Cu Zn9 Pb2

Common name: Leaded Commercial "Bronze"

A copper–zinc–lead alloy with an alpha phase structure containing a dispersion of fine lead particles. It is generally supplied as extruded rod or sections. The alloy has good machining properties with relatively good electrical conductivity and is mainly used for electrical components requiring extensive machining operations.

COMPOSITION (weight %)

Cu	87.5–90.5
Pb	1.3–2.5
Zn	rem.

1 SOME TYPICAL USES

Electrical
Screws and threaded machine parts for electrical devices; male and female connectors for computer and other electrical circuits.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.8 g/cm³	0.320 lb/in³
2.2	Melting range	1 010–1 040 °C	1 850–1 905 °F
2.3	Coefficient of thermal expansion (linear) at: 20 to 100 °C *68 to 212 °F* 20 to 300 °C *68 to 572 °F*	 0.000 018 per °C 0.000 018 ,, ,,	 0.000 010 per °F 0.000 010 ,, ,,
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*	0.43 cal cm/cm² s °C	104 Btu ft/ft² h °F
2.6	Electrical conductivity (volume) at: 20 °C *68 °F* (annealed)	24 m/ohm mm²	42% IACS
2.7	Electrical resistivity (volume) at: 20 °C *68 °F* (annealed)	0.041 ohm mm²/m 4.1 microhm cm	25 ohms (circ mil/ft) 1.6 microhm in
2.8	Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 8 per °C (42% IACS)	0.001 0 per °F (42% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F* (annealed or cold worked)	11 900 kg/mm²	16 900 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F* (annealed or cold worked)	4 400 kg/mm²	6 300 000 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 6); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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DATA SHEET No. E 1
Cu Zn9 Pb2
1970 Edition

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	1 120–1 170 °C	2 050–2 140 °F
3.2 Annealing temperature range	425– 600 °C	795–1 110 °F
Stress relieving temperature range	200– 320 °C	390– 610 °F
3.3 Hot working temperature range	775– 850 °C	1 425–1 560 °F
3.4 Hot formability	Limited	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	75% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	80	
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 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.

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	27	7	45	$5.65\sqrt{S_o}$	55	58	20	—
Rod	Typical Cold Worked Tempers	33	24	28	$5.65\sqrt{S_o}$	85	89	23	6–40 mm diam. or equivalent area
Rod	Typical Cold Worked Tempers	40	35	12	$5.65\sqrt{S_o}$	105	110	26	6–12 mm diam. or equivalent area

(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.

5.1.2 Typical Tensile Properties and Hardness Values—English Units

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties.

At the date of publication of this sheet, no data relating to this material have been traced.

5.3.2 Creep Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod [1] [a] **12.7 mm diam. 0.5 in. diam.**	Cold Worked 30%	300	38.5	16.5 [b]	24.5	10.5 [b]	**54 900**	**23 500** [b]
Rod [2] **16 mm diam. 0.625 in. diam.**	Cold Worked 17%	100	31.5	14 [b]	20	9 [b]	**45 000**	**20 000** [b]

[a] Alloy containing Cu 85.16%, Zn 13.0%, Pb 1.82% (i.e. just outside composition range of Cu Zn9 Pb2).

[b] Rotating-beam test.

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

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Anderson, A.R., Swan, E.F. and Palmer, E.W. Fatigue Tests on Some Additional Copper Alloys. Proc. ASTM, Vol. 46 (1946), pp. 678–692.

(2) Burghoff, H.L. and Blank, A.I. Fatigue Characteristics of Some Copper Alloys. Proc. ASTM, Vol. 47 (1947), pp. 695–712.

Cu Zn34 Pb1

Common names: Clock Brass
Medium-Leaded Brass

A copper–zinc–lead alloy with an alpha phase structure containing a dispersion of fine lead particles; small amounts of retained beta phase may also be present. The alloy, which is readily cold formed and machined, has good punching and shearing properties.

COMPOSITION (weight %)

Cu	62.5–66.5
Pb	0.5– 1.5
Zn	rem.

1 SOME TYPICAL USES

Mechanical

Parts requiring good coldforming and machining properties; nuts, rivets, screws and other headed components; instrument parts and end plates; clock and watch components; key blanks.

Miscellaneous

Printers' matrices.

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	885–925 °C	1 625–1 695 °F
2.3	Coefficient of thermal expansion (linear) at:		
	20 to 100 °C *68 to 212 °F*	0.000 019 per °C	0.000 011 per °F
	20 to 300 °C *68 to 572 °F*	0.000 020 „ „	0.000 011 „ „
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*	0.28 cal cm/cm² s °C	68 Btu ft/ft² h °F
2.6	Electrical conductivity (volume) at: 20 °C *68 °F* (annealed)	15 m/ohm mm²	26% IACS
2.7	Electrical resistivity (volume) at: 20 °C *68 °F* (annealed)	0.066 ohm mm²/m 6.6 microhm cm	40 ohms (circ mil/ft) 2.6 microhm in
2.8	Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 5 per °C (26% IACS)	0.000 8 per °F (26% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F* (annealed or cold worked)	10 500 kg/mm²	14 900 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F* (annealed or cold worked)	3 900 kg/mm²	5 500 000 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 6); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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1970 Edition

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	1 000–1 030 °C	1 830–1 885 °F
3.2 Annealing temperature range	450– 650 °C	840–1 200 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	725– 800 °C	1 335–1 470 °F
3.4 Hot formability	Limited	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	65% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	70	
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		
Plate Sheet Strip	Annealed	33	12	45	$5.65\sqrt{S_o}$	65	68	25	—
	Typical Cold Worked Tempers	42	28	25	$5.65\sqrt{S_o}$	95	100	30	0.3–2 mm thick
		52	40	10	$5.65\sqrt{S_o}$	135	140	34	"
Rod	Annealed	33	12	45	$5.65\sqrt{S_o}$	65	68	25	—
	Typical Cold Worked Tempers	40	25	28	$5.65\sqrt{S_o}$	95	100	28	6–40 mm diam. or equivalent area
		48	38	15	$5.65\sqrt{S_o}$	120	125	32	6–12 mm diam. or equivalent area
		55	46	8	$5.65\sqrt{S_o}$	135	140	36	up to 6 mm diam. or equivalent area

(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.

5.1.2 Typical Tensile Properties and Hardness Values—English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 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[a]	Tensile Strength ton/in²	Proof Stress 0.1% offset ton/in²	Elongation		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown[b]
				%	gauge length			
Strip	Annealed	21	7	50	2 in.	70	16	—
	Cold Worked							
	Half Hard	25	18	25	2 in.	125	18	0.01–0.20 in. thick
	Hard	30	25	12	2 in.	150	20	0.01–0.125 in. thick
	Extra Hard	34	30	7	2 in.	170	21	"

(a) The recognised temper designations used in the relevant or nearest British Standards are also given, to clarify the cold-worked tempers shown.

