WROUGHT MATERIALS

COPPER-TIN ALLOYS
Tin Bronzes
Phosphor Bronzes

Cu Sn2

Common names: Low-Tin Bronze
Conductivity Bronze
Phosphor Bronze, 1.25% E

A copper-tin alloy with an alpha phase structure and containing a small amount of phosphorus. The alloy has relatively high conductivity, particularly when the tin and phosphorus contents are near the lower limits of the composition range. It is somewhat harder and stronger than unalloyed copper, while retaining good cold-workability. Cu Sn2 has good resistance to corrosion, including stress-corrosion. The most commonly used wrought forms are strip, rod and wire.

COMPOSITION (weight %)

Sn	1.0 -2.5
P	0.02–0.30
Cu	rem.

1 SOME TYPICAL USES

Electrical
Contacts; communications equipment; current-carrying light-duty springs; rotor bars; reinforcement tape for sheaths of power cables.
Others
Flexible tubes; cold-headed screws, rivets and bolts; welding rods.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.90 g/cm³	0.320 lb/in³
2.2 Melting range [a]	1 000–1 080 °C	1 830–1 975 °F
2.3 Coefficient of thermal expansion (linear) at:		
—70 to 20 °C *—94 to 68 °F*	0.000 015 per °C	0.000 008 per °F
20 to 100 °C *68 to 212 °F*	0.000 017 „ „	0.000 009 „ „
20 to 300 °C *68 to 572 °F*	0.000 018 „ „	0.000 010 „ „
2.4 Specific heat (thermal capacity) at: 20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
2.5 Thermal conductivity at: 20 °C *68 °F*	0.45 [b]–0.55 [b] cal cm/cm² s °C 0.35 [c]–0.40 [c] „	110 [b]–130 [b] Btu ft/ft² h °F 85 [c]– 97 [c] „
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed)	23 [b]–29 [b] m/ohm mm² 15 [c]–20 [c] „ „	40 [b]–50 [b] % IACS 25 [c]–35 [c] „ „
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed)	0.043 [b]–0.034 [b] ohm mm²/m 4.3 [b]–3.4 [b] microhm cm 0.069 [c]–0.049 [c] ohm mm²/m 6.9 [c]–4.9 [c] microhm cm	26 [b]–21 [b] ohms (circ mil/ft) 1.7 [b]–1.4 [b] microhm in 41 [c]–30 [c] ohms (circ mil/ft) 2.7 [c] –1.9 [c] microhm in
2.8 Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed)	0.002 3 [b] per °C (40% IACS) 0.002 9 [b] „ „ (50% IACS) 0.001 3 [c] „ „ (25% IACS) 0.001 9 [c] „ „ (35% IACS)	0.001 3 [b] per °F (40% IACS) 0.001 6 [b] „ „ (50% IACS) 0.000 7 [c] „ „ (25% IACS) 0.001 1 [c] „ „ (35% IACS)
applicable over range from 0 to 100 °C *32 to 212 °F*		
2.9 Modulus of elasticity (tension) at 20°C *68 °F*: annealed or cold worked	12 500 kg/mm²	17 800 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*: annealed or cold worked	4 600 kg/mm²	6 600 000 lb/in²

(a) For high phosphorus contents, the temperatures, especially at the bottom of the range, will be lower.
(b) Alloy composition:- 1.0–1.5% Sn, 0.02–0.10% P, Cu rem. (mainly for electrical applications).
(c) Alloy composition:- 2.0–2.5% Sn, 0.02–0.30% P, Cu rem. (for electrical applications, the recommended phosphorus content is about 0.1%, with a resulting conductivity towards the higher end of the range quoted above).
N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition range involved, are based on selected literature references.

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE.

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3 FABRICATION PROPERTIES

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

	Metric Units	English Units
3.1 Casting temperature range	1 120–1 200 °C	2 050–2 190 °F
3.2 Annealing temperature range	475– 650 °C	885–1 200 °F
Stress relieving temperature range	200– 350 °C	390– 660 °F
3.3 Hot working temperature range	750– 875 °C	1 380–1 605 °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)	20	
3.8 Joining methods:	See General Data Sheet No. 3.7	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Fair	
Resistance welding: spot and seam	Fair	
butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	Br Sn2	—	—	—	266.21	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	INDITECNOR	—	—	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	Cu Sn2 (2.1010)	17 662	17 670	—	17 682	17 671	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	B 2	—	2527	2527	2527	2527	2527	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN[b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	Cu Sn2	—	37 103	37 103	37 103	—	37 103	—
Sweden	SIS	54 20	—	14 54 20	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States[c]	ASTM	No. 505	—	—	—	B 105	—	—	—
International Organization for Standardization	ISO	Cu Sn2	R 427	—	—	—	—	—	—

(a) Applicable when the chemical composition is not given in the specifications for wrought forms.

(b) Older specifications bear prefix N; for new specifications the NEN prefix is used.

(c) In the United States, bar and flat wire are covered under the Plate-Sheet-Strip column.

5.1 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		
Sheet Strip	Annealed (grain size 0.025 mm)	28	11	45	50 mm	60	63	21	0.2–3 mm thick
	Typical Cold Worked Tempers	34 38 45 53	23 30 39 50	25 20 10 3	$5.65\sqrt{S_o}$ 50 mm 50 mm 50 mm	90 105 125 150	95 110 130 155	24 25 29 32	over 1 mm thick 0.5–3 mm thick 0.2–1.5 mm thick up to 0.5 mm thick
Rod [c]	Annealed	28	11	45	$5.65\sqrt{S_o}$	60	63	21	—
	Typical Cold Worked Tempers	35 50	18 44	20 6	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	95 140	100 145	24 30	5–40 mm diam. or equivalent area 3–6 mm diam. or equivalent area
Wire	Annealed	30	—	40	100 mm	—	—	22	0.5–3 mm diam.
	Typical Cold Worked Tempers	55 60 65	— — —	2 — —	100 mm — —	— — —	— — —	32 33 34	0.5–3 mm diam. 0.5–2 mm diam. up to 1 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, SI and 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—SI and English Units[a]

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 [b]	Tensile Strength		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [c]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Strip	Annealed (grain size~0.03 mm)	28	18	9	6	50	50 mm (2 in.)	65	21	14	0.2–3 mm (0.008–0.125 in.) thick
	Cold Worked										
	Quarter Hard	34	22	20	13	27	50 mm (2 in.)	95	24	15	0.2–3 mm (0.008–0.125 in.) thick
	Half Hard	43	28	36	23	13	50 mm (2 in.)	130	28	18	"
	Hard	48	31	40	26	8	50 mm (2 in.)	145	29	19	"
	Extra Hard	51	33	43	28	5	50 mm (2 in.)	155	31	20	"
Rod [d]	Annealed	28	18	9	6	45	$5.65\sqrt{S_o}$	65	21	14	—
	Cold Worked										
	As Manufactured	34	22	19	12	22	$5.65\sqrt{S_o}$	100	26	17	40–70 mm (1.6–2.8 in.) diam. or equivalent area
		40	26	32	21	15	$5.65\sqrt{S_o}$	120	30	20	20–40 mm (0.8–1.6 in.) diam. or equivalent area
		43	28	36	23	10	$5.65\sqrt{S_o}$	130	32	21	6–20 mm (0.25–0.8 in.) diam. or equivalent area

(a) The properties quoted are typical for an alloy of low phosphorus content containing 1.0–1.5% tin, which is the usual "conductivity bronze" employed in the UK.
(b) The recognised temper designations used in the nearest British Standards are also given to clarify the cold-worked tempers shown.
(c) 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.
(d) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American standards. For British and other European countries' practices, see tables 5.1.2 and 5.1.1, respectively.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.
For a given temper, individual elongation values may show some variation above or below the typical values indicated.

Form	Temper	Tensile Strength psi	Yield Strength 0.5% extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [a]
				%	gauge length	F	B	30 T		
Flat Products (Strip)	Annealed (grain size 0.025 mm)	42 000	15 000	50	2 in.	64	—	—	31 000	0.040 in. thick
	Cold Worked									
	Half Hard	58 000	46 000	20	2 in.	—	66	—	38 000	0.040 in. thick
	Hard	68 000	57 000	8	2 in.	—	78	—	41 000	"
	Spring	82 000	66 000	4	2 in.	—	83	—	47 000	"
Rod [b]	Annealed	40 000	—	—	—	64	—	—	30 000	0.20 in. diam.
	Cold Worked									
	Hard	78 000	—	—	—	—	80	—	46 000	0.20 in. diam.
	Half Hard (20%)	58 000	50 000	20	2 in.	—	63	—	38 000	1.0 in. diam.
Wire	Annealed	40 000	—	—	—	—	—	—	30 000	0.080 in. diam.
	Cold Worked									
	Quarter Hard	53 000	—	—	—	—	—	—	36 000	0.080 in. diam.
	Half Hard	65 000	—	—	—	—	—	—	40 000	"
	Hard	85 000	—	—	—	—	—	—	48 000	"

(a) It is possible to obtain sizes different from those given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.
(b) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation		Reduction of Area %
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length	
Rod (1) 5 mm diam. 0.2 in. diam.	Cold Worked and Stress Relieved	27	81	**42**	26.5	59 500	**45**	$11.3\sqrt{S_o}$	—
		—73	—99	**50**	31.5	71 000	**50**	$11.3\sqrt{S_o}$	—
		—173	—279	**67**	42.5	95 500	**60**	$11.3\sqrt{S_o}$	—
		—198	—324	**72**	45.5	102 500	**70**	$11.3\sqrt{S_o}$	—
— (a) (2)	Cold Worked 20%	20	68	**42**	26.5	59 500	**8**	— (b)	**48**
		—196	—321	**59**	37.5	84 000	**13**	— (b)	**50**
		—253	—423	**69**	44	98 000	**14**	— (b)	**45**

(a) Form not stated in original document.

(b) Gauge length not stated in original document.

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

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress ton/in²	Elongation	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length
Rod (1) 5 mm diam. 0.2 in. diam.	Cold Worked and Stress Relieved	27	81	**42**	26.5	59 500	—	**44**	$11.3\sqrt{S_o}$
		77	171	**38**	24	54 000	—	**45**	$11.3\sqrt{S_o}$
		127	261	**39**	25	55 500	—	**44**	$11.3\sqrt{S_o}$
		227	441	**40**	25.5	57 000	—	**42**	$11.3\sqrt{S_o}$
		277	531	**36**	23	51 000	—	**35**	$11.3\sqrt{S_o}$
		327	621	**28**	18	40 000	—	**30**	$11.3\sqrt{S_o}$
		377	711	**23**	14.5	32 500	—	**32**	$11.3\sqrt{S_o}$
		427	801	**17**	11	24 000	—	**35**	$11.3\sqrt{S_o}$
		477	891	**10**	6.5	14 000	—	**35**	$11.3\sqrt{S_o}$
Rod (3) 25.4 mm diam. 1 in. diam.	Rolled	16	60	30	**19.13**	43 000	**4.83** (a)	**56.0**	2 in.
		204	400	26.5	**16.77**	37 500	**2.84** (a)	**53.0**	2 in.
		260	500	25.5	**16.25**	36 500	**2.84** (a)	**45.0**	2 in.
		316	600	23	**14.54**	32 500	**2.84** (a)	**23.5**	2 in.
		371	700	18	**11.36**	25 500	**2.55** (a)	**21.0**	2 in.
		427	800	20.5	**12.97**	29 000	**3.12** (a)	**36.5**	2 in.
		466	870	19.5	**12.31**	27 500	**2.84** (a)	**38.5**	2 in.

(a) 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.

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

— Further data can be obtained from the following paper:-

■ Köster, W. and Speidel, M. O. Der Einfluss der Temperatur und der Korngrösse auf die ausgeprägte Streckgrenze von Kupferlegierungen. Z. Metallkunde, vol. 56 (1965), pp. 585–598. (Alloy containing 0.98% Sn)

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Creep %
		°C	°F	kg/mm²	ton/in²	psi		
Rod [9] [b] **17 mm diam.** **0.67 in. diam.**	Annealed	200	392	**4.0** **6.0** **8.0**	2.5 3.8 5.1	5 700 8 500 11 400	**2 764** **2 764** **2 764**	**0.19** **0.78** **1.75**
	Cold Worked [a]	200	392	**14.0** **16.0** **18.0**	8.9 10.2 11.4	19 900 22 800 25 600	**3 018** **3 018** **3 018**	**0.15** **0.19** **0.22**

[a] Quoted as "hard" in original document, but amount of cold work not defined.
[b] Alloy containing 0.91 % Sn.
N.B.:—Original values are printed in **bold type**; other values are converted.
—Ref. [9] also gives stresses for designated extensions in 500, 1 000, 2 000 and 5 000 h.

