 1 mm 0.040 in.	Precipitation Hardened	1 000	123	24.5 [a]	78	15.5 [a]	175 000	35 000 [a]
	Precipitation Hardened after Cold Working 21%	1 000	137	27.5 [a]	87	17.5 [a]	195 000	39 000 [a]
	37%	1 000	140.5	29.5 [a]	89.5	18.5 [a]	200 000	42 000 [a]
Rod [14] 13 mm diam. 0.5 in. diam.	Precipitation Hardened	6 000	81	29.5 [m]	51.5	18.5 [m]	115 000	42 000 [m]
Rod [15] 16 mm diam. 0.625 in. diam.	Precipitation Hardened [g]	100	123	24 [f]	78	15 [f]	175 300	34 000 [f]
Wire [16] [17]	Precipitation Hardened	100	125	25 [h]	79.5	16 [h]	178 000	35 500 [h]
	Precipitation Hardened after Cold Drawing	100	135	30 [h]	85.5	19 [h]	192 000	42 500 [h]
		100	135	10 [l]	85.5	6.5 [l]	192 000	14 000 [l]

(continued overleaf)

(a) Reversed-bending test,

(b) 3 h at 600 °F (*316 °C*) in purified nitrogen.

(c) 3 h at 600 °F (*316 °C*) in muffle furnace. Fatigue specimens were polished with No. 400 Aloxite paper prior to test.

(d) 2 h at 600 °F (*316 °C*) in purified nitrogen.

(e) 2 h at 600 °F (*316 °C*) in muffle furnace Fatigue specimens were polished with No. 400 Aloxite paper prior to test.

(f) Rotating-beam test.

(g) 3 h at 600 °F (*316 °C*).

(h) Bending fatigue test.

(i) 2 h at 600 °F (*316 °C*).

(l) Rotating cantilever test.

(m) Alternating torsion fatigue.

N.B.:—Original values are printed in **bold type**; other values are converted.

—Further data can be obtained from the following papers:

■Bornemann, A. and Gela, T. Studies in the Behavior of Certain Non-Ferrous Metals at Low Temperatures. Pierce Memorial Laboratory for Metallurgy, Stevens Institute of Technology, Vol. I (1953). pp. 95-109 (tests on 0.062 in. sheet in precipitation-hardened condition; also precipitation-hardened after 37% cold work).

■Weisman, M. H., Melill, J. and Matsuda, T. Uni-Directional Axial-Tension Fatigue Tests of Beryllium Copper and Several Precipitation-Hardening Corrosion-Resistant Steels. ASTM Spec. Tech. Pub. No. 196 (1957), pp. 123-142 (tests on precipitation-hardened 0.5 in. plate and on 1.125 in. rod precipitation hardened after cold working).

■Favor, R. J. et al. Investigation of Fatigue Behavior of Certain Alloys in the Temperature Range Room Temperature to —423°F. WADD Tech. Rept. 61-132 (1961). 116 pp. (tests on 0.02 in. sheet in precipitation-hardened condition).

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(3) Warren, K. A. and Reed, R. P. Tensile and Impact Properties of Selected Materials from 20 to 300 °K US Dept. Commerce, Nat. Bureau of Standards Monograph 63 (1963).

(4) Gillett, H. W. Impact Resistance and Tensile Properties of Metals at Sub-Atmospheric Temperatures. ASTM-ASME Joint Research Committee on Effect of Temperature on the Properties of Metals. Project No. 13 (1941).

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(6) Studies on the Behavior of Certain Non-Ferrous Metals at Low Temperatures. Stevens Institute of Technology, Rept. to Signal Corps. Engng. Labs., Fort Monmouth, N.J. Third Quarterly Rept. (1952).

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(11) *Gohn, G. R. and Arnold, S. M. The Fatigue Properties of Beryllium-Copper Strip and Their Relation to Other Physical Properties. Proc. ASTM, Vol. 46,* (1946), pp. 741-782.

(12) Gohn, G. R., Herbert, G. J. and Kuhn, J. B. The Mechanical Properties of Copper-Beryllium Alloy Strip. ASTM Spec. Tech. Publ. No. 367 (1964), 114 pp.

(13) Bulow, C. L. Which Alloy and Which Temper for Current-Carrying Springs. Prod. Engng., Vol. 34 (1963), No. 1, pp. 60-67.

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