(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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress ton/in²	Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Rod[1]	Annealed [a]	18	64	32.5	**20.6**	46 000	**6.9**[b]	**55**	—	**61**	4.7[c]	**27**[c]
		−30	− 22	32	**20.8**	46 500	**6.6**[b]	**65**	—	**69**	4.8[c]	**28**[c]
		−80	−112	35	**22.2**	49 500	**7.0**[b]	**66**	—	**64**	4.8[c]	**28**[c]

[a] Alloy containing Cu 63.8%, Pb 0.43%, Zn remainder (i.e. just outside composition range of Cu Zn34 Pb1).

[b] Quoted as yield point but offset strain not defined.

[c] Charpy test, V-notch; cross-sectional area at the notch 0.8 cm².

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:
Proof stress, 0.1% and 0.2% offset,
Yield strength, 0.5% extension under load.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.3.2 Creep Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

At the date of publication of this sheet, no data relating to this material have been traced.

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REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Teed, P.L. The Properties of Metallic Materials at Low Temperatures, Vol. I. Chapman and Hall, Ltd., London (1950), pp. 162–187.

Cu Zn36 Pb2

Common names: Clock Brass
Engraving Brass
High-Leaded Brass—Riveting Brass

A copper–zinc–lead alloy with a duplex alpha-plus-beta phase structure containing a dispersion of fine lead particles. The alloy, which is fairly readily cold formed and easily machined, is typically used in the production of headed components and for clock manufacture.

COMPOSITION (weight %)

Cu	61.0–64.0
Pb	1.0– 2.0
Zn	rem.

1 SOME TYPICAL USES

Mechanical

Parts requiring good machinability with limited cold forming; nuts, rivets, screws and other headed components; tyre valves and nipples; instrument parts and end plates; clock and watch components; key blanks.

Electrical

Sparking plug and battery terminals.

Miscellaneous

Dials and other mechanically engraved work; printers' matrices.

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	885–910 °C	1 625–1 670 °F
2.3 Coefficient of thermal expansion (linear) at: 20 to 100 °C *68 to 212 °F*	0.000 019 per °C	0.000 011 per °F
20 to 300 °C *68 to 572 °F*	0.000 020 „ „	0.000 011 „ „
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*	0.28 cal cm/cm² s °C	68 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed)	15 m/ohm mm²	26% IACS
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed)	0.066 ohm mm²/m 6.6 microhm cm	40 ohms (circ mil/ft) 2.6 microhm in
2.8 Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 5 per °C (26% IACS)	0.000 8 per °F (26% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F* (annealed or cold worked)	10 200 kg/mm²	14 500 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F* (annealed or cold worked)	3 800 kg/mm²	5 400 000 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.

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Cu Zn36 Pb2

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	1 020–1 070 °C	1 870–1 960 °F
3.2 Annealing temperature range	450– 650 °C	840–1 200 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	700– 800 °C	1 290–1 470 °F
3.4 Hot formability	Fair	
3.5 Cold formability	Fair	
3.6 Cold reduction between anneals	50% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	75	
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		
Plate Sheet Strip	Annealed	34	15	45	$5.65\sqrt{S_o}$	70	74	26	—
	Typical Cold Worked Tempers	42	30	28	$5.65\sqrt{S_o}$	105	110	30	1–10 mm thick
		50	45	10	$5.65\sqrt{S_o}$	125	130	35	1–4 mm thick
Rod	Annealed	34	15	45	$5.65\sqrt{S_o}$	70	74	26	—
	Hot Worked	36	20	35	$5.65\sqrt{S_o}$	75	79	27	10–60 mm diam. or equivalent area
	Typical Cold Worked Tempers	40	30	30	$5.65\sqrt{S_o}$	100	105	28	6–40 mm diam. or equivalent area
		50	46	12	$5.65\sqrt{S_o}$	125	130	35	6–12 mm diam. or equivalent area
Wire	Annealed	38	—	35	100 mm	—	—	29	1.5–6 mm diam.
	Typical Cold Drawn Tempers	48	—	15	100 mm	—	—	34	1.5–6 mm diam.
		70	—	2	100 mm	—	—	40	0.5–1.5 mm diam.
Tube	Annealed	34	15	45	$5.65\sqrt{S_o}$	70	74	26	—
	Typical Cold Drawn Tempers	40	27	30	$5.65\sqrt{S_o}$	100	105	28	over 3 mm wall
		48	40	12	$5.65\sqrt{S_o}$	125	130	34	up to 3 mm wall

(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.

5.1.2 Typical Tensile Properties and Hardness Values—English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 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[a]	Tensile Strength ton/in²	Proof Stress 0.1% offset ton/in²	Elongation %	Elongation gauge length	Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown[b]
Strip	Annealed	22	8	50	2 in.	75	17	—
	Cold Worked							
	Half Hard	26	18	25	2 in.	125	18	0.01–0.20 in. thick
	Hard	31	25	12	2 in.	155	20	0.01–0.125 in. thick
	Extra Hard	35	30	7	2 in.	175	22	"
Rod	Annealed	22	7	45	$5.65\sqrt{S_o}$	80	17	—
	Cold Worked							
	As-Manufactured	24	10	40	$5.65\sqrt{S_o}$	100	17	1-2 in. diam. or equivalent area
		26	14	35	$5.65\sqrt{S_o}$	120	18	0.375-1 in. diam. or equiv. area
		28	18	25	$5.65\sqrt{S_o}$	140	20	0.125-0.375 in. diam. or equiv. area
Wire	Annealed	22	—	50	2 in.	—	17	0.06–0.25 in. diam.
	Cold Drawn							
	Half Hard	26	—	25	2 in.	—	18	0.125–0.25 in. diam.
	Hard	32	—	—	—	—	21	"
	Half Hard	27	—	20	2 in.	—	19	0.06–0.125 in. diam.
	Hard	33	—	—	—	—	21	"
Tube[c]	Annealed	22	—	—	—	80	17	—
	Cold Drawn or Temper Annealed							
	Temper Annealed	26	—	—	—	120	18	1–2.5 in. O.D., 0.12–0.25 in. wall
	As-Drawn	27	—	—	—	140	19	"
	Temper Annealed	29	—	—	—	125	20	0.3–1 in. O.D., 0.04–0.12 in. wall
	As-Drawn	30	—	—	—	150	20	"

[a] The recognised temper designations used in the relevant or nearest British Standards are also given, to clarify the cold-worked tempers shown.

[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] Intermediate tempers may be obtained by temper annealing. Drawn tubes are usually stress relieved after the final draw.

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 %	Elongation gauge length	Rockwell Hardness F	Rockwell Hardness B	Rockwell Hardness 30 T	Shear Strength psi	Typical Size Related to Properties Shown[a]
First Products (Sheet, Strip and Bar)	Annealed (grain size 0.035 mm)	49 000	17 000	50	2 in.	68	—	31	30 000	0.040 in. thick
	Cold Worked									
	Quarter Hard	54 000	40 000	35	2 in.	—	55	54	39 000	0.040 in. thick
	Half Hard	61 000	50 000	20	2 in.	—	70	65	43 000	"
	Hard	74 000	60 000	7	2 in.	—	80	69	48 000	"
Rod	Annealed	48 000	17 000	53	2 in.	66	—	—	30 000	1.0 in. diam.
	Cold Worked Half Hard (20%)	58 000	45 000	25	2 in.	—	75	—	34 000	1.0 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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.3.2 Creep Properties

At the date of publication of this sheet, no data relating to this material have been traced.