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 [4] **0.8 mm** **0.032 in.**	Cold Worked 60 % 75 %	100 100	48.5 51.5	13.5 [a] 14.5 [a]	31 33	8.5 [a] 9 [a]	**68 900** **73 600**	**19 000** [a] **20 500** [a]
Strip [5] **1 mm** **0.04 in.**	Annealed (grain size 0.035 mm) (grain size 0.015 mm)	100 100	28 29.5	11.5 [a] 12.5 [a]	18 19	7.5 [a] 8 [a]	**40 000** **42 000**	**16 500** [a] **17 500** [a]
	Cold Worked 21 % [b] 21 % [c]	100 100	37.5 38	16.5 [a] 17.5 [a]	23.5 24	10.5 [a] 11 [a]	**53 000** **54 000**	**23 500** [a] **25 000** [a]
	Cold Worked 37 % [b] 37 % [c]	100 100	43 45	18.5 [a] 19.5 [a]	27 28.5	11.5 [a] 12.5 [a]	**61 000** **64 000**	**26 000** [a] **27 500** [a]
	Cold Worked 50 % [b] 50 % [c]	100 100	47 49	17.5 [a] 19.5 [a]	30 31.5	11 [a] 12.5 [a]	**67 000** **70 000**	**25 000** [a] **28 000** [a]
	Cold Worked 60.5 % [b] 60.5 % [c]	100 100	49 52	20 [a] 20.5 [a]	31.5 33	12.5 [a] 13 [a]	**70 000** **74 000**	**28 500** [a] **29 500** [a]
	Cold Worked 69 % [b] 69 % [c]	100 100	52 53.5	20 [a] 21.5 [a]	33 34	12.5 [a] 13.5 [a]	**74 000** **76 000**	**28 500** [a] **30 500** [a]
Rod [8] **10 mm diam.** **0.398 in. diam.**	Cold Worked 36.6 %	300 300	41.5 44	22 [d] 23 [d]	26.5 28	14 [d] 14.5 [d]	**59 200** **62 400**	**31 300** [d] **32 700** [d]
Wire [7] **1.8 mm diam.** **0.072 in. diam.**	Cold Worked 60 % 84 %	100 100	46.5 50.5	20 [d] 22.5 [d]	29.5 32	12.5 [d] 14.5 [d]	**66 000** **72 000**	**28 500** [d] **32 000** [d]
Wire [6] **2 mm diam.** **0.08 in. diam.**	Cold Worked 80 %	100	55.5	22.5 [d]	35.5	14.5 [d]	**79 000**	**32 000** [d]

[a] Reversed-bending test.
[b] Ready-to-finish grain size: 0.035 mm.
[c] Ready-to-finish grain size: 0.015 mm.
[d] Rotating-beam test.
N.B.: Original values are printed in **bold type**; other values are converted.

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WROUGHT MATERIALS

COPPER-TIN ALLOYS
Tin Bronzes
Phosphor Bronzes

Cu Sn4

Common name: 3% Phosphor Bronze

A copper-tin alloy with an alpha phase structure and containing a small amount of phosphorus. The alloy offers a good combination of cold-working properties, strength and hardness. Cu Sn4 has good resistance to corrosion, including stress-corrosion. The most commonly used wrought forms are strip, rod and wire.

COMPOSITION (weight %)*

Sn	3.0 –4.5
P	0.02–0.40
Cu	rem.

*The tin content of this material falls within the wider range of 3.0–5.5% defined for Cu Sn4 in ISO Recommendation R427; the narrower tin ranges of 3.0–4.5% and 4.5–5.5% have, however, been adopted for data sheets G2 and G3 respectively, in order to define the properties of these alloys more precisely.

1 SOME TYPICAL USES

Architectural
Masonry fixings.

Electrical
Springs, clips, switch components and contacts.

Mechanical
Springs, bellows and diaphragms; cold-headed screws, rivets and bolts; nuts, washers and cotter pins; wire brushes.

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 [(a)]	950–1 070 °C	1 740–1 960 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 017 per °C	0.000 009 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:		
20 °C *68 °F*	0.15 – 0.28 cal cm/cm² s °C	36–68 Btu ft/ft² h °F
200 °C *392 °F*	0.20 – 0.35 „ „	48–85 „ „
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	8.7–15 m/ohm mm²	15–25% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.11–0.069 ohm mm²/m 11–6.9 microhm cm	69–41 ohms (circ mil/ft) 4.5–2.7 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F*	0.000 7 per °C (15% IACS) 0.001 3 „ „ (25% IACS)	0.000 4 per °F (15% IACS) 0.000 7 „ „ (25% IACS)
applicable over range from 0 to 100 °C *32 to 212 °F*		
2.9 Modulus of elasticity (tension) at 20°C *68 °F*		
annealed	12 200 kg/mm²	17 400 000 lb/in²
cold worked	11 200 kg/mm²	15 950 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20°C *68 °F*		
annealed	4 500 kg/mm²	6 400 000 lb/in²
cold worked	4 150 kg/mm²	5 900 000 lb/in²

(a) For high phosphorus contents, the temperatures, especially at the bottom of the range, will be lower.

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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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	1 110–1 180 °C	2 030–2 155 °F
3.2 Annealing temperature range	500– 700 °C	930–1 290 °F
Stress relieving temperature range	200– 350 °C	390– 660 °F
3.3 Hot working temperature range	700– 800 °C	1 290–1 470 °F
3.4 Hot formability	Limited	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	80% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	20	
3.8 Joining methods:	See General Data Sheet No. 3.7	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Fair	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Fair	
Resistance welding: spot	Good	
seam	Fair	
butt	Excellent	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	—	—	—	—	—	—	—	—
Canada	CSA	HC. TJ50 510	—	HC.4.5	HC.5.5	—	—	HC.5.5	—
Chile	INDITECNOR	—	—	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	—	—	—	—	—	—	—	—
India	IS	P Cu Sn4	—	1385	1385	1385	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	PBP1 PBB1 PBR1 PBW1	—	H 3731	H 3741	H 3751	—	—	—
Netherlands	N or NEN[b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	PB101	—	407 2870 2875	—	—	—	—	—
United States[c]	ASTM	No. 511	—	B 100 B 103	—	B105	—	—	—
International Organization for Standardization	ISO	Cu Sn4	R 427	—	—	—	—	—	—

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

5.1 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		
Sheet Strip	Annealed (grain size 0.025 mm)	33	13	50	50 mm	70	74	25	0.2–3 mm thick
	Typical Cold Worked Tempers	40	25	35	$5.65\sqrt{S_o}$	115	120	30	over 1 mm thick
		50	40	12	50 mm	160	170	34	0.5–3 mm thick
		60	51	5	50 mm	180	190	37	0.2–1.5 mm thick
		66	58	2	50 mm	195	205	38	up to 0.5 mm thick
Rod [c]	Annealed	33	13	50	$5.65\sqrt{S_o}$	70	74	25	—
	Typical Cold Worked Tempers	40	25	35	$5.65\sqrt{S_o}$	115	120	30	5–40 mm diam. or equivalent area
		60	50	5	$5.65\sqrt{S_o}$	180	190	39	3– 6 mm diam. or equivalent area
Wire	Annealed	35	—	45	100 mm	—	—	26	0.5–3 mm diam.
	Typical Cold Worked Tempers	63	—	2	100 mm	—	—	37	0.5–3 mm diam.
		68	—	—	—	—	—	38	0.5–2 mm diam.
		78	—	—	—	—	—	39	up to 1 mm diam.
		90	—	—	—	—	—	40	up to 0.5 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, SI and 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—SI and 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		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [b]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Plate	Annealed	31	20	9	6	50	$5.65\sqrt{S_o}$	75	23	15	—
	Hot Rolled	32	21	12	8	45	$5.65\sqrt{S_o}$	90	24	16	12–50 mm (0.5–2 in.) thick
	Cold Rolled Hard	40 42	26 27	23 28	15 18	35 25	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	120 135	30 32	20 20	16–25 mm (0.625–1 in.) thick 10–16 mm (0.375–0.625 in.) thick
Sheet Strip	Annealed (grain size ~0.03 mm)	32	21	11	7	55	50 mm (2 in.)	75	24	16	0.2–3 mm (0.008–0.125 in.) thick
	Cold Worked Quarter Hard Half Hard Hard Extra Hard	 37 51 59 65	 24 33 38 42	 22 40 46 51	 14 26 30 33	 33 13 8 5	 50 mm (2 in.) 50 mm (2 in.) 50 mm (2 in.) 50 mm (2 in.)	 125 165 185 200	 26 33 35 39	 17 21 23 25	 0.2–3 mm (0.008–0.125 in.) thick " " "
Rod [c]	Annealed	32	21	11	7	50	$5.65\sqrt{S_o}$	75	24	16	—
	Cold Worked As Manufactured	40 48 51	26 31 33	23 37 40	15 24 26	30 20 15	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	130 150 160	28 31 33	18 20 21	40–70 mm (1.6–2.8 in.) diam. or equivalent area 20–40 mm (0.8–1.6 in.) diam. or equivalent area 6–20 mm (0.25–0.8 in.) diam. or equivalent area

[a] The recognised temper designations used in the relevant or nearest British Standards are also given to clarify the cold-worked tempers shown.
[b] It is possible to obtain sizes outside the ranges given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.
[c] The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American standards. For British and other European countries' practices, see tables 5.1.2 and 5.1.1, respectively.
The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.
For a given temper, individual elongation values may show some variations above or below the typical values indicated.

Form	Temper	Tensile Strength psi	Yield Strength 0.5% extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [a]
				%	gauge length	F	B	30 T		
Flat Products (Plate, Sheet Strip and Bar)	Annealed (grain size 0.025 mm)	49 000	20 000	55	2 in.	74	—	—	37 000	0.040 in. thick
	Cold Worked Half Hard Hard Spring	 66 000 79 000 95 000	 52 000 65 000 76 000	 24 10 4	 2 in. 2 in. 2 in.	 — — —	 77 88 94	 68 74 78	 47 000 50 000 54 000	 0.040 in. thick " "
Rod [b]	Annealed	47 000	—	—	—	—	—	—	36 000	0.20 in. diam.
	Cold Worked Hard Half Hard (20%)	 98 000 67 000	 — 56 000	 — 23	 — 2 in.	 — —	 — 76	 — —	 54 000 47 000	 0.20 in. diam. 1.0 in. diam.
Wire	Annealed	47 000	—	—	—	—	—	—	36 000	0.080 in. diam.
	Cold Worked Quarter Hard Half Hard Hard	 64 000 80 000 104 000	 — — —	 — — —	 — — —	 — — —	 — — —	 — — —	 46 000 51 000 55 000	 0.080 in. diam. " "

[a] It is possible to obtain sizes different from those given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.
[b] The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties — Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Reduction of Area %	Impact [b] Strength
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% extension under load psi	%	gauge length		ft lb
Rod (1) **5 mm diam.** **0.2 in. diam.**	Cold Worked and Stress Relieved	27 —73 —173 —198	81 —99 —279 —324	**48** **60** **85** **95**	30.5 38 54 60.5	68 500 85 500 121 000 135 000	— — — —	— — — —	— — — —	**50** **62** **80** **90**	$11.3\sqrt{S_o}$ $11.3\sqrt{S_o}$ $11.3\sqrt{S_o}$ $11.3\sqrt{S_o}$	— — — —	— — — —
Rod (2) (3) **13 mm diam.** **0.5 in. diam.**	Cold Worked (a)	20 —41	68 —42	61 65.5	39 41.5	**87 000** **93 000**	— —	— —	**82 500** **85 000**	**19.5** **20**	2 in. 2 in.	**69.5** **68**	**46.5** **44**
Rod (4) (5)	Annealed	0 —100 —188	32 —148 —306	34.5 42 52	**21.9** **26.8** **33.0**	49 000 60 000 74 000	— — —	**8.0** **10.27** **14.3**	— — —	— — —	— — —	— — —	— — —
Rod (3) (6)	Rolled	20 —183	68 —297	43.5 65.5	27.5 41.5	**61 600** **93 200**	**40.1** (c) **50.5** (c)	— —	— —	**36** **56.3**	2 in. 2 in.	**65.4** **58.0**	— —

(a) Quoted as "hard drawn" in original document, but amount of cold work not defined.

(b) Round Izod specimen. Cross-sectional area at the notch not reported in original document; therefore impossible to give conversion from ft lb into kg m/cm².

(c) Quoted as "yield strength by drop of beam" in original document, but offset strain not defined.

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

— Data not available: Proof stress 0.2% offset.

