Cu Zn5

Common names: 95/5 Brass
95/5 Gilding Metal

A copper-zinc alloy with an alpha phase structure. The alloy has excellent cold-working properties and is generally not susceptible to dezincification and stress corrosion. It is widely used for small-arms ammunition and, due to its attractive golden colour, for decorative applications.

COMPOSITION (weight %)

Cu	94.0–96.0
Zn	rem.

1 SOME TYPICAL USES

Coinage
Coins, medals and tokens.

Decorative
Emblems, costume jewellery, plaques; good base material for gold plate and vitreous enamel.

Munitions
Small arms ammunition including bullet envelopes (clad on steel), fuse caps and primer caps.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.85 g/cm³	0.320 lb/in³
2.2 Melting range	1 055–1 070 °C	1 930–1 960 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 017 per °C	0.000 010 per °F
20 to 300 °C *68 to 572 °F*	0.000 018 ,, ,,	0.000 010 ,, ,,
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
2.5 Thermal conductivity at:		
−200 °C *−328 °F*	0.31 cal cm/cm² s °C	74 Btu ft/ft² h °F
20 °C *68 °F*	0.56 ,,	135 ,,
200 °C *392 °F*	0.65 ,,	157 ,,
2.6 Electrical conductivity (volume) at:		
−196 °C *−321 °F* (annealed)	71 m/ohm mm²	123 % IACS
20 °C *68 °F* (,,)	32 ,,	56 ,, ,,
200 °C *392 °F* (,,)	23 ,,	40 ,, ,,
−196 °C *−321 °F* (fully cold worked)	67 ,,	115 ,, ,,
20 °C *68 °F* (,, ,, ,,)	31 ,,	53 ,, ,,

continued overleaf

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. D1
Cu Zn5
1970 Edition

Cu Zn10

Common names: 90/10 Brass
90/10 Gilding Metal
Commercial "Bronze"

A copper-zinc alloy with an alpha phase structure. The alloy has excellent cold-working properties and is generally not susceptible to dezincification and stress corrosion. Due to its cold formability and attractive golden colour, the alloy is widely used for architectural and decorative applications.

COMPOSITION (weight %)

Cu . .	89.0–91.0
Zn . .	rem.

1 SOME TYPICAL USES

Architectural
Showcase and window fittings, grillwork, weatherstrip, cold-formed angles and channels, ornamental pressings and trim.

Decorative
Cosmetic compacts, lipstick cases, costume jewellery, emblems and medallions; base material for vitreous enamel.

Hardware
Marine hardware; rivets and screws; wire gauze; slide (zip) fasteners.

Munitions
Primer caps and shell bands; bullet envelopes (clad on steel).

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.80 g/cm³	0.320 lb/in³
2.2	Melting range	1 025–1 045 °C	1 875–1 915 °F
2.3	Coefficient of thermal expansion (linear) at:		
	20 to 100 °C *68 to 212 °F*	0.000 018 per °C	0.000 010 per °F
	20 to 300 °C *68 to 572 °F*	0.000 018 ,, ,,	0.000 010 ,, ,,
2.4	Specific heat (thermal capacity) at:		
	20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
	200 °C *392 °F*	0.10 ,,	0.10 ,,
2.5	Thermal conductivity at:		
	20 °C *68 °F*	0.45 cal cm/cm² s °C	109 Btu ft/ft² h °F
	200 °C *392 °F*	0.54 ,,	131 ,,
2.6	Electrical conductivity (volume) at:		
	—196 °C *—321 °F* (annealed)	45 m/ohm mm²	78 % IACS
	20 °C *68 °F* (,,)	26 ,,	44 ,, ,,
	200 °C *392 °F* (,,)	19 ,,	33 ,, ,,
	—196 °C *—321 °F* (fully cold worked)	40 ,,	69 ,, ,,
	20 °C *68 °F* (,, ,, ,,)	23 ,,	40 ,, ,,

continued overleaf

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

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DATA SHEET No. D 2
Cu Zn10
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2 PHYSICAL PROPERTIES (continued)

	Metric Units	English Units
2.7 Electrical resistivity (volume) at:		
—196 °C — *321 °F* (annealed)	0.022 ohm mm²/m 2.2 microhm cm	13 ohms (circ mil/ft) 0.86 microhm in
20 °C *68 °F* (,,)	0.039 ohm mm²/m 3.9 microhm cm	24 ohms (circ mil/ft) 1.5 microhm in
200 °C *392 °F* (,,)	0.053 ohm mm²/m 5.3 microhm cm	32 ohms (circ mil/ft) 2.1 microhm in
—196 °C — *321 °F* (fully cold worked)	0.025 ohm mm²/m 2.5 microhm cm	15 ohms (circ mil/ft) 0.98 microhm in
20 °C *68 °F* (,, ,, ,,)	0.043 ohm mm²/m 4.3 microhm cm	26 ohms (circ mil/ft) 1.7 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 9 per °C (44% IACS)	0.001 0 per °F (44% IACS)
20°C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 7 ,, ,, (40% IACS)	0.000 9 ,, ,, (40% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	12 700 kg/mm²	18 000 000 lb/in²
cold worked	12 000–12 700 kg/mm²	17 000 000–18 000 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	4 650 kg/mm²	6 600 000 lb/in²
cold worked	4 400–4 650 kg/mm²	6 250 000–6 600 000 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.

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	1 120–1 180 °C	2 050–2 155 °F
3.2 Annealing temperature range	425– 600 °C	795–1 110 °F
Stress relieving temperature range	200– 300 °C	390– 570 °F
3.3 Hot working temperature range	750– 900 °C	1 380–1 650 °F
3.4 Hot formability	Good	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	90% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	25	
3.8 Joining methods:	See General Data Sheet No. 3.4	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Not recommended	
butt	Good	

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 (grain size 0.025 mm)	28	10	48	50 mm	60	63	21	0.2–2.5 mm thick
	Typical Cold Worked Tempers	32	20	30	50 mm	75	79	22	0.2–3 mm thick
		35	28	22	50 mm	95	100	23	,,
		43	35	10	50 mm	120	125	26	0.2–2 mm thick
		48	42	5	50 mm	125	130	29	0.2–1.5 mm thick
Rod	Annealed	26	9	50	$5.65\sqrt{S_o}$	55	58	20	—
	Typical Cold Worked Tempers	32	20	32	$5.65\sqrt{S_o}$	80	84	22	6–40 mm diam. or equivalent area
		40	32	15	$5.65\sqrt{S_o}$	115	120	26	6–12 mm diam. or equivalent area
Wire	Annealed	28	—	33	100 mm	—	—	21	1.5–6 mm diam.
		30	—	30	100 mm	—	—	23	0.2–1.5 mm diam.
	Typical Cold Drawn Tempers	48	—	4	100 mm	—	—	29	0.2–1.5 mm diam.
		57	—	—	—	—	—	30	,,
Tube	Annealed	27	10	48	$5.65\sqrt{S_o}$	60	63	20	—
	Typical Cold Drawn Tempers	34	22	28	$5.65\sqrt{S_o}$	85	89	23	10–50 mm O.D. over 2 mm wall
		42	35	12	$5.65\sqrt{S_o}$	115	120	26	up to 25 mm O.D., up to 2 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)]
Sheet Strip	Annealed							
	grain size 0.035 mm	16	4	55	2 in.	60	11	0.01–0.125 in. thick
	grain size 0.025 mm	17	5	55	2 in.	65	12	"
	grain size 0.015 mm	18	6	52	2 in.	80	13	"
	Cold Worked							
	Quarter Hard	18	12	40	2 in.	90	14	0.01–0.375 in. thick
	Half Hard	21	17	25	2 in.	110	15	0.01–0.25 in. thick
	Hard	24	22	12	2 in.	125	16	0.01–0.1 in. thick
	Extra Hard	29	25	8	2 in.	140	17	"
Rod	Annealed	16	5	50	$5.65\sqrt{S_o}$	60	11	—
	Cold Worked As Manufactured	20	12	35	$5.65\sqrt{S_o}$	90	14	0.25–1 in. diam. or equivalent area
		22	16	25	$5.65\sqrt{S_o}$	110	15	
Wire	Annealed	18	—	50	2 in.	—	13	0.02–0.10 in. diam.
	Cold Drawn							
	Half Hard	27	—	10	2 in.	—	19	0.02–0.10 in. diam.
	Hard	32	—	—	—	—	21	"
Tube[(c)]	Annealed	16	5	50	$5.65\sqrt{S_o}$	60	11	—
	Cold Drawn or Temper Annealed							
	Temper Annealed	19	9	35	$5.65\sqrt{S_o}$	90	14	2–10 in. O.D., 0.08–0.2 in. wall
	As Drawn	23	17	25	$5.65\sqrt{S_o}$	125	16	"
	Temper Annealed	19	9	35	$5.65\sqrt{S_o}$	90	14	0.25–2 in. O.D., 0.02–0.08 in. wall
	As Drawn	27	21	20	$5.65\sqrt{S_o}$	140	18	"

(a) The recognised temper designations used in the relevant or nearest British Standards are also given in this table, 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 tube tempers are generally obtained by temper annealing. Drawn tubes are usually stress relieved after the final draw.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation % on $4.52\sqrt{S_o}$	Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi				kg m/cm²	ft lb
Rod[1] 19 mm diam. 0.75 in. diam.	Annealed	22	72	27	17	**38 500**	**6.75**[a]	**56**	**84**	19.4[b]	**112**[b]
		−78	−108	29.5	18.5	**41 800**	**7.17**[a]	**57**	**80**	19.7[b]	**114**[b]
		−197	−323	39	24.5	**55 200**	**9.28**[a]	**86**	**78**	19.4[b]	**112**[b]
		−253	−423	51.5	32.5	**73 200**	**11.0**[a]	**95**	**73**	19.9[b]	**115**[b]
		−269	−452	48	30.5	**68 200**	**10.5**[a]	**91**	**73**	—	—
Rod[2]	Annealed (grain size 0.022 mm)	−195	−319	40.5	25.5	**57 400**	**10.5**[a]	—	—	—	—

(a) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.
(b) Charpy test, 10 × 10 × 55 mm specimen, 45° V-notch, 2 mm deep; 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% 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		Elongation	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	%	gauge length
Rod[3][a] 12 mm diam. 0.47 in. diam.	Cold Worked 44% and Stress Relieved[b]	20	68	**63.3**	40	90 000	**57.1**	**32.0**[c]	**14.8**	$5.65\sqrt{S_o}$
		200	392	**54.9**	35	78 000	**51.7**	**30.5**[c]	**10.9**	$5.65\sqrt{S_o}$
		300	572	**47.2**	30	67 000	**43.3**	**25.0**[c]	**9.0**	$5.65\sqrt{S_o}$
Rod[4] 12.7 mm diam 0.5 in. diam.	Annealed	25	77	26	16.5	**37 000**	**6.78**[d]	—	—	—
		300	572	18.5	11.5	**26 100**	**5.30**[d]	—	—	—
		500	932	9.5	6	**13 700**	**4.34**[d]	—	—	—
Rod[5] 12.8 mm diam. 0.505 in. diam.	Annealed	25	77	26	16.5	**36 700**	—	—	**56**	2 in.
		250	482	20.5	13	**29 500**	—	—	**35**	2 in.
		375	707	14	9	**19 800**	—	—	**9**	2 in.
		500	932	9.5	6	**13 700**	—	—	**14**	2 in.
		625	1 157	6	4	**8 500**	—	—	**17**	2 in.
		750	1 382	3	2	**4 500**	—	—	**18**	2 in.
		875	1 607	2	1	**2 700**	—	—	**16**	2 in.
		975	1 787	1	0.7	**1 500**	—	—	**14**	2 in.

(a) Containing 0.4% Sn.
(b) Stress relieved for 1 h at 400 °C (*752 °F*).
(c) This value was originally reported in kg/mm²; in this table it is given in ton/in² to 3 significant figures.
(d) 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.
—The yield strength 0.5% extension under load values are not available.

5.3.2. Creep Properties

5.3.2.1. Original Creep Data

Form	Temper	Testing Temperature °C	Testing Temperature °F	Stress kg/mm²	Stress ton/in²	Stress psi	Duration h	Total Extension %[a]
Rod[3] [b] **12 mm diam. 0.47 in. diam.**	Cold Worked 44% and Stress Relieved[c]	200	392	**8.0**	5.1	11 000	**3 278**	**0.080**
				10.0	6.3	14 200	**3 386**	**0.081**
				12.0	7.6	17 100	**3 503**	**0.116**
				14.0	8.9	19 900	**3 160**	**0.154**
				16.0	10.2	22 800	**3 018**	**0.182**

(a) Total creep; does not include the initial elastic extension.
(b) Containing 0.4% Sn.
(c) Stress relieved for 1 h at 400 °C *(752 °F)*.

N.B.—Original values are printed in **bold type**; other values are converted.
—Data not available:
Intercept,
Minimum creep rate.

5.3.2.2. Stress for Designated Extension

Form	Temper	Testing Temperature °C	Testing Temperature °F	0.1% in 1 000 h kg/mm²	0.1% in 1 000 h ton/in²	0.1% in 1 000 h psi	0.2% in 1 000 h kg/mm²	0.2% in 1 000 h ton/in²	0.2% in 1 000 h psi	0.1% in 2 000 h kg/mm²	0.1% in 2 000 h ton/in²	0.1% in 2 000 h psi	0.2% in 2 000 h kg/mm²	0.2% in 2 000 h ton/in²	0.2% in 2 000 h psi
Rod[3] [a] **12 mm diam. 0.47 in. diam.**	Cold Worked 44% and Stress Relieved[b]	200	392	**13.2**	8.4	18 800	**17.2**	10.9	24 500	**12.1**	7.7	17 200	**16.6**	10.5	23 500

(a) Containing 0.4% Sn.
(b) Stress relieved for 1 h at 400 °C *(752 °F)*

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 $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Strip[6] 0.81 mm 0.032 in.	Annealed (grain size 0.030 mm)	100	27.5	7[a][f]	17.5	4.5[a][f]	**39 000**	**10 000**[a][f]
	Cold Worked 21%	100	33	11[a]	21	7[a]	**47 000**	**16 000**[a]
	Cold Worked 37%	100	42	11.5[a]	26.5	7.5[a]	**59 700**	**16 500**[a]
	Cold Worked 60%	100	47	12.5[a]	30	8[a]	**66 900**	**18 000**[a]
	Cold Worked 68%	100	51.5	14[a]	32.5	9[a]	**73 300**	**20 000**[a]
Flat Products[7] 1 mm 0.04 in.	Cold Worked[b]	15	50.5	15[a]	32	9.5[a]	**72 000**	**21 000**[a]
Wire[8] [c] 1.8 mm diam. 0.072 in. diam.	Cold Worked 60%	100	43	15[d]	27	9.5[d]	**61 000**	**21 000**[d]
	Cold Worked 84%	100	51	16[d]	32.5	10.5[d]	**72 500**	**23 000**[d]
Wire[7] 2 mm diam. 0.08 in. diam.	Cold Worked[e]	100	52	16[d]	33	10.5[d]	**74 000**	**23 000**[d]

[a] Reversed-bending test.
[b] Quoted as "spring" in original document, but amount of cold work not defined.
[c] Just outside the composition range (8.80% Zn).
[d] Rotating-beam test.
[e] Quoted as "hard" in original document, but amount of cold work not defined.
[f] By extrapolation.

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

2 PHYSICAL PROPERTIES (continued)

		Metric Units	English Units
2.7	Electrical resistivity (volume) at:		
	−196 °C *−321 °F* (annealed)	0.014 ohm mm²/m 1.4 microhm cm	8.4 ohms (circ mil/ft) 0.55 microhm in
	20 °C *68 °F* (,,)	0.031 ohm mm²/m 3.1 microhm cm	19 ohms (circ mil/ft) 1.2 microhm in
	200 °C *392 °F* (,,)	0.043 ohm mm²/m 4.3 microhm cm	26 ohms (circ mil/ft) 1.7 microhm in
	−196 °C *−321 °F* (fully cold worked)	0.015 ohm mm²/m 1.5 microhm cm	9.0 ohms (circ mil/ft) 0.59 microhm in
	20 °C *68 °F* (,, ,, ,,)	0.032 ohm mm²/m 3.2 microhm cm	20 ohms (circ mil/ft) 1.3 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*	0.002 3 per °C (56% IACS)	0.001 3 per °F (56% IACS)
	20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.002 2 ,, ,, (53% IACS)	0.001 2 ,, ,, (53% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*:		
	annealed	13 000 kg/mm²	18 500 000 lb/in²
	cold worked	12 300–13 000 kg/mm²	17 500 000–18 500 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*:		
	annealed	4 750 kg/mm²	6 750 000 lb/in²
	cold worked	4 500–4 750 kg/mm²	6 400 000–6 750 000 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.

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	1 140–1 200 °C	2 085–2 190 °F
3.2	Annealing temperature range	425– 600 °C	795–1 110 °F
	Stress relieving temperature range	200– 300 °C	390– 570 °F
3.3	Hot working temperature range	750– 900 °C	1 380–1 650 °F
3.4	Hot formability	Good	
3.5	Cold formability	Excellent	
3.6	Cold reduction between anneals	90% max.	
3.7	Machinability:	See General Data Sheet No. 2	
	Machinability rating (free-cutting brass = 100)	25	
3.8	Joining methods:	See General Data Sheet No. 3.4	
	Soldering	Excellent	
	Brazing	Excellent	
	Oxy-acetylene welding	Good	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Good	
	Coated metal-arc welding	Not recommended	
	Resistance welding: spot and seam	Not recommended	
	butt	Good	

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 (grain size 0.015 mm)	27	10	45	50 mm	65	68	20	0.2–1.5 mm thick
	Typical Cold Worked Tempers	34 39 43	24 32 38	20 8 4	50 mm 50 mm 50 mm	85 105 120	89 110 125	24 25 26	0.2–3 mm thick 0.2–2 mm thick 0.2–1.5 mm thick
Wire	Annealed	27 30	— —	33 30	100 mm 100 mm	— —	— —	20 23	1.5–6 mm diam. 0.2–1.5 mm diam.
	Typical Cold Drawn Tempers	45 55	— —	3 —	100 mm —	— —	— —	26 28	0.2–1.5 mm diam. „

(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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²
		°C	°F	kg/mm²	ton/in²	psi	
Rod[1][a]	Annealed (grain size 0.023 mm)	−195	−319	38	24	**54 000**	9.60 [b]

[a] These values were determined on material just outside the composition range of the alloy and are presented for guidance only, since no other information is available.