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
Strip[1][a] 0.8 mm 0.032 in.	Annealed (grain size 0.035 mm)	100	34.5	10.5[b]	22	6.5[b]	**49 000**	**15 000**[b]
	Cold Worked 21%	100	45.5	11[b]	29	7[b]	**64 500**	**16 000**[b]
	Cold Worked 37%	100	53	13.5[b]	33.5	8.5[b]	**75 500**	**19 000**[b]
Rod[2] 13.5 mm diam. 0.531 in. diam.	Annealed (grain size 0.035 mm)	100	34.5	10[c]	22	6[c]	**49 200**	**14 000**[c]
	Cold Worked 28%	100	49.5	19.5[c]	31.5	12.5[c]	**70 600**	**27 500**[c]

(a) Alloy containing Cu 64.09%, Pb 2.03%, Zn remainder (i.e. just outside composition range of Cu Zn36 Pb2).

(b) Reversed-bending test.

(c) Rotating-beam test.

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

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Burghoff, H.L. and Blank, A.I. Fatigue Properties of Some Coppers and Copper Alloys in Strip Form. Proc. ASTM, Vol. 48 (1948), pp.709–736.

(2) Burghoff, H.L. and Blank, A.I. Fatigue Characteristics of Some Copper Alloys. Proc. ASTM, Vol. 47 (1947), pp. 695–712.

Cu Zn36 Pb3

Common names: Free-Cutting Brass
American Free-Machining Brass
Extra-High-Leaded Brass

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 American-type free-cutting brass, generally supplied as rod. It is widely used where extensive machining is required, especially on automatic machines.

COMPOSITION (weight %)

Cu	60.0–63.0
Pb	2.5– 3.7
Zn	rem.

1 SOME TYPICAL USES

Mechanical

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

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	885 - 900 °C	1 625 - 1 650 °F
2.3 Coefficient of thermal expansion (linear) at:		
—170 °C *—275 °F*	0.000 013 per °C	0.000 007 per °F
— 70 °C *— 95 °F*	0.000 017 ,, ,,	0.000 009 ,, ,,
20 to 100 °C *68 to 212 °F*	0.000 019 ,, ,,	0.000 011 ,, ,,
20 to 300 °C *68 to 572 °F*	0.000 020 ,, ,,	0.000 011 ,, ,,
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*	0.28 cal cm/cm² s °C	68 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed)	15 m/ohm mm²	26% IACS
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed)	0.066 ohm mm²/m 6.6 microhm cm	40 ohms (circ mil/ft) 2.6 microhm in
2.8 Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 5 per °C (26% IACS)	0.000 8 per °F (26% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F* (annealed or cold worked)	10 100 kg/mm²	14 400 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F* (annealed or cold worked)	3 700 kg/mm²	5 300 000 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 6); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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DATA SHEET No. E 4
Cu Zn36 Pb3
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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	1 020–1 070 °C	1 870–1 960 °F
3.2 Annealing temperature range	450– 650 °C	840–1 200 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	700– 775 °C	1 290–1 425 °F
3.4 Hot formability	Fair	
3.5 Cold formability	Limited	
3.6 Cold reduction between anneals	35% 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	36	15	40	$5.65\sqrt{S_o}$	75	79	27	—
	Typical Cold Worked Tempers	44	30	25	$5.65\sqrt{S_o}$	105	110	31	6–40 mm diam. or equivalent area
		52	45	12	$5.65\sqrt{S_o}$	135	140	34	6–12 mm diam. or equivalent area
Sections / Shapes	Annealed[c]	36	15	40	$5.65\sqrt{S_o}$	75	79	27	—
	Typical Cold Worked Temper[c]	42	30	25	$5.65\sqrt{S_o}$	100	105	30	—

(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.

5.1.2 Typical Tensile Properties and Hardness Values—English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 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[a]	Tensile Strength ton/in²	Proof Stress 0.1% offset ton/in²	Elongation		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown[b]
				%	gauge length			
Rod	Annealed	22	8	40	$5.65\sqrt{S_o}$	80	17	—
	Cold Worked							
	Half Hard	23	10	35	$5.65\sqrt{S_o}$	90	17	1–2 in. diam. or equivalent area
		26	16	25	$5.65\sqrt{S_o}$	120	18	0.25–1 in. diam. or equivalent area
	Hard	32	22	10	$5.65\sqrt{S_o}$	160	21	0.2–0.3 in. diam. or equivalent area
		36	25	—	—	—	23	0.125–0.2 in. diam. or equivalent area
Sections (extruded)	Hot Worked[c]	23	10	35	$5.65\sqrt{S_o}$	90	17	—
	Cold Drawn As-Manufactured[c]	25	12	30	$5.65\sqrt{S_o}$	110	18	—

(a) The recognised temper designations used in the relevant or nearest British Standard are also given, to clarify the cold-worked tempers shown.

(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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Yield Strength psi	Elongation % on 2 in.	Reduction of Area %	Impact Strength (b)	
		°C	°F	kg/mm²	ton/in²	psi				kg m/cm²	ft lb
Rod (1)	Cold Rolled	20 –183	68 –310	25 30	16 19	**35 600** **42 800**	**24 400** (a) **32 100** (a)	**17.0** **13.0**	**22.2** **19.0**	— —	— —
Rod (2)	Annealed	27 – 23 – 73 –123 –173 –223 –253	81 – 9 – 99 –189 –279 –369 –423	— — — — — — —	— — — — — — —	— — — — — — —	— — — — — — —	— — — — — — —	— — — — — — —	3.9 4.0 4.4 4.7 4.8 4.7 3.8	**14** **14.5** **16** **17** **17.5** **17** **13.5**
	Cold Worked (c)	27 – 23 – 73 –123 –173 –223 –253	81 – 9 – 99 –189 –279 –369 –423	— — — — — — —	— — — — — — —	— — — — — — —	— — — — — — —	— — — — — — —	— — — — — — —	2.4 2.8 3.0 3.0 3.1 3.3 3.5	**8.5** **10** **11** **11** **11.5** **12** **13**

(a) Quoted as yield point, but offset strain not defined.
(b) Charpy test, keyhole notch; cross-sectional area at the notch 0.5 cm².
(c) Quoted as "Half Hard" in original document, but amount of cold work 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:
Proof stress, 0.1% and 0.2% offset.
Yield strength, 0.5% extension under load.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.3.2 Creep Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

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
Rod (3) 12.7 mm diam. 0.5 in. diam.	Cold Worked 21%	300	37	9.5 (a)	23.5	6 (a)	**52 800**	**13 500** (a)
Rod (4) 16 mm diam. 0.625 in. diam.	Cold Worked 20%	100	38.5	14 (a)	24.5	9 (a)	**55 000**	**20 000** (a)
Rod (5) 51 mm diam. 2 in. diam.	Cold Worked 18%	300	38.5	10 (a)	24.5	6.5 (a)	**55 000**	**14 000** (a)

(a) 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:
■ Shives, T.R. and Bennett, J.A. The Effect of Environment on the Fatigue Properties of Selected Engineering Alloys. J. Materials, Vol. 3 (1968), pp. 695-715.