— Further data can be obtained from the following papers:-

- McAdam, D. J. Jr., and Geil, G. W. The Variation of the Strength, Resistance to Oxidation, and Electrical Conductivity of Metals with Temperature. Trans. A.S.M., Vol. 33 (1944), pp. 514–534.
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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	psi	%	gauge length
Rod (1) **5 mm diam. 0.2 in. diam.**	Cold Worked and Stress Relieved	27	81	**49**	31	69 500	—	**50**	$11.3\sqrt{S_o}$
		77	171	**48**	30.5	68 500	—	**48**	$11.3\sqrt{S_o}$
		127	261	**48**	30.5	68 500	—	**45**	$11.3\sqrt{S_o}$
		177	351	**54**	34.5	77 000	—	**57**	$11.3\sqrt{S_o}$
		227	441	**50**	31.5	71 000	—	**50**	$11.3\sqrt{S_o}$
		277	531	**36**	23	51 000	—	**25**	$11.3\sqrt{S_o}$
		327	621	**28**	18	40 000	—	**25**	$11.3\sqrt{S_o}$
		377	711	**24**	15	34 000	—	**32**	$11.3\sqrt{S_o}$
		427	801	**18**	11.5	25 500	—	**40**	$11.3\sqrt{S_o}$
		477	891	**12**	7.5	17 000	—	**48**	$11.3\sqrt{S_o}$
Rod (7) **19 mm diam. 0.75 in. diam.**	Annealed	21	70	33.5	21.5	**47 800**	**21 400** (a)	**74.0**	2 in.
		149	300	33	21	**47 200**	**17 000** (a)	**81.5**	2 in.
		232	450	33.5	21.5	**47 900**	**17 000** (a)	**70.0**	2 in.
		288	550	29	18.5	**41 300**	**16 700** (a)	**31.5**	2 in.
		343	650	24.5	15.5	**34 800**	**14 000** (a)	**18.5**	2 in.
		427	800	19.5	12	**27 400**	**10 800** (a)	**34.0**	2 in.

(a) 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.

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

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total creep (a) %	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod (7) (b) **19 mm diam. 0.75 in. diam.**	Annealed	149	300	7.0	4.5	**10 000**	**250**	**0.012**	**0.012**	**0**
		177	350	7.0	4.5	**10 000**	**250**	**0.011**	**0.011**	**0**
		204	400	7.0	4.5	**10 000**	**250**	**0.008**	**0.002**	**0.028**
		232	450	2.1 7.0	1.3 4.5	**3 000** **10 000**	**250** **250**	**0.013** **0.046**	**0.013** **0**	**0** **0.184**
		260	500	2.1 7.0	1.3 4.5	**3 000** **10 000**	**250** **250**	**0.018** **0.067**	**0.018** **0**	**0** **0.268**
		288	550	2.1 7.0	1.3 4.5	**3 000** **10 000**	**250** **500**	**0.026** **0.350**	**0.023** **0**	**0.011** **0.70**
		316	600	2.1 7.0	1.3 4.5	**3 000** **10 000**	**500** **250**	**0.070** **0.850**	**0.022** **0**	**0.096** **3.4**
		343	650	0.70 2.1	0.45 1.3	**1 000** **3 000**	**500** **500**	**0.083** **0.172**	**0.064** **0**	**0.038** **0.35**
		371	700	0.70 2.1	0.45 1.3	**1 000** **3 000**	**500** **500**	**0.070** **0.575**	**0.010** **0**	**0.126** **1.15**
		399	750	0.70	0.45	**1 000**	**250**	**0.106**	**0.018**	**0.342**
		427	800	0.70	0.45	**1 000**	**1 000**	**0.870**	**0**	**0.87**

(a) Total creep = Intercept + (Minimum creep rate × Duration).
(b) Alloy containing 0.22% Fe.
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 0.1% per 1 000 h Creep Rate		
		°C	°F	kg/mm²	ton/in²	psi
Rod (8) (a)	Annealed (b)	238 321 368	460 610 695	7.0 2.1 0.70	4.5 1.3 0.45	**10 000** **3 000** **1 000**

(a) Form not stated in original document, but probably rod.
(b) Temper not stated in original document, but probably annealed.
N.B.: — Original values are printed in **bold type**; other values are converted.
— The stresses for 0.001% per 1 000 h and 0.01% per 1 000 h creep rate values are not available.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles $\times 10^6$	Metric Units kg/mm² Tensile Strength	Metric Units kg/mm² Fatigue Strength	English Units ton/in² Tensile Strength	English Units ton/in² Fatigue Strength	American Units psi Tensile Strength	American Units psi Fatigue Strength
Sheet [9] **0.5 mm 0.02 in.**	Annealed	100	38.5	9.5 [a]	24.5	6 [a]	**55 100**	**13 750** [a]
	Cold Worked 37%	100	55.5	18 [a]	35	11.5 [a]	**78 800**	**25 500** [a]
	Cold Worked 60.5%	100	63.5	15.5 [a]	40.5	10 [a]	**90 200**	**22 000** [a]
Strip [10] **0.8 mm 0.032 in.**	Cold Worked 60%	100	67	14 [a]	42.5	9 [a]	**95 000**	**20 000** [a]
Strip [11] **1 mm 0.04 in.**	Annealed (grain size 0.035 mm)	100	33.5	15 [a]	21	9.5 [a]	**47 500**	**21 000** [a]
	Annealed (grain size 0.015 mm)	100	38	20.5 [a]	24	13 [a]	**54 000**	**29 000** [a]
	Cold Worked 21% [d]	100	42	18.5 [a]	27	11.5 [a]	**60 000**	**26 000** [a]
	Cold Worked 21% [e]	100	47	24 [a]	30	15 [a]	**67 000**	**34 000** [a]
	Cold Worked 37% [d]	100	52.5	20.5 [a]	33.5	13 [a]	**75 000**	**29 000** [a]
	Cold Worked 37% [e]	100	57.5	24 [a]	36.5	15 [a]	**82 000**	**34 000** [a]
	Cold Worked 50% [d]	100	60	22 [a]	38	14 [a]	**85 000**	**31 000** [a]
	Cold Worked 50% [e]	100	64	24 [a]	40.5	15 [a]	**91 000**	**34 000** [a]
	Cold Worked 60.5% [d]	100	64.5	22 [a]	41	14 [a]	**92 000**	**31 500** [a]
	Cold Worked 60.5% [e]	100	68	24.5 [a]	43.5	15.5 [a]	**97 000**	**35 000** [a]
	Cold Worked 69% [d]	100	67.5	22 [a]	43	14 [a]	**96 000**	**31 000** [a]
	Cold Worked 69% [e]	100	71.5	24.5 [a]	45.5	15.5 [a]	**102 000**	**35 000** [a]
Rod [12] **13 mm diam. 0.5 in. diam.**	Annealed (grain size 0.025 mm)	1 000	35.5	20.5 [b]	22.5	13 [b]	**50 600**	**29 000** [b]
	Cold Worked 15.2%	1 000	40	19.5 [b]	25.5	12.5 [b]	**56 700**	**27 500** [b]
	Cold Worked 30.1%	1 000	49	20 [b]	31	12.5 [b]	**69 800**	**28 500** [b]
	Cold Worked 50.1%	1 000	68	22.5 [b]	43	14.5 [b]	**96 600**	**32 000** [b]
Rod [13] **5 mm diam. 0.75 in diam.**	Cold Worked [f]	100 [c]	43.5	15.5 [b]	**27.6**	**9.8** [b]	62 000	22 000 [b]
Rod [14] **25.4 mm diam. 1 in. diam.**	Rolled	100 [c]	46.5	20.5 [b]	29.5	13 [b]	**66 400**	**29 000** [b]
Wire [15] **1.8 mm diam. 0.072 in. diam.**	Cold Worked 84%	100	85	21 [b]	54	13.5 [b]	**121 000**	**30 000** [b]

(a) Reversed-bending test.
(b) Rotating beam test.
(c) Extrapolated value.
(d) Ready-to-finish grain size 0.035 mm.
(e) Ready-to-finish grain size 0.015 mm.
(f) Rolled, drawn and stress relieved 30 minutes 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 papers:-

- McAdam, D. J., Jr. Effect of Cold Working on Endurance and Other Properties of Metals–Parts 1 and 2. Trans. ASST, vol. 8 (1925), pp. 782–836.
- 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), pp. 633–646.

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Cu Sn5

Common names: 5% Phosphor Bronze
Phosphor Bronze, 5% A

A copper-tin alloy with an alpha phase structure and containing a small amount of phosphorus. The alloy has good cold-working properties and corrosion resistance, combined with somewhat higher strength and hardness than Cu Sn4. The most commonly used wrought forms are strip, rod and wire.

COMPOSITION (weight %)*

Sn	4.5 –5.5
P	0.02–0.40
Cu	rem.

*The tin content of this material falls within the wider range of 3.0–5.5% defined for Cu Sn4 in ISO Recommendation R427; the narrower tin ranges of 3.0–4.5% and 4.5–5.5% have, however, been adopted for data sheets G2 and G3 respectively, in order to define the properties of these alloys more precisely.

1 SOME TYPICAL USES

Architectural
Masonry fixings.

Chemical
Tubes for acid mine waters; components for the chemical, textile and papermaking industries.

Electrical
Springs, clips, switch components and contacts.

Mechanical
Springs, bellows and diaphragms; cold-headed screws, rivets and bolts; nuts, washers and cotter pins; wire brushes; Bourdon tubing; welding rods and arc-welding electrodes.

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 [a]	930–1 060 °C	1 705–1 940 °F
2.3	Coefficient of thermal expansion (linear) at:		
	—193 °C *—315 °F*	0.000 008 per °C	0.000 004 per °F
	—183 °C *—297 °F*	0.000 009 „ „	0.000 005 „ „
	20 to 100 °C *68 to 212 °F*	0.000 017 „ „	0.000 009 „ „
	20 to 300 °C *68 to 572 °F*	0.000 018 „ „	0.000 010 „ „
2.4	Specific heat (thermal capacity) at:		
	20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
2.5	Thermal conductivity at:		
	20 °C *68 °F*	0.15–0.23 cal cm/cm² s °C	36–56 Btu ft/ft² h °F
	200 °C *392 °F*	0.20–0.28 „ „	48–68 „ „
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (annealed)	7.5–10 m/ohm mm²	13–18 % IACS
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (annealed)	0.13–0.096 ohm mm²/m 13–9.6 microhm cm	80 –58 ohms (circ mil/ft) 5.2–3.8 microhm in
2.8	Temperature coefficient of electrical resistance at:		
	20 °C *68 °F* (annealed)	0.000 7 per °C (13% IACS) 0.000 9 „ „ (18% IACS)	0.000 4 per °F (13% IACS) 0.000 5 „ „ (18% IACS)
	applicable over range from 0 to 100 °C *32 to 212 °F*		
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*:		
	annealed	12 400 kg/mm²	17 600 000 lb/in²
	cold worked	10 800 kg/mm²	15 400 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*:		
	annealed	4 600 kg/mm²	6 500 000 lb/in²
	cold worked	4 000 kg/mm²	5 700 000 lb/in²

(a) For high phosphorus contents, the temperatures, especially at the bottom of the range, will be lower.

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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Herts.

DATA SHEET No. G 3
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1971 Edition

3 FABRICATION PROPERTIES

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

	Metric Units	English Units
3.1 Casting temperature range	1 110–1 180 °C	2 030–2 155 °F
3.2 Annealing temperature range	500– 700 °C	930–1 290 °F
Stress relieving temperature range	200– 350 °C	390– 660 °F
3.3 Hot working temperature range	650– 750 °C	1 200–1 380 °F
3.4 Hot formability	Limited	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	75% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	20	
3.8 Joining methods:	See General Data Sheet No. 3.7	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Fair	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Fair	
Resistance welding: spot	Good	
seam	Fair	
butt	Excellent	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	Br Sn5 P	—	266.21	266.21	266.21	—	—	—
Canada	CSA	HC. TJ50 510	—	HC.4.5	HC.5.5	HC.5.23	—	HC.5.5	—
Chile	INDITECNOR	Cu Sn5 P	NCh248.of.68	—	—	—	—	—	—
France	NF	U-E5 P	—	A 53-607	—	—	—	—	—
Germany	DIN	—	—	—	—	—	—	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	PBP1 PBB1 PBR1 PBW1	—	H 3731	H 3741	H 3751	—	—	—
Netherlands	N or NEN[b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	Cu Sn5	—	37 103	—	37 103	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Sn5	—	10 801	10 801	10 801	—	—	—
United Kingdom	BS	PB102	—	407 2870 2875	369 2874	384 2873	2871[d]	369 2874	—
United States[c]	ASTM	No. 510	—	B103 B139	B139	B159	—	B139	—
International Organization for Standardization	ISO	Cu Sn4	R 427	—	—	—	—	—	—

[a] Applicable when the chemical composition is not given in the specifications for wrought forms.

[b] Older specifications bear prefix N; for new specifications the NEN prefix is used.

[c] In the United States, bar and flat wire are covered under the Plate-Sheet-Strip column.

[d] Included in imperial units edition (1957) but deleted from metricated revision (1971).