[b] 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
Elongation
Reduction of area
Impact strength.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress		Elongation % on $5.65\sqrt{S_o}$
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	
Rod[2] [a] **10.5 mm diam. 0.41 in. diam.**	Cold Worked 51%	20	68	**37.0**	23.5	52 500	**35.4**	**20.3**[b]	**19.2**
		200	392	**31.6**	20	45 000	**30.0**	**17.1**[b]	**17.4**
		300	572	**27.3**	17.5	39 000	**25.0**	**14.6**[b]	**13.0**
Rod[3] **12.7 mm diam. 0.5 in. diam.**	Annealed	25	77	23.5	15	**33 500**	4.85[c]	—	—
		300	572	16.5	10.5	**23 500**	3.71[c]	—	—
		500	932	9.5	6	**13 380**	3.16[c]	—	—

[a] These values were determined on material just outside the composition range of the alloy and are presented for guidance only, since no other information is available.

[b] This value was originally reported in kg/mm²; in this table it is given in ton/in² to 3 significant figures.

[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.

—The 0.5% extension under load yield strength values are not available.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature °C	Testing Temperature °F	Stress kg/mm²	Stress ton/in²	Stress psi	Duration h	Total Extension %[a]
Rod[2] [b] **10.5 mm diam. 0.41 in. diam.**	Cold Worked 51%	200	392	**10.0**	6.3	14 200	**3 305**	**0.123**
				12.0	7.6	17 100	**1 995**	**0.21**
				14.0	8.9	19 900	**1 989**	**0.38**
				14.3	9.1	20 300	**2 011**	**0.51**

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

(b) These values were determined on material just outside the composition range of the alloy and are presented for guidance only, since no other information is available.

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

—Data not available:
Intercept,
Minimum creep rate.

5.3.2.2 Stress for Designated Extension

Form	Temper	Testing Temperature °C	Testing Temperature °F	0.1% in 1 000 h kg/mm²	0.1% in 1 000 h ton/in²	0.1% in 1 000 h psi	0.2% in 1 000 h kg/mm²	0.2% in 1 000 h ton/in²	0.2% in 1 000 h psi	0.1% in 2 000 h kg/mm²	0.1% in 2 000 h ton/in²	0.1% in 2 000 h psi	0.2% in 2 000 h kg/mm²	0.2% in 2 000 h ton/in²	0.2% in 2 000 h psi
Rod[2] [a] **10.5 mm diam. 0.41 in. diam.**	Cold Worked 51%	200	392	**10.0**	6.3	14 200	**12.8**	8.1	18 200	**9.3**	5.9	13 200	**11.9**	7.5	16 900

(a) These values were determined on material just outside the composition range of the alloy and are presented for guidance only, since no other information is available.

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

Data has recently been published in the following paper:

- France, W.D., Trout, D.E. and Mulholland, J.A. Fatigue Characteristics of Five Copper-Base Strip Alloys Commonly Used for Spring Applications. J. Materials, Vol. 4 (1969), No. 3, Sept., pp. 633–646.

PRINTED IN ENGLAND BY IMPRESS (WORCES[illegible]) LTD.

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Roberson, J.A. and Grosskreutz, J.C. Fatigue of Copper-Zinc Alloys at 100 K. Acta Metall., Vol. 11 (1963) July, pp. 795–798.

(2) Dies, K. and Jung-König, W. Zeitstandverhalten einiger technischer Kupferlegierungen in der Wärme. Metall, Vol. 16 (1962) No. 11, pp. 1097–1102.

(3) Crowe, C.H. Properties of Some Copper Alloys at Elevated Temperatures. ASTM Bull. No. 250, (1960) Dec., pp. 30–31.

Cu Zn15

Common names: 85/15 Brass
85/15 Gilding Metal
Red Brass

A copper–zinc alloy with an alpha phase structure. The alloy has excellent cold-working properties and is generally not susceptible to dezincification and stress corrosion. Due to this combination of properties and its attractive colour, the alloy is used for decorative purposes as well as for a wide variety of drawn and formed parts.

COMPOSITION (weight %)

Cu	84.0–86.0
Zn	rem.

1 SOME TYPICAL USES

Architectural
Trim, weatherstrip, cold-formed angles and channels.

Chemical
Flexible hose and wide range of process piping.

Decorative
Badges, cosmetic compacts, costume jewellery, instrument and clock dials, etched articles, lipstick containers and engraved nameplates.

Hardware
Eyelets and fasteners.

Mechanical
Miscellaneous components required to be brazed; numerous drawn and formed parts; bellows; flexible hose; slide (zip) fasteners.

Plumbing
Water service lines and traps.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.75 g/cm³	0.315 lb/in³
2.2	Melting range	1 000—1 025 °C	1 830–1 875 °F
2.3	Coefficient of thermal expansion (linear) at:		
	20 to 100 °C *68 to 212 °F*	0.000 018 per °C	0.000 010 per °F
	20 to 300 °C *68 to 572 °F*	0.000 019 ,, ,,	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*	0.38 cal cm/cm² s °C	92 Btu ft/ft² h °F
	200 °C *392 °F*	0.44 ,,	106 ,,
2.6	Electrical conductivity (volume) at:		
	—196 °C *—321 °F* (annealed)	31 m/ohm mm²	54 % IACS
	20 °C *68 °F* (,,)	21 ,,	37 ,, ,,
	200 °C *392 °F* (,,)	16 ,,	27 ,, ,,
	—196 °C *—321 °F* (fully cold worked)	27 ,,	47 ,, ,,
	20 °C *68 °F* (,, ,, ,,)	19 ,,	32 ,, ,,

continued overleaf

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 12); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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2 PHYSICAL PROPERTIES (continued)

		Metric Units	English Units
2.7	Electrical resistivity (volume) at: —196 °C *—321 °F* (annealed)	0.032 ohm mm²/m 3.2 microhm cm	19 ohms (circ mil/ft) 1.3 microhm in
	20 °C *68 °F* („)	0.047 ohm mm²/m 4.7 microhm cm	28 ohms (circ mil/ft) 1.8 microhm in
	200 °C *392 °F* („)	0.064 ohm mm²/m 6.4 microhm cm	38 ohms (circ mil/ft) 2.5 microhm in
	—196 °C *—321 °F* (fully cold worked)	0.037 ohm mm²/m 3.7 microhm cm	22 ohms (circ mil/ft) 1.5 microhm in
	20 °C *68 °F* („ „ „)	0.054 ohm mm²/m 5.4 microhm cm	32 ohms (circ mil/ft) 2.1 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 6 per °C (37% IACS)	0.000 9 per °F (37% IACS)
	20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 4 „ „ (32% IACS)	0.000 8 „ „ (32% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	12 400 kg/mm²	17 600 000 lb/in²
	cold worked	11 400–12 400 kg/mm²	16 200 000–17 600 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*		
	annealed	4 550 kg/mm²	6 450 000 lb/in²
	cold worked	4 300–4 550 kg/mm²	6 100 000–6 450 000 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.

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	1 100–1 160 °C	2 010–2 120 °F
3.2	Annealing temperature range	425– 600 °C	795–1 110 °F
	Stress relieving temperature range	200– 300 °C	390– 570 °F
3.3	Hot working temperature range	750– 900 °C	1 380–1 650 °F
3.4	Hot formability	Fair	
3.5	Cold formability	Excellent	
3.6	Cold reduction between anneals	85% max.	
3.7	Machinability:	See General Data Sheet No. 2	
	Machinability rating (free-cutting brass = 100)	25	
3.8	Joining methods:	See General Data Sheet No. 3.4	
	Soldering	Excellent	
	Brazing	Excellent	
	Oxy-acetylene welding	Good	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Good	
	Coated metal-arc welding	Not recommended	
	Resistance welding: spot and seam	Fair	
	butt	Good	

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 (grain size 0.015 mm)	31	13	40	50 mm	80	84	23	0.2–1.5 mm thick
	Typical Cold Worked Tempers	34 38 48	25 30 42	30 22 10	50 mm 50 mm 50 mm	85 105 135	89 110 140	24 25 31	0.2–3 mm thick " 0.2–2 mm thick
Rod	Annealed	28	10	50	$5.65\sqrt{S_o}$	60	63	21	—
	Typical Cold Worked Tempers	36 42	28 34	28 16	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	90 120	95 125	25 27	6–40 mm diam. or equivalent area 6–12 mm diam. or equivalent area
Wire	Annealed	30 32	— —	35 32	100 mm 100 mm	— —	— —	23 24	1.5–6 mm diam. 0.2–1.5 mm diam.
	Typical Cold Drawn Tempers	42 50 60	— — —	8 4 —	100 mm 100 mm —	— — —	— — —	27 28 30	1.5–6 mm diam. 1.5–3 mm diam. 0.2–1.5 mm diam.
Tube	Annealed	28	11	50	$5.65\sqrt{S_o}$	60	63	21	—
	Typical Cold Drawn Tempers	36 44	28 38	25 12	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	95 125	100 130	25 29	10–50 mm O.D. over 2 mm wall up to 25 mm O.D. up to 2 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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation % on $4.52\sqrt{S_o}$	Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi				kg m/cm²	ft lb
Rod(1) **19 mm diam. 0.75 in. diam.**	Cold Worked 14%	22	72	28.5	18	**40 400**	**9.14**(a)	**48**	**74**	16.6(b)	**96**(b)
		– 78	–108	32.5	21	**46 500**	**9.84**(a)	**63**	**79**	14.2(b)	**82**(b)
		–197	–323	43.5	27.5	**62 000**	**11.5**(a)	**83**	**77**	13.5(b)	**78**(b)
		–253	–423	55.5	35.5	**79 200**	**14.7**(a)	**80**	**75**	13.1(b)	**76**(b)
		–269	–452	50	31.5	**71 000**	**12.9**(a)	**82**	**71**	—	—
Rod(2)	Annealed (grain size 0.020 mm)	–195	–319	46.5	29.5	**65 800**	**13.7**(a)	—	—	—	—
Rod(3)	Annealed	10	50	—	—	—	—	—	—	14.4(c)	**52**(c)
		– 18	0	—	—	—	—	—	—	14.7(c)	**53**(c)
		– 29	– 20	—	—	—	—	—	—	15.2(c)	**55**(c)
		– 51	– 60	—	—	—	—	—	—	15.5(c)	**56**(c)
		– 79	–110	—	—	—	—	—	—	15.5(c)	**56**(c)
		–118	–180	—	—	—	—	—	—	16.6(c)	**60**(c)

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

(b) Charpy test, 10 × 10 × 55 mm specimen, 45° V-notch, 2 mm deep; cross-sectional area at the notch 0.8 cm².

(c) Charpy specimen, keyhole notch; 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 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% 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			Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	
Plate[4]	Annealed	20	68	30	**19.2**	43 000	**8.66**[a]	**5.1**	—	**50**
		66	150	28	**17.7**	39 500	**8.19**[a]	**4.9**	—	**51**
		121	250	26.5	**16.8**	37 500	**8.50**[a]	**5.1**	—	**45**
		177	350	25.5	**16.1**	36 000	**7.87**[a]	**4.8**	—	**45**
		232	450	24.5	**15.4**	34 500	**7.87**[a]	**4.8**	—	**36**
Rod[5] **3.2 mm diam 0.125 in. diam.**	Annealed (grain size 0.060 mm)	24	75	29	18.5	**41 000**	—	—	**10 000**	**47.0**
		149	300	—	—	—	—	—	**9 700**	—
		204	400	—	—	—	—	—	**9 500**	—
		260	500	—	—	—	—	—	**8 500**	—
	Cold Worked 37%	24	75	47.5	30	**67 500**	—	—	**59 000**	**10.5**
		204	400	—	—	—	—	—	**47 000**	—
	Cold Worked 84%	24	75	68	43	**96 500**	—	—	**67 000**	**7.0**
		204	400	—	—	—	—	—	**52 000**	—
Rod[6] **12.7 mm diam. 0.5 in. diam.**	Annealed	25	77	28	17.5	**39 500**	**8.79**[b]	—	—	—
		300	572	21.5	13.5	**30 600**	**7.56**[b]	—	—	—
		500	932	10	6.5	**14 500**	**5.23**[b]	—	—	—
Rod[7] **19 mm diam. 0.75 in. diam.**	Hot Worked (grain size 0.030 mm)	24	75	31	19.5	**43 800**	—	—	—	**47.0**
		204	400	27	17	**38 525**	—	—	—	**35.5**
		316	600	21	13.5	**29 950**	—	—	—	—
		427	800	14	9	**20 250**	—	—	—	**4.2**
Rod[8]	Cold Worked 37%	200	392	41.5	26	**58 800**	—	—	**54 800**	**7.3**
		300	572	36.5	23	**51 800**	—	—	**49 000**	**4.5**
		400	752	22	14	**31 400**	—	—	**24 500**	**17.0**
		500	932	11	7	**15 800**	—	—	**10 500**	**25.7**
		600	1 112	6.5	4	**9 200**	—	—	**7 600**	**27.7**
		700	1 292	4	2.5	**5 600**	—	—	**4 700**	**62.0**
Tube[9]	Annealed	Room	Room	28	18	**40 000**	—	—	**12 000**	—
		66	150	28	18	**40 000**	—	—	**12 000**	—
		121	250	27.5	17.5	**39 000**	—	—	**12 000**	—
		149	300	26.5	17	**38 000**	—	—	**12 000**	—
		177	350	26	16.5	**37 000**	—	—	**12 000**	—
		204	400	25.5	16	**36 000**	—	—	**12 000**	—
		232	450	24.5	15.5	**35 000**	—	—	**11 500**	—
		260	500	23	14.5	**33 000**	—	—	**11 000**	—

(a) This value was originally reported in ton/in²; in this table it is given in kg/mm² to 3 significant figures.
(b) 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.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension %[a]	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod[5] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.060 mm)	149	300	3.2	2.0	**4 500**	**4 500**	**0.031**	**0.006**	**0.000 7**
				4.9	3.1	**6 960**	**5 100**	**0.087**	**0.024**	**0.002 9**
				6.9	4.4	**9 800**	**4 500**	**1.07**	**0.44**	**0.026**
		204	400	0.70	0.45	**1 000**	**4 400**	**0.022**	**0.008**	**0.000 8**
				1.4	0.92	**2 050**	**5 060**	**0.042**	**0.013**	**0.001 9**
				2.5	1.6	**3 500**	**5 100**	**0.092**	**0.040**	**0.003 3**
				3.5	2.3	**5 040**	**5 400**	**0.097**	**0.015**	**0.005 9**
				4.9	3.1	**6 940**	**6 600**	**0.482**	**0.187**	**0.034**
				6.3	4.0	**8 940**	**2 000**	**1.060**	**0.390**	**0.10**
				8.1	5.1	**11 500**	**4 130**	**3.620**	**0.750**	**0.283**
		260	500	0.60	0.38	**850**	**5 140**	**0.042**	**0.010**	**0.004 0**
				1.4	0.89	**2 000**	**5 000**	**0.091**	**0.026**	**0.008 0**
				2.5	1.6	**3 520**	**5 300**	**0.241**	**0.037**	**0.030**
				3.5	2.2	**4 980**	**5 000**	**0.507**	**0.083**	**0.073**
				4.2	2.7	**6 000**	**5 140**	**0.958**	**0.180**	**0.138**
				4.9	3.1	**6 950**	**1 600**	**1.100**	**0.510**	**0.32**
	Cold Worked 37%	149	300	3.5	2.3	**5 040**	**5 200**	**0.050**	**0.018**	**0.000 4**
				7.0	4.4	**9 900**	**4 800**	**0.110**	**0.037**	**0.002 4**
				9.2	5.8	**13 050**	**5 050**	**0.138**	**0.044**	**0.002 8**
				12.4	7.9	**17 650**	**5 100**	**0.227**	**0.083**	**0.006 7**
				16.8	10.6	**23 850**	**6 050**	**0.366**	**0.153**	**0.011**
				21.2	13.5	**30 200**	**4 800**	**0.628**	**0.220**	**0.043**
		204	400	3.5	2.2	**4 980**	**5 200**	**0.077**	**0.039**	**0.002 6**
				5.7	3.6	**8 100**	**5 400**	**0.135**	**0.054**	**0.006 9**
				8.3	5.3	**11 850**	**5 200**	**0.283**	**0.146**	**0.013**
				11.0	7.0	**15 650**	**4 420**	**0.422**	**0.151**	**0.041**
		260	500	0.37	0.23	**520**	**5 100**	**0.042**	**0.008**	**0.005 6**
				0.69	0.44	**980**	**10 370**	**0.179**	**0.055**	**0.011**
				2.1	1.4	**3 050**	**10 000**	**0.967**	**0.073**	**0.086**
				4.3	2.7	**6 050**	**4 800**	**1.114**	**−0.70**	**0.37**[b]
	Cold Worked 84%	149	300	7.0	4.4	**9 960**	**4 400**	**0.096**	**0.029**	**0.000 7**
				13.9	8.8	**19 800**	**5 100**	**0.197**	**0.054**	**0.002 6**
				27.9	17.7	**39 700**	**4 500**	**0.445**	**0.108**	**0.011**
				37.8	24.0	**53 800**	**5 100**	**0.860**	**0.250**	**0.033**
		204	400	0.73	0.46	**1 040**	**5 160**	**0.040**	**0.029**	**0.001 1**
				2.2	1.4	**3 190**	**5 000**	**0.163**	**0.061**	**0.017**
				3.8	2.4	**5 400**	**5 160**	**0.461**	**0.110**	**0.063**
				4.2	2.7	**6 040**	**5 000**	**0.505**	**0.120**	**0.069**
		260	500	0.42	0.27	**600**	**5 540**	**0.096**	**0.038**	**0.010**
				0.67	0.43	**960**	**5 300**	**0.270**	**0.080**	**0.034**
				1.4	0.87	**1 940**	**2 950**	**0.678**	**0.104**	**0.19**
				2.1	1.3	**2 990**	**3 650**	**2.715**	**−0.045**	**0.76**[b]

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Accelerating creep rate.