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(1) Strauss, J. Metals and Alloys for Industrial Applications Requiring Extreme Stability. Trans. ASST, Vol. 16 (1929), pp. 191-226.
(2) McClintock, R.M., and Gibbons, H.P. Mechanical Properties of Structural Materials at Low Temperatures. NBS Monograph 13, June (1960).
(3) Anderson, A.R., Swan, E.F. and Palmer, E.W. Fatigue Tests on Some Additional Copper Alloys. Proc. ASTM, Vol. 46 (1946), pp. 678–692.
(4) Burghoff, H.L. and Blank, A.I. Fatigue Characteristics of Some Copper Alloys. Proc. ASTM, Vol. 47 (1947), pp. 695-712.
(5) Metals Handbook, Vol. 1, 8th ed. American Society for Metals, Cleveland, Ohio (1961).

Cu Zn38 Pb1

**Common names: Free-cutting Muntz Metal
Engraving Brass**

A copper–zinc–lead alloy with a duplex alpha-plus-beta phase structure containing a dispersion of fine lead particles. The alloy has good hot working and machining properties and is mainly supplied as tube for the manufacture of machined tubular parts.

COMPOSITION (weight %)

Cu	59.0 - 63.0
Pb	0.5 - 1.5
Zn	rem.

1 SOME TYPICAL USES

Mechanical

Numerous types of machined tubular components; sections requiring limited ductility. Swiss clock, watch and instrument parts are mainly produced from a similar alloy of higher lead content (up to 3%).

Miscellaneous

Eyelets; printers' rules; mechanical engraved work.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.4 g/cm^3	0.305 lb/in^3
2.2 Melting range	885–900 °C	1 625–1 650 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 020 per °C	0.000 011 per °F
20 to 300 °C *68 to 572 °F*	0.000 021 „ „	0.000 012 „ „
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/cm^2 s °C	70 Btu ft/ft^2 h °F
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	16 m/ohm mm^2	27% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.064 ohm mm^2/m 6.4 microhm cm	38 ohms (circ mil/ft) 2.5 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed)	0.001 6 per °C (27% IACS)	0.000 9 per °F (27% 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)	9 900 kg/mm^2	14 100 000 lb/in^2
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F* (annealed or cold worked)	3 700 kg/mm^2	5 300 000 lb/in^2

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	1 010 –1 050 °C	1 850 –1 920 °F
3.2 Annealing temperature range	450 – 650 °C	840 –1 200 °F
Stress relieving temperature range	250 – 350 °C	480 – 660 °F
3.3 Hot working temperature range	700 – 800 °C	1 290 –1 470 °F
3.4 Hot formability	Good	
3.5 Cold formability	Fair	
3.6 Cold reduction between anneals	25% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	70	
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		
Plate[c] Sheet Strip	Annealed	38	18	40	$5.65\sqrt{S_o}$	80	84	29	—
	Typical Cold Worked Tempers	47	38	15	$5.65\sqrt{S_o}$	120	125	33	0.3–2 mm thick
		58	52	8	$5.65\sqrt{S_o}$	150	160	41	"
Rod	Annealed	38	18	40	$5.65\sqrt{S_o}$	75	79	29	—
	Typical Cold Worked Tempers	45	33	28	$5.65\sqrt{S_o}$	110	115	32	6–40 mm diam. or equivalent area
		52	44	12	$5.65\sqrt{S_o}$	135	140	35	6–12 mm diam. or equivalent area
Wire	Annealed	40	—	25	100 mm	—	—	30	1.5–6 mm diam.
	Typical Cold Drawn Temper	50	—	12	100 mm	—	—	34	over 1.5 mm diam.
Tube	Annealed	39	18	40	$5.65\sqrt{S_o}$	75	79	29	—
	Typical Cold Drawn Tempers	42	30	30	$5.65\sqrt{S_o}$	105	110	31	over 3 mm wall
		50	42	15	$5.65\sqrt{S_o}$	130	135	34	up to 3 mm wall

(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) These forms can be obtained in Cu Zn38 Pb1 alloy although they are generally produced in a similar alloy of higher lead content (up to 3%).

5.1.2 Typical Tensile Properties and Hardness Values—English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 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[a]	Tensile Strength ton/in²	Proof Stress 0.1% offset ton/in²	Elongation %	Elongation gauge length	Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown[b]
Sheet Strip	Annealed	23	9	45	2 in.	90	17	—
Sheet Strip	Cold Worked Half Hard	30	20	25	2 in.	140	21	0.02–0.20 in. thick
Sheet Strip	Cold Worked Hard	34	25	15	2 in.	160	22	0.02–0.125 in. thick
Rod	Annealed	23	8	40	$5.65\sqrt{S_o}$	90	17	—
Rod	Hot Worked	24	9	35	$5.65\sqrt{S_o}$	100	18	0.5–2 in. diam. or equivalent area
Rod	Cold Worked As-Manufactured	25	10	35	$5.65\sqrt{S_o}$	110	18	1–2 in. diam. or equivalent area
Rod	Cold Worked As-Manufactured	27	14	30	$5.65\sqrt{S_o}$	125	19	0.375–1 in. diam. or equivalent area
Rod	Cold Worked As-Manufactured	30	18	20	$5.65\sqrt{S_o}$	140	20	0.125–0.375 in. diam. or equivalent area
Sections (extruded)	Hot Worked[c]	24	9	35	$5.65\sqrt{S_o}$	100	18	—
Sections (extruded)	Cold Drawn As-Manufactured[c]	26	12	30	$5.65\sqrt{S_o}$	120	18	—

(a) The recognised temper designations used in the relevant or nearest British Standards are also given, to clarify the cold-worked tempers shown.

(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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength (a)			Elongation % on $11.3\sqrt{S_o}$	Reduction of Area %	Impact Strength (b)	
		°C	°F	kg/mm²	ton/in²	psi			kg m/cm²	ft lb
Rod(1)	Annealed	20	68	**37.1**	23.5	53 000	**50.2**	**62.5**	**4.40**	15.9
		− 78	−108	**38.4**	24.5	54 500	**49.8**	**64.0**	**4.91**	17.8
		−183	−297	**48.5**	31	69 000	**50.6**	**62.1**	**4.61**	16.7
	Cold Worked 12%	20	68	**44.8**	28.5	63 500	**28.2**	**57.0**	**2.23**	8.1
		− 78	−108	**49.5**	31.5	70 500	**27.0**	**59.0**	**2.48**	9.0
		−183	−297	**60.8**	38.5	86 500	**30.8**	**57.0**	**2.19**	7.9

(a) 5 mm (0.2 in.) diam. test specimen.