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 variation in composition and manufacturing procedures. For design purposes, national specifications should be consulted.
For a given temper, individual elongation values may show 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		
Sheet Strip	Annealed (grain size 0.025 mm)	35	13	55	50 mm	75	79	26	0.2–3 mm thick
	Typical Cold Worked Tempers	43	28	38	$5.65\sqrt{S_o}$	120	125	31	over 1 mm thick
		54	44	14	50 mm	165	175	35	0.5–3 mm thick
		66	56	5	50 mm	185	195	38	0.2–1.5 mm thick
		72	62	2	50 mm	205	215	39	up to 0.5 mm thick
Rod [c]	Annealed	35	13	55	$5.65\sqrt{S_o}$	75	79	26	—
	Typical Cold Worked Tempers	43	28	38	$5.65\sqrt{S_o}$	120	125	31	5–40 mm diam. or equivalent area
		65	55	5	$5.65\sqrt{S_o}$	190	200	38	3–6 mm diam. or equivalent area
Wire	Annealed	37	—	50	100 mm	—	—	28	0.5–3 mm diam.
	Typical Cold Drawn Tempers	66	—	3	100 mm	—	—	38	0.5–3 mm diam.
		73	—	—	—	—	—	39	0.5–2 mm diam.
		82	—	—	—	—	—	40	up to 1 mm diam.
		95	—	—	—	—	—	41	up to 0.5 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, SI and 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—SI and 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		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [b]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Plate	Annealed	32	21	11	7	55	$5.65\sqrt{S_o}$	80	24	16	—
	Hot Rolled	34	22	14	9	50	$5.65\sqrt{S_o}$	95	26	17	12–50 mm (0.5–2 in.) thick
	Cold Rolled										
	Hard	42	27	26	17	40	$5.65\sqrt{S_o}$	130	32	20	16–25 mm (0.625–1 in.) thick
		43	28	31	20	30	$5.65\sqrt{S_o}$	145	33	21	10–16 mm (0.375–0.625 in.) thick
Sheet Strip	Annealed (grain size ~0.03 mm)	34	22	12	8	60	50 mm (2 in.)	80	26	17	0.2–3 mm (0.008–0.125 in.) thick
	Cold Worked										
	Quarter Hard	39	25	23	15	45	50 mm (2 in.)	130	27	18	0.2–3 mm (0.008–0.125 in.) thick
	Half Hard	54	35	42	27	17	50 mm (2 in.)	175	35	23	"
	Hard	63	41	51	33	8	50 mm (2 in.)	190	38	25	"
	Extra Hard	70	45	56	36	5	50 mm (2 in.)	210	39	25	"
Rod [c]	Annealed	34	22	12	8	55	$5.65\sqrt{S_o}$	80	26	17	—
	Cold Worked										
		43	28	28	18	30	$5.65\sqrt{S_o}$	140	31	20	40–70 mm (1.6–2.8 in.) diam. or equivalent area
	As Manufactured	51	33	39	25	25	$5.65\sqrt{S_o}$	160	32	21	20–40 mm (0.8–1.6 in.) diam. or equivalent area
		54	35	42	27	20	$5.65\sqrt{S_o}$	170	35	23	6–20 mm (0.25–0.8 in.) diam. or equivalent area
Wire	Annealed	34	22	—	—	53	100 mm (4 in.)	—	24	16	2.5–6 mm (0.10–0.25 in.) diam.
		36	23	—	—	50	100 mm (4 in.)	—	27	17	0.5–2.5 mm (0.02–0.10 in.) diam.
	Cold Drawn										
	Quarter Hard [d]	42	27	—	—	25	100 mm (4 in.)	—	29	19	1–6 mm (0.04–0.25 in.) diam.
	Half Hard	59	38	—	—	8	100 mm (4 in.)	—	38	25	2.5–6 mm (0.10–0.25 in.) diam.
	Hard	74	48	—	—	—	—	—	41	27	"
	Extra Hard	85	55	—	—	—	—	—	47	30	"
	Half Hard	60	39	—	—	6	100 mm (4 in.)	—	39	25	0.5–2.5 mm (0.02–0.10 in.) diam.
	Hard	77	50	—	—	—	—	—	43	28	"
	Extra Hard	93	60	—	—	—	—	—	46	30	"
Tube	Annealed	36	23	15	10	50	$5.65\sqrt{S_o}$	85	27	17	—
	Cold Drawn										
	Quarter Hard [e]	40	26	23	15	30	$5.65\sqrt{S_o}$	130	28	18	6–25 mm (0.25–1 in.) O.D. 0.1–1 mm (0.004–0.04 in.) wall
	As Drawn	62	40	46	30	15	$5.65\sqrt{S_o}$	190	43	28	6–50 mm (0.25–2 in.) O.D. 1–4 mm (0.04–0.16 in.) wall
Sections (Extruded)	Cold Drawn As Manufactured [c]	Simple sections are available, with mechanical properties similar to those of "As Manufactured" rod of equivalent cross-sectional area.									

[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 different from those 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.

[d] Typical temper for cold heading and similar applications.

[e] Typical temper for Bourdon-gauge tubes.

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American standards. For British and other European countries' practices, see tables 5.1.2 and 5.1.1, respectively.

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

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

Form	Temper	Tensile Strength psi	Yield Strength 0.5% extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [a]
				%	gauge length	F	B	30 T		
Flat Products (Plate, Sheet Strip and Bar)	Annealed (grain size 0.025 mm)	50 000	21 000	52	2 in.	77	30	—	37 000	0.040 in. thick
	Cold Worked									
	Half Hard	68 000	55 000	28	2 in.	—	78	69	47 000	0.040 in. thick
	Hard	81 000	75 000	10	2 in.	—	87	75	51 000	"
	Spring	100 000	80 000	4	2 in.	—	95	79	54 000	"
	Extra Spring	107 000	80 000	3	2 in.	—	97	80	55 000	"
Rod [b]	Cold Worked									
	Half Hard (20%)	75 000	65 000	25	2 in.	—	80	—	50 000	0.5 in. diam.
	Half Hard (20%)	70 000	58 000	25	2 in.	—	78	—	48 000	1.0 in. diam.
Wire	Annealed (grain size 0.035 mm)	50 000	—	58	2 in.	—	—	—	37 000	0.080 in. diam.
	Cold Worked									
	Half Hard	85 000	—	8	2 in.	—	—	—	53 000	0.080 in. diam.
	Hard	110 000	—	5	2 in.	—	—	—	55 000	"
	Spring (84%)	140 000	—	2	2 in.	—	—	—	57 000	"

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

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Sheet (1) 1.6 mm 0.06 in.	Annealed	27	80	36.5	23	**52 000**	**15.8** (a)	**61**	2 in.	—	—	—
		— 1	30	38	24	**54 000**	**16.2** (a)	**69**	2 in.	—	—	—
		—18	0	39.5	25	**56 000**	**16.5** (a)	**71**	2 in.	—	—	—
		—40	— 40	40	25.5	**57 000**	**17.6** (a)	**73**	2 in.	—	—	—
		—57	— 70	41.5	26.5	**59 000**	**17.9** (a)	**74**	2 in.	—	—	—
		—73	—100	43.5	27.5	**62 000**	**18.3** (a)	**76**	2 in.	—	—	—
	Cold Worked 61%	27	80	69	44	**98 000**	**63.3** (a)	**7**	2 in.	—	—	—
		— 1	30	70.5	44.5	**100 000**	**63.3** (a)	**8**	2 in.	—	—	—
		—18	0	71	45	**101 000**	**64.7** (a)	**8**	2 in.	—	—	—
		—40	— 40	71.5	45.5	**102 000**	**66.1** (a)	**9.5**	2 in.	—	—	—
		—57	— 70	74.5	47.5	**106 000**	**68.2** (a)	**10.5**	2 in.	—	—	—
		—73	—100	75	48	**107 000**	**68.9** (a)	**11**	2 in.	—	—	—
Rod (2) 5 mm diam. 0.2 in. diam.	Cold Worked and Stress Relieved	27	81	**52**	33	74 000	—	**58**	$11.3\sqrt{S_o}$	—	—	—
		— 73	—99	**65**	41.5	92 500	—	**68**	$11.3\sqrt{S_o}$	—	—	—
		—173	—279	**90**	57	128 000	—	**80**	$11.3\sqrt{S_o}$	—	—	—
		—198	—324	**98**	62	139 500	—	**86**	$11.3\sqrt{S_o}$	—	—	—
Rod (3) 19 mm diam. 0.75 in. diam.	Cold Worked 85%	22	72	54.5	34.5	**77 400**	**50.6** (a)	**18**	$4.52\sqrt{S_o}$	**78**	18.3 (b)	**106** (b)
		— 78	—108	60	38	**85 600**	**55.3** (a)	**20**	$4.52\sqrt{S_o}$	**78**	14 (b)	**82** (b)
		—197	—323	74	47	**105 200**	**62.7** (a)	**34**	$4.52\sqrt{S_o}$	**67**	9.3 (b)	**54** (b)
		—253	—423	92	58.5	**131 000**	**73.7** (a)	**39**	$4.52\sqrt{S_o}$	**62**	8.8 (b)	**51** (b)
		—269	—452	82	52	**116 400**	**70.6** (a)	**34**	$4.52\sqrt{S_o}$	**58**	—	—

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

(b) Standard Charpy specimen, V-notch; cross-sectional area at the notch 0.8 cm²; fracture area 95%.

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.

— Further data can be obtained from the following paper:-

- McAdam, D. J., Jr., Geil, G. W. and Mebs, R. W. Effects of Combined Stresses and Low Temperatures on the Mechanical Properties of Some Non-Ferrous Metals. Trans. ASM, Vol. 37 (1946), pp. 497–537.

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	Yield Strength 0.5% ext. under load psi	%	gauge length
Rod (4) **3.2 mm diam. 0.125 in. diam.**	Annealed (grain size 0.050 mm)	24	75	36.5	23	**52 000**	—	**20 000**	**66**	2 in.
		204	400	—	—	—	—	**17 000**	—	—
Rod (2) **5 mm diam. 0.2 in. diam.**	Cold Worked and Stress Relieved	27	81	**52**	33	74 000	—	—	**60**	$11.3\sqrt{S_o}$
		77	171	**50**	31.5	71 000	—	—	**48**	$11.3\sqrt{S_o}$
		127	261	**60**	38	85 500	—	—	**73**	$11.3\sqrt{S_o}$
		177	351	**64**	40.5	91 000	—	—	**79**	$11.3\sqrt{S_o}$
		227	441	**55**	35	78 500	—	—	**63**	$11.3\sqrt{S_o}$
		277	531	**38**	24	54 000	—	—	**29**	$11.3\sqrt{S_o}$
		327	621	**28**	18	40 000	—	—	**26**	$11.3\sqrt{S_o}$
		377	711	**24**	15	34 000	—	—	**26**	$11.3\sqrt{S_o}$
		427	801	**18**	11.5	25 500	—	—	**26.5**	$11.3\sqrt{S_o}$
		477	891	**12**	7.5	17 000	—	—	**27**	$11.3\sqrt{S_o}$
Rod (5) **6.35 mm diam. 0.25 in. diam.**	Cold Worked (c)	20	68	56.5	**36.0**	80 500	—	—	**27**	$4\sqrt{S_o}$
		100	212	54.5	**34.6**	77 500	—	—	**25**	$4\sqrt{S_o}$
		200	392	63.5	**40.2**	90 000	—	—	**30**	$4\sqrt{S_o}$
		300	572	39.5	**25.2**	56 500	—	—	**5**	$4\sqrt{S_o}$
		400	752	34.5	**21.8**	49 000	—	—	**11**	$4\sqrt{S_o}$
		500	932	16.5	**10.5**	23 500	—	—	**56**	$4\sqrt{S_o}$
		600	1 112	10	**6.4**	14 500	—	—	**49**	$4\sqrt{S_o}$
		700	1 292	5.5	**3.4**	7 500	—	—	**45**	$4\sqrt{S_o}$
		800	1 472	3	**1.8**	4 000	—	—	**35**	$4\sqrt{S_o}$
		900	1 652	2	**1.4**	3 000	—	—	**24**	$4\sqrt{S_o}$
Rod (6) **13 mm diam. 0.5 in. diam.**	Cold Worked (d)	27	80	49	31.5	**70 000**	—	—	**23.0**	2 in.
		149	300	47	30	**67 000**	—	—	**26.0**	2 in.
		260	500	42	27	**60 000**	—	—	**11.0**	2 in.
		371	700	26.5	17	**38 000**	—	—	**7.0**	2 in.
Rod (7) **16 mm diam. 0.625 in. diam.**	Annealed (a)	17	63	34.5	22	**48 800**	—	—	**84**	$4\sqrt{S_o}$
		150	302	35	22.5	**50 000**	**11.8** (b)	—	**84**	$4\sqrt{S_o}$
		260	500	28.5	18	**40 300**	**10.2** (b)	—	**34**	$4\sqrt{S_o}$
		350	662	21	13.5	**30 000**	**9.45** (b)	—	**25**	$4\sqrt{S_o}$
		500	932	14.5	9	**20 400**	**6.61** (b)	—	**6**	$4\sqrt{S_o}$
Wire (5) **6.35 mm diam. 0.25 in. diam.**	— (e)	16	61	57	**36.20**	81 000	—	—	**24**	2 in.
		100	212	56	**35.61**	80 000	—	—	**21**	2 in.
		200	392	55.5	**35.16**	79 000	—	—	**15**	2 in.
		300	572	51.5	**32.69**	73 500	—	—	**19**	2 in.
		350	662	44	**27.98**	62 500	—	—	**8**	2 in.
		400	752	39	**24.65**	55 000	—	—	**6**	2 in.
		500	932	16	**10.18**	23 000	—	—	**36**	2 in.
		600	1 112	7.5	**4.72**	10 500	—	—	—	2 in.