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

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate								
				0.001% per 1 000 h			0.01% per 1 000 h			0.1% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod[5] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.060 mm)	149	300	3.7	2.3	**5 200**	6.0	3.8	**8 600**	> 7.0	> 4.5	> **10 000**
		204	400	0.88	0.56	**1 250**	3.9	2.5	**5 500**	6.3	4.0	**9 000**
		260	500	—	—	—	1.6	1.0	**2 250**	3.7	2.3	**5 200**
	Cold Worked 37%	149	300	5.5	3.5	**7 800**	15.5	9.8	**22 000**	> 21.0	> 13.4	> **30 000**
		204	400	2.0	1.3	**2 800**	7.0	4.5	**10 000**	13.1	8.3	**18 700**
		260	500	—	—	—	0.60	0.38	**850**	2.3	1.5	**3 300**
	Cold Worked 84%	149	300	8.4	5.5	**12 000**	26.0	16.5	**37 000**	> 38.7	> 24.6	> **55 000**
		204	400	0.70	0.44	**1 000**	1.8	1.2	**2 600**	4.8[a]	3.0[a]	**6 800**[a]
		260	500	—	—	—	0.42	0.27	**600**	1.0	0.65	**1 450**

[a] Extrapolated value.

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
Strip[10] 0.81 mm 0.032 in.	Annealed (grain size 0.020 mm)	100	31	11.5[a]	19.5	7.5[a]	**44 000**	**16 500**[a]
	Annealed (grain size 0.025 mm)	100	29.5	10[a]	18.5	6.5[a]	**42 000**	**14 500**[a]
	Annealed (grain size 0.075 mm)	100	27.5	7.5[a]	17.5	4.5[a]	**39 000**	**10 500**[a]
	Annealed (grain size 0.090 mm)	100	27	7.5[a]	17	5[a]	**38 500**	**11 000**[a]
	Cold Worked 21%[b]	100	39.5	16[a]	25	10[a]	**56 500**	**22 500**[a]
	Cold Worked 21%[c]	100	35	10.5[a]	22.5	6.5[a]	**50 000**	**15 000**[a]
	Cold Worked 37%[d]	100	48.5	15[a]	31	9.5[a]	**69 000**	**21 000**[a]
	Cold Worked 37%[e]	100	45	13.5[a]	28.5	8.5[a]	**64 000**	**19 000**[a]
	Cold Worked 60%[f]	100	55.5	17[a]	35.5	10.5[a]	**79 000**	**24 000**[a]
	Cold Worked 60%[e]	100	55.5	16.5[a]	35.5	10.5[a]	**79 000**	**23 500**[a]
Strip[11] 1 mm 0.04 in.	Cold Worked[g]	100	59	10.5[a]	37.5	6.5[a]	**84 000**	**15 000**[a]
Rod[12] 12.7 mm diam. 0.5 in. diam.	Cold Worked 4%	300	31.5	14[h]	20	9[h]	**44 700**	**20 000**[h]
Rod[13]	Cold Worked and Stress Relieved[i]	60	37.5	11[h]	23.5	7[h]	**53 000**	**16 000**[h]
	Cold Worked and Annealed[j]	100	28.5	11[h]	18	7[h]	**40 500**	**15 500**[h]

[a] Reversed-bending test. [b] Ready-to-finish grain size 0.020 mm. [c] Ready-to-finish grain size 0.060 mm. [d] Ready-to-finish grain size 0.030 mm. [e] Ready-to-finish grain size 0.070 mm. [f] Ready-to-finish grain size 0.025 mm. [g] Quoted as "spring" in original document, but amount of cold work not defined. [h] Rotating-beam test. [i] Stress relieved for 3 h at 232 °C (*450 °F*) [j] Annealed for 3 h at 482 °C (*900 °F*).

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

UDC 669.35'5

Cu Zn15

Common names: 85/15 Brass
85/15 Gilding Metal
Red Brass

A copper–zinc alloy with an alpha phase structure. The alloy has excellent cold-working properties and is generally not susceptible to dezincification and stress corrosion. Due to this combination of properties and its attractive colour, the alloy is used for decorative purposes as well as for a wide variety of drawn and formed parts.

COMPOSITION (weight %)

Cu . . . 84.0–86.0
Zn . . . rem.

1 SOME TYPICAL USES

Architectural
Trim, weatherstrip, cold-formed angles and channels.

Chemical
Flexible hose and wide range of process piping.

Decorative
Badges, cosmetic compacts, costume jewellery, instrument and clock dials, etched articles, lipstick containers and engraved nameplates.

Hardware
Eyelets and fasteners.

Mechanical
Miscellaneous components required to be brazed; numerous drawn and formed parts; bellows; flexible hose; slide (zip) fasteners.

Plumbing
Water service lines and traps.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.75 g/cm³	0.315 lb/in³
2.2	Melting range	1 000—1 025 °C	1 830–1 875 °F
2.3	Coefficient of thermal expansion (linear) at:		
	20 to 100 °C *68 to 212 °F*	0.000 018 per °C	0.000 010 per °F
	20 to 300 °C *68 to 572 °F*	0.000 019 ,, ,,	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*	0.38 cal cm/cm² s °C	92 Btu ft/ft² h °F
	200 °C *392 °F*	0.44 ,,	106 ,,
2.6	Electrical conductivity (volume) at:		
	—196 °C *—321 °F* (annealed)	31 m/ohm mm²	54 % IACS
	20 °C *68 °F* (,,)	21 ,,	37 ,, ,,
	200 °C *392 °F* (,,)	16 ,,	27 ,, ,,
	—196 °C *—321 °F* (fully cold worked)	27 ,,	47 ,, ,,
	20 °C *68 °F* (,, ,, ,,)	19 ,,	32 ,, ,,

continued overleaf

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 12); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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2 PHYSICAL PROPERTIES (continued)

	Metric Units	English Units
2.7 Electrical resistivity (volume) at: —196 °C *—321 °F* (annealed)	0.032 ohm mm²/m 3.2 microhm cm	19 ohms (circ mil/ft) 1.3 microhm in
20 °C *68 °F* („)	0.047 ohm mm²/m 4.7 microhm cm	28 ohms (circ mil/ft) 1.8 microhm in
200 °C *392 °F* („)	0.064 ohm mm²/m 6.4 microhm cm	38 ohms (circ mil/ft) 2.5 microhm in
—196 °C *—321 °F* (fully cold worked)	0.037 ohm mm²/m 3.7 microhm cm	22 ohms (circ mil/ft) 1.5 microhm in
20 °C *68 °F* („ „ „)	0.054 ohm mm²/m 5.4 microhm cm	32 ohms (circ mil/ft) 2.1 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 6 per °C (37% IACS)	0.000 9 per °F (37% IACS)
20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 4 „ „ (32% IACS)	0.000 8 „ „ (32% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	12 400 kg/mm²	17 600 000 lb/in²
cold worked	11 400–12 400 kg/mm²	16 200 000–17 600 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	4 550 kg/mm²	6 450 000 lb/in²
cold worked	4 300–4 550 kg/mm²	6 100 000–6 450 000 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.

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	1 100–1 160 °C	2 010–2 120 °F
3.2 Annealing temperature range	425– 600 °C	795–1 110 °F
Stress relieving temperature range	200– 300 °C	390– 570 °F
3.3 Hot working temperature range	750– 900 °C	1 380–1 650 °F
3.4 Hot formability	Fair	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	85% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	25	
3.8 Joining methods:	See General Data Sheet No. 3.4	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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 (grain size 0.015 mm)	31	13	40	50 mm	80	84	23	0.2–1.5 mm thick
	Typical Cold Worked Tempers	34	25	30	50 mm	85	89	24	0.2–3 mm thick
		38	30	22	50 mm	105	110	25	"
		48	42	10	50 mm	135	140	31	0.2–2 mm thick
Rod	Annealed	28	10	50	$5.65\sqrt{S_o}$	60	63	21	—
	Typical Cold Worked Tempers	36	28	28	$5.65\sqrt{S_o}$	90	95	25	6–40 mm diam. or equivalent area
		42	34	16	$5.65\sqrt{S_o}$	120	125	27	6–12 mm diam. or equivalent area
Wire	Annealed	30	—	35	100 mm	—	—	23	1.5–6 mm diam.
		32	—	32	100 mm	—	—	24	0.2–1.5 mm diam.
	Typical Cold Drawn Tempers	42	—	8	100 mm	—	—	27	1.5–6 mm diam.
		50	—	4	100 mm	—	—	28	1.5–3 mm diam.
		60	—	—	—	—	—	30	0.2–1.5 mm diam.
Tube	Annealed	28	11	50	$5.65\sqrt{S_o}$	60	63	21	—
	Typical Cold Drawn Tempers	36	28	25	$5.65\sqrt{S_o}$	95	100	25	10–50 mm O.D. over 2 mm wall
		44	38	12	$5.65\sqrt{S_o}$	125	130	29	up to 25 mm O.D. up to 2 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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation % on $4.52\sqrt{S_o}$	Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi				kg m/cm²	ft lb
Rod[1] 19 mm diam. 0.75 in. diam.	Cold Worked 14%	22	72	28.5	18	**40 400**	**9.14**[a]	**48**	**74**	16.6[b]	**96**[b]
		− 78	−108	32.5	21	**46 500**	**9.84**[a]	**63**	**79**	14.2[b]	**82**[b]
		−197	−323	43.5	27.5	**62 000**	**11.5**[a]	**83**	**77**	13.5[b]	**78**[b]
		−253	−423	55.5	35.5	**79 200**	**14.7**[a]	**80**	**75**	13.1[b]	**76**[b]
		−269	−452	50	31.5	**71 000**	**12.9**[a]	**82**	**71**	—	—
Rod[2]	Annealed (grain size 0.020 mm)	−195	−319	46.5	29.5	**65 800**	**13.7**[a]	—	—	—	—
Rod[3]	Annealed	10	50	—	—	—	—	—	—	14.4[c]	**52**[c]
		− 18	0	—	—	—	—	—	—	14.7[c]	**53**[c]
		− 29	− 20	—	—	—	—	—	—	15.2[c]	**55**[c]
		− 51	− 60	—	—	—	—	—	—	15.5[c]	**56**[c]
		− 79	−110	—	—	—	—	—	—	15.5[c]	**56**[c]
		−118	−180	—	—	—	—	—	—	16.6[c]	**60**[c]

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

(b) Charpy test, 10 × 10 × 55 mm specimen, 45° V-notch, 2 mm deep; cross-sectional area at the notch 0.8 cm².

(c) Charpy specimen, keyhole notch; 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 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% 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			Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	
Plate[4]	Annealed	20	68	30	**19.2**	43 000	**8.66**[a]	**5.1**	—	**50**
		66	150	28	**17.7**	39 500	**8.19**[a]	**4.9**	—	**51**
		121	250	26.5	**16.8**	37 500	**8.50**[a]	**5.1**	—	**45**
		177	350	25.5	**16.1**	36 000	**7.87**[a]	**4.8**	—	**45**
		232	450	24.5	**15.4**	34 500	**7.87**[a]	**4.8**	—	**36**
Rod[5] 3.2 mm diam 0.125 in. diam.	Annealed (grain size 0.060 mm)	24	75	29	18.5	**41 000**	—	—	**10 000**	**47.0**
		149	300	—	—	—	—	—	**9 700**	—
		204	400	—	—	—	—	—	**9 500**	—
		260	500	—	—	—	—	—	**8 500**	—
	Cold Worked 37%	24	75	47.5	30	**67 500**	—	—	**59 000**	**10.5**
		204	400	—	—	—	—	—	**47 000**	—
	Cold Worked 84%	24	75	68	43	**96 500**	—	—	**67 000**	**7.0**
		204	400	—	—	—	—	—	**52 000**	—
Rod[6] 12.7 mm diam. 0.5 in. diam.	Annealed	25	77	28	17.5	**39 500**	8.79[b]	—	—	—
		300	572	21.5	13.5	**30 600**	7.56[b]	—	—	—
		500	932	10	6.5	**14 500**	5.23[b]	—	—	—
Rod[7] 19 mm diam. 0.75 in. diam.	Hot Worked (grain size 0.030 mm)	24	75	31	19.5	**43 800**	—	—	—	**47.0**
		204	400	27	17	**38 525**	—	—	—	**35.5**
		316	600	21	13.5	**29 950**	—	—	—	—
		427	800	14	9	**20 250**	—	—	—	**4.2**
Rod[8]	Cold Worked 37%	200	392	41.5	26	**58 800**	—	—	**54 800**	**7.3**
		300	572	36.5	23	**51 800**	—	—	**49 000**	**4.5**
		400	752	22	14	**31 400**	—	—	**24 500**	**17.0**
		500	932	11	7	**15 800**	—	—	**10 500**	**25.7**
		600	1 112	6.5	4	**9 200**	—	—	**7 600**	**27.7**
		700	1 292	4	2.5	**5 600**	—	—	**4 700**	**62.0**
Tube[9]	Annealed	Room	Room	28	18	**40 000**	—	—	**12 000**	—
		66	150	28	18	**40 000**	—	—	**12 000**	—
		121	250	27.5	17.5	**39 000**	—	—	**12 000**	—
		149	300	26.5	17	**38 000**	—	—	**12 000**	—
		177	350	26	16.5	**37 000**	—	—	**12 000**	—
		204	400	25.5	16	**36 000**	—	—	**12 000**	—
		232	450	24.5	15.5	**35 000**	—	—	**11 500**	—
		260	500	23	14.5	**33 000**	—	—	**11 000**	—

(a) This value was originally reported in ton/in²; in this table it is given in kg/mm² to 3 significant figures.
(b) 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.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature °C	Testing Temperature °F	Stress kg/mm²	Stress ton/in²	Stress psi	Duration h	Total Extension %[(a)]	Intercept %	Min. Creep Rate % per 1 000 h
Rod[(5)] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.060 mm)	149	300	3.2	2.0	**4 500**	**4 500**	**0.031**	**0.006**	**0.000 7**
				4.9	3.1	**6 960**	**5 100**	**0.087**	**0.024**	**0.002 9**
				6.9	4.4	**9 800**	**4 500**	**1.07**	**0.44**	**0.026**
		204	400	0.70	0.45	**1 000**	**4 400**	**0.022**	**0.008**	**0.000 8**
				1.4	0.92	**2 050**	**5 060**	**0.042**	**0.013**	**0.001 9**
				2.5	1.6	**3 500**	**5 100**	**0.092**	**0.040**	**0.003 3**
				3.5	2.3	**5 040**	**5 400**	**0.097**	**0.015**	**0.005 9**
				4.9	3.1	**6 940**	**6 600**	**0.482**	**0.187**	**0.034**
				6.3	4.0	**8 940**	**2 000**	**1.060**	**0.390**	**0.10**
				8.1	5.1	**11 500**	**4 130**	**3.620**	**0.750**	**0.283**
		260	500	0.60	0.38	**850**	**5 140**	**0.042**	**0.010**	**0.004 0**
				1.4	0.89	**2 000**	**5 000**	**0.091**	**0.026**	**0.008 0**
				2.5	1.6	**3 520**	**5 300**	**0.241**	**0.037**	**0.030**
				3.5	2.2	**4 980**	**5 000**	**0.507**	**0.083**	**0.073**
				4.2	2.7	**6 000**	**5 140**	**0.958**	**0.180**	**0.138**
				4.9	3.1	**6 950**	**1 600**	**1.100**	**0.510**	**0.32**
	Cold Worked 37%	149	300	3.5	2.3	**5 040**	**5 200**	**0.050**	**0.018**	**0.000 4**
				7.0	4.4	**9 900**	**4 800**	**0.110**	**0.037**	**0.002 4**
				9.2	5.8	**13 050**	**5 050**	**0.138**	**0.044**	**0.002 8**
				12.4	7.9	**17 650**	**5 100**	**0.227**	**0.083**	**0.006 7**
				16.8	10.6	**23 850**	**6 050**	**0.366**	**0.153**	**0.011**
				21.2	13.5	**30 200**	**4 800**	**0.628**	**0.220**	**0.043**
		204	400	3.5	2.2	**4 980**	**5 200**	**0.077**	**0.039**	**0.002 6**
				5.7	3.6	**8 100**	**5 400**	**0.135**	**0.054**	**0.006 9**
				8.3	5.3	**11 850**	**5 200**	**0.283**	**0.146**	**0.013**
				11.0	7.0	**15 650**	**4 420**	**0.422**	**0.151**	**0.041**
		260	500	0.37	0.23	**520**	**5 100**	**0.042**	**0.008**	**0.005 6**
				0.69	0.44	**980**	**10 370**	**0.179**	**0.055**	**0.011**
				2.1	1.4	**3 050**	**10 000**	**0.967**	**0.073**	**0.086**
				4.3	2.7	**6 050**	**4 800**	**1.114**	**−0.70**	**0.37[(b)]**
	Cold Worked 84%	149	300	7.0	4.4	**9 960**	**4 400**	**0.096**	**0.029**	**0.000 7**
				13.9	8.8	**19 800**	**5 100**	**0.197**	**0.054**	**0.002 6**
				27.9	17.7	**39 700**	**4 500**	**0.445**	**0.108**	**0.011**
				37.8	24.0	**53 800**	**5 100**	**0.860**	**0.250**	**0.033**
		204	400	0.73	0.46	**1 040**	**5 160**	**0.040**	**0.029**	**0.001 1**
				2.2	1.4	**3 190**	**5 000**	**0.163**	**0.061**	**0.017**
				3.8	2.4	**5 400**	**5 160**	**0.461**	**0.110**	**0.063**
				4.2	2.7	**6 040**	**5 000**	**0.505**	**0.120**	**0.069**
		260	500	0.42	0.27	**600**	**5 540**	**0.096**	**0.038**	**0.010**
				0.67	0.43	**960**	**5 300**	**0.270**	**0.080**	**0.034**
				1.4	0.87	**1 940**	**2 950**	**0.678**	**0.104**	**0.19**
				2.1	1.3	**2 990**	**3 650**	**2.715**	**−0.045**	**0.76[(b)]**

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Accelerating creep rate.

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

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate								
		°C	°F	0.001% per 1 000 h			0.01% per 1 000 h			0.1% per 1 000 h		
				kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod[5] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.060 mm)	149	300	3.7	2.3	**5 200**	6.0	3.8	**8 600**	> 7.0	> 4.5	> **10 000**
		204	400	0.88	0.56	**1 250**	3.9	2.5	**5 500**	6.3	4.0	**9 000**
		260	500	—	—	—	1.6	1.0	**2 250**	3.7	2.3	**5 200**
	Cold Worked 37%	149	300	5.5	3.5	**7 800**	15.5	9.8	**22 000**	> 21.0	> 13.4	> **30 000**
		204	400	2.0	1.3	**2 800**	7.0	4.5	**10 000**	13.1	8.3	**18 700**
		260	500	—	—	—	0.60	0.38	**850**	2.3	1.5	**3 300**
	Cold Worked 84%	149	300	8.4	5.5	**12 000**	26.0	16.5	**37 000**	> 38.7	> 24.6	> **55 000**
		204	400	0.70	0.44	**1 000**	1.8	1.2	**2 600**	4.8[a]	3.0[a]	**6 800**[a]
		260	500	—	—	—	0.42	0.27	**600**	1.0	0.65	**1 450**

(a) Extrapolated value.