(b) Charpy test, 10 × 8 × 100 mm specimen, 45° V-notch, 3 mm deep; cross sectional area at the notch 0.5 cm².

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 kg m/cm² into ft lb taking into account the actual cross-sectional area of the specimen at the notch.

—Data not available:
Proof stress 0.1% and 0.2% offset,
Yield strength 0.5% extension under load.

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	Elongation	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length
Rod(2)(a) 16 mm diam. 0.625 in. diam.	—(b)	17	63	42.5	27	**60 700**	—	**41**	2 in.
		150	302	36.5	23.5	**52 200**	**21.4**(c)	**55**	2 in.
		250	482	28	18	**39 900**	**18.3**(c)	**21.5**	2 in.
		350	662	14	9	**20 160**	**6.94**(c)	**42**	2 in.
		500	932	4	2.5	**5 380**	**1.89**(c)	**30**	2 in.
Rod(1)	Annealed	20	68	**37.1**	23.5	53 000	—	**50.2**	$11.3\sqrt{S_o}$
		53	127	**36.2**	23	51 500	—	**49.1**	$11.3\sqrt{S_o}$
		109	228	**36.1**	23	51 500	—	**46.2**	$11.3\sqrt{S_o}$
		150	302	**33.6**	21.5	48 000	—	**45.5**	$11.3\sqrt{S_o}$
		200	392	**31.7**	20	45 000	—	**42.2**	$11.3\sqrt{S_o}$
		248	478	**30.0**	19	42 500	—	**37.4**	$11.3\sqrt{S_o}$
		301	574	**26.9**	17	38 500	—	**28.1**	$11.3\sqrt{S_o}$
		354	669	**22.9**	14.5	32 500	—	**17.5**	$11.3\sqrt{S_o}$
		400	752	**16.6**	10.5	23 500	—	**25.4**	$11.3\sqrt{S_o}$
		450	842	**11.5**	7.5	16 500	—	**24.8**	$11.3\sqrt{S_o}$
		496	925	**5.9**	3.5	8 500	—	**21.8**	$11.3\sqrt{S_o}$
		555	1 031	**4.1**	2.5	6 000	—	**22.6**	$11.3\sqrt{S_o}$
		610	1 130	**3.1**	2	4 500	—	**22.5**	$11.3\sqrt{S_o}$
		650	1 202	**1.5**	1	2 000	—	**24.0**	$11.3\sqrt{S_o}$
		700	1 292	**1.1**	0.7	1 500	—	**26.7**	$11.3\sqrt{S_o}$
	Cold Worked 12%	22	72	**44.8**	28.5	63 500	—	**28.2**	$11.3\sqrt{S_o}$
		51	124	**44.8**	28.5	63 500	—	**27.1**	$11.3\sqrt{S_o}$
		116	241	**43.9**	28	62 500	—	**24.5**	$11.3\sqrt{S_o}$
		150	302	**41.8**	26.5	59 500	—	**22.0**	$11.3\sqrt{S_o}$
		200	392	**39.2**	25	56 000	—	**17.6**	$11.3\sqrt{S_o}$
		250	482	**36.1**	23	51 500	—	**8.5**	$11.3\sqrt{S_o}$
		301	574	**30.4**	19.5	43 000	—	**5.2**	$11.3\sqrt{S_o}$
		354	669	**22.8**	14.5	32 500	—	**5.3**	$11.3\sqrt{S_o}$
		416	781	**16.1**	10	23 000	—	**10.9**	$11.3\sqrt{S_o}$
		450	842	**10.9**	7	15 500	—	**21.7**	$11.3\sqrt{S_o}$
		504	939	**4.8**	3	7 000	—	**22.1**	$11.3\sqrt{S_o}$

(a) Alloy containing 0.34% Sn.

(b) Not stated in original document.

(c) 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 not available:
Proof stress, 0.1% offset,
Yield strength, 0.5% extension under load.
Impact strength

5.3.2 Creep Properties

Form	Temper	Testing Temperature		Stress			Duration h	Total Creep % [a]	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod[2] [b] 16 mm diam. 0.625 in. diam.	— [c]	150	302	15.7 18.9	10.0 12.0	**22 400** **26 880**	**1 000** **500**	**0.239** **0.56**	**0.082** **0.22**	**0.16** [d] **0.68** [d]
		250	482	1.6 3.1	1.0 2.0	**2 240** **4 480**	**250** **150**	**0.082** **0.32**	**0.018** **0.06**	**0.26** [d] [e] **1.7** [d] [e]
		350	662	0.20 0.34	0.13 0.22	**291** **483**	**500** **500**	**0.50** **3.2**	**0** **0**	**0.76** [d] **6.1** [d]

(a) Total creep; does not include the initial elastic extension.
(b) Alloy containing 0.34% Sn.
(c) Not stated in original document.
(d) Creep rate at end of test (tangent to creep curve).
(e) Increasing at end of test.
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 ×10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod [3]	As Received	50	41.5	16 [a]	26.5	10.5 [a]	**59 000**	**23 000** [a]

(a) Rotating-beam test.
N.B.: Original values are printed in **bold type**; other values are converted.

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Broniewski, W. and Wesolowski, K. L'influence de la température sur les propriétés mécaniques des laitons—Part 2. Rev. Mét., Vol. 30 (1933), pp. 453–457.
(2) Compilation of Available High-Temperature Creep Characteristics of Metals and Alloys. ASTM-ASME (1938).
(3) Wilkins, R.A. and Bunn, E.S. Copper and Copper-Base Alloys—The Physical and Mechanical Properties of Copper and its Commercial Alloys in Wrought Form. McGraw-Hill Book Company, New York (1943).

Printed in England by the Martin Cadbury Printing Group

Cu Zn40 Pb

Common names: 60/40 Brass (Leaded)
Leaded Muntz Metal

A copper–zinc–lead alloy with a duplex alpha-plus-beta phase structure containing a dispersion of fine lead particles. The alloy has excellent hot-working properties and is generally supplied as hot-rolled plate. The material has somewhat inferior cold-working and joining properties, but is more readily machined than the similar non-leaded alloy, Cu Zn40.

COMPOSITION (weight %)

Cu	59.0–62.0
Pb	0.3– 0.8
Zn	rem.

1 SOME TYPICAL USES

Chemical and Marine

Condenser and heat-exchanger tubeplates; porthole windows and surrounds.