(a) Temper not stated in original document, but probably annealed.

(b) Quoted as "0.2% permanent set stress" in original document. This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.

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

(d) ASTM alloy "Phosphor Bronze Grade A" containing 4.2%–5.8% Sn.

(e) Temper not stated in original document.

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

— The 0.1% offset proof stress values are not available.

— Further data can be obtained from the following papers:-

- Tapsell, H. J., Johnson, A. E. and Clenshaw, W. J. Properties of Materials at High Temperatures. 6.–The Strength at High Temperatures of Six Steels and Three Non-Ferrous Metals. Dept. Sci. Ind. Res., Engng. Res., Special Report No. 18 (1932). HMSO, London.
- Koster, W. and Speidel, M. O. Der Einfluss der Temperatur und der Korngrösse auf die ausgeprägte Streckgrenze von Kupferlegierungen. Z. Metallkunde, vol. 56 (1965), pp. 585–598. (Alloy containing 5.55% Sn.)
- Crowe C. H. Properties of Some Copper Alloys at Elevated Temperatures. ASTM Bulletin, No. 250, December (1960), pp. 30–31.

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 [4] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.050 mm)	149	300	3.2	2.0	**4 530**	**5 620**	**0.028**	**0.003**	**0.000 3**
				7.0	4.5	**10 000**	**5 620**	**0.072**	**0.009**	**0.000 8**
				10.6	6.7	**15 100**	**5 620**	**0.142**	**0.016**	**0.001 9**
				12.0	7.6	**17 050**	**4 750**	**0.978**	**0.008**	**0.009 4**
		204	400	1.4	0.88	**1 960**	**4 100**	**0.020**	**0.008**	**0.000 3**
				2.8	1.8	**4 000**	**4 100**	**0.045**	**0.018**	**0.001 2**
				4.1	2.6	**5 870**	**5 100**	**0.065**	**0.020**	**0.002 4**
				7.2	4.5	**10 170**	**5 100**	**0.125**	**0.041**	**0.005 3**
		260	500	0.51	0.32	**720**	**5 100**	**0.014**	**0.005**	**0.000 4**
				1.1	0.69	**1 550**	**5 100**	**0.039**	**0.017**	**0.001 6**
				1.7	1.1	**2 470**	**5 000**	**0.066**	**0.020**	**0.005 0**
				3.5	2.2	**4 970**	**5 800**	**0.216**	**0.065**	**0.018**
				7.4	4.7	**10 550**	**5 640**	**1.191**	**—0.100**	**0.213** [b]
	Cold Worked 84%	149	300	3.2	2.0	**4 580**	**5 620**	**0.045**	**0.009**	**0.000 9**
				10.5	6.7	**14 950**	**5 620**	**0.170**	**0.050**	**0.002 6**
				13.9	8.8	**19 800**	**5 620**	**0.235**	**0.075**	**0.003 7**
				21.0	13.3	**29 800**	**5 620**	**0.367**	**0.112**	**0.008 0**
				35.1	22.3	**49 950**	**4 750**	**0.726**	**0.250**	**0.027**
		204	400	2.1	1.4	**3 040**	**4 500**	**0.081**	**0.047**	**0.002 9**
				4.1	2.6	**5 870**	**5 060**	**0.143**	**0.071**	**0.006 1**
				7.3	4.6	**10 400**	**4 100**	**0.245**	**0.090**	**0.019**
				10.5	6.7	**15 000**	**5 750**	**0.435**	**0.161**	**0.028**
		260	500	0.22	0.14	**320**	**5 100**	**0.113**	**0.025**	**0.016 4**
				0.37	0.24	**530**	**5 640**	**0.285**	**0.090**	**0.033 6**
				0.70	0.44	**990**	**8 150**	**0.797**	**0.269**	**0.063 4**
				1.3	0.81	**1 820**	**5 750**	**2.511**	**—0.243**	**0.47** [b]
				2.1	1.3	**3 020**	**1 780**	**2.714**	**—0.034**	**1.53** [b]
				3.5	2.2	**4 960**	**830**	**2.685**	**—1.520**	**5.00** [b]
Rod [7] 16 mm diam. 0.625 in. diam.	— [d]	250	482	7.9	5.0	**11 200**	**500**	**0.058** [c]	**0.028**	**0.060**
				13.1	8.3	**18 680**	**500**	**0.53** [c]	**0.305**	**0.45**
				14.2	9.0	**20 160**	**500**	**6.16** [c]	**4.90**	**2.5**
				17.3	11.0	**24 640**	**132**	**16**	—	**75.0** [e]
		350	662	1.6	1.0	**2 240**	**500**	**0.063** [c]	**0.023**	**0.08**
				2.4	1.5	**3 360**	**500**	**0.165** [c]	**0.042**	**0.25**
				4.7	3.0	**6 720**	**1 008**	**18.5** [c]	—	**4.0** [e]
				6.3	4.0	**8 960**	**360**	**10.5** [c]	—	**13.0** [e]
				9.4	6.0	**13 440**	**48**	**5** [c]	—	**67.0** [e]
		500	932	0.19	0.12	**269**	**500**	**0.17** [c]	**0**	**0.34** [e]
				0.33	0.21	**470**	**500**	**0.35** [c]	**0**	**0.70** [e]
				0.79	0.50	**1 120**	**204**	**16** [c]	—	**75.0** [e]
Wire [8] 1 mm diam. 0.04 in. diam.	Cold Worked [f]	200	392	78.3	49.7	**111 000**	**5** [g]	—	—	—
				72.0	45.7	**102 000**	**14** [g]	—	—	—
				65.8	41.8	**94 000**	**60** [g]	—	—	—
				63.0	40.0	**89 600**	**80** [g]	—	—	—
				56.5	35.9	**80 400**	**140** [g]	—	—	—
				48.5	31.4	**70 400**	**190** [g]	—	—	—

[a] Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration). [b] Accelerating creep rate. [c] Total creep. [d] Temper not stated in original document. [e] Fractured specimen. [f] Quoted as "spring" in original document, but amount of cold work not defined.
[g] Rupture test.

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

— Further data can be obtained from the following paper:-

- Tapsell, H. J., Johnson, A. E. and Clenshaw, W. J. Properties of Materials at High Temperatures. 6.-The Strength at High Temperatures of Six Steels and Three Non-Ferrous Metals, Dept. Sci. Ind. Res., Engng. Res. Special Report No. 18 (1932). HMSO, London.

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 [4] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.050 mm)	149	300	7.7	4.9	**11 000**	12.0	7.6	**17 000**	—	—	—
		204	400	2.6	1.7	**3 700**	>7.0	>4.5	**>10 000**	—	—	—
		260	500	0.81	0.51	**1 150**	2.5	1.6	**3 600**	6.3	4.0	**9 000**
	Cold Worked 84%	149	300	3.5	2.2	**5 000**	23.9	15.2	**34 000**	>35.1	>22.3	**>50 000**
		204	400	1.1 [a]	0.67 [a]	**1 500** [a]	5.3	3.3	**7 500**	>10.5	>6.7	**>15 000**
		260	500	—	—	—	0.14 [a]	0.09 [a]	**200** [a]	0.77	0.49	**1 100**
Rod [7] 16 mm diam. 0.625 in. diam.	— [b]	250	482	7.0 [c]	4.4 [c]	**9 900** [c]	—	—	—	—	—	—
		350	662	1.6 [c]	1.0 [c]	**2 240** [c]	—	—	—	—	—	—

(a) Extrapolated value.
(b) Temper not stated in original document.
(c) Designated creep rate: 0.04% per 1 000 h.

N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following paper:

- Tapsell, H. J., Johnson, A. E. and Clenshaw, W. J. Properties of Materials at High Temperatures. 6.-The Strength at High Temperatures of Six Steels and Three Non-Ferrous Metals. Dept. Sci. Ind. Res., Engng Res, Special Report No. 18 (1932). HMSO, London.

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 [9] 0.6 mm 0.025 in.	Cold Worked 50% [m]	50	69	25.5 [a]	43.5	16 [a]	**97 900**	**36 000** [a]
	Cold Worked 50% [n]	50	69.5	25 [a]	44	16 [a]	**98 700**	**35 500** [a]
Strip [10] 1 mm 0.04 in.	Annealed (grain size 0.035 mm)	100	34.5	17.5 [a]	22	11 [a]	**49 000**	**25 000** [a]
	Annealed (grain size 0.015 mm)	100	39.5	22 [a]	25	14 [a]	**56 000**	**31 000** [a]
	Cold Worked 21% [b]	100	46.5	21 [a]	29.5	13.5 [a]	**66 000**	**30 000** [a]
	Cold Worked 21% [c]	100	48	23 [a]	30.5	14.5 [a]	**68 000**	**33 000** [a]
	Cold Worked 37% [b]	100	57.5	23 [a]	36.5	14.5 [a]	**82 000**	**33 000** [a]
	Cold Worked 37% [c]	100	59	22.5 [a]	37.5	14.5 [a]	**84 000**	**32 000** [a]
	Cold Worked 50% [b]	100	64	22.5 [a]	40.5	14.5 [a]	**91 000**	**32 000** [a]
	Cold Worked 50% [c]	100	66	21 [a]	42	13.5 [a]	**94 000**	**30 000** [a]
	Cold Worked 60.5% [b]	100	70.5	23 [a]	44.5	14.5 [a]	**100 000**	**33 000** [a]
	Cold Worked 60.5% [c]	100	71	22.5 [a]	45	14.5 [a]	**101 000**	**32 000** [a]
	Cold Worked 69% [b]	100	73	22.5 [a]	46.5	14.5 [a]	**104 000**	**32 000** [a]
	Cold Worked 69% [c]	100	75	22.5 [a]	48	14.5 [a]	**107 000**	**32 000** [a]
Strip [11] 1 mm 0.04 in.	Cold Worked [d]	100	57	17.5 [a]	36	11 [a]	**81 000**	**25 000** [a]
	Cold Worked [e]	100	70.5	15.5 [a]	44.5	10 [a]	**100 000**	**22 000** [a]
Sheet [12] 2.5 mm 0.1 in.	Annealed	100	35.5	18.5 [a]	**22.7**	**11.8** [a]	51 000	26 500 [a]
	Cold Worked 20%	100	43	22 [a]	**27.2**	**13.9** [a]	61 000	31 000 [a]
	Cold Worked 40%	100	58	23.5 [a]	**36.9**	**15.0** [a]	82 500	33 500 [a]
	Cold Worked 60%	100	73	26.5 [a]	**46.4**	**16.9** [a]	104 000	38 000 [a]
Rod [13] 19 mm diam. 0.75 in. diam.	Annealed	100	32	16 [f]	20.5	10.5 [f]	**45 700**	**23 000** [f]
Rod [14] 25.4 mm diam. 1 in. diam.	Annealed	100 [k]	33.5	14 [f]	21.5	9 [f]	**48 000**	**20 000** [f]
	Cold Worked and Stress Relieved [g]	100 [k]	44.5	16 [f]	28	10.5 [f]	**63 000**	**23 000** [f]
	Cold Worked and Stress Relieved [h]	100 [k]	57	16 [f]	36.5	10.5 [f]	**81 300**	**23 000** [f]
	Cold Worked	100 [k]	44	19 [f]	28	12 [f]	**62 900**	**27 000** [f]
		100 [k]	44	8.5 [j]	28	5.5 [j]	**62 900**	**12 000** [j]
Rod [15] 25.4 mm. diam. 1 in. diam.	Cold Rolled	100 [k]	41	8.5 [j]	26	5.5 [j]	**58 600**	**12 000** [j]
Rod [13] 25.4 mm. diam. 1 in. diam.	Cold Worked 66%	100	60	19 [f]	38	12 [f]	**85 100**	**27 000** [f]
Wire [16] 2 mm diam. 0.08 in. diam.	Cold Worked [d]	100	77.5	19 [f]	49	12 [f]	**110 000**	**27 000** [f]
	Cold Worked 75%	100	91.5	21 [f]	58	13.5 [f]	**130 000**	**30 000** [f]

[a] Reversed-bending test. [b] Ready-to-finish grain size 0.035 mm. [c] Ready-to-finish grain size 0.015 mm. [d] Quoted as "hard" in original document, but amount of cold work not defined. [e] Quoted as "spring" in original document, but amount of cold work not defined. [f] Rotating-beam. [g] Stress relieved 3 h at 204°C (*400°F*) in and cooled in oil bath. [h] Stress relieved 3 h at 191°C (*375°F*) in and cooled in oil bath. [j] Alternating-torsion test. [k] Extrapolated value. [m] Alloy containing 0.032% P. [n] Alloy containing 0.106% P.