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 $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Strip[10] 0.81 mm 0.032 in.	Annealed (grain size 0.020 mm)	100	31	11.5[a]	19.5	7.5[a]	**44 000**	**16 500**[a]
	Annealed (grain size 0.025 mm)	100	29.5	10[a]	18.5	6.5[a]	**42 000**	**14 500**[a]
	Annealed (grain size 0.075 mm)	100	27.5	7.5[a]	17.5	4.5[a]	**39 000**	**10 500**[a]
	Annealed (grain size 0.090 mm)	100	27	7.5[a]	17	5[a]	**38 500**	**11 000**[a]
	Cold Worked 21%[b]	100	39.5	16[a]	25	10[a]	**56 500**	**22 500**[a]
	Cold Worked 21%[c]	100	35	10.5[a]	22.5	6.5[a]	**50 000**	**15 000**[a]
	Cold Worked 37%[d]	100	48.5	15[a]	31	9.5[a]	**69 000**	**21 000**[a]
	Cold Worked 37%[e]	100	45	13.5[a]	28.5	8.5[a]	**64 000**	**19 000**[a]
	Cold Worked 60%[f]	100	55.5	17[a]	35.5	10.5[a]	**79 000**	**24 000**[a]
	Cold Worked 60%[e]	100	55.5	16.5[a]	35.5	10.5[a]	**79 000**	**23 500**[a]
Strip[11] 1 mm 0.04 in.	Cold Worked[g]	100	59	10.5[a]	37.5	6.5[a]	**84 000**	**15 000**[a]
Rod[12] 12.7 mm diam. 0.5 in. diam.	Cold Worked 4%	300	31.5	14[h]	20	9[h]	**44 700**	**20 000**[h]
Rod[13]	Cold Worked and Stress Relieved[i]	60	37.5	11[h]	23.5	7[h]	**53 000**	**16 000**[h]
	Cold Worked and Annealed[j]	100	28.5	11[h]	18	7[h]	**40 500**	**15 500**[h]

[a] Reversed-bending test. [b] Ready-to-finish grain size 0.020 mm. [c] Ready-to-finish grain size 0.060 mm. [d] Ready-to-finish grain size 0.030 mm. [e] Ready-to-finish grain size 0.070 mm. [f] Ready-to-finish grain size 0.025 mm. [g] Quoted as "spring" in original document, but amount of cold work not defined. [h] Rotating-beam test. [i] Stress relieved for 3 h at 232 °C (*450 °F*) [j] Annealed for 3 h at 482 °C (*900 °F*).

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

Cu Zn20

Common names: 80/20 Brass
80/20 Gilding Metal
Low Brass

A copper–zinc alloy with an alpha phase structure. The alloy has excellent cold-working properties and is generally resistant to dezincification and stress corrosion in most environments. Due to this combination of properties and its attractive colour, the alloy is widely used for decorative purposes and for miscellaneous formed and brazed components.

COMPOSITION (weight %)

Cu	78.5–81.5
Zn	rem.

1 SOME TYPICAL USES

Architectural
Ornamental metalwork; cold-formed angles, channels and trim.

Chemical
Wire for Fourdrinier paper screens; wire cloth.

Decorative
Clock and instrument dials; costume jewellery.

Electrical
Battery caps.

Mechanical
Miscellaneous components required to be brazed; numerous drawn and formed parts; bellows; flexible hose; slide (zip) fasteners.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.65 g/cm³	0.315 lb/in³
2.2	Melting range	970–1 010 °C	1 780–1 850 °F
2.3	Coefficient of thermal expansion (linear) at:		
	20 to 100 °C *68 to 212 °F*	0.000 018 per °C	0.000 010 per °F
	20 to 300 °C *68 to 572 °F*	0.000 019 ,, ,,	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:		
	–200 °C *–328 °F*	0.17 cal cm/cm² s °C	40 Btu ft/ft² h °F
	20 °C *68 °F*	0.33 ,,	81 ,,
	200 °C *392 °F*	0.40 ,,	97 ,,
2.6	Electrical conductivity (volume) at:		
	–196 °C *–321 °F* (annealed)	28 m/ohm mm²	49 % IACS
	20 °C *68 °F* (,,)	19 ,,	32 ,, ,,
	200 °C *392 °F* (,,)	14 ,,	25 ,, ,,
	–196 °C *–321 °F* (fully cold worked)	23 ,,	40 ,, ,,
	20 °C *68 °F* (,, ,, ,,)	16 ,,	27 ,, ,,

continued overleaf

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. D4
Cu Zn20

2 PHYSICAL PROPERTIES (continued)

	Metric Units	English Units
2.7 Electrical resistivity (volume) at:		
—196 °C *—321 °F* (annealed)	0.035 ohm mm²/m 3.5 microhm cm	21 ohms (circ mil/ft) 1.4 microhm in
20 °C *68 °F* (,,)	0.054 ohm mm²/m 5.4 microhm cm	32 ohms (circ mil/ft) 2.1 microhm in
200 °C *392 °F* (,,)	0.070 ohm mm²/m 7.0 microhm cm	42 ohms (circ mil/ft) 2.8 microhm in
—196 °C *—321 °F* (fully cold worked)	0.043 ohm mm²/m 4.3 microhm cm	26 ohms (circ mil/ft) 1.7 microhm in
20 °C *68 °F* (,, ,, ,,)	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) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 5 per °C (32% IACS)	0.000 9 per °F (32% IACS)
20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 3 ,, ,, (27% IACS)	0.000 7 ,, ,, (27% IACS)
2.9 Modulus of elasticity (tension) at 20°C *68 °F*		
annealed	12 100 kg/mm²	17 200 000 lb/in²
cold worked	10 600–12 100 kg/mm²	15 100 000–17 200 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	4 400 kg/mm²	6 250 000 lb/in²
cold worked	4 150–4 400 kg/mm²	5 900 000–6 250 000 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.

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	1 100–1 150 °C	2 010–2 100 °F
3.2 Annealing temperature range	425– 600 °C	795–1 110 °F
Stress relieving temperature range	200– 300 °C	390– 570 °F
3.3 Hot working temperature range	750– 900 °C	1 380–1 650 °F
3.4 Hot formability	Fair	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	85% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	30	
3.8 Joining methods:	See General Data Sheet No. 3.4	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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 grain size 0.025 mm	31	12	52	50 mm	75	79	23	0.2–2.5 mm thick
	Annealed grain size 0.015 mm	33	14	50	50 mm	85	89	25	0.2–1.5 mm thick
	Typical Cold Worked Tempers	42	30	28	50 mm	115	120	29	0.2–3 mm thick
		51	44	10	50 mm	145	150	30	0.2–2 mm thick
		57	48	5	50 mm	155	160	32	0.2–1.5 mm thick
Rod	Annealed	30	12	58	$5.65\sqrt{S_o}$	65	68	23	—
	Typical Cold Worked Tempers	38	29	35	$5.65\sqrt{S_o}$	90	95	27	6–40 mm diam. or equivalent area
		44	38	20	$5.65\sqrt{S_o}$	125	130	29	6–12 mm diam. or equivalent area
Wire	Annealed	33	—	40	100 mm	—	—	25	1.5–6 mm diam.
		35	—	38	100 mm	—	—	26	0.2–1.5 mm diam.
	Typical Cold Drawn Tempers	43	—	10	100 mm	—	—	29	1.5–6 mm diam.
		54	—	3	100 mm	—	—	30	1.5–3 mm diam.
		64	—	—	—	—	—	32	0.2–1.5 mm diam.
Tube	Annealed	32	12	52	$5.65\sqrt{S_o}$	70	74	24	—
	Typical Cold Drawn Tempers	38	29	30	$5.65\sqrt{S_o}$	100	105	27	10–50 mm O.D. over 2 mm wall
		46	39	16	$5.65\sqrt{S_o}$	130	135	30	up to 25 mm O.D. up to 2 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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Impact Properties

Form	Temper	Testing Temperature		Impact Strength[a]	
		°C	°F	kg m/cm²	ft lb
—[1][b]	Annealed	20	68	15.0	**54**
		–23	–9	15.1	**54.5**
		–77	–107	15.2	**55**
		–123	–189	16.6	**60**
		–173	–279	18.5	**67**
		–195	–319	19.1	**69**
	Cold Drawn 27%	20	68	8.8	**32**
		–23	–9	9.4	**34**
		–77	–107	10.0	**36**
		–123	–189	10.2	**37**
		–173	–279	10.5	**38**
		–195	–319	10.6	**38.5**

(a) Charpy specimen, keyhole notch; cross-sectional area at the notch 0.5 cm².

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

—Data not available:
Tensile strength
Proof stress, 0.1% and 0.2% offset
Yield strength, 0.5% extension under load
Elongation
Reduction of Area

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi	
Rod[2] **12.8 mm diam. 0.505 in. diam.**	Cold Worked 30%	23	73	57	36	**80 800**	**13**
		250	482	34	21.5	**48 700**	**0**
		400	752	14.5	9.5	**20 800**	**7**
		500	932	4.5	3	**6 600**	**16**
		625	1 157	2.5	1.5	**3 800**	**19**
		750	1 382	2	1	**2 700**	**29**
		850	1 562	1	0.6	**1 400**	**30**
		900	1 652	0.7	0.4	**1 000**	**36**

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% extension under load.

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[3] 0.81 mm 0.032 in.	Annealed (grain size 0.035 mm)	100	32.5	10[a]	20.5	6.5[a]	**46 200**	**14 000[a]**
	Cold Worked 21%	100	44.5	13.5[a]	28.5	8.5[a]	**63 600**	**19 000[a]**
	Cold Worked 37%	100	54	16[a]	34.5	10[a]	**76 900**	**22 500[a]**
	Cold Worked 60%	100	62	15.5[a]	39.5	10[a]	**88 000**	**22 000[a]**
Flat Products[4] 1 mm 0.04 in.	Cold Worked[b]	20	64	17[a]	40.5	10.5[a]	**91 000**	**24 000[a]**
Sheet[5] 2.54 mm 0.10 in.	Annealed (grain size 0.04 mm)	2	—	14[a]	—	9[a]	—	**20 000[a]**
Rod[6] 19 mm diam. 0.75 in. diam.	Annealed	50	32	15.5[c]	20	10[c]	**45 300**	**22 400[c]**
	Cold Worked 27%	50	51	15[c]	32.5	9.5[c]	**72 700**	**21 500[c]**
	Cold Worked 27% and Stress Relieved[d]	50	49	17.5[c]	31.5	11[c]	**70 300**	**25 000[c]**
Rod[7] 25.4 mm diam. 1 in. diam.	Annealed	90	31	12.5[c]	19.5	8[c]	**44 000**	**17 500[c]**
	Cold Worked	100	54	16[c]	34	10.5[c]	**76 500**	**23 000[c]**
	Cold Worked and Stress Relieved[e]	40	56.5	18.5[c]	36	11.5[c]	**80 500**	**26 000[c]**
Rod[8] 25.4 mm diam. 1 in. diam.	Cold Worked and Stress Relieved[f]	100	41	15[c]	26	9.5[c]	**58 000**	**21 000[c]**
	Cold Worked and Annealed[g]	40	32	12[c]	20.5	7.5[c]	**45 500**	**17 000[c]**
Wire[9] 1.8 mm diam. 0.072 in. diam.	Cold Worked 60%	100	62.5	16[c]	39.5	10.5[c]	**89 000**	**23 000[c]**
	Cold Worked 84%	100	76	18.5[c]	48	12[c]	**108 000**	**26 500[c]**
Wire[4] 2 mm diam. 0.08 in. diam.	Cold Worked[h]	100	75	16[c]	48	10.5[c]	**107 000**	**23 000[c]**
	Cold Worked[b]	100	88	18.5[c]	56	11.5[c]	**125 000**	**26 000[c]**

[a] Reversed-bending test. [b] Quoted as "spring" in original document, but amount of cold work not defined. [c] Rotating-beam test. [d] Stress relieved for 1 h at 275 °C *(527 °F)*. [e] Stress relieved for 1 h at 232 °C *(450 °F)*. [f] Stress relieved for 2 h at 232 °C *(450 °F)*. [g] Annealed for 2 h at 482 °C *(900 °F)*. [h] 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.

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Reed, R.P. and Mikesell, R.P. Low-Temperature Mechanical Properties of Copper and Selected Copper Alloys. US Dept. Commerce, Nat. Bureau of Standards Monograph 101 (1967).

(2) Price, W.B. Properties of Copper and Some of its Important Industrial Alloys at Elevated Temperatures. ASTM-ASME Symposium on Effect of Temperature on the Properties of Metals, (1931), pp. 340–367.

(3) 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.

(4) Metals Handbook. Vol. 1, 8th ed. American Society for Metals, Cleveland, Ohio, (1961), p. 1018.

(5) Phillips, W.L. Effect of Prestress Level on Fatigue Life of Alpha-Brass. Trans. ASM, Vol. 58 (1965), pp. 223–225.

(6) Kommers, J.B. The Static and Fatigue Properties of Brass. Proc. ASTM, Vol. 31 (1931), Pt. 2, pp. 243–258.

(7) McAdam, D.J., Jr. Effect of Cold Working on Endurance and Other Properties of Metals, Part I. Trans. ASST, Vol. 8 (1925), pp. 782–822.

(8) Wilkins, R.A. and Bunn, E.S. Copper and Copper-Base Alloys. McGraw-Hill Book Company, New York, (1943).

(9) Burghoff, H.L. and Blank, A.I. Fatigue Tests on Some Copper Alloys in Wire Form. Proc. ASTM, Vol. 43 (1943), pp. 774–784.

Cu Zn28
Cu Zn30

This data sheet covers both Cu Zn28 and Cu Zn30, since these alloys have very similar compositions and properties.

Common names: 70/30 Brass
Cartridge Brass
Deep-Drawing Brass

Two copper–zinc alloys with an alpha phase structure. The alloys exhibit the optimum combination of strength and ductility in the copper–zinc series and are commonly used whenever extreme cold deformation is involved. Cu Zn28 is produced only in some European countries for applications for which American and British industrial practice would specify Cu Zn30. Service environment for both alloys must be considered to predict corrosion behaviour. A typical application of these alloys is for deep-drawn components such as cartridge cases. Cu Zn30 also includes the inhibited variety containing arsenic, which is generally used for heat-exchanger tubes.

COMPOSITION (weight %)

Cu Zn28		Cu Zn30*	
Cu	71.0–73.0	Cu	68.5–71.5
Zn	rem.	Zn	rem.

*Arsenic is sometimes added as a corrosion inhibitor.

1 SOME TYPICAL USES

Chemical
Heat-exchanger tubes handling fresh, clean water; sugar evaporators and juice heaters; fire-extinguisher bodies.

Electrical
Lamp caps and lampholder components.

Hardware
Chain, eyelets, fasteners, hinges, locks, fingerplates, wire cloth, wire brushes.

Mechanical
Wide variety of deep-drawn and spun components, including cartridge cases and musical instruments; automobile radiator tanks and tubes; carburettor parts; wire reinforcements in brake and clutch linings; general industrial pressings formed from sheet and strip; torch and flashlight cases; reflectors; cold-headed or "upset" products such as rivets, pins and screws.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.55 g/cm³	0.310 lb/in³
2.2 Melting range	910–965 °C	1 670–1 770 °F
2.3 Coefficient of thermal expansion (linear) at:		
–128 to 20 °C *–200 to 68 °F*	0.000 009 per °C	0.000 005 per °F
20 to 100 °C *68 to 212 °F*	0.000 019 ,, ,,	0.000 010 ,, ,,
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
200 °C *392 °F*	0.11 ,,	0.11 ,,
2.5 Thermal conductivity at:		
–200 °C *–328 °F*	0.12 cal cm/cm² s °C	30 Btu ft/ft² h °F
20 °C *68 °F*	0.29 ,,	70 ,,
200 °C *392 °F*	0.35 ,,	85 ,,
2.6 Electrical conductivity (volume) at:		
–196 °C *–321 °F* (annealed)	24 m/ohm mm²	41 % IACS
20 °C *68 °F* (,,)	16 ,,	28 ,, ,,
200 °C *392 °F* (,,)	13 ,,	22 ,, ,,
–196 °C *–321 °F* (fully cold worked)	18 ,,	31 ,, ,,
20 °C *68 °F* (,, ,, ,,)	13 ,,	22 ,, ,,

continued overleaf

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 12); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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Cu Zn28 — Cu Zn30
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2 PHYSICAL PROPERTIES (continued)

	Metric Units	English Units
2.7 Electrical resistivity (volume) at:		
−196 °C −*321* °F (annealed)	0.042 ohm mm²/m 4.2 microhm cm	25 ohms (circ mil/ft) 1.7 microhm in
20 °C *68* °F (,,)	0.062 ohm mm²/m 6.2 microhm cm	37 ohms (circ mil/ft) 2.4 microhm in
200 °C *392* °F (,,)	0.079 ohm mm²/m 7.9 microhm cm	47 ohms (circ mil/ft) 3.1 microhm in
−196 °C −*321* °F (fully cold worked)	0.056 ohm mm²/m 5.6 microhm cm	33 ohms (circ mil/ft) 2.2 microhm in
20 °C *68* °F (,, ,, ,,)	0.078 ohm mm²/m 7.8 microhm cm	47 ohms (circ mil/ft) 3.1 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 (28% IACS)	0.000 8 per °F (28% IACS)
20 °C *68* °F (fully cold worked) applicable over range from 0 to 100 °C *32 to 212* °F	0.001 2 ,, ,, (22% IACS)	0.000 7 ,, ,, (22% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68* °F		
annealed	11 700 kg/mm²	16 600 000 lb/in²
cold worked	9 900–11 700 kg/mm²	14 100 000–16 600 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68* °F		
annealed	4 150 kg/mm²	5 900 000 lb/in²
cold worked	3 700–4 150 kg/mm²	5 250 000–5 900 000 lb/in²

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

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	1 070–1 110 °C	1 960–2 030 °F
3.2 Annealing temperature range	450– 680 °C	840–1 255 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	750– 870 °C	1 380–1 600 °F
3.4 Hot formability	Fair	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	90% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	30	
3.8 Joining methods:	See General Data Sheet No. 3.4	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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								
	grain size 0.035 mm	33	12	60	$5.65\sqrt{S_o}$	65	68	25	0.2–5 mm thick
	grain size 0.025 mm	35	14	57	50 mm	80	84	26	0.2–2.5 mm thick
	grain size 0.015 mm	37	15	55	50 mm	85	89	28	0.2–1.5 mm thick
	Typical Cold Worked Tempers	38	23	40	50 mm	95	100	27	0.2–3 mm thick
		42	32	32	50 mm	120	125	28	"
		48	40	18	50 mm	135	140	30	0.2–2 mm thick
		52	47	10	50 mm	145	150	31	"
		57	54	6	50 mm	155	160	32	0.2–1.5 mm thick
		60	—	—	—	160	170	33	0.2–1 mm thick
Rod	Annealed	32	12	62	$5.65\sqrt{S_o}$	65	68	24	—
	Typical Cold Worked Tempers	36	20	45	$5.65\sqrt{S_o}$	80	84	26	—
		40	30	35	$5.65\sqrt{S_o}$	110	115	28	6–40 mm diam. or equivalent area
		46	39	20	$5.65\sqrt{S_o}$	125	130	30	6–12 mm diam. or equivalent area
Wire	Annealed	36	—	48	100 mm	—	—	26	1.5–6 mm diam.
		38	—	38	100 mm	—	—	27	0.5–1.5 mm diam.
		42	—	22	100 mm	—	—	28	up to 0.5 mm diam.
	Typical Cold Drawn Tempers	40	—	35	100 mm	—	—	27	1.5–6 mm diam.
		55	—	10	100 mm	—	—	30	"
		65	—	—	—	—	—	35	1.5–3 mm diam.
		78	—	—	—	—	—	39	"
		44	—	18	100 mm	—	—	29	0.5–1.5 mm diam.
		58	—	3	100 mm	—	—	32	"
		70	—	—	—	—	—	35	"
		85	—	—	—	—	—	43	"
Tube[(c)]	Annealed								
	—[(d)]	33	13	58	$5.65\sqrt{S_o}$	65	68	25	—
	grain size 0.030 mm	**34**	**13**	**55**	$5.65\sqrt{S_o}$	**65**	**68**	**26**	15—30 mm O.D. 0.8— 2 mm wall
	grain size 0.020 mm	**37**	**18**	**45**	$5.65\sqrt{S_o}$	**75**	**79**	**27**	"
	Typical Cold Drawn Tempers	40	32	30	$5.65\sqrt{S_o}$	110	115	28	10–50 mm O.D. over 2 mm wall
		48	42	15	$5.65\sqrt{S_o}$	135	140	31	up to 25 mm O.D. up to 2 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) Tubes for heat exchangers and condensers are generally supplied only to the tempers whose representative mechanical properties are printed in **bold type.**

(d) Grain size not defined.