Mechanical and Miscellaneous

Hot forged components and 'upset' products with fair machinability and requiring limited bending or riveting; brake shoe rivets; bending and blanking alloy for decorative brassware trade; extruded sections, including angles, channels and trim.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.4 g/cm³	0.305 lb/in³
2.2 Melting range	885–900 °C	1 625–1 650 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 020 per °C	0.000 011 per °F
20 to 300 °C *68 to 572 °F*	0.000 021 ,, ,,	0.000 012 ,, ,,
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	27% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.064 ohm mm²/m 6.4 microhm cm	38 ohms (circ mil/ft) 2.5 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed)	0.001 6 per °C (27% IACS)	0.000 9 per °F (27% 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)	10 000 kg/mm²	14 200 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F* (annealed or cold worked)	3 700 kg/mm²	5 300 000 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– 650 °C	840–1 200 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	650– 750 °C	1 200–1 380 °F
3.4 Hot formability	Good	
3.5 Cold formability	Limited	
3.6 Cold reduction between anneals	35% max	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	60	
3.8 Joining methods:	See General Data Sheet No. 3.5	
Soldering	Excellent	
Brazing	Good	
Oxy-acetylene welding	Fair	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
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		
Plate Sheet	Annealed	38	16	35	$5.65\sqrt{S_o}$	85	89	29	—
	Hot Rolled	38	16	30	$5.65\sqrt{S_o}$	85	89	29	20–60 mm thick
	Typical Cold Worked Temper	43	30	20	$5.65\sqrt{S_o}$	125	130	32	5–20 mm thick
Forgings	Hot Worked [c]	38	16	30	$5.65\sqrt{S_o}$	85	89	29	—

(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.

5.1.2 Typical Tensile Properties and Hardness Values—English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 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[a]	Tensile Strength ton/in²	Proof Stress 0.1% offset ton/in²	Elongation %	Elongation gauge length	Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown[b]
Plate Sheet	Annealed	24	10	45	$5.65\sqrt{S_o}$	95	18	—
	Hot Rolled	25	11	40	$5.65\sqrt{S_o}$	110	19	0.5–2 in. thick
	Cold Rolled	27	16	30 35	$5.65\sqrt{S_o}$ 2 in.	130	19	0.25–0.75 in. thick
Rod	Annealed	23	8	45	$5.65\sqrt{S_o}$	90	17	—
	Hot Worked	24	9	40	$5.65\sqrt{S_o}$	100	18	0.5–2 in. diam. or equivalent area
	Cold Worked As-Manufactured	25 27 30	10 14 18	40 35 25	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	110 125 140	18 19 21	1–2 in. diam. or equivalent area 0.375–1 in. diam. or equivalent area 0.125–0.375 in. diam. or equivalent area
Wire	Annealed	23	—	40	2 in.	—	17	0.04–0.25 in. diam.
	Cold Drawn Half Hard Hard Half Hard Hard	 30 36 32 40	 — — — —	 22 — 18 —	 2 in. — 2 in. —	 — — — —	 21 23 22 26	 0.125–0.25 in. diam. " 0.04–0.125 in. diam. "
Sections (extruded)	Hot Worked[c]	24	9	40	$5.65\sqrt{S_o}$	100	18	—
	Cold Drawn As-Manufactured[c]	26	12	35	$5.65\sqrt{S_o}$	120	19	—
Forgings	Hot Worked[c]	24	9	40	$5.65\sqrt{S_o}$	100	18	—

[a] The recognised temper designations used in the relevant or nearest British Standards are also given, to clarify the cold-worked tempers shown.

[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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength [a]			Elongation % on $11.3\sqrt{S_o}$	Reduction of Area %	Impact Strength [b]	
		°C	°F	kg/mm²	ton/in²	psi			kg m/cm²	ft lb
Rod [1] [c]	Annealed	20 – 78 –183	68 –108 –297	**37.1** **38.4** **48.5**	23.5 24.5 31	53 000 54 500 69 000	**50.2** **49.8** **50.6**	**62.5** **64.0** **62.1**	**4.40** **4.91** **4.61**	15.9 17.8 16.7
	Cold Worked 12%	20 – 78 –183	68 –108 –297	**44.8** **49.5** **60.8**	28.5 31.5 38.5	63 500 70 500 86 500	**28.2** **27.0** **30.8**	**57.0** **59.0** **57.0**	**2.23** **2.48** **2.19**	8.1 9.0 7.9

(a) 5 mm (0.2 in.) diam. test specimen.

(b) Charpy test, 10 × 8 × 100 mm specimen, 45° V-notch, 3 mm deep; cross-sectional area at the notch 0.5 cm².

(c) Alloy containing Zn 40% Pb 1.3% Cu rem. (i.e. outside the composition range of Cu Zn40 Pb). The results are presented for guidance only, since other information has not been traced.

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 kg m/cm² into ft lb taking into account the actual cross-sectional area of the specimen at the notch.

—Data not available:
Proof stress, 0.1% and 0.2% offset,
Yield strength, 0.5% extension under load.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.3.2 Creep Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

At the date of publication of this sheet, no data relating to this material have been traced.

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Broniewski, W. and Wesolowski, K. L'influence de la température sur les propriétés mécaniques des laitons.—Part 2. Rev. Mét., Vol. 30 (1933), pp. 453–457.

Printed in England by the Martin Cadbury Prin[illegible] Group

Cu Zn39 Pb2

**Common names: Forging Brass
Clock Brass**

A copper–zinc–lead alloy with a duplex alpha-plus-beta phase structure containing a dispersion of fine lead particles. It is mainly supplied as rod for forging stock. The alloy exhibits an excellent combination of hot-working and machining properties and is widely used for hot pressed components.

COMPOSITION (weight %)

Cu	57.0–60.0
Pb	1.0– 2.5
Zn	rem.

1 SOME TYPICAL USES

Mechanical and General

Wide variety of hot forged and pressed components including sanitary appliances, door furniture, window fittings, taps, valves and valve parts, automobile components, decorative items, parts for mechanical handling equipment, brackets, clamps, housings, gears, cams, nuts, unions and miscellaneous machine components. Clock, watch and instrument parts (UK only), especially gears and plates requiring high degree of precision machining.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.4 g/cm³	0.305 lb/in³
2.2 Melting range	880–895 °C	1 615–1 645 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 020 per °C	0.000 011 per °F
20 to 300 °C *68 to 572 °F*	0.000 021 „ „	0.000 012 „ „
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*	0.28 cal cm/cm² s °C	68 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	16 m/ohm mm²	27% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.064 ohm mm²/m	38 ohms (circ mil/ft)
	6.4 microhm cm	2.5 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed)	0.001 6 per °C (27% IACS)	0.000 9 per °F (27% 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)	9 800 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	5 200 000 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	650– 775 °C	1 200–1 425 °F
3.4 Hot formability	Excellent	
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)	85	
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	40	22	35	$5.65\sqrt{S_o}$	90	95	30	—
Rod	Hot Worked	42	23	30	$5.65\sqrt{S_o}$	95	100	32	10–60 mm diam. or equivalent area
Rod	Typical Cold Worked Tempers	45	30	20	$5.65\sqrt{S_o}$	120	125	34	6–40 mm diam. or equivalent area
		56	48	15	$5.65\sqrt{S_o}$	140	145	38	6–12 mm diam. or equivalent area
Sections / Shapes	Hot Worked[c]	42	22	30	$5.65\sqrt{S_o}$	95	100	31	—
Sections / Shapes	Typical Cold Worked Temper[c]	45	30	20	$5.65\sqrt{S_o}$	115	120	34	—
Forgings	Hot Worked[c]	38	18	28	$5.65\sqrt{S_o}$	85	89	29	—

(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.