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

— Further data can be obtained from the following papers:-

- 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), pp. 633–646.
- Torrey, M. N. and Gohn, G. R. A Study of Statistical Treatments of Fatigue Data. Proc. ASTM, Vol. 56 (1956), pp. 1091–1123.
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- Polakowski, N. H. and Palchoudhuri, A. Softening of Certain Cold-Worked Metals Under the Action of Fatigue Loads. Proc. ASTM, Vol. 54 (1954), pp. 701–716.
- Fox, A. Reversed Bending Fatigue Characteristics of Copper Alloy 510 Strip. J. Materials, Vol. 5 (1970), No. 2, pp. 273–293.

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MECHANICAL PROPERTIES (SECTION 5)

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(2) Vöhringer, O. Das Verfestigungsverhalten von vielkristallinen α-Kupfer-Zinn-Legierungen. Thesis, Stuttgart University (1966).

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(5) Private communication from Thomas Bolton and Sons, Ltd., England.

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(8) Parker, E. R. and Ferguson, C. Rupture Tests at 200 Degrees Cent. On Some Copper Alloys. Trans. ASM, Vol. 31, (1943), pp. 699–715.

(9) Price W. B. and Bailey R. W. Fatigue Properties of Five Cold-Rolled Copper Alloys. Trans. AIME, Inst. of Metals Div., Vol. 124 (1937), pp. 271–286.

(10) Gohn, G. R., Guerard, J. P., and Freynik, H. S. The Mechanical Properties of Wrought Phosphor Bronze Alloys. ASTM Special Technical Publication No. 183 (1956).

(11) Standards Handbook: Wrought Copper and Copper Alloy Mill Products – Part 2, Alloy Data. CDA, Inc., New York. Pub. No. 102/8, 6th ed. (1968), p. 74.

(12) Private Communication from Imperial Metal Industries, Ltd., England.

(13) Moore, H. F., and Jasper, T. M. An Investigation of the Fatigue of Metals. Bull. Univ. Illinois Engng. Expt. Stn., No. 152, (1925), Nov.

(14) McAdam, D. J., Jr. Fatigue and Corrosion-Fatigue of Spring Material. Trans. ASME, Applied Mechanics, Vol. 51 (1929), pp. 45–58.

(15) McAdam, D. J. Jr., Endurance Properties of Alloys of Nickel and of Copper – Part 1. Trans. ASST, Vol. 7 (1925), pp. 54–81.

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WROUGHT MATERIALS

COPPER-TIN ALLOYS
Tin Bronzes
Phosphor Bronzes

Cu Sn6

Common name: 7% Phosphor Bronze

A copper-tin alloy with an alpha phase structure and containing a small amount of phosphorus which improves wear resistance and fatigue strength. The alloy has relatively good cold-working properties, combined with high strength, hardness and resistance to corrosion, including corrosion-erosion. The most commonly used wrought forms are strip, rod, wire and tube.

COMPOSITION (weight %)

Sn	5.5 –7.5
P	0.02–0.40
Cu	rem.

1 SOME TYPICAL USES

Chemical
Tubes for acid mine waters; wire for Fourdrinier cloth; components for the chemical, textile and papermaking industries.

Electrical
Springs, clips and switch components.

Mechanical
Springs and diaphragms; wire brushes; Bourdon tubing; pinions, gears and sleeve bushings; pump components; welding rods and arc-welding electrodes.

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 [a]	900–1 050 °C	1 650–1 920 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 017 per °C	0.000 009 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:		
20 °C *68 °F*	0.11–0.16 cal cm/cm² s °C	27–39 Btu ft/ft² h °F
200 °C *392 °F*	0.15–0.22 ,, ,,	36–53 ,, ,,
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	6.4–8.7 m/ohm mm²	11–15% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.16–0.11 ohm mm²/m 16 –11 microhm cm	94 –69 ohms (circ mil/ft) 6.2–4.5 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed)	0.000 6 per °C (11% IACS) 0.000 7 ,, ,, (15% IACS)	0.000 3 per °F (11% IACS) 0.000 4 ,, ,, (15% IACS)
applicable over range from 0 to 100 °C *32 to 212 °F*		
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*:		
annealed	12 000 kg/mm²	17 000 000 lb/in²
cold worked[b]	9 000–11 400 kg/mm²	12 800 000–16 200 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:		
annealed	4 500 kg/mm²	6 400 000 lb/in²
cold worked[b]	3 300–4 200 kg/mm²	4 700 000–6 000 000 lb/in²

[a] For high phosphorus contents, the temperatures, especially at the bottom of the range, will be lower.

[b] The modulus values progressively decrease, within the ranges shown, as the amount of cold work increases.

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

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE.

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3 FABRICATION PROPERTIES

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

	Metric Units	English Units
3.1 Casting temperature range	1 100–1 170 °C	2 010–2 140 °F
3.2 Annealing temperature range	500– 700 °C	930–1 290 °F
Stress relieving temperature range	200– 350 °C	390– 660 °F
3.3 Hot working temperature range	—	—
3.4 Hot formability	Very limited (Not recommended)	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	70% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	20	
3.8 Joining methods:	See General Data Sheet No. 3.7	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Fair	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Fair	
Resistance welding: spot and seam	Good	
butt	Excellent	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	—	—	—	—	—	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	INDITECNOR	Cu Sn7 P	NCh248.of.68	—	—	—	—	—	—
France	NF	U-E7 P	—	—	—	A 53-667 A 53-668	—	—	—
Germany	DIN	Cu Sn6 (2.1020)	17 662	1780 17 670	17 672	17 672 17 682	17 671	—	—
India	IS	P Cu Sn6	—	1385	1385	1385	—	—	—
Italy	UNI	B 6 B 7	—	2527	2527	2527	—	2527	—
Japan	JIS	PBP2 PBB2 PBR2 PBW2	—	H 3731	H 3741	H 3751	—	—	—
Netherlands	N or NEN[b]	Cu Sn7	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	54 28	—	14 54 28	14 54 28	14 54 28	—	—	—
Switzerland	VSM	Cu Sn7	—	10 801	10 801	10 801	10 801	—	—
United Kingdom	BS	PB103	—	407 2870	—	384 2873	—	—	—
United States[c]	ASTM	No. 519	—	—	—	—	—	—	—
International Organization for Standardization	ISO	Cu Sn6	R 427	—	—	—	—	—	—

(a) Applicable when the chemical composition is not given in the specifications for wrought forms.

(b) Older specifications bear prefix N; for new specifications the NEN prefix is used.

(c) In the United States, bar and flat wire are covered under the Plate-Sheet- Strip column.

5.1 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		
Sheet Strip	Annealed (grain size 0.025 mm)	37	15	60	50 mm	80	84	26	0.2–3 mm thick
	Typical Cold Worked Tempers	45	32	35	$5.65\sqrt{S_o}$	130	135	32	over 1 mm thick
		56	47	15	50 mm	170	180	37	0.5–3 mm thick
		66	59	8	50 mm	190	200	42	0.2–1.5 mm thick
		75	70	5	50 mm	210	220	43	up to 0.5 mm thick
		80	76	2	50 mm	225	235	44	up to 0.2 mm thick
Rod [c]	Annealed	37	15	60	$5.65\sqrt{S_o}$	80	84	26	—
	Typical Cold Worked Tempers	45	32	35	$5.65\sqrt{S_o}$	130	135	32	5–40 mm diam. or equivalent area
		55	46	18	$5.65\sqrt{S_o}$	160	170	37	5–12 mm diam. or equivalent area
		68	62	8	$5.65\sqrt{S_o}$	195	205	42	3– 6 mm diam. or equivalent area
Wire	Annealed	39	—	55	100 mm	—	—	28	0.5–3 mm diam.
	Typical Cold Drawn Tempers	70	—	4	100 mm	—	—	43	0.5–3 mm diam.
		78	—	2	100 mm	—	—	44	0.5–2 mm diam.
		85	—	—	—	—	—	45	up to 1 mm diam.
		100	—	—	—	—	—	46	up to 0.5 mm diam.
Tube	Annealed	37	15	60	$5.65\sqrt{S_o}$	80	84	26	—
	Typical Cold Drawn Tempers	44	30	35	$5.65\sqrt{S_o}$	125	130	32	10–35 mm O.D. 2–5 mm wall
		50	40	25	$5.65\sqrt{S_o}$	145	150	35	10–35 mm O.D. 1–5 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, SI and 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—SI and 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		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [b]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Sheet Strip	Annealed (grain size∼0.03 mm)	37	24	14	9	65	50 mm (2 in.)	85	28	18	0.2–3 mm (0.008–0.125 in.) thick
	Cold Worked										
	Quarter Hard	42	27	28	18	50	50 mm (2 in.)	135	29	19	0.2–3 mm (0.008–0.125 in.) thick
	Half Hard	56	36	45	29	22	50 mm (2 in.)	185	36	23	"
	Hard	65	42	57	37	14	50 mm (2 in.)	210	39	25	"
	Extra Hard	71	46	65	42	8	50 mm (2 in.)	220	40	25	"
	Spring Hard	74	48	66	43	7	50 mm (2 in.)	230	37	24	0.2–0.5 mm (0.008–0.02 in.) thick
	Extra Spring Hard	79	51	71	46	5	50 mm (2 in.)	245	40	26	"
Wire	Annealed	37	24	—	—	58	100 mm (4 in.)	—	28	18	2.5–6 mm (0.10–0.25 in.) diam.
		39	25	—	—	55	100 mm (4 in.)	—	29	19	0.5–2.5 mm (0.02–0.10 in.) diam.
	Cold Drawn										
	Half Hard	62	40	—	—	12	100 mm (4 in.)	—	40	26	2.5–6 mm (0.10–0.25 in.) diam.
	Hard	77	50	—	—	—	—	—	46	30	"
	Extra Hard	88	57	—	—	—	—	—	48	31	"
	Half Hard	65	42	—	—	10	100 mm (4 in.)	—	42	27	0.5–2.5 mm (0.02–0.10 in.) diam.
	Hard	82	53	—	—	—	—	—	49	32	"
	Extra Hard	97	63	—	—	—	—	—	53	35	"

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

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

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American standards. For British and other European countries' practices, see tables 5.1.2 and 5.1.1 respectively.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.
For a given temper, individual elongation values may show some variation above or below the typical values indicated.

Form	Temper	Tensile Strength psi	Yield Strength 0.5% extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [a]
				%	gauge length	F	B	30 T		
Flat Products (Strip)	Annealed (grain size 0.025 mm)	55 000	23 000	60	2 in.	80	—	—	40 000	0.040 in. thick
	Cold Worked									
	Half Hard	74 000	56 000	27	2 in.	—	83	71	51 000	0.040 in. thick
	Hard	87 000	71 000	11	2 in.	—	92	77	54 000	"
	Spring	104 000	83 000	4	2 in.	—	97	81	61 000	"
Rod [b]	Annealed	54 000	—	—	—	—	—	—	40 000	0.20 in. diam.
	Cold Worked									
	Hard	112 000	—	—	—	—	—	—	63 000	0.20 in. diam.
	Half Hard (20%)	74 000	61 000	28	2 in.	—	82	—	51 000	1.0 in. diam.
Wire	Annealed	55 000	—	—	—	—	—	—	40 000	0.080 in. diam.
	Cold Worked									
	Quarter Hard	75 000	—	—	—	—	—	—	51 000	0.080 in. diam.
	Half Hard	93 000	—	—	—	—	—	—	58 000	"
	Hard	120 000	—	—	—	—	—	—	63 000	"

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

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation % on $5.65\sqrt{S_o}$	Reduction of Area %
		°C	°F	kg/mm²	ton/in²	psi		
Rod (1) 8–10 mm diam. 0.3–0.4 in. diam.	Cold Worked	17	63	**63**	40	89 500	**12**	**61**
		—196	—321	**84**	53.5	119 500	**29**	**54**
		—253	—423	**95**	60.5	135 000	**29**	**51**

N.B.: — Original data are printed in **bold type**; other values are converted.
— Data not available: Proof stress, 0.2% and 0.1% offset,
Yield strength, 0.5% extension under load,
Impact strength.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation	
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length
Strip (2)	Cold Worked	20	68	**68**	43	96 500	**5**	$11.3\sqrt{S_o}$
		100	212	**69**	44	98 000	**7**	$11.3\sqrt{S_o}$
		150	302	**68**	43	96 500	**10**	$11.3\sqrt{S_o}$
		200	392	**67**	42.5	95 500	**13**	$11.3\sqrt{S_o}$
		250	482	**66**	42	94 000	**18**	$11.3\sqrt{S_o}$
		300	572	**64**	40.5	91 000	**26**	$11.3\sqrt{S_o}$
		350	662	**61**	38.5	87 000	**35**	$11.3\sqrt{S_o}$
		400	752	**54**	34.5	77 000	**39**	$11.3\sqrt{S_o}$
		450	842	**43**	27.5	61 000	**42**	$11.3\sqrt{S_o}$
		500	932	**39**	25	55 500	**43**	$11.3\sqrt{S_o}$
Wire (3) 6.35 mm diam. 0.25 in. diam.	Cold Worked (a)	16	61	61	**38.78**	87 000	**25**	2 in.
		100	212	60	**38.05**	85 500	**20**	2 in.
		200	392	60	**38.05**	85 500	**18**	2 in.
		300	572	49.5	**31.53**	70 500	**9**	2 in.
		350	662	47	**29.97**	67 000	**8**	2 in.
		400	752	35.5	**22.55**	50 500	**6**	2 in.
		500	932	18	**11.43**	25 500	**59**	2 in.
		600	1 112	8.5	**5.52**	12 500	—	—
Wire (2)	Cold Worked	20	68	**92**	58.5	131 000	**3**	100 mm
		100	212	**90**	57	128 000	**3**	100 mm
		150	302	**87**	55	123 500	**4**	100 mm
		200	392	**85**	54	121 000	**6**	100 mm
		250	482	**81**	51.5	115 000	**9**	100 mm
		300	572	**74**	47	105 500	**14**	100 mm
		350	662	**55**	35	78 000	**22**	100 mm
		400	752	**42**	26.5	59 500	**40**	100 mm

(a) Amount of cold work not defined in original document.