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]
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	10	40	$5.65\sqrt{S_o}$	110	19	1–2 in. diam. or equivalent area
		27	14	35	$5.65\sqrt{S_o}$	125	20	0.375–1 in. diam. or equivalent area
		30	18	25	$5.65\sqrt{S_o}$	140	21	0.125–0.375 in. diam. or equivalent area
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			Proof Stress			Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength psi	%	gauge length		kg m/cm²	ft lb
Rod[1] **19 mm diam. 0.75 in. diam.**	Cold Worked[a]	20	68	67	42.5	**95 200**	**42.8**[b]	—	—	**14.2**	$4.52\sqrt{S_o}$	**58.3**	2.7[c]	**15.5**[c]
		-78	-108	71	45	**100 800**	**45.2**[b]	—	—	**17.3**	$4.52\sqrt{S_o}$	**62.3**	2.7[c]	**15.5**[c]
		-197	-323	82.5	52	**117 000**	**48.2**[b]	—	—	**28.4**	$4.52\sqrt{S_o}$	**63.4**	2.7[c]	**15.5**[c]
		-253	-423	93	59	**132 500**	**51.6**[b]	—	—	**32.2**	$4.52\sqrt{S_o}$	**58.2**	—	—
Rod[2] **25.4 mm diam. 1.0 in. diam.**	Annealed[d]	20	68	36	**22.8**	51 000	—	**12.57**	—	**49.4**	2 in.	**77.0**	11.3[e]	**65.5**[e]
		-10	14	37.5	**23.7**	53 000	—	**12.75**	—	**48.5**	2 in.	**77.0**	—	—
		-40	-40	38.5	**24.4**	54 500	—	**12.0**	—	**57.7**	2 in.	**77.0**	11.4[e]	**66.0**[e]
		-80	-112	40	**25.5**	57 000	—	**12.17**	—	**59.5**	2 in.	**79.0**	11.9[e]	**69.0**[e]
		-120	-184	43	**27.3**	61 000	—	**12.5**	—	**54.7**	2 in.	**77.5**	12.2[e]	**70.5**[e]
		-180	-292	51.5	**32.8**	73 500	—	**13.2**	—	**74.6**	2 in.	**73.0**	13.6[e]	**78.5**[e]
	Annealed[f]	20	68	37.5	**23.9**	53 500	—	**15.4**	—	**58.0**	2 in.	**74.0**	11.3[e]	**65.5**[e]
		-180	-292	51.5	**32.8**	73 500	—	**19.2**[g]	—	**81.0**	2 in.	**74.0**	13.6[e]	**78.5**[e]
Rod[3]	Annealed	18	64	29	18.5	**41 500**	—	—	**9 500**[g]	**82.6**	2 in.	**76.4**	14.7[c]	**85**[c]
		0	32	30	19	**42 800**	—	—	**9 800**[g]	**79.7**	2 in.	**78.7**	14.9[c]	**86**[c]
		-30	-22	30.5	19.5	**43 200**	—	—	**10 400**[g]	**75.9**	2 in.	**79.7**	15.5[c]	**89.5**[c]
		-80	-112	34	21.5	**48 600**	—	—	**12 200**[g]	**74.5**	2 in.	**80.0**	15.4[c]	**89**[c]

[a] Quoted as "¾ hard" in original document, but amount of cold work not defined. [b] This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures. [c] Charpy specimen, V-notch; cross-sectional area at the notch 0.8 cm². [d] Tensile specimen 6.35 mm (0.25 in.) diam. [e] Izod specimen, cross-sectional area at the notch 0.8 cm². [f] Tensile specimen 12.8 mm (0.505 in.) diam. [g] Quoted as 'yield point' in original document, but offset strain not defined.

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

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

—The yield strength 0.5% extension under load values are not available.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	
Strip[4] 2 mm 0.08 in.	Annealed (grain size 0.035 mm)	20	68	34	**21.5**	48 000	—	**6.4**	—	**64**
		100	212	32	**20.4**	45 500	—	**6.1**	—	**58**
		200	392	30	**19.0**	42 500	—	**6.0**	—	**54**
		250	464	27.5	**17.5**	39 000	—	**5.8**	—	**46**
		300	572	24.5	**15.4**	34 500	—	**5.7**	—	**32**
Plate[5]	Annealed	20	68	33.5	**21.4**	48 000	9.13[a]	**5.6**	—	**68**
		66	150	31.5	**20.1**	45 000	8.35[a]	**5.2**	—	**64**
		121	250	30.5	**19.3**	43 000	8.82[a]	**5.5**	—	**63**
		177	350	29.5	**18.8**	42 000	8.82[a]	**5.3**	—	**64**
		232	450	25.5	**16.1**	36 000	8.50[a]	**5.2**	—	**33**
Rod[6] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.016 mm)	24	75	42	26.5	**59 500**	—	—	**22 200**	**42**
		149	300	—	—	—	—	—	**22 900**	—
		204	400	—	—	—	—	—	**22 200**	—
		260	500	—	—	—	—	—	**19 900**	—
	Annealed (grain size 0.022 mm)	24	75	36.5	23	**52 000**	—	—	**19 000**	**49.0**
		149	300	—	—	—	—	—	**19 000**	—
		204	400	—	—	—	—	—	**18 800**	—
		260	500	—	—	—	—	—	**16 900**	—
	Annealed (grain size 0.085 mm)	24	75	34	21.5	**48 500**	—	—	**11 300**	**57.0**
		149	300	—	—	—	—	—	**12 700**	—
		204	400	—	—	—	—	—	**11 500**	—
		260	500	—	—	—	—	—	**11 000**	—
Rod[7] 12.8 mm diam. 0.505 in. diam.	Cold Worked 20%	25	77	44.5	28.5	**63 300**	—	—	—	**25**
		200	392	41.5	26.5	**58 800**	—	—	—	**16**
		310	590	34	21.5	**48 200**	—	—	—	**4**
		460	860	9.5	6	**13 500**	—	—	—	**25**
		615	1 139	3	2	**4 500**	—	—	—	**26**
		735	1 355	1.5	1	**2 300**	—	—	—	**53**
		835	1 535	0.8	0.5	**1 200**	—	—	—	**91**
		885	1 625	0.4	0.3	**600**	—	—	—	**43**
Rod[8] 16 mm diam. 0.625 in. diam.	Cold Worked 30%	24	75	49	31.5	**70 000**	—	—	—	**24.3**
		204	400	46	29.5	**65 550**	—	—	—	**12.0**
		316	600	36	23	**51 500**	—	—	—	**4.5**
		427	800	15	9.5	**21 000**	—	—	—	**26.0**
		538	1 000	6.5	4	**9 400**	—	—	—	**24.5**

[a] This value was originally reported in ton/in²; 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.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature °C	Testing Temperature °F	Stress kg/mm²	Stress ton/in²	Stress psi	Duration h	Total Extension %(a)	Intercept %	Min. Creep Rate % per 1 000 h
Rod(6) 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.016 mm)	149	300	3.2	2.0	4 500	5 210	0.045	0.016	0.002 2
				10.6	6.7	15 050	4 680	0.204	0.081	0.014
				14.1	9.0	20 100	4 800	0.570	0.240	0.053
		204	400	0.72	0.46	1 020	5 100	0.047	0.024	0.002 9
				1.4	0.88	1 980	3 240	0.044	0.011	0.005 7
				2.1	1.4	3 040	5 400	0.104	0.023	0.011
				4.2	2.7	5 980	5 400	0.339	0.069	0.042
		260	500	0.37	0.23	520	5 000	0.111	0.059	0.009 3
				0.70	0.44	990	5 000	0.190	0.038	0.028 2
				1.0	0.66	1 480	4 650	0.335	0.033	0.061 0
				2.1	1.4	3 050	2 950	1.495	0.255	0.413
	Annealed (grain size 0.022 mm)	204	400	2.0	1.2	2 790	3 300	0.052	0.016	0.008 1
				4.0	2.5	5 690	1 600	0.104	0.025	0.036
				6.0	3.8	8 580	3 300	0.430	0.035	0.11
		260	500	0.79	0.50	1 125	4 080	0.115	0.014	0.021
				1.4	0.86	1 930	3 720	0.357	0.061	0.074
				1.9	1.2	2 730	4 080	0.908	0.090	0.195
				2.6	1.6	3 680	3 720	1.557	0.147	0.37
	Annealed (grain size 0.085 mm)	149	300	3.2	2.0	4 500	4 680	0.029	0.006	0.000 4
				7.1	4.5	10 100	5 210	0.110	0.026	0.001 2
				10.6	6.7	15 100	4 770	1.932	0.210	0.006 0
		204	400	1.0	0.66	1 470	4 050	0.013	0.002	<0.000 5
				2.1	1.4	3 050	5 400	0.034	0.013	0.001 1
				2.8	1.8	4 000	5 060	0.048	0.020	0.001 5
				5.7	3.6	8 050	5 060	0.147	0.031	0.014
		260	500	1.0	0.65	1 460	4 650	0.035	0.007	0.003 3
				2.1	1.3	3 020	8 150	0.319	−0.076	0.045
				4.3	2.7	6 150	5 000	2.559	0.340	0.44
	Cold Worked 37% (fine grained)	149	300	3.5	2.2	5 030	5 100	0.037	0.017	0.000 6
				10.5	6.7	14 950	4 800	0.160	0.059	0.004 4
				14.0	8.9	19 900	5 230	0.230	0.090	0.006 4
				21.0	13.3	29 800	4 800	0.470	0.190	0.017 6
				34.8	22.1	49 550	4 680	1.900	0.470	0.223
		204	400	0.70	0.45	1 000	5 400	0.030	−0.012	0.007(b)
				2.5	1.4	3 500	6 500	0.160	−0.043	0.027(b)
				3.5	2.3	5 040	12 200	0.427	−0.124	0.042(b)
		260	500	0.44	0.28	620	5 000	0.186	0.070	0.021 4
				0.70	0.45	1 000	4 650	0.460	0.080	0.079 6
				1.5	0.93	2 080	4 800	1.912	0.160	0.366
	Cold Worked 84% (fine grained)	149	300	7.0	4.5	10 000	5 200	0.156	0.058	0.002 5
				13.9	8.8	19 700	5 230	0.326	0.129	0.005 4
				28.1	17.8	39 950	6 850	0.780	0.260	0.026
				35.6	22.6	50 600	4 750	1.430	0.540	0.10
		204	400	0.72	0.46	1 020	5 100	0.128	0.084	0.006 7
				2.2	1.4	3 060	5 060	0.530	0.180	0.063 6
				3.5	2.2	5 030	4 700	1.494	0.213	0.265
		260	500	0.35	0.22	500	5 000	0.311	0.121	0.037
				0.56	0.36	800	5 000	0.970	0.175	0.159
				1.0	0.66	1 480	2 620	3.015	0.212	1.07

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).

(b) Accelerating creep rate.

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

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate								
				0.001% per 1 000 h			0.01% per 1 000 h			0.1% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod[6] **3.2 mm diam** **0.125 in. diam.**	Annealed (grain size 0.016 mm)	149	300	—	—	—	9.1	5.8	**13 000**	—	—	—
		204	400	—	—	—	2.0	1.3	**2 900**	—	—	—
		260	500	—	—	—	0.46[a]	0.29[a]	**650**[a]	1.2	0.78	**1 750**
	Annealed (grain size 0.022 mm)	204	400	—	—	—	2.1	1.3	**3 000**	6.0	3.8	**8 500**
		260	500	—	—	—	0.56[a]	0.36[a]	**800**[a]	1.5	0.98	**2 200**
	Annealed (grain size 0.085 mm)	149	300	6.7	4.2	**9 500**	11.2[a]	7.1[a]	**16 000**[a]	—	—	—
		204	400	—	—	—	5.4	3.4	**7 700**	—	—	—
		260	500	0.70	0.45	**1 000**	1.4	0.89	**2 000**	2.8	1.8	**4 000**
	Cold Worked 37% (fine grained)	149	300	—	—	—	16.9	10.7	**24 000**	30.9	19.6	**44 000**
		260	500	—	—	—	0.32[a]	0.20[a]	**450**[a]	0.81	0.51	**1 150**
	Cold Worked 84% (fine grained)	149	300	—	—	—	15.5	9.8	**22 000**	35.2	22.2	**50 000**
		204	400	—	—	—	0.98[a]	0.63[a]	**1 400**[a]	2.5	1.6	**3 500**
		260	500	—	—	—	0.18[a]	0.11[a]	**250**[a]	0.49[a]	0.31[a]	**700**[a]

[a] Extrapolated value.

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
Strip[9] 0.81 mm 0.032 in.	Annealed (grain size 0.025 mm)	100	34.5	11[a]	22	7[a]	49 000	15 500[a]
	Annealed (grain size 0.035 mm)	100	35	9[a]	22	5.5[a]	49 500	12 500[a]
	Annealed (grain size 0.100 mm)	100	31.5	7.5[a]	20	4.5[a]	45 000	10 500[a]
	Annealed (grain size 0.120 mm)	100	31.5	8[a]	20	5[a]	45 000	11 500[a]
	Cold Worked 21%[b]	100	44.5	13[a]	28.5	8.5[a]	63 400	18 500[a]
	Cold Worked 21%[c]	100	43.5	12.5[a]	27.5	8[a]	62 000	18 000[a]
	Cold Worked 37%[d]	100	54	15.5[a]	34	10[a]	76 500	22 000[a]
	Cold Worked 37%[e]	100	50.5	15[a]	32	9.5[a]	71 500	21 000[a]
	Cold Worked 60%[b]	100	65	15.5[a]	41.5	10[a]	92 500	22 000[a]
	Cold Worked 60%[e]	100	64.5	17[a]	41	10.5[a]	92 000	24 000[a]
Strip[10] 1 mm 0.04 in.	Cold Worked 60% and Stress Relieved[f]	10	67	19[a]	42.5	12[a]	95 000	27 000[a]
Sheet[11] 1 mm thick 0.04 in. thick	Quarter Hard[g]	100	38.5	12[a]	24.5	7.5[a]	54 900	17 000[a]
	Half Hard[h]	100	43.5	15[a]	27.5	9.5[a]	61 700	21 000[a]
	Three Quarter Hard[i]	100	61.5	16[a]	39	10[a]	87 800	22 600[a]
	Hard[h]	100	54	17[a]	34	10.5[a]	76 600	23 900[a]
	Extra Hard[i]	100	66	18[a]	42	11.5[a]	93 900	25 500[a]
	Spring[i]	100	66.5	18[a]	42	11.5[a]	94 300	25 500[a]
	Extra Spring[i]	100	70.5	19[a]	44.5	12[a]	100 200	27 200[a]
	Super Spring[i]	100	77.5	20[a]	49	13[a]	110 000	28 700[a]
Rod[12] 16 mm diam. 0.625 in. diam.	Cold Worked 21%	100	40	10.5[j]	25.5	6.5[j]	57 000	15 000[j]

continued overleaf

5.4.1. Fatigue Strength at Room Temperature (continued)

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(13) 19 mm diam. 0.75 in. diam.	Annealed	50	33	16(j)	21	10(j)	**47 200**	**22 500**(j)
	Cold Worked 27%	50	52	15.5(j)	33	10(j)	**74 100**	**22 000**(j)
	Cold Worked 27% and Stress Relieved (k)	50	51.5	19.5(j)	33	12.5(j)	**73 500**	**28 000**(j)
Rod(14) 25.4 mm diam. 1 in. diam.	Annealed	100	31.5	10.5(j)	20	6.5(j)	**45 000**	**15 000**(j)
	Cold Worked	100	51.5	12.5(j)	32.5	8(j)	**73 200**	**17 500**(j)
	Cold Worked and Stress Relieved (l)	80	51.5	14(j)	32.5	9(j)	**73 000**	**20 000**(j)
	Cold Worked and Stress Relieved (m)	80	52	14(j)	33	9(j)	**73 800**	**20 000**(j)
	Cold Worked and Stress Relieved (n)	70	51.5	15(j)	33	9.5(j)	**73 400**	**21 500**(j)
Rod(15)	Annealed (grain size 0.016 mm)	50	38	14(j)	**24.2**	**9**(j)	54 000	20 000(j)
	Annealed (grain size 0.04 mm)	50	33	10(j)	**21.0**	**6.5**(j)	47 000	14 500(j)
Wire(16) 1.8 mm diam. 0.072 in. diam.	Cold Worked 60%	100	69.5	13.5(j)	44	8.5(j)	**98 500**	**19 500**(j)
	Cold Worked 84%	100	84.5	15.5(j)	53.5	10(j)	**120 000**	**22 000**(j)

(a) Reversed-bending test. (b) Ready-to-finish grain size 0.025 mm. (c) Ready-to-finish grain size 0.080 mm. (d) Ready-to-finish grain size 0.035 mm. (e) Ready-to-finish grain size 0.075mm. (f) Stress relieved for 1 h at 204 °C *(400 °F)*. (g) Ready-to-finish grain size 0.025 mm. (h) Ready-to-finish grain size 0.015 mm. (i) Ready-to-finish grain size 0.010 mm. (j) Rotating-beam test. (k) Stress relieved at 275 °C *(527 °F)*. (l) Stress relieved for 1.5 h at 204 °C *(400 °F)*. (m) Stress relieved for 1.5 h at 232 °C *(450 °F)*. (n) Stress relieved for 1.5 h at 260 °C *(500 °F)*.