5.1.2 Typical Tensile Properties and Hardness Values—English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 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[(a)]	Tensile Strength ton/in²	Proof Stress 0.1% offset ton/in²	Elongation		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown[(b)]
				%	gauge length			
Strip	Cold Worked							
	Half Hard	28	17	25	2 in.	130	20	0.01–0.20 in. thick
	Hard	34	25	10	2 in.	160	22	0.01–0.125 in. thick
	Extra Hard	38	32	5	2 in.	185	23	"
Rod	Hot Worked	27	11	30	$5.65\sqrt{S_0}$	110	20	0.5–2 in. diam. or equivalent area
	Cold Worked							
	As-Manufactured	28	13	30	$5.65\sqrt{S_0}$	120	20	1–2 in. diam. or equivalent area
		30	16	25	$5.65\sqrt{S_0}$	140	21	0.375–1 in. diam. or equivalent area
		32	18	20	$5.65\sqrt{S_0}$	160	22	0.125–0.375 in. diam. or equivalent area
	Hard	32	18	20	$5.65\sqrt{S_0}$	160	22	0.25–1.5 in. diam. or equivalent area
Sections (extruded)	Hot Worked[(c)]	27	11	30	$5.65\sqrt{S_0}$	110	20	—
	Cold Drawn As-Manufactured[(c)]	29	14	25	$5.65\sqrt{S_0}$	130	21	—
Forgings	Hot Worked[(c)]	26	11	35	$5.65\sqrt{S_0}$	100	20	—

(a) The recognised temper designations used in the relevant or nearest British Standards are also given, to clarify the cold-worked tempers shown.

(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	52 000	20 000	45	2 in.	78	—	—	39 000	1.0 in. diam.
Shapes	As Extruded	52 000	20 000	45	2 in.	78	—	—	39 000	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—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation		Reduction of Area %	Impact Strength (b)	
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length		kg m/cm²	ft lb
Sheet (1) **8–10 mm** **0.3–0.4 in.**	— (c)	17	68	**45**	28.5	64 000	**32**	—	**35**	—	—
		–196	–321	**59**	37.5	84 000	**37**	—	**38**	—	—
		–253	–423	**68**	43	96 500	**34**	—	**35**	—	—
Rod (2) (d)	Annealed	20	68	**37.1** (a)	23.5 (a)	53 000 (a)	**50.2**	$11.3\sqrt{S_o}$	**62.5**	**4.40**	15.9
		– 78	–108	**38.4** (a)	24.5 (a)	54 500 (a)	**49.8**	$11.3\sqrt{S_o}$	**64.0**	**4.91**	17.8
		–183	–297	**48.5** (a)	31 (a)	69 000 (a)	**50.6**	$11.3\sqrt{S_o}$	**62.1**	**4.61**	16.7
	Cold Worked 12%	20	68	**44.8** (a)	28.5 (a)	63 500 (a)	**28.2**	$11.3\sqrt{S_o}$	**57.0**	**2.23**	8.1
		– 78	–108	**49.5** (a)	31.5 (a)	70 500 (a)	**27.0**	$11.3\sqrt{S_o}$	**59.0**	**2.48**	9.0
		–183	–297	**60.8** (a)	38.5 (a)	86 500 (a)	**30.8**	$11.3\sqrt{S_o}$	**57.0**	**2.19**	7.9
—(3) (c)	Cold Worked (e)	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) 5 mm (0.2 in.) diam. test specimen.

(b) Charpy test, 10 × 8 × 100 mm specimen, 45° V-notch, 3 mm deep; cross-sectional area at the notch 0.5 cm².

(c) Not stated in original document.

(d) Alloy containing Zn 40%, Pb 1.3%, Cu rem.

(e) 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.

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

—Data not available:
Proof stress, 0.1% and 0.2% offset,
Yield strength, 0.5% extension under load.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation		Impact Strength [a]	
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length	kg m/cm²	ft lb
Rod [2]	Annealed	20	68	**37.1**	23.5	53 000	**50.2**	$11.3\sqrt{S_o}$	—	—
		53	127	**36.2**	23	51 500	**49.1**	$11.3\sqrt{S_o}$	—	—
		109	228	**36.1**	23	51 500	**46.2**	$11.3\sqrt{S_o}$	—	—
		150	302	**33.6**	21.5	48 000	**45.5**	$11.3\sqrt{S_o}$	—	—
		200	392	**31.7**	20	45 000	**42.2**	$11.3\sqrt{S_o}$	—	—
		248	478	**30.0**	19	42 500	**37.4**	$11.3\sqrt{S_o}$	—	—
		301	574	**26.9**	17	38 500	**28.1**	$11.3\sqrt{S_o}$	—	—
		354	669	**22.9**	14.5	32 500	**17.5**	$11.3\sqrt{S_o}$	—	—
		400	752	**16.6**	10.5	23 500	**25.4**	$11.3\sqrt{S_o}$	—	—
		450	842	**11.5**	7.5	16 500	**24.8**	$11.3\sqrt{S_o}$	—	—
		496	925	**5.9**	3.5	8 500	**21.8**	$11.3\sqrt{S_o}$	—	—
		555	1 031	**4.1**	2.5	6 000	**22.6**	$11.3\sqrt{S_o}$	—	—
		610	1 130	**3.1**	2	4 500	**22.5**	$11.3\sqrt{S_o}$	—	—
		650	1 202	**1.5**	1	2 000	**24.0**	$11.3\sqrt{S_o}$	—	—
		700	1 292	**1.1**	0.7	1 500	**26.7**	$11.3\sqrt{S_o}$	—	—
	Cold Worked 12%	22	72	**44.8**	28.5	63 500	**28.2**	$11.3\sqrt{S_o}$	—	—
		51	124	**44.8**	28.5	63 500	**27.1**	$11.3\sqrt{S_o}$	—	—
		116	241	**43.9**	28	62 500	**24.5**	$11.3\sqrt{S_o}$	—	—
		150	302	**41.8**	26.5	59 500	**22.0**	$11.3\sqrt{S_o}$	—	—
		200	392	**39.2**	25	56 000	**17.6**	$11.3\sqrt{S_o}$	—	—
		250	482	**36.1**	23	51 500	**8.5**	$11.3\sqrt{S_o}$	—	—
		301	574	**30.4**	19.5	43 000	**5.2**	$11.3\sqrt{S_o}$	—	—
		354	669	**22.8**	14.5	32 500	**5.3**	$11.3\sqrt{S_o}$	—	—
		416	781	**16.1**	10	23 000	**10.9**	$11.3\sqrt{S_o}$	—	—
		450	842	**10.9**	7	15 500	**21.7**	$11.3\sqrt{S_o}$	—	—
		504	939	**4.8**	3	7 000	**22.1**	$11.3\sqrt{S_o}$	—	—
Rod [4]	— [b]	20	68	**36**	23	51 000	**41**	$5.65\sqrt{S_o}$	**15**	86.8
		100	212	**32**	20.5	45 500	**38**	$5.65\sqrt{S_o}$	**13**	75.2
		200	392	**28**	18	40 000	**31**	$5.65\sqrt{S_o}$	**9**	52.1
		300	572	**22**	14	31 500	**18**	$5.65\sqrt{S_o}$	**5**	28.9
		400	752	**18**	11.5	25 500	**8**	$5.65\sqrt{S_o}$	**2**	11.6
		500	932	**13**	8.5	18 500	**10**	$5.65\sqrt{S_o}$	**2.5**	14.5
		600	1 112	**11**	7	15 500	**14**	$5.65\sqrt{S_o}$	**3**	17.4
		700	1 292	**8**	5	11 500	**57**	$5.65\sqrt{S_o}$	**4**	27.1
		800	1 472	**3**	2	4 500	**4**	$5.65\sqrt{S_o}$	**1**	5.8