N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following paper:
■ Wanke, K. and Heinke, J. Tempering of Cold-Formed Springs. Wire (Engl. ed Draht), No. 66 (1963) pp. 164–170.

5.3.2 Creep Properties

Form	Temper	Testing Temperature		Stress			Duration h	Total Creep %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi			
Rod (4) (a)	Annealed	250	482	4	**2.5**	5 600	**1 608**	**0.149**	**0.0317**

(a) Alloy containing 7.57% Sn.

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles × 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 (5) **0.6 mm 0.025 in.**	Cold Worked 50%	50	73.5	23.5 (a)	46.5	15 (a)	**104 200**	**33 600** (a)
Strip (6) **1 mm 0.04 in.**	Cold Worked (b)	100	70.5	19.5 (a)	44.5	12.5 (a)	**100 000**	**28 000** (a)
	Cold Worked (c)	100	81	21 (a)	51.5	13.5 (a)	**115 000**	**30 000** (a)
Rod (7) **1 to 5 mm diam. 0.04 to 0.19 in. diam.**	Cold Worked 25%	(f)	**40**	**17**	25.5	11	57 000	24 000
		(f)	**50**	**21**	31.5	13.5	71 000	30 000
Rod (3) **24 mm diam. 0.94 in. diam.**	Cold Worked (d)	50	—	26 (e)	—	**16.5** (e)	—	37 000 (e)

(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 "hard drawn" in original document but amount of cold work not defined.
(e) Rotating-beam test.
(f) Number of cycles not stated, but probably 10^7.

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

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Kostenets, V. I. Mechanical Properties of Non-ferrous Alloys Under Static Load at Low Temperatures. Zhürnal Tekhnicheskoi Fiziki, Vol. 16 (1946), pp. 527–538.

(2) Wauke, Kl. and Heinke, J. Das Anlassen kalt geformter Federn. Drahat, vol. 13 (1962), pp. 101–107.

(3) Private communication from Thomas Bolton and Sons, Ltd., England.

(4) Voce, E. and Davies, D. A. Creep of Some Tin Bronzes at 250°C. BNFMRA Research Report No. A 595 (1942), 10 pp.

(5) Price, W. B., and Bailey, R. W. Fatigue Properties of Five Cold-Rolled Copper Alloys. Trans. AIME, Inst. of Metals Div., Vol. 124 (1937), pp. 271–286.

(6) 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), pp. 633–646.

(7) "Kopperdata". Strenska Metallverken, Sweden (1963).

Print[illegible]n England by Martin Cadbury Printing Group

Cu Sn8

Common names: 9% Phosphor Bronze
Phosphor Bronze, 8% C

A copper-tin alloy with an alpha phase structure, possibly also containing a small amount of delta phase depending upon fabrication history. The high tin content and the phosphorus addition impart to the alloy excellent wear resistance, fatigue strength and bearing properties. Cu Sn8 also has high strength and hardness, as well as good resistance to corrosion. The most commonly used wrought forms are strip, rod, wire and tube.

COMPOSITION (weight %)

Sn	7.5 –9.0
P	0.02–0.40
Cu	rem.

1 SOME TYPICAL USES

Chemical
Wire for Fourdrinier cloth; components for the chemical, textile and papermaking industries.

Electrical
Heavy-duty springs, clips and switch components.

Mechanical
Heavy-duty springs; diaphragms; wire brushes; Bourdon tubing; pinions, gears and sleeve bushings; pump components; clutch friction plates; bridge bearing plates.

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 [(a)]	860–1 040 °C	1 580–1 905 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 017 per °C	0.000 009 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: 20 °C *68 °F*	0.11–0.15 cal cm/cm² s °C	27–36 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed)	5.8–8.1 m/ohm mm²	10–14% IACS
2.7 Electrical resisitivity (volume) at: 20 °C *68 °F* (annealed)	0.17–0.12 ohm mm²/m 17 –12 microhm cm	100 –74 ohms (circ mil/ft) 6.8–4.8 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*	0.000 6 per °C (10% IACS) 0.000 7 „ „ (14% IACS)	0.000 3 per °F (10% IACS) 0.000 4 „ „ (14% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*:		
annealed	11 400 kg/mm²	16 200 000 lb/in²
cold worked [(b)]	9 000–10 800 kg/mm²	12 800 000–15 400 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:		
annealed	4 200 kg/mm²	6 000 000 lb/in²
cold worked [(b)]	3 300–4 000 kg/mm²	4 700 000–5 700 000 lb/in²

(a) For high phosphorus contents, the temperatures, especially at the bottom of the range, will be lower.

(b) The modulus values progressively decrease, within the ranges shown, as the amount of cold work increases.

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

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE.

Prepared by
CONSEIL INTERNATIONAL POUR LE DEVELOPPEMENT DU CUIVRE (CIDEC)
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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	1 090–1 150 °C	1 995–2 100 °F
3.2 Annealing temperature range	500– 725 °C	930–1 335 °F
Stress relieving temperature range	200– 350 °C	390– 660 °F
3.3 Hot working temperature range	—	—
3.4 Hot formability	Very limited (Not recommended)	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	60% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	20	
3.8 Joining methods:	See General Data Sheet No. 3.7	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Fair	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Fair	
Resistance welding: spot and seam	Good	
butt	Excellent	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	Br Sn8 P	—	266.21	266.21	266.21	—	—	—
Canada	CSA	HC. TJ80 521	—	HC.4.5	HC.5.5.	HC.5.23	—	HC.5.5	—
Chile	INDITECNOR	Cu Sn8 P	NCh248.of.68	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	Cu Sn8 (2.1030)	17 662	1780 17 670	17 672	17 672 17 682	17 671	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	B 8	—	2527	2527	2527	2527	2527	—
Japan	JIS	PBP3 PBSP PBSR PBR3 PBSPS PBSRS PBB3 PBW3	—	H 3731 H 3732	H3741	H3751	—	—	—
Netherlands	N or NEN[b]	Cu-Sn9	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	Cu Sn8	—	37 103	—	37 103	—	—	—
Sweden	SIS	54 31	—	14 54 31	14 54 31	—	—	—	—
Switzerland	VSM	Cu Sn8	—	10 801	10 801	10 801	10 801	—	—
United Kingdom	BS	PB104	—	—	2874[d]	—	2871[e]	—	—
United States[c]	ASTM	No. 521	—	B 103 B 139	B 139	B 159	—	B 139	—
International Organization for Standardization	ISO	Cu Sn8	R 427	—	—	—	—	—	—

[a] Applicable when the chemical composition is not given in the specifications for wrought forms.
[b] Older specifications bear prefix N; for new specifications the NEN prefix is used.
[c] In the United States, bar and flat wire are covered under the Plate-Sheet-Strip column.
[d] Included in imperial units edition (1962) but deleted from metricated revision (1969).
[e] Included in imperial units edition (1957) but deleted from metricated revision (1971).

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		
Sheet Strip	Annealed (grain size 0.025 mm)	42	17	65	50 mm	85	89	31	0.2–3 mm thick
	Typical Cold Worked Tempers	50	40	32	$5.65\sqrt{S_o}$	150	155	35	over 1 mm thick
		60	53	14	50 mm	180	190	39	0.5–3 mm thick
		70	65	6	50 mm	200	210	41	0.2–1.5 mm thick
		80	77	2	50 mm	225	235	42	up to 0.5 mm thick
		85	82	—	—	240	250	43	up to 0.2 mm thick
Rod [c]	Annealed	42	17	65	$5.65\sqrt{S_o}$	85	89	31	—
	Typical Cold Worked Tempers	50	40	35	$5.65\sqrt{S_o}$	150	155	35	5–40 mm diam. or equivalent area
		60	53	18	$5.65\sqrt{S_o}$	180	190	39	5–12 mm diam. or equivalent area
		70	65	8	$5.65\sqrt{S_o}$	200	210	41	3– 6 mm diam. or equivalent area
Wire	Annealed	43	—	55	100 mm	—	—	30	0.5–3 mm diam.
	Typical Cold Drawn Tempers	75	—	4	100 mm	—	—	42	0.5–3 mm diam.
		85	—	2	100 mm	—	—	43	0.5–2 mm diam.
		95	—	—	—	—	—	44	up to 1 mm diam.
		105	—	—	—	—	—	45	up to 0.5 mm diam.
Tube	Annealed	42	17	65	$5.65\sqrt{S_o}$	85	89	31	—
	Typical Cold Worked Tempers	48	35	30	$5.65\sqrt{S_o}$	140	145	34	10–35 mm O.D. 2–5 mm wall
		56	50	20	$5.65\sqrt{S_o}$	175	185	37	10–35 mm O.D. 1–5 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, SI and 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—SI and 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		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [b]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Strip	Annealed (grain size~0.03 mm)	42	27	15	10	65	50 mm (2 in.)	90	32	20	0.2–3 mm (0.008–0.125 in.) thick
	Cold Worked Extra Spring Hard	83	54	71	46	4	50 mm (2 in.)	245	46	30	0.2–0.5 mm (0.008–0.02 in.) thick
Rod [c]	Annealed	42	27	15	10	60	$5.65\sqrt{S_o}$	90	32	20	—
	Cold Worked As Manufactured	48	31	32	21	30	$5.65\sqrt{S_o}$	150	34	22	40–70 mm (1.6–2.8 in.) diam. or equivalent area
		51	33	36	23	28	$5.65\sqrt{S_o}$	170	36	23	20–40 mm (0.8–1.6 in.) diam. or equivalent area
		54	35	39	25	23	$5.65\sqrt{S_o}$	180	37	24	6–20 mm (0.25–0.8 in.) diam. or equivalent area
Wire	Annealed	43	28	—	—	60	100 mm (4 in.)	—	32	21	0.5–2.5 mm (0.02–0.10 in.) diam.

(a) The recognised temper designations used in the relevant or nearest British Standards are also given to clarify the cold-worked tempers shown.
(b) It is possible to obtain sizes outside the ranges given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.
(c) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American standards. For British and other European countries' practices, see tables 5.1.2 and 5.1.1 respectively.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.
For a given temper, individual elongation values may show some variation above or below the typical values indicated.

