WROUGHT MATERIALS

COPPER-ZINC-LEAD ALLOYS
Leaded Brasses

Cu Zn40 Pb3

Common names: Free-Machining Brass
Architectural "Bronze"

A copper-zinc-lead alloy with a duplex alpha-plus-beta phase structure containing a dispersion of fine lead particles. This alloy is the standard European-type free-cutting brass, generally supplied as rod. It is widely used where extensive machining is required, especially on automatic machines. The alloy is used for architectural purposes in North America.

COMPOSITION (weight %)

Cu	56.0–59.0
Pb	2.0– 3.5
Zn	rem.

1 SOME TYPICAL USES

Mechanical

Wide variety of machined components usually made on automatic high-speed lathes, including nuts, bolts, screws, bushings, bearings, pins, washers, and tubular products with open or closed ends; hollow extrusions; butts and hinges; lock bodies.

Architectural

Extruded sections; shop and store fronts; door treads; window frames; trim.

Electrical

Plug pins; switch terminals.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.5 g/cm³	0.305 lb/in³
2.2 Melting range	875–890 °C	1 605–1 635 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 300 °C *68 to 572 °F*	0.000 021 per °C	0.000 012 per °F
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.29 cal cm/cm² s °C	70 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	16 m/ohm mm²	28% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.062 ohm mm²/m 6.2 microhm cm	37 ohms (circ mil/ft) 2.4 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed)	0.001 7 per °C (28% IACS)	0.000 9 per °F (28% IACS)
applicable over range from 0 to 100 °C *32 to 212 °F*		
2.9 Modulus of elasticity (tension) at 20 °C *68 °F* (annealed or cold worked)	9 750 kg/mm²	13 900 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20° °C *68 °F* (annealed or cold worked)	3 600 kg/mm²	5 100 000 lb/in²

N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition range involved, are based on selected literature references.

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 8): 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.

		Metric Units	English Units
3.1	Casting temperature range	1 000–1 050 °C	1 830–1 920 °F
3.2	Annealing temperature range	450– 600 °C	840–1 110 °F
	Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3	Hot working temperature range	625– 725 °C	1 155–1 335 °F
3.4	Hot formability	Good	
3.5	Cold formability	Limited	
3.6	Cold reduction between anneals	20% max.	
3.7	Machinability:	See General Data Sheet No. 2	
	Machinability rating (free-cutting brass = 100)	100	
3.8	Joining methods	See General Data Sheet No. 3.5	
	Soldering	Excellent	
	Brazing	Good	
	Oxy-acetylene welding	Not recommended	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Not recommended	
	Coated metal-arc welding	Not recommended	
	Resistance welding: spot and seam	Not recommended	
	butt	Fair	

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 British and American practices, see tables 5.1.2 and 5.1.3 respectively.

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.

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		
Rod	Annealed	42	20	32	$5.65\sqrt{S_o}$	95	100	32	—
Rod	Typical Cold Worked Tempers	47	38	15	$5.65\sqrt{S_o}$	120	125	35	6–40 mm diam. or equivalent area
		55	50	8	$5.65\sqrt{S_o}$	145	155	39	6–12 mm diam. or equivalent area
Wire	Annealed	44	—	25	100 mm	—	—	33	1.5–6 mm. diam.
Wire	Typical Cold Drawn Tempers	53	—	8	100 mm	—	—	38	3–6 mm diam.
		65	—	—	—	—	—	42	0.5–3 mm diam.
Sections / Shapes	Annealed [c]	42	20	32	$5.65\sqrt{S_o}$	95	100	32	—
Sections / Shapes	Typical Cold Worked Temper [c]	46	38	15	$5.65\sqrt{S_o}$	120	125	34	—

(a) It will be noted that tables 5.1.1, 5.1.2 and 5.1.3 giving typical tensile properties and hardness values in Metric, English 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.

5.1.3 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 British and other European countries' practices, see tables 5.1.2 and 5.1.1, respectively.

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.

Form	Temper	Tensile Strength psi	Yield Strength 0.5% extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [(a)]
				%	gauge length	F	B	30 T		
Rod	As Extruded	60 000	20 000	30	2 in.	—	65	—	35 000	1.0 in. diam.
	Cold Worked Quarter Hard	70 000	42 000	18	2 in.	—	75	—	40 000	1.0 in. diam.
Shapes	As Extruded	60 000	20 000	30	2 in.	—	65	—	35 000	1.0 in. thick

(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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.5% offset ton/in²	Elongation		Reduction of Area %
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length	
Rod [(1) (a)] 9.5–12.7 mm diam. 0.375–0.5 in. diam.	Annealed	20	68	43.5	**27.7**	62 000	**11.8**	**33**	0.75 in.	**47**
		– 78	–108	47	**30.0**	67 000	**13.8**	**34**	0.75 in.	**51**
		–196	–321	58.5	**37.2**	83 500	**17.7**	**40**	0.75 in.	**45**
— [(2) (b)]	Cold Worked [(c)]	20	68	**57**	36	81 000	—	**27**	$5.65\sqrt{S_o}$	—
		– 30	– 22	**58**	37	82 500	—	**27**	$5.65\sqrt{S_o}$	—
		– 80	–112	**61**	38.5	87 000	—	**27**	$5.65\sqrt{S_o}$	—
		–120	–184	**64**	40.5	91 000	—	**26**	$5.65\sqrt{S_o}$	—
		–195	–319	**75**	47.5	106 500	—	**26**	$5.65\sqrt{S_o}$	—

(a) Alloy containing Cu 57.6%, Pb 3.0%, Sn 0.55%, Zn 38.6%.