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

— Further data can be obtained from the following:

- France, W.D., Trout, D.E. and Mulholland, J.A. Fatigue Characteristics of Five Copper-Base Strip Alloys Commonly Used for Spring Applications. J. Materials, Vol. 4 (1969), No. 3, Sept., pp. 633–646.
- Contribution by A. Fox to discussion of paper under reference (11) in bibliography.
- Sinclair, G.M. and Craig, W.J. Influence of Grain Size on Work Hardening and Fatigue Characteristics of Alpha Brass. Trans. ASM, Vol. 44 (1952) pp. 929–948.

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Warren, K.A. and Reed, R.P. Tensile and Impact Properties of Selected Materials from 20 to 300°K. US Dept Commerce, Nat. Bureau of Standards Monograph 63 (1963).
(2) Colbeck, E.W. and McGillivray, W.E. The Mechanical Properties of Metals at Low Temperatures, (Part 2—Non-Ferrous Materials). Trans. Instn. Chem. Engrs, Vol. 11 (1933), pp. 107–123.
(3) Russell, H.W. Effect of Low Temperatures on Metals and Alloys. ASTM-ASME Symposium on Effect of Temperature on the Properties of Metals (1931), pp. 658–682.
(4) Private communication from Imperial Metal Industries Limited, England.
(5) Ashbolt, D. and Bowers, J.E. The Properties of Copper and Copper Alloys at Elevated Temperatures. BNFMRA Research Report A1550 (1965), July.
(6) Upthegrove, C. and Burghoff, H.L. Elevated-Temperature Properties of Coppers and Copper-Base Alloys. American Society for Testing and Materials, Philadelphia, Pa. (1956); (ASTM Spec. Tech. Pub. No. 181).
(7) Price, W.B. Properties of Copper and Some of its Important Industrial Alloys at Elevated Temperatures. ASTM-ASME Symposium on Effect of Temperature on the Properties of Metals (1931), pp. 340–367.
(8) Clark, C.L. and White, A.E. Properties of Non-Ferrous Alloys at Elevated Temperatures. Trans. ASME, Vol. 43 (1931), pp. 183–191.
(9) 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.
(10) Favor, R.J. et al. Investigation of Fatigue Behavior of Certain Alloys in the Temperature Range Room Temperature to -423 F. WADD Technical Report 61-132 (1961), June. Directorate of Materials & Processes, Contract No. AF 33 (616)—6888, Project No. 7351.
(11) Tyler, C.M., Jr. Influence of Temper on the Fatigue Strength of Cartridge Brass (Alloy 260) Sheet. Mater. Res. Standards, Vol. 7 (1967), pp. 59–64.
(12) Burghoff, H.L. and Blank, A.I. Fatigue Characteristics of Some Copper Alloys. Proc. ASTM, Vol. 47 (1947), pp. 695–712.
(13) Kommers, J.B. The Static and Fatigue Properties of Brass. Proc. ASTM, Vol. 31 (1931), Pt. 2, pp. 243–258.
(14) McAdam, D.J., Jr. Effect of Cold Working on Endurance and Other Properties of Metals, Part 1. Trans. ASST, Vol. 8 (1925), pp. 782–822.
(15) Forrest, P.G. and Tate, A.E.L. The Influence of Grain Size on the Fatigue Behaviour of 70/30 Brass. J. Inst. Metals, Vol. 93 (1964–65), pp. 438–444.
(16) Burghoff, H.L. and Blank, A.I. Fatigue Tests on Some Copper Alloys in Wire Form. Proc. ASTM, Vol. 43 (1943), pp. 774–784.

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Cu Zn33

Common names: 67/33 Brass
2/1 Brass
67/33 Yellow Brass

A copper–zinc alloy with an alpha phase structure. The alloy exhibits a good combination of strength and ductility, and is commonly selected whenever excellent cold-working properties and relatively low cost are desirable. Service environment must be considered to predict corrosion behaviour. The alloy is often used for a variety of deep-drawn components.

COMPOSITION (weight %)

Cu . .	65.5–68.5
Zn . .	rem.

1 SOME TYPICAL USES

Architectural
Grillwork

Electrical
Lamp caps and lampholder components.

Hardware
General coppersmithing work; chain, eyelets, fasteners, hinges, locks and fingerplates.

Mechanical
Wide variety of deep-drawn and spun components; automobile radiator tanks, tubes and fins; general industrial pressings formed from sheet and strip, including clock, watch and instrument cases; cold-headed or "upset" products such as rivets, pins and screws; torch and flashlight cases; reflectors; etched and chemically engraved work; springs.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.50 g/cm³	0.305 lb/in³
2.2 Melting range	902–940 °C	1 655–1 725 °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
200 °C *392 °F*	0.11 ,,	0.11 ,,
2.5 Thermal conductivity at:		
−200 °C *−328 °F*	0.12 cal cm/cm² s °C	30 Btu ft/ft² h °F
20 °C *68 °F*	0.29 ,,	70 ,,
200 °C *392 °F*	0.34 ,,	82 ,,
2.6 Electrical conductivity (volume) at:		
−196 °C *−321 °F* (annealed)	24 m/ohm mm²	41 % IACS
20 °C *68 °F* (,,)	16 ,,	27 ,, ,,
200 °C *392 °F* (,,)	12 ,,	21 ,, ,,
2.7 Electrical resistivity (volume) at:		
−196 °C *−321 °F* (annealed)	0.042 ohm mm²/m 4.2 microhm cm	25 ohms (circ mil/ft) 1.7 microhm in
20 °C *68 °F* (,,)	0.064 ohm mm²/m 6.4 microhm cm	38 ohms (circ mil/ft) 2.5 microhm in
200 °C *392 °F* (,,)	0.082 ohm mm²/m 8.2 microhm cm	49 ohms (circ mil/ft) 3.2 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 6 per °C (27% IACS)	0.000 9 per °F (27% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	11 400 kg/mm²	16 200 000 lb/in²
cold worked	9 700–11 400 kg/mm²	13 800 000–16 200 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	4 050 kg/mm²	5 750 000 lb/in²
cold worked	3 600–4 050 kg/mm²	5 100 000–5 750 000 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 10); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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Cu Zn33
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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	990–1 020 °C	1 815–1 870 °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	750– 850 °C	1 380–1 560 °F
3.4 Hot formability	Fair	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	85% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	30	
3.8 Joining methods:	See General Data Sheet No. 3.4	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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 grain size 0.035 mm	34	13	58	$5.65\sqrt{S_o}$	65	68	26	0.2–5 mm thick
	grain size 0.025 mm	36	14	55	50 mm	80	84	27	0.2–2.5 mm thick
	grain size 0.015 mm	38	16	52	50 mm	85	89	28	0.2–1.5 mm thick
	Typical Cold Worked Tempers	39	25	38	50 mm	100	105	28	0.2–3 mm thick
		43	33	30	50 mm	120	125	29	,,
		49	41	15	50 mm	135	140	31	0.2–2 mm thick
		53	48	8	50 mm	145	150	32	,,
		58	55	3	50 mm	155	160	33	0.2–1.5 mm thick
		63	—	—	—	165	170	34	0.2–1 mm thick
Rod	Annealed	34	14	60	$5.65\sqrt{S_o}$	65	68	26	—
	Typical Cold Worked Tempers	38	23	42	$5.65\sqrt{S_o}$	95	100	28	—
		41	32	32	$5.65\sqrt{S_o}$	115	120	29	6–40 mm diam. or equivalent area
		47	41	16	$5.65\sqrt{S_o}$	130	135	31	6–12 mm diam. or equivalent area
Wire	Annealed	37	—	45	100 mm	—	—	27	1.5–6 mm diam.
		39	—	35	100 mm	—	—	28	0.5–1.5 mm diam.
		43	—	20	100 mm	—	—	29	up to 0.5 mm diam.
	Typical Cold Drawn Tempers	41	—	32	100 mm	—	—	28	1.5–6 mm diam.
		56	—	8	100 mm	—	—	31	,,
		66	—	—	—	—	—	36	1.5–3 mm diam.
		79	—	—	—	—	—	40	,,
		45	—	15	100 mm	—	—	30	0.5–1.5 mm diam.
		59	—	2	100 mm	—	—	33	,,
		71	—	—	—	—	—	36	,,
		86	—	—	—	—	—	44	,,
Tube	Annealed	35	13	55	$5.65\sqrt{S_o}$	80	84	26	—
	Typical Cold Drawn Tempers	42	33	30	$5.65\sqrt{S_o}$	110	115	29	10–50 mm O.D. over 2 mm wall
		49	44	12	$5.56\sqrt{S_o}$	135	140	32	up to 25 mm O.D. up to 2 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		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown[b]
				%	gauge length			
Sheet Strip	Annealed							
	grain size 0.070 mm	20	6	67	2 in.	60	15	—
	grain size 0.050 mm	21	7	65	2 in.	65	16	—
	grain size 0.035 mm	21	7	60	2 in.	70	16	—
	grain size 0.025 mm	22	8	58	2 in.	80	17	—
	grain size 0.015 mm	23	9	55	2 in.	90	17	0.01–0.125 in. thick
	Cold Worked							
	Quarter Hard	23	15	50	2 in.	95	17	0.01–0.375 in. thick
	Half Hard	26	19	38	2 in.	125	18	0.01–0.25 in. thick
	Hard	31	25	18	2 in.	150	20	0.01–0.1 in. thick
	Extra Hard	37	31	8	2 in.	175	21	,,
Rod	Annealed	21	7	55	$5.65\sqrt{S_o}$	70	16	—
	Cold Worked							
	As Manufactured	23	14	45	$5.65\sqrt{S_o}$	90	17	0.25–1 in. diam. or equivalent area
		25	18	35	$5.65\sqrt{S_o}$	110	18	
Wire	Annealed	22	—	65	2 in.	—	17	0.10–0.25 in. diam.
		23	—	60	2 in.	—	17	0.02–0.10 in. diam.
	Cold Drawn							
	Quarter Hard	27	—	35	2 in.	—	19	0.10–0.25 in. diam.
	Half Hard	35	—	12	2 in.	—	25	,,
	Hard	43	—	—	—	—	28	,,
	Extra Hard	48	—	—	—	—	29	,,
	Half Hard	37	—	10	2 in.	—	26	0.02–0.10 in. diam.
	Hard	45	—	—	—	—	29	,,
	Extra Hard	50	—	—	—	—	30	,,
Tube[c]	Annealed	21	7	55	$5.65\sqrt{S_o}$	70	16	—
	Cold Drawn							
	As Drawn	31	25	15	$5.65\sqrt{S_o}$	160	20	0.25–2 in. O.D., 0.02–0.08 in. wall

(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) Drawn tubes are usually stress relieved after the final draw. Tubes for heat exchangers are mainly supplied in the two tempers whose representative mechanical properties are shown.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation % on $11.3\sqrt{S_o}$	Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi			kg m/cm²	ft lb
Rod[1]	Annealed	20	68	—	—	—	—	—	**14.35**[a][b]	51.9[a][b]
		23	73	**40.0**	25.5	57 000	**50.4**	**72.0**	—	—
		− 78	−108	**43.0**	27.5	61 000	**49.8**	**76.6**	**16.89**[a][b]	61.1[a][b]
		−183	−297	**53.7**	34	76 500	**50.8**	**70.7**	**14.15**[a]	51.2[a]
	Cold Worked 12%	20	68	—	—	—	—	—	**8.12**[a]	29.4[a]
		− 78	−108	—	—	—	—	—	**9.2**[a]	33.3[a]
		−183	−297	—	—	—	—	—	**9.4**[a]	34.0[a]
	Cold Worked 40%	23	73	**60.0**	38	85 500	**6.3**	**66.5**	—	—
		− 78	−108	**65.0**	41.5	92 500	**7.8**	**71.5**	—	—
		−183	−297	**72.3**	46	103 000	**10.1**	**66.5**	—	—
Square Rod[2] 12.7 mm 0.5 in.	Annealed	21	70	—	—	—	—	—	3.9[c]	**14**[c]
		− 83	−117	—	—	—	—	—	4.4[c]	**16**[c]
		−200	−328	—	—	—	—	—	5.0[c]	**18**[c]
		−243	−405	—	—	—	—	—	3.9[c]	**14**[c]
	Soft	21	70	—	—	—	—	—	3.0[c]	**11**[c]
		− 83	−117	—	—	—	—	—	3.3[c]	**12**[c]
		−200	−328	—	—	—	—	—	3.9[c]	**14**[c]

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

(b) Unbroken specimen.

(c) Charpy test, 10 × 10 × 50 mm specimen, keyhole notch; 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 (and vice versa) 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	
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length	kg m/cm²	ft lb
Rod[1]	Annealed	20	68	—	—	—	—	—	**14.35**[(a)(b)]	51.9[(a)(b)]
		23	73	**40.0**	25.5	57 000	**50.4**	$11.3\sqrt{S_o}$	—	—
		46	115	—	—	—	—	—	**12.1**[(a)]	43.8[(a)]
		106	223	—	—	—	—	—	**11.1**[(a)]	40.1[(a)]
		108	226	**38.2**	24.5	54 500	**49.7**	$11.3\sqrt{S_o}$	—	—
		150	302	—	—	—	—	—	**10.9**[(a)]	39.4[(a)]
		200	392	**35.6**	22.5	50 500	**45.3**	$11.3\sqrt{S_o}$	—	—
		203	397	—	—	—	—	—	**10.6**[(a)]	38.3[(a)]
		251	484	—	—	—	—	—	**9.52**[(a)]	34.4[(a)]
		298	568	**32.7**	21	46 500	**34.8**	$11.3\sqrt{S_o}$	—	—
		301	574	—	—	—	—	—	**3.37**[(a)]	12.2[(a)]
		350	662	—	—	—	—	—	**1.55**[(a)]	5.6[(a)]
		352	666	**30.6**	19.5	43 500	**26.9**	$11.3\sqrt{S_o}$	—	—
		400	752	**22.6**	14.5	32 000	**20.7**	$11.3\sqrt{S_o}$	—	—
		401	754	—	—	—	—	—	**1.30**[(a)]	4.7[(a)]
		450	842	—	—	—	—	—	**1.01**[(a)]	3.7[(a)]
		498	928	—	—	—	—	—	**1.08**[(a)]	3.9[(a)]
		500	932	**10.9**	7	15 500	**16.8**	$11.3\sqrt{S_o}$	—	—
		550	1 022	—	—	—	—	—	**0.86**[(a)]	3.1[(a)]
		598	1 108	—	—	—	—	—	**0.80**[(a)]	2.9[(a)]
		617	1 143	**4.2**	3	6 000	**17.3**	$11.3\sqrt{S_o}$	—	—
		646	1 195	—	—	—	—	—	**0.97**[(a)]	3.5[(a)]
		695	1 283	—	—	—	—	—	**0.96**[(a)]	3.5[(a)]
		697	1 287	**2.7**	1.5	4 000	**16.3**	$11.3\sqrt{S_o}$	—	—
	Cold Worked 12%	20	68	—	—	—	—	—	**8.12**[(a)]	29.4[(a)]
		50	122	—	—	—	—	—	**8.44**[(a)]	30.5[(a)]
		100	212	—	—	—	—	—	**8.10**[(a)]	29.3[(a)]
		152	306	—	—	—	—	—	**7.10**[(a)]	25.7[(a)]
		200	392	—	—	—	—	—	**7.03**[(a)]	25.4[(a)]
		250	482	—	—	—	—	—	**5.91**[(a)]	21.4[(a)]
		302	576	—	—	—	—	—	**3.70**[(a)]	13.4[(a)]
		350	662	—	—	—	—	—	**1.82**[(a)]	6.6[(a)]
		401	754	—	—	—	—	—	**1.01**[(a)]	3.7[(a)]
		450	842	—	—	—	—	—	**0.93**[(a)]	3.4[(a)]
		500	932	—	—	—	—	—	**0.79**[(a)]	2.9[(a)]
		550	1 022	—	—	—	—	—	**0.60**[(a)]	2.2[(a)]
		600	1 112	—	—	—	—	—	**1.01**[(a)]	3.7[(a)]
		650	1 202	—	—	—	—	—	**1.20**[(a)]	4.3[(a)]
		700	1 292	—	—	—	—	—	**0.99**[(a)]	3.6[(a)]
	Cold Worked 40%	23	73	**60.0**	38	85 500	**6.3**	$11.3\sqrt{S_o}$	—	—
		109	228	**58.6**	37	83 500	**6.3**	$11.3\sqrt{S_o}$	—	—
		200	392	**56.3**	35.5	80 000	**5.2**	$11.3\sqrt{S_o}$	—	—
		306	583	**52.8**	33.5	75 000	**4.0**	$11.3\sqrt{S_o}$	—	—
		347	657	**44.9**	28.5	64 000	**4.3**	$11.3\sqrt{S_o}$	—	—
		378	712	**28.5**	18	40 500	**19.6**	$11.3\sqrt{S_o}$	—	—
		396	745	**23.6**	15	33 500	**21.8**	$11.3\sqrt{S_o}$	—	—
Rod[3] 12.8 mm diam. 0.505 in. diam.	Cold Worked 50%	25	77	58.5	37	**83 000**	**11**	2 in.	—	—
		250	482	49.5	31.5	**70 700**	**3**	2 in.	—	—
		375	707	19.5	12	**27 400**	**35**	2 in.	—	—
		500	932	6.5	4	**9 300**	**28**	2 in.	—	—
		625	1 157	3	2	**4 200**	**19**	2 in.	—	—
		750	1 382	1.5	0.9	**2 100**	**17**	2 in.	—	—
		875	1 607	0.6	0.4	**900**	**10**	2 in.	—	—

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

(b) Unbroken specimen.