[a] Izod specimen: cross-sectional area at the notch 0.8 cm².

[b] Not stated in original document.

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 kg m/cm² into ft lb taking into account the actual cross-sectional area of the specimen at the notch.

—Data not available:
Proof stress, 0.1% and 0.2% offset,
Yield strength, 0.5% extension under load.

5.3.2 Creep Properties

Form	Temper	Testing Temperature		Stress			Duration	Total Creep	Min. Creep Rate
		°C	°F	kg/mm²	ton/in²	psi	h	%[(a)]	% per 1 000 h
Rod [(5)] **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**	—

(a) 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.

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

—Data not available:
Intercept.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

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
Rod [(6)] **12.7 mm diam. 0.5 in. diam.**	Cold Worked 21%	300	53	15.5 [(a)]	33.5	10 [(a)]	**75 500**	**22 000** [(a)]

(a) Rotating-beam test.

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

REFERENCES

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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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DATA SHEET No. E 8
Cu Zn40 Pb3

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	—
	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.
	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	—
	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		Tensile Strength			Yield Strength psi	Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi		
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		Stress			Duration h	Total Creep % [a]	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
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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MECHANICAL PROPERTIES (SECTION 5)

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(3) Compilation of Available High-Temperature Creep Characteristics of Metals and Alloys. ASTM-ASME (1938).

(4) McKeown, J. and Lushey, R.D.S. Creep Properties of Three Copper Alloys. Metal Ind. (Lond.), Vol 92, (1958), pp. 327–329.

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WROUGHT MATERIALS

COPPER-ZINC-LEAD ALLOYS
Leaded Brasses

Cu Zn43 Pbl

Common name: Architectural "Bronze"

A copper-zinc-lead alloy with a duplex alpha-plus-beta phase structure containing a dispersion of fine lead particles. A small amount of aluminium is sometimes added to improve the tarnish resistance of the alloy, which is generally supplied only as extruded rod and sections. The material has excellent hot-working properties and good machinability, and is typically used for decorative and architectural applications.

COMPOSITION (weight %)

Cu	54.0–57.5
Pb	0.8– 2.5
Zn	rem.

1 SOME TYPICAL USES

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

Mechanical
Extruded bolt and other sections; hinges and lock bodies.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.4 g/cm³	0.305 lb/in³
2.2 Melting range	870–885 °C	1 600–1 625 °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*	0.26 cal cm/cm² s °C	63 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	18 m/ohm mm²	31% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.055 ohm mm²/m 5.5 microhm cm	33 ohms (circ mil/ft) 2.2 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed)	0.001 9 per °C (31% IACS)	0.001 1 per °F (31% IACS)
applicable over range from 0 to 100 °C *31 to 212 °F*		
2.9 Modulus of elasticity (tension) at 20 °C *68 °F* (annealed or cold worked)	8 500 kg/mm²	12 100 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F* (annealed or cold worked)	3 100 kg/mm²	4 500 000 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 6): 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	990–1 040 °C	1 815–1 905 °F
3.2 Annealing temperature range	425– 550 °C	795–1 020 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	600– 700 °C	1 110–1 290 °F
3.4 Hot formability	Excellent	
3.5 Cold formability	Limited	
3.6 Cold reduction between anneals	15% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	75	
3.8 Joining methods:	See General Data Sheet No. 3.5	
Soldering	Good	
Brazing	Fair	
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 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	Hot Worked	48	22	18	$5.65\sqrt{S_o}$	115	120	36	10–60 mm diam.
Sections / Shapes	Hot Worked[c]	48	22	18	$5.65\sqrt{S_o}$	115	120	36	—

[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.

5.1.2 Typical Tensile Properties and Hardness Values—English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 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[a]	Tensile Strength ton/in²	Proof Stress 0.1% offset ton/in²	Elongation		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown
				%	gauge length			
Sections (extruded)	Hot Worked[b]	26	10	25	$5.65\sqrt{S_o}$	110	20	—
	Cold Drawn As-Manufactured[b]	28	13	20	$5.65\sqrt{S_o}$	130	20	—

[a] The recognised temper designation used in the relevant or nearest British Standards is also given, to clarify the cold-worked temper shown.

[b] 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 Hot Worked	72 000	20 000	27	2 in.	87	58	—	45 000	1.0 in. diam.
Shapes	As Extruded	72 000	20 000	27	2 in.	87	58	—	45 000	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—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation % on $5.65\sqrt{S_0}$	Reduction of Area %	Impact Strength [c]	
		°C	°F	kg/mm²	ton/in²	psi			kg m/cm²	ft lb
— [1] [a]	— [b]	20	68	36.5	23	**51 900**	**22.3**	**19.9**	**5.23**	18.9
		–183	–297	51	32.5	**72 300**	**26.9**	**19.2**	**5.18**	18.7

[a] Not stated in original document; alloy containing Cu 57.14%, Zn 40.75%, Pb 0.69%, Fe 0.90% (i.e. just outside composition range of Cu Zn43 Pb1).

[b] Not stated in original document.

[c] Charpy test, 10 × 8 × 100 mm specimen, 45° V-notch, 3 mm deep; cross-sectional area at the notch 0.5 cm².

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 kg m/cm² into ft lb taking into account the actual cross-sectional area of the specimen at the notch.

—Data not available:
Proof stress, 0.1% and 0.2% offset.
Yield Strength, 0.5% extension under load.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.3.2 Creep Properties

At the date of publication of this sheet, no data relating to this material have been traced.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

At the date of publication of this sheet, no data relating to this material have been traced.

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MECHANICAL PROPERTIES (SECTION 5)

(1) Smith, C.S. Mechanical Properties of Copper and its Alloys at Low Temperatures: a Review. Proc. ASTM, Vol. 39 (1939), pp. 642–648.

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