(b) Not stated in original document.

(c) Quoted as "Hard" in original document, but amount of cold work not defined.

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

—Data not available:
Proof Stress, 0.1% and 0.2% offset,
Yield Strength, 0.5% ext. under load,
Impact Strength.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature °C	Testing Temperature °F	Tensile Strength kg/mm²	Tensile Strength ton/in²	Tensile Strength psi	Yield Strength psi	Elongation % on 2 in.
Rod [3] 20 mm diam. 0.8 in. diam.	Extruded	21	70	48.5	31	**69 200**	**54 800** [a]	**22.5**
		232	450	37.5	24	**53 550**	**30 700** [a]	**29.5**
		288	550	32	20	**45 250**	**21 500** [a]	**27.5**
		316	600	27.5	17.5	**38 850**	**15 500** [a]	**24.0**
		343	650	24	15	**33 900**	**13 000** [a]	**23.0**
		427	800	10.5	7	**15 200**	**6 000** [a]	**31.0**
		482	900	7.5	5	**11 000**	**3 200** [a]	**33.5**
Rod [3] 19 mm diam. 0.75 in. diam.	Annealed	21	70	38.5	24.5	**55 000**	**17 500** [a]	**36.5**
		149	300	33.5	21	**47 300**	**20 000** [a]	**41.0**
		232	450	28	18	**40 100**	**18 500** [a]	**31.0**
		288	550	23	14.5	**32 800**	**16 000** [a]	**22.0**
		427	800	8.5	5.5	**12 000**	**3 500** [a]	**17.0**

(a) Quoted as yield point, but offset strain not defined.

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

—Data not available:
Proof stress, 0.1% and 0.2% offset.

5.3.2 Creep Properties

Form	Temper	Testing Temperature °C	Testing Temperature °F	Stress kg/mm²	Stress ton/in²	Stress psi	Duration h	Total Creep % [a]	Intercept %	Min. Creep Rate % per 1 000 h
Rod [4] 18 mm diam. 0.708 in. diam.	Hot Worked [b]	204	400	0.79	**0.5**	1 100	**10 000**	**0.052**	—	**0.002**
				1.6	**1**	2 200	**10 000**	**0.230**	—	**0.02**
				3.1	**2**	4 500	**10 000**	**0.950**	—	**0.08**
				6.3	**4**	9 000	**500**	**0.564**	—	—
				9.4	**6**	13 400	**500**	**5.42**	—	—
	Hot Worked [c]	204	400	0.79	**0.5**	1 100	**10 000**	**0.024**	—	**0.001**
				1.6	**1**	2 200	**10 000**	**0.85** [d]	—	**0.003**
				3.1	**2**	4 500	**10 000**	**0.530**	—	**0.04**
				6.3	**4**	9 000	**500**	**0.492**	—	—
				9.4	**6**	13 400	**144**	**0.558**	—	—
Rod [3] 19 mm diam. 0.75 in. diam.	Annealed	149	300	7.0	4.5	**10 000**	**250**	**0.023**	**0.023**	**0** [e]
		177	350	2.1	1.3	**3 000**	**250**	**0.033**	**0.033**	**0** [e]
				7.0	4.5	**10 000**	**250**	**0.096**	**0.022**	**0.30** [e]
		204	400	2.1	1.3	**3 000**	**250**	**0.022**	**0.013**	**0.036** [e]
				7.0	4.5	**10 000**	**250**	**0.440**	**0**	**1.76** [e]
		232	450	2.1	1.3	**3 000**	**250**	**0.128**	**0.043**	**0.346** [e]
		260	500	2.1	1.3	**3 000**	**250**	**0.412**	**0.085**	**1.29** [e]
		288	550	0.70	0.45	**1 000**	**750**	**1.585**	**0.150**	**1.93** [e]

(a) Total creep; does not include the initial elastic extension.

(b) Hot-stamped at 680–700 °C (*1 255–1 290 °F*).

(c) Hot-stamped at 790–820 °C (*1 455–1 510 °F*).

(d) Extrapolated value.

(e) Creep rate at end of test (tangent to creep curve).

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles × 10^6	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod (5) (a)	As Received	50	41	13.5–16 (b)	26	8.5–10.5 (b)	**58 000**	**19 000–23 000** (b)

(a) Alloy containing Cu 59.40%, Pb 3.43%, Zn rem. (i.e. just outside composition range of Cu Zn 40 Pb3).

(b) Rotating-beam test.

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

—Further data can be obtained from the following paper:

■ Martin, J.W. and Smith, G.C. A Preliminary Study of the Fatigue of Metals in Liquid Metal Environments. Metallurgia, Vol. 54 (1956), pp. 227–232, 238.

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