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

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
Flat Products[4] **1 mm 0.04 in.**	Annealed (grain size 0.070 mm)	100	32.5	8.5[a]	20.5	5.5[a]	**46 000**	**12 000**[a]
	Cold Worked[b]	100	52	10[a]	33	6.5[a]	**74 000**	**14 000**[a]
	Cold Worked[c]	100	64	14[a]	40.5	9[a]	**91 000**	**20 000**[a]
Strip[5] **1 mm 0.04 in.**	Cold Worked[d]	100	67	10.5[a]	42.5	6.5[a]	**95 500**	**15 000**[a]
Wire[4] **2 mm diam. 0.08 in.diam.**	Cold Worked[e]	300	49	15.5[f]	31.5	10[f]	**70 000**	**22 000**[f]

[a] Reversed-bending test. [b] Quoted as "hard" in original document, but amount of cold work not defined. [c] Quoted as "spring" in original document, but amount of cold work not defined. [d] Quoted as "extra spring" in original document, but amount of cold work not defined. [e] Quoted as "quarter hard" in original document, but amount of cold work not defined. [f] 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:

■Walker, H.L. and Craig, W.J. Effect of Grain Size on Tensile Strength, Elongation and Endurance Limit of Deep-Drawing Brass. Trans. AIME, Vol. 180 (1949), pp. 42–51.

Cu Zn37

Common names: 63/37 Brass
Basis Brass
Common Brass
63/37 Yellow Brass

A copper-zinc alloy with an alpha phase structure possibly also containing a small amount of beta phase, depending upon fabrication history. Service environment must be considered to predict corrosion behaviour. The alloy can be hot or cold worked and its ductility, although lower than that of Cu Zn28, Cu Zn30 and Cu Zn33, permits quite severe deformation, including cold heading of rod and wire. Cu Zn37 is mainly used for simple cold presswork not involving deep-drawing.

COMPOSITION (weight %)

Cu	62.0–65.5
Zn	rem.

1 SOME TYPICAL USES

Electrical

Lamp caps, lampholder and switch components.

Hardware

General coppersmithing work; chain; eyelets, fasteners, hinges, kicking plates, locks, fingerplates and wire brushes.

Mechanical

Miscellaneous cold presswork products, including instrument covers and containers, and blanked articles, such as instrument plates and wheels; cold-headed items including pins, rivets and screws; springs; ink containers for ball-point pens; automobile radiator tanks; torch and flashlight cases; reflectors.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.45 g/cm³	0.305 lb/in³
2.2 Melting range	902–920 °C	1 655–1 690 °F
2.3 Coefficient of thermal expansion (linear) at:		
–243 °C *–459 °F*	0.000 000 5 per °C	0.000 000 3 per °F
–173 °C *–279 °F*	0.000 013 ,, ,,	0.000 007 ,, ,,
– 73 °C *– 99 °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*	0.000 021 ,, ,,	0.000 012 ,, ,,
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
200 °C *392 °F*	0.11 ,,	0.11 ,,
2.5 Thermal conductivity at:		
–200 °C *–328 °F*	0.12 cal cm/cm² s °C	30 Btu ft/ft² h °F
20 °C *68 °F*	0.30 ,,	73 ,,
200 °C *392 °F*	0.34 ,,	82 ,,
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	15 m/ohm mm²	26 % IACS
200 °C *392 °F* (,,)	12 ,,	21 ,, ,,
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
200 °C *392 °F* (,,)	0.082 ohm mm²/m 8.2 microhm cm	49 ohms (circ mil/ft) 3.2 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 7 per °C (26% IACS)	0.000 9 per °F (26 % IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	11 100 kg/mm²	15 800 000 lb/in²
cold worked	9 700–11 100 kg/mm²	13 800 000–15 800 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	4 000 kg/mm²	5 700 000 lb/in²
cold worked	3 550–4 000 kg/mm²	5 050 000–5 700 000 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 10); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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DATA SHEET No. D 7
Cu Zn37

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	1 040–1 080 °C	1 905–1 975 °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	720– 820 °C	1 330–1 510 °F
3.4 Hot formability	Good	
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)	35	
3.8 Joining methods	See General Data Sheet No. 3.4	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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 %	Elongation gauge length	Hardness Brinell	Hardness Vickers	Shear Strength kg/mm²	Typical Size Related to Properties Shown[(b)]
Plate Sheet Strip	Annealed grain size 0.035 mm	34	13	56	$5.65\sqrt{S_o}$	65	68	26	0.2–5 mm thick
	Annealed grain size 0.025 mm	36	14	53	50 mm	80	84	27	0.2–2.5 mm thick
	Annealed grain size 0.015 mm	38	16	50	50 mm	85	89	28	0.2–1.5 mm thick
	Typical Cold Worked Tempers	39	25	35	50 mm	100	105	28	0.2–3 mm thick
		43	33	26	50 mm	120	125	29	,,
		49	41	12	50 mm	135	140	31	0.2–2 mm thick
		53	48	5	50 mm	145	150	32	,,
		58	55	—	—	155	160	33	0.2–1.5 mm thick
		63	—	—	—	165	170	34	0.2–1 mm thick
Rod	Annealed	34	14	55	$5.65\sqrt{S_o}$	65	68	26	—
	Typical Cold Worked Tempers	38	23	38	$5.65\sqrt{S_o}$	95	100	28	—
		41	32	28	$5.65\sqrt{S_o}$	115	120	29	6–40 mm diam. or equivalent area
		47	41	12	$5.65\sqrt{S_o}$	130	135	31	6–12 mm diam. or equivalent area
Wire	Annealed	37	—	42	100 mm	—	—	27	1.5–6 mm diam.
		39	—	32	100 mm	—	—	28	0.5–1.5 mm diam.
		43	—	18	100 mm	—	—	29	up to 0.5 mm diam.
	Typical Cold Drawn Tempers	41	—	30	100 mm	—	—	28	1.5–6 mm diam.
		56	—	5	100 mm	—	—	31	,,
		66	—	—	—	—	—	37	1.5–3 mm diam.
		79	—	—	—	—	—	40	,,
		45	—	12	100 mm	—	—	30	0.5–1.5 mm diam.
		59	—	—	—	—	—	33	,,
		71	—	—	—	—	—	36	,,
		86	—	—	—	—	—	44	,,
Tube	Annealed	35	13	52	$5.65\sqrt{S_o}$	80	84	26	—
	Typical Cold Drawn Tempers	42	33	28	$5.65\sqrt{S_o}$	110	115	29	10–50 mm O.D. over 2 mm wall
		49	44	10	$5.65\sqrt{S_o}$	135	140	32	up to 25 mm O.D. up to 2 mm wall
Sections / Shapes	Annealed	34	13	50	$5.65\sqrt{S_o}$	65	68	26	—
	Typical Cold Worked Tempers[(c)]	38	20	33	$5.65\sqrt{S_o}$	90	95	27	—
		40	30	26	$5.65\sqrt{S_o}$	110	115	28	—

(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	Hot Rolled	23	9	45	$5.65\sqrt{S_o}$	90	17	0.5–2 in. thick
	Cold Rolled							
	Hard	25	17	35	$5.65\sqrt{S_o}$	100	18	0.625–1 in. thick
		27	20	25	$5.65\sqrt{S_o}$	120	19	0.375–0.625 in. thick
Sheet Strip	Annealed							
	grain size 0.050 mm	22	7	60	2 in.	65	17	—
	grain size 0.035 mm	22	7	58	2 in.	70	17	—
	grain size 0.025 mm	23	8	55	2 in.	80	17	—
	grain size 0.015 mm	24	9	52	2 in.	90	18	0.01–0.125 in. thick
	Cold Worked							
	Quarter Hard	24	16	40	2 in.	100	18	0.01–0.375 in. thick
	Half Hard	27	21	30	2 in.	130	19	0.01–0.25 in. thick
	Hard	32	26	15	2 in.	155	21	0.01–0.1 in. thick
	Extra Hard	38	31	7	2 in.	180	22	"
Rod	Annealed	22	8	50	$5.65\sqrt{S_o}$	75	17	—
	Cold Worked							
	As Manufactured	24	15	35	$5.65\sqrt{S_o}$	100	18	0.25–1 in. diam. or equivalent area
		26	20	30	$5.65\sqrt{S_o}$	120	19	
Wire	Annealed	22	—	60	2 in.	—	17	0.10–0.25 in. diam.
		23	—	55	2 in.	—	17	0.02–0.10 in. diam.
	Cold Drawn							
	Quarter Hard	29	—	20	2 in.	—	19	0.10–0.25 in. diam.
	Half Hard	36	—	10	2 in.	—	26	"
	Hard	44	—	—	—	—	29	"
	Extra Hard	47	—	—	—	—	30	"
	Half Hard	38	—	8	2 in.	—	26	0.02–0.10 in. diam.
	Hard	46	—	—	—	—	29	"
	Extra Hard	50	—	—	—	—	31	"
Tube[c]	Annealed	22	8	50	$5.65\sqrt{S_o}$	75	17	—
	Cold Drawn or Temper Annealed							
	Temper Annealed	24	12	45	$5.65\sqrt{S_o}$	90	18	0.25–2 in. O.D., 0.02–0.08 in. wall
	As Drawn	32	26	15	$5.65\sqrt{S_o}$	160	21	"

[a] The recognised temper designations used in the relevant or nearest British Standards are also given in this table, 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 tube tempers are generally obtained by temper annealing. Drawn tubes are usually stress relieved after the final draw.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Yield Strength psi	Elongation		Reduction of Area %	Impact Strength[a]	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Rod[1][b] 12.7 mm diam. 0.5 in. diam.	Cold Worked[c]	20	68	50.5	32	**72 000**	**54 000**[d]	**23.5**	2 in.	**65**	6.6	**38**
		− 41	− 42	52.5	33.5	**74 500**	**58 000**[d]	**25.5**	2 in.	**65**	6.4	**37**
—[2][e]	Cold Worked[f]	20	68	**38**	24	54 000	—	**41**	$5.65\sqrt{S_o}$	—	—	—
		− 40	− 40	**40**	25.5	57 000	—	**41**	$5.65\sqrt{S_o}$	—	—	—
		− 80	−112	**41**	26	58 500	—	**44**	$5.65\sqrt{S_o}$	—	—	—
		−120	−184	**44**	28	62 500	—	**49**	$5.65\sqrt{S_o}$	—	—	—
		−195	−319	**52**	33	74 000	—	**53**	$5.65\sqrt{S_o}$	—	—	—

[a] Izod specimen; cross-sectional area at the notch 0.8 cm². [b] Containing 0.31% Sn. [c] Quoted as "hard drawn" in original document, but amount of cold work not defined. [d] Quoted as "yield strength" in original document, but offset strain not defined. [e] Form not stated in original document. [f] 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.
—The 0.1% and 0.2% offset proof stress values are not available.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.1% offset ton/in²	Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi		
Strip[3] 2 mm 0.08 in.	Annealed (grain size 0.035 mm)	20	68	35.5	**22.5**	50 500	**8.1**	**60**
		100	212	34	**21.5**	48 000	**7.8**	**57**
		200	392	32.5	**20.5**	46 000	**7.8**	**54**
		250	464	30.5	**19.5**	43 500	**7.7**	**50**
		300	572	27	**17.3**	38 500	**7.2**	**39**
Rod[4] 12.8 mm diam. 0.505 in. diam.	Cold Worked 20%	25	77	43	27	**61 000**	—	**27**
		250	482	37.5	24	**53 700**	—	**20**
		390	734	14.5	9.5	**20 900**	—	**41**
		500	932	5.5	3.5	**7 500**	—	**43**
		550	1 022	4	2.5	**5 800**	—	**32**
		630	1 166	2	1	**2 800**	—	**27**
		725	1 337	0.7	0.5	**1 040**	—	**40**
		800	1 472	0.4	0.2	**530**	—	**139**
		875	1 607	0.1	0.08	**180**	—	**167**

N.B.:—Original values are printed in **bold type**; other values are converted.
—Data not available:
Proof stress, 0.2% offset,
Yield strength, 0.5% extension under load.

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/mm^2 Tensile Strength	Metric Units kg/mm^2 Fatigue Strength	English Units ton/in^2 Tensile Strength	English Units ton/in^2 Fatigue Strength	American Units psi Tensile Strength	American Units psi Fatigue Strength
Strip[5] 0.51 mm 0.02 in.	Annealed[a]	100	33	10.5[b]	21	6.5[b]	46 600	15 000[b]
	Cold Worked[a] 37.1% 68.7%	100 100	54.5 67	13.5[b] 14[b]	34.5 42.5	8.5[b] 9[b]	77 200 95 600	19 500[b] 20 000[b]
	Annealed[c]	100	33	9.5[b]	21	6[b]	46 600	13 500[b]
	Cold Worked[c] 37.1% 60.5%	100 100	52 64.5	12[b] 12[b]	33 41	8[b] 8[b]	73 700 91 900	17 500[b] 17 500[b]
	Hot Rolled[d]	100	—	9.5[b]	—	6[b]	—	13 500[b]
	Cold Worked[d] 37.1% 68.7%	100 100	49 66	10.5[b] 14.5[b]	31 42	6.5[b] 9[b]	69 600 93 900	15 000[b] 20 500[b]
Strip[6] 0.81 mm 0.032 in.	Annealed (grain size 0.030 mm)	100	36.5	10.5[b]	23	6.5[b]	51 700	15 000[b]
	Cold Worked 21% 37% 60%	100 100 100	45.5 56.5 66	13.5[b] 13.5[b] 13.5[b]	29 36 42	8.5[b] 8.5[b] 8.5[b]	64 800 80 700 94 000	19 000[b] 19 000[b] 19 000[b]
Rod[7] 12.7 mm diam. 0.5 in. diam.	Cold Worked 30.1%	300	51	16[e]	32	10[e]	72 200	22 700[e]
Rod[8] 12.7 mm diam. 0.5 in. diam.	Cold Worked 15.2% 30.1% 50.1%	0.1 0.1 0.1	40 51 64.5	31.5[e] 38[e] 43.5[e]	25.5 32 41	20[e] 24[e] 27.5[e]	57 200 72 200 91 600	44 500[e] 54 000[e] 62 000[e]
	Cold Worked 15.2% 30.1% 50.1%	1 1 1	40 51 64.5	23[e] 25.5[e] 29[e]	25.5 32 41	14.5[e] 16[e] 18.5[e]	57 200 72 200 91 600	33 000[e] 36 000[e] 41 000[e]
	Cold Worked 15.2% 30.1% 50.1%	10 10 10	40 51 64.5	15[e] 17[e] 23[e]	25.5 32 41	9.5[e] 10.5[e] 14.5[e]	57 200 72 200 91 600	21 500[e] 24 000[e] 33 000[e]
	Cold Worked 15.2% 30.1% 50.1%	100 100 100	40 51 64.5	13.5[e] 16[e] 21[e]	25.5 32 41	8.5[e] 10.5[e] 13.5[e]	57 200 72 200 91 600	19 000[e] 23 000[e] 30 000[e]
	Cold Worked 15.2% 30.1% 50.1%	300 300 300	40 51 64.5	13[e] 16[e] 20.5[e]	25.5 32 41	8.5[e] 10[e] 13[e]	57 200 72 200 91 600	18 500[e] 22 500[e] 29 500[e]
	Cold Worked 15.2% 30.1% 50.1%	1 000 1 000 1 000	40 51 64.5	12.5[e] 15.5[e] 20.5[e]	25.5 32 41	8[e] 10[e] 13[e]	57 200 72 200 91 600	18 000[e] 22 000[e] 29 000[e]

continued on opposite page

5.4.1. Fatigue Strength at Room Temperature (continued)

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(9) 25.4 mm diam. 1 in. diam.	Annealed	10	33	12.5(e)	21	8(e)	**47 000**	**18 000**(e)
		20	30.5	10.5(e)	19.5	6.5(e)	**43 500**	**15 000**(e)
	Cold Worked and Stress Relieved(f)	5	50	12(e)	31.5	7.5(e)	**71 000**	**17 000**(e)
		20	38	9(e)	24	6(e)	**54 000**	**13 000**(e)
		40	58	17.5(e)	37	11(e)	**82 500**	**25 000**(e)
Wire(10) 1.8 mm diam. 0.072 in. diam.	Cold Worked 60%	100	65.5	13.5(e)	41.5	8.5(e)	**93 000**	**19 000**(e)
	Cold Worked 84%	100	83	15.5(e)	52.5	10(e)	**118 000**	**22 000**(e)

(a) Cu 65.09%. (b) Reversed-bending test. (c) Cu 64.78%. (d) Cu 65.01%. (e) Rotating-beam test. (f) Stress relieved for 3 h at 232 °C (*450 °F*).

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

Cu Zn40

Common names: 60/40 Brass (Lead-Free)
Muntz Metal
Yellow Metal

A copper–zinc alloy with a duplex alpha-plus-beta phase structure and excellent hot-working properties. Service environment must be considered to predict corrosion behaviour. Cu Zn40 has somewhat better cold-working and joining properties, but is less readily machined, than the similar low-leaded alloy Cu Zn40 Pb. The most commonly used wrought forms are plate, rod and sections/shapes.

COMPOSITION (weight %)

Cu .	. 59.0–62.0
Zn .	. rem.

1 SOME TYPICAL USES

Architectural

Extruded sections including angles, channels and trim; heavy-gauge panels and sheets.

Chemical and Marine

Condenser and heat exchanger tubeplates.

Mechanical

Hot forgings and "upset" products requiring limited cold bending or riveting.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.40 g/cm³	0.305 lb/in³
2.2 Melting range	895–900 °C	1 645–1 650 °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:		
—200 °C *—328 °F*	0.15 cal cm/cm² s °C	37 Btu ft/ft² h °F
20 °C *68 °F*	0.30 ,,	73 ,,
200 °C *392 °F*	0.34 ,,	82 ,,
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	16 m/ohm mm²	28 % IACS
200 °C *392 °F* (,,)	12 ,,	21 ,,
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
200 °C *392 °F* (,,)	0.082 ohm mm²/m 8.2 microhm cm	49 ohms (circ mil/ft) 3.2 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*	0.002 0 per °C (28% IACS)	0.001 1 per °F (28% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	10 400 kg/mm²	14 800 000 lb/in²
cold worked	9 600–10 400 kg/mm²	13 650 000–14 800 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	3 900 kg/mm²	5 550 000 lb/in²
cold worked	3 500–3 900 kg/mm²	5 000 000–5 550 000 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 12*); *INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE*

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Cu Zn40
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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	650– 750 °C	1 200–1 380 °F
3.4 Hot formability	Excellent	
3.5 Cold formability	Limited	
3.6 Cold reduction between anneals	40% max.	
3.7 Machinability :	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	45	
3.8 Joining methods :	See General Data Sheet No. 3.4	
Soldering	Excellent	
Brazing	Good	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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	38	16	40	$5.65\sqrt{S_o}$	85	89	29	—
	Hot Rolled	38	16	30	$5.65\sqrt{S_o}$	85	89	29	30–80 mm thick
	Typical Cold Worked Tempers	45 52	32 45	25 8	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	125 145	130 150	32 34	0.5–20 mm thick 0.5– 5 mm thick
Rod	Annealed	38	16	40	$5.65\sqrt{S_o}$	85	89	29	—
	Hot Worked	38	16	30	$5.65\sqrt{S_o}$	85	89	29	10–80 mm diam. or equivalent area
	Typical Cold Worked Tempers	43 50	32 45	28 10	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	120 135	125 140	30 33	6–40 mm diam. or equivalent area 6–12 mm diam. or equ valent area
Wire	Annealed	42	—	35	100 mm	—	—	32	1.5–6 mm diam.
	Typical Cold Drawn Tempers	48 60	— —	15 4	100 mm 100 mm	— —	— —	31 33	1.5–6 mm diam. "
Tube	Annealed	40	18	40	$5.65\sqrt{S_o}$	85	89	30	—
	Typical Cold Drawn Tempers	45 50	33 40	20 8	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	125 140	130 145	32 33	10–50 mm O.D. over 2 mm wall up to 25 mm O.D. up to 2 mm wall
Sections / Shapes	Annealed	38	16	40	$5.65\sqrt{S_o}$	85	89	29	—
	Hot Worked[c]	38	16	30	$5.65\sqrt{S_o}$	85	89	29	—
	Typical Cold Worked Temper[c]	42	25	28	$5.65\sqrt{S_o}$	100	105	29	—
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		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown[(b)]
				%	gauge length			
Rod	Annealed	23	8	45	$5.65\sqrt{S_o}$	90	17	—
Rod	Hot Worked	24	9	40	$5.65\sqrt{S_o}$	100	18	0.5–2 in. diam. or equivalent area
Rod	Cold Worked As Manufactured	25	10	40	$5.65\sqrt{S_o}$	110	19	1–2 in. diam. or equivalent area
		27	14	35	$5.65\sqrt{S_o}$	125	20	0.375–1 in. diam. or equivalent area
		30	18	25	$5.65\sqrt{S_o}$	140	21	0.125–0.375 in. diam. or equivalent area
Sections (extruded)	Hot Worked[(c)]	24	9	40	$5.65\sqrt{S_o}$	100	18	—
Sections (extruded)	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			Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length		kg m/cm²	ft lb
Plate[1] 12.7—19 mm 0.5—0.75 in.	—[a]	20	68	29.5[b]	**18.6**[b]	41 500[b]	**14**	2 in.	**26.5**	6.0[c]	**34.5**[c]
		− 50	− 58	—	—	—	—	—	—	6.6[c]	**38**[c]
		−100	−148	—	—	—	—	—	—	6.6[c]	**38**[c]
		−120	−184	33.5[b]	**21.4**[b]	48 000[b]	**15**	2 in.	**27.0**	—	—
		−150	−238	35.5[b]	**22.5**[b]	50 500[b]	**15**	2 in.	**26.5**	6.3[c]	**36.5**[c]
		−196	−321	39[b]	**24.9**[b]	56 000[b]	**14**	2 in.	**24.5**	6.7[c]	**39**[c]
Rod[2]	Annealed	20	68	**40.5**	25.5	57 500	**51.3**	$11.3\sqrt{S_0}$	**75.5**	**8.55**[d]	30.9[d]
		− 78	−108	**43.0**	27.5	61 000	**53.0**	$11.3\sqrt{S_0}$	**74.6**	**8.57**[d]	31.0[d]
		−183	−297	**53.3**	34	76 000	**55.3**	$11.3\sqrt{S_0}$	**71.0**	**8.30**[d]	30.0[d]
	Cold Worked 17%	20	68	—	—	—	—	—	—	**5.08**[d]	18.4[d]
		− 78	−108	—	—	—	—	—	—	**5.29**[d]	19.1[d]
		−183	−297	—	—	—	—	—	—	**5.27**[d]	19.0[d]
	Cold Worked 25%	20	68	**56.0**	35.5	79 500	**19.8**	$11.3\sqrt{S_0}$	**65.5**	—	—
		− 78	−108	**58.3**	37	83 000	**21.0**	$11.3\sqrt{S_0}$	**67.7**	—	—
		−183	−297	**69.2**	44	98 500	**24.4**	$11.3\sqrt{S_0}$	**64.1**	—	—
—[3][e]	Annealed	20	68	**36**	23	51 000	**51**	$5.65\sqrt{S_0}$	—	—	—
		− 80	−112	**38**	24	54 000	**53**	$5.65\sqrt{S_0}$	—	—	—
		−195	−319	**47**	30	67 000	**55**	$5.65\sqrt{S_0}$	—	—	—
	Cold Worked[f]	20	68	**50**	31.5	71 000	**20**	$5.65\sqrt{S_0}$	—	—	—
		− 80	−112	**52**	32.5	72 500	**21**	$5.65\sqrt{S_0}$	—	—	—
		−195	−319	**61**	38.5	87 000	**24**	$5.65\sqrt{S_0}$	—	—	—

[a] Temper not stated in original document; probably annealed.

[b] Tipper notched tensile test; section of notch 19 × 15 mm (0.750 × 0.610 in.). [c] Charpy test; 10 × 10 × 100 mm specimen; 45° V-notch, 2 mm deep; cross-sectional area at the notch 0.8 cm². [d] Charpy test; 10 × 8 × 100 mm specimen; 45° V-notch, 3 mm deep; cross-sectional area at the notch 0.5 cm². [e] Form not stated in original document. [f] 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 ft lb into kg m/cm² (and vice versa) 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.

5.2.2 Navy Tear Test

Form	Temper	Testing Temperature		Maximum Load			Corrected Energy Values						Reduction of Plate Thickness at Fracture		
							initiation		propagation		total				
		°C	°F	kg	ton	lb	kg m	ft lb	kg m	ft lb	kg m	ft lb	mm	in.	%
Plate[1] 12.7 − 19 mm 0.5 − 0.75 in.	—[a]	20	68	9 195	**9.05**	20 270	15.5	**112**	80.5	**582**	95.9	**694**	3.8	**0.150**	**20.0**
		−120	−184	10 975	**10.8**	24 190	30.1	**218**	94.7	**685**	124.8	**903**	4	**0.160**	**21.5**
		−196	−321	13 410	**13.2**	29 570	33.7	**244**	117.7	**851**	151.4	**1 095**	3.8	**0.150**	**20.0**

[a] Temper not stated in original document; probably annealed.

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% extension under load psi	%	gauge length	kg m / cm²	ft lb
Plate[4]	Annealed	20	68	34	**21.5**	48 000	**10.1**[a]	**6.2**	—	**62**	2 in.	—	—
		66	150	34.5	**21.8**	49 000	**10.1**[a]	**6.2**	—	**65**	2 in.	—	—
		121	250	32	**20.2**	45 000	**10.1**[a]	**6.2**	—	**62**	2 in.	—	—
		177	350	30.5	**19.4**	43 500	**10.5**[a]	**6.5**	—	**63**	2 in.	—	—
		204	400	30	**19.2**	43 000	**11.2**[a]	**6.8**	—	**62**	2 in.	—	—
Rod[5] 3.2 mm diam. 0.125 in. diam.	Annealed	24	75	38.5	24.5	**54 700**	**13.1**[b]	—	**18 600**	**51.0**	2 in.	—	—
		149	300	—	—	—	**12.9**[b]	—	**18 500**	—	—	—	—
		204	400	—	—	—	**12.9**[b]	—	**18 500**	—	—	—	—
		260	500	—	—	—	**12.4**[b]	—	**17 900**	—	—	—	—
Rod[2]	Annealed	19	66	—	—	—	—	—	—	—	—	**8.55**[c]	30.9[c]
		20	68	**40.5**	25.5	57 500	—	—	—	**51.3**	$11.3\sqrt{S_o}$	—	—
		51	124	—	—	—	—	—	—	—	—	**8.26**[c]	29.9[c]
		55	131	**39.7**	25	56 500	—	—	—	**51.0**	$11.3\sqrt{S_o}$	—	—
		100	212	**38.8**	24.5	55 000	—	—	—	**50.8**	$11.3\sqrt{S_o}$	**7.56**[c]	27.3[c]
		151	304	—	—	—	—	—	—	—	—	**6.94**[c]	25.0[c]
		154	309	**35.2**	22.5	50 000	—	—	—	**50.3**	$11.3\sqrt{S_o}$	—	—
		200	392	—	—	—	—	—	—	—	—	**6.27**[c]	22.7[c]
		206	403	**34.4**	22	49 000	—	—	—	**49.8**	$11.3\sqrt{S_o}$	—	—
		250	482	**31.5**	20	45 000	—	—	—	**48.7**	$11.3\sqrt{S_o}$	**5.17**[c]	18.7[c]
		283	541	**30.6**	19.5	43 500	—	—	—	**47.8**	$11.3\sqrt{S_o}$	—	—
		300	572	—	—	—	—	—	—	—	—	**2.38**[c]	8.6[c]
		327	621	—	—	—	—	—	—	—	—	**2.13**[c]	7.7[c]
		336	637	**26.9**	17	38 500	—	—	—	**33.2**	$11.3\sqrt{S_o}$	—	—
		351	664	—	—	—	—	—	—	—	—	**1.08**[c]	3.9[c]
		355	671	**25.3**	16	36 000	—	—	—	**37.2**	$11.3\sqrt{S_o}$	—	—
		400	752	**21.2**	13.5	30 000	—	—	—	**41.6**	$11.3\sqrt{S_o}$	**0.81**[c]	2.9[c]
		450	842	—	—	—	—	—	—	—	—	**0.92**[c]	3.3[c]
		454	849	**16.7**	10.5	23 500	—	—	—	**34.7**	$11.3\sqrt{S_o}$	—	—
		500	932	**9.6**	6	13 500	—	—	—	**33.3**	$11.3\sqrt{S_o}$	**0.77**[c]	2.8[c]
		550	1022	—	—	—	—	—	—	—	—	**1.14**[c]	4.1[c]
		599	1110	—	—	—	—	—	—	—	—	**1.37**[c]	5.0[c]
		650	1202	—	—	—	—	—	—	—	—	**7.18**[c][d]	26.0[c][d]
		704	1299	—	—	—	—	—	—	—	—	**4.82**[c][d]	17.4[c][d]
	Cold Worked 17%	19	66	—	—	—	—	—	—	—	—	**5.08**[c]	18.4[c]
		53	127	—	—	—	—	—	—	—	—	**5.09**[c]	18.4[c]
		100	212	—	—	—	—	—	—	—	—	**4.85**[c]	17.7[c]
		152	306	—	—	—	—	—	—	—	—	**4.41**[c]	17.4[c]
		201	394	—	—	—	—	—	—	—	—	**4.11**[c]	14.9[c]
		250	482	—	—	—	—	—	—	—	—	**3.27**[c]	11.8[c]
		301	574	—	—	—	—	—	—	—	—	**2.06**[c]	7.5[c]
		351	664	—	—	—	—	—	—	—	—	**1.06**[c]	3.8[c]
		400	752	—	—	—	—	—	—	—	—	**0.96**[c]	3.5[c]
		450	842	—	—	—	—	—	—	—	—	**1.68**[c]	6.1[c]
		500	932	—	—	—	—	—	—	—	—	**1.59**[c]	5.8[c]
		550	1022	—	—	—	—	—	—	—	—	**2.07**[c]	7.5[c]
		600	1112	—	—	—	—	—	—	—	—	**2.84**[c]	10.3[c]
		650	1202	—	—	—	—	—	—	—	—	**7.93**[c][d]	28.7[c][d]
		700	1292	—	—	—	—	—	—	—	—	**5.10**[c][d]	18.4[c][d]

continued on opposite page

5.3.1 Short-Time Tensile Properties—Impact Properties *(continued)*

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% extension under load psi	%	gauge length	kg m / cm²	ft lb
Rod[(2)]	Cold Worked 25%	21	70	**56.0**	35.5	79 500	—	—	—	**19.8**	$11.3\sqrt{S_o}$	—	—
		50	122	**54.2**	34.5	77 000	—	—	—	**19.6**	$11.3\sqrt{S_o}$	—	—
		100	212	**53.0**	33.5	75 500	—	—	—	**19.4**	$11.3\sqrt{S_o}$	—	—
		156	313	**49.3**	31.5	70 000	—	—	—	**19.2**	$11.3\sqrt{S_o}$	—	—
		194	381	**45.1**	28.5	64 000	—	—	—	**20.0**	$11.3\sqrt{S_o}$	—	—
		253	487	**43.2**	27.5	61 500	—	—	—	**19.6**	$11.3\sqrt{S_o}$	—	—
		296	565	**38.4**	24.5	54 500	—	—	—	**16.5**	$11.3\sqrt{S_o}$	—	—
		325	617	**36.7**	23.5	52 000	—	—	—	**14.2**	$11.3\sqrt{S_o}$	—	—
		365	689	**22.7**	14.5	32 500	—	—	—	**14.7**	$11.3\sqrt{S_o}$	—	—
		396	745	**20.7**	13	29 500	—	—	—	**23.4**	$11.3\sqrt{S_o}$	—	—
		450	842	**13.6**	8.5	19 500	—	—	—	**32.5**	$11.3\sqrt{S_o}$	—	—
		505	941	**5.5**	3.5	8 000	—	—	—	**31.8**	$11.3\sqrt{S_o}$	—	—
Rod[(6)] **19 mm diam.** **0.75 in. diam.**	Hot Worked (grain size 0.020 mm)	24	75	39	24.5	**55 350**	—	—	—	**51.0**	2 in.	—	—
		204	400	33.5	21.5	**45 750**	—	—	—	**50.5**	2 in.	—	—
		316	600	17.5	11	**25 150**	—	—	—	**40.0**	2 in.	—	—
		427	800	6	4	**8 700**	—	—	—	**18.0**	2 in.	—	—
Tube[(7)]	Annealed	Room	Room	28	18	**40 000**	—	—	**20 000**	—	—	—	—
		66	150	28	18	**40 000**	—	—	**20 000**	—	—	—	—
		121	250	31.5	20	**45 000**	—	—	**20 000**	—	—	—	—
		149	300	30	19	**43 000**	—	—	**20 000**	—	—	—	—
		177	350	28	18	**40 000**	—	—	**20 000**	—	—	—	—
		204	400	26	16.5	**37 000**	—	—	**20 000**	—	—	—	—
		232	450	24	15	**34 000**	—	—	**18 000**	—	—	—	—

[(a)] This value was originally reported in ton/in²; in this table it is given in kg/mm² to 3 significant figures.

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

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

[(d)] Unbroken specimen.

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.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension %[(a)]	Intercept %	Minimum Creep Rate % per 1000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod[(5)] 3.2 mm diam. 0.125 in. diam.	Annealed	149	300	3.5	2.2	**5 000**	**6 430**	**0.053 5**	**0.009 5**	**0.001 1**
				5.2	3.3	**7 450**	**6 430**	**0.099**	**0.029**	**0.002 3**
				7.0	4.4	**10 000**	**6 430**	**0.158**	**0.039**	**0.006**
				10.5	6.7	**15 000**	**6 430**	**0.313**	**0.084**	**0.011 5**
				14.0	8.9	**19 900**	**6 430**	**3.580**	**1.265**	**0.20**
		204	400	0.74	0.47	**1 050**	**7 700**	**0.048**	**0.013 2**	**0.002 9**
				1.4	0.92	**2 050**	**7 700**	**0.090**	**0.025**	**0.005 8**
				2.8	1.8	**4 050**	**2 280**	**0.18**	**0.010**	**0.022**
				4.3	2.7	**6 100**	**7 680**	**1.975**	**0.053**	**0.246**

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).

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

5.3.2.2 Stress for Designated Creep Data

Form	Temper	Testing Temperature		Stress for Designated Creep Rate								
				0.001 % per 1 000 h			0.01 % per 1 000 h			0.1 % per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod[(5)] 3.2 mm diam. 0.125 in. diam.	Annealed	149	300	3.3	2.1	**4 700**	9.7	6.2	**13 800**	13.6	8.6	**19 300**
Rod[(8)] 19 mm diam. 0.75 in. diam.	Hot Rolled (alpha grain size 0.020 mm)	149	300	—	—	—	6.3	4.0	**9 000**	8.4	5.4	**12 000**
		204	400	—	—	—	1.4	0.89	**2 000**	3.3	2.1	**4 750**

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 $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod[9] **19 mm diam. 0.75 in. diam.**	Annealed	50	42	15[a]	26.5	9.5[a]	**59 500**	**21 500**[a]
	Cold Worked 25%	50	54.5	19.5[a]	34.5	12.5[a]	**77 600**	**27 700**[a]
	Cold Worked 25% and Stress Relieved[e]	50	51.5	21.5[a]	32.5	13.5[a]	**73 200**	**30 400**[a]
Rod[10] **25.4 mm diam. 1 in. diam.**	Hot Worked[b]	100	54	11[a]	34	7[a]	**76 600**	**16 000**[a]
	Hot Worked[c]	100	55.5	13[a]	35.5	8.5[a]	**79 200**	**18 500**[a]
	Hot Worked[d]	100	46	12.5[a]	29.5	8[a]	**65 600**	**18 000**[a]

[a] Rotating-beam test. [b] Drawn at 249 °C (*480 °F*). [c] Drawn at 343 °C (*650 °F*). [d] Drawn at 450 °C (*840 °F*). [e] Stress relieved at 275 °C (*527 °F*).

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

—Further data can be obtained from the following paper:

- Frost, N.E. and Greenan, A.F. Further Experiments on the Propagation of Edge Cracks in Plate Specimens. National Engineering Laboratory, East Kilbride, Glasgow: NEL Report No. 132 (1964), Feb.