Form	Temper	Tensile Strength psi	Yield Strength 0.5% extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [a]
				%	gauge length	F	B	30 T		
Flat Products (Plate Sheet Strip and Bar)	Annealed (grain size 0.025 mm)	60 000	25 000	64	2 in.	82	—	—	44 000	0.040 in. thick
	Cold Worked Half Hard	78 000	59 000	31	2 in.	—	88	73	53 000	0.040 in. thick
	Hard	93 000	75 000	12	2 in.	—	95	78	57 000	"
	Spring	111 000	89 000	4	2 in.	—	98	81	61 000	"
	Extra Spring	120 000	—	2	2 in.	—	100	82	61 000	"
Rod [b]	Annealed	60 000	—	—	—	—	—	—	44 000	0.20 in. diam.
	Cold Worked Hard	124 000	—	—	—	—	—	—	63 000	0.20 in. diam.
	Half Hard (20%)	81 000	65 000	33	2 in.	—	85	—	54 000	1.0 in. diam.
Wire	Annealed	60 000	—	—	—	—	—	—	44 000	0.080 in. diam.
	Cold Worked Quarter Hard	84 000	—	—	—	—	—	—	54 000	0.080 in. diam.
	Half Hard	106 000	—	—	—	—	—	—	60 000	"
	Hard	133 000	—	—	—	—	—	—	64 000	"
	Extra Hard	140 000	—	—	—	—	—	—	64 000	"

(a) It is possible to obtain sizes different from those given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.
(b) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length
Rod (1) **5 mm diam. 0.2 in. diam.**	Cold Worked and Stress Relieved	27	81	**68**	43	96 500	—	**75**	$11.3\sqrt{S_o}$
		— 73	— 99	**82**	52	116 500	—	**83**	$11.3\sqrt{S_o}$
		—173	—279	**104**	66	148 000	—	**81**	$11.3\sqrt{S_o}$
		—198	—324	**110**	70	156 500	—	**82**	$11.3\sqrt{S_o}$
Rod (2) **19 mm diam. 0.75 in. diam.**	Cold Worked (a)	24	75	83	52.5	**118 000**	**78.7** (b)	**20**	1 in.
		—196	—320	107	68	**152 000**	**98.4** (b)	**30**	1 in.
		—253	—423	118	75	**168 000**	**108** (b)	**25**	1 in.

(a) Quoted as "hard drawn (Rockwell hardness B 100)" 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.

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

— Data not available: Proof stress, 0.1% offset,
Yield strength, 0.5% extension under load,
Impact strength,
Reduction of area.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length
Rod (1) **5 mm diam. 0.2 in. diam.**	Cold Worked and Stress Relieved	27	81	**69**	44	98 000	—	**75**	$11.3\sqrt{S_o}$
		77	171	**65**	41.5	92 500	—	**63**	$11.3\sqrt{S_o}$
		127	261	**75**	47.5	106 500	—	**80**	$11.3\sqrt{S_o}$
		177	351	**70**	44.5	99 500	—	**73**	$11.3\sqrt{S_o}$
		227	441	**49**	31	69 500	—	**45**	$11.3\sqrt{S_o}$
		277	531	**30**	19	42 500	—	**15**	$11.3\sqrt{S_o}$
		327	621	**23**	14.5	32 500	—	**12**	$11.3\sqrt{S_o}$
		377	711	**20**	12.5	28 500	—	**13**	$11.3\sqrt{S_o}$
		427	801	**17**	11	24 000	—	**14**	$11.3\sqrt{S_o}$
		477	891	**11**	7	15 500	—	**15**	$11.3\sqrt{S_o}$
		527	981	**11** (a)	7	15 500	—	**15** (a)	$11.3\sqrt{S_o}$
Rod (3) **10 mm diam. 0.4 in. diam.**	Cold Worked ~10–15%	20	68	**58**	37	82 500	**50**	**30**	$11.3\sqrt{S_o}$
		100	212	**57**	36	81 000	**47**	**34**	$11.3\sqrt{S_o}$
		200	392	**54**	34.5	77 000	**44**	**28**	$11.3\sqrt{S_o}$
		300	572	**43**	27.5	61 000	**35**	**26**	$11.3\sqrt{S_o}$
		400	752	**28**	18	40 000	**22**	**14**	$11.3\sqrt{S_o}$
Tube (5) **4–5 mm wall 0.16–0.2 in. wall**	Cold Worked (b)	20	68	**57**	36	81 000	**45**	**47**	$5.65\sqrt{S_o}$
		100	212	**57**	36	81 000	**47**	**48**	$5.65\sqrt{S_o}$
		200	392	**55**	35	78 000	**46**	**37**	$5.65\sqrt{S_o}$
		300	572	**49**	31	69 500	**40**	**17**	$5.65\sqrt{S_o}$
		400	752	**35**	22	50 000	**31**	**6**	$5.65\sqrt{S_o}$
Tube (4)	Cold Worked	21	70	55	35	**78 000**	—	**30**	2 in.
		99	210	55	35	**78 000**	—	**32**	2 in.
		199	390	54	34.5	**77 000**	—	**28**	2 in.
		299	570	52	33	**74 000**	—	**27**	2 in.
		399	750	33	21	**47 000**	—	**15**	2 in.
		499	930	28	18	**40 000**	—	**11**	2 in.

(a) Extrapolated value.

(b) Quoted as "Hard and stress relieved" in original document, but amount of cold work not defined.

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

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

— Further data can be obtained from the following papers:

- Leech, E. A., Gregory, P. and Eborall, R. A Hot Impact Tensile Test and its Relation to Hot-Working Properties, J. Inst. Metals, Vol. 83 (1954–55), pp. 347–353.
- Köster, W. and Speidel, M. O. Der Einfluss der Temperatur und der Korngrösse auf die ausgeprägte Streckgrenze von Kupferlegierungen. Z. Metallkunde, vol. 56 (1965), pp. 585–598.

5.3.2 Creep Properties

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Sheet [6] **0.5 mm 0.02 in.**	Annealed	100	36.5	12 [a]	23	7.5 [a]	**51 800**	**17 250** [a]
	Cold Worked 37%	100	62	15.5 [a]	39.5	10 [a]	**88 000**	**22 000** [a]
	Cold Worked 60.5%	100	79.5	19 [a]	50.5	12 [a]	**112 900**	**27 000** [a]
	Cold Worked 69%	100	87.5	17 [a]	55.5	11 [a]	**124 800**	**24 500** [a]
Strip [7] **1 mm 0.04 in.**	Annealed (grain size 0.035 mm)	100	39.5	17.5 [a]	25	11 [a]	**56 000**	**25 000** [a]
	Annealed (grain size 0.015 mm)	100	43	22 [a]	27	14 [a]	**61 000**	**31 000** [a]
	Cold Worked 21% [b]	100	50	22 [a]	31.5	14 [a]	**71 000**	**31 000** [a]
	Cold Worked 21% [c]	100	57	22.5 [a]	36	14.5 [a]	**81 000**	**32 000** [a]
	Cold Worked 37% [b]	100	64	22.5 [a]	40.5	14.5 [a]	**91 000**	**32 000** [a]
	Cold Worked 37% [c]	100	68	22 [a]	43.5	14 [a]	**97 000**	**31 000** [a]
	Cold Worked 50% [b]	100	71.5	21 [a]	45.5	13.5 [a]	**102 000**	**30 000** [a]
	Cold Worked 50% [c]	100	74	22 [a]	47	14 [a]	**105 000**	**31 000** [a]
	Cold Worked 60.5% [b]	100	78	23 [a]	49.5	14.5 [a]	**111 000**	**33 000** [a]
	Cold Worked 60.5% [c]	100	78	22 [a]	49.5	14 [a]	**111 000**	**31 000** [a]
	Cold Worked 69% [b]	100	81	22 [a]	51.5	14 [a]	**115 000**	**31 000** [a]
	Cold Worked 69% [c]	100	83.5	22 [a]	53	14 [a]	**119 000**	**31 000** [a]
Flat Products [8] **1 mm 0.04 in.**	Cold Worked [d]	100	65.5	15.5 [a]	41.5	10 [a]	**93 000**	**22 000** [a]
Rod [9] **13 mm diam. 0.5 in. diam.**	Annealed (grain size 0.020 mm)	1 000	41.5	22.5 [e]	26.5	14.5 [e]	**59 200**	**32 000** [e]
	Annealed (grain size 0.070 mm)	1 000	39	16 [e]	25	10.5 [e]	**55 500**	**23 000** [e]
	Cold Worked 15.2%	1 000	46.5	20.5 [e]	29.5	13 [e]	**66 000**	**29 000** [e]
	Cold Worked 30.1%	1 000	57	24 [e]	36	15 [e]	**81 000**	**34 000** [e]
	Cold Worked 50.1%	1 000	77.5	20.5 [e]	49	13 [e]	**110 300**	**29 000** [e]
Rod [10] **25.4 mm diam. 1 in. diam.**	Annealed	100 [h]	39	15 [e]	24.5	9.5 [e]	**55 400**	**21 000** [e]
	Cold Worked and [f]	100 [h]	57	15.5 [e]	36	10 [e]	**81 000**	**22 000** [e]
	Stress Relieved [g]	100 [h]	66.5	12 [e]	42	7.5 [e]	**94 600**	**17 000** [e]

(a) Reversed-bending test.
(b) Ready-to-finish grain size 0.035 mm.
(c) Ready-to-finish grain size 0.015 mm.
(d) Quoted as "hard" in original document, but amount of cold work not defined.
(e) Rotating-beam test.
(f) Stress relieved 4 h at 191°C *(375°F)* in and cooled in oil bath.
(g) Stress relieved 4 h at 177°C *(350°F)* in and cooled in oil bath.
(h) Extrapolated value.

N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following papers:-

- McKeown, J. A Rapid Method of Estimating the Fatigue Limit or Endurance Limit of Metals in Reverse Bending. Metallurgia (Manchr), Vol. 54 (1956) pp. 151–156, 158.
- Gohn, G. R. and Ellis, W. C. The Fatigue Characteristics of Copper-Nickel-Zinc and Phosphor Bronze Strip in Bending Under Conditions of Unsymmetrical Loading. Proc. ASTM, Vol. 47 (1947), pp. 713–724.

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MECHANICAL PROPERTIES (SECTION 5)

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(2) McClintock, R. M., Van Gundy, D. A. and Kropschot, R. H. Low-Temperature Tensile Properties of Copper and Four Bronzes. ASTM Bull. No. 240 (1959), Sept., pp. 47–50.
(3) Private communication from Carobronze AG, Germany.
(4) Wilkins, R. A., and Bunn, E. S. Copper and Copper-Base Alloys. McGraw-Hill Book Company, New York (1943).
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(6) Greenall, C. H., and Gohn, G. R. Fatigue Properties of Non-ferrous Sheet Metals. Proc. ASTM, Vol. 37 (1937), pp. 160–194.
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(8) Standards Handbook: Wrought Copper and Copper Alloy Mill Products – Part 2, Alloy Data CDA. Inc., New York. Pub. No. 102/8, 6th ed. (1968), p. 76
(9) Anderson, A. R., Swan, E. F. and Palmer, E. W. Fatigue Tests on Some Additional Copper Alloys, Proc. ASTM, Vol. 46 (1946), pp. 678–692.
(10) McAdam, D. J., Jr., Fatigue and Corrosion-Fatigue of Spring Material. Trans. ASME, Applied Mechanics, Vol. 51 (1929), pp. 45–58.

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Cu Sn10

Common names: 10% Phosphor Bronze
Phosphor Bronze, 10% D

A copper-tin alloy with a duplex alpha-plus-delta phase structure. The high tin content and the phosphorus addition impart to the alloy excellent wear resistance, fatigue strength and bearing properties. The alloy exhibits the highest strength and hardness in the copper-tin series. The most commonly used wrought forms are strip and wire.

COMPOSITION (weight %)

Sn	9.0 -11.0
P	0.02- 0.40
Cu	rem.

1 SOME TYPICAL USES

Chemical
Components for the papermaking industry.

Mechanical
Heavy-duty springs and washers; bridge bearing plates.

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 [(a)]	830–1 020 °C	1 525–1 870 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 017 per °C	0.000 009 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: 20 °C *68 °F*	0.10–0.12 cal cm/cm² s °C	24–29 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed)	5.8–7.0 m/ohm mm²	10–12% IACS
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed)	0.17–0.14 ohm mm²/m 17–14 microhm cm	100–86 ohms (circ mil/ft) 6.8–5.7 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*	0.000 6 per °C (10–12% IACS)	0.000 3 per °F (10–12% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	11 000 kg/mm²	15 600 000 lb/in²
cold worked [(b)]	8 400–10 000 kg/mm²	11 900 000–14 200 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:		
annealed	4 100 kg/mm²	5 800 000 lb/in²
cold worked [(b)]	3 100–3 700 kg/mm²	4 400 000–5 300 000 lb/in²

(a) For high phosphorus contents, the temperatures, especially at the bottom of the range, will be lower.

(b) The modulus values progressively decrease, within the ranges shown, as the amount of cold work increases.

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

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE.

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3 FABRICATION PROPERTIES

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

	Metric Units	English Units
3.1 Casting temperature range	1 060–1 130 °C	1 940–2 065 °F
3.2 Annealing temperature range	500– 725 °C	930–1 335 °F
Stress relieving temperature range	200– 350 °C	390–660 °F
3.3 Hot working temperature range	—	—
3.4 Hot formability	Very limited (Not recommended)	
3.5 Cold formability	Fair	
3.6 Cold reduction between anneals	40% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	20	
3.8 Joining methods:	See General Data Sheet No. 3.7	
Soldering	Excellent	
Brazing	Good	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Fair	
Resistance welding: spot and seam	Good	
butt	Excellent	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	—	—	—	—	—	—	—	—
Canada	CSA	HC. TJ100 524	—	HC.4.5	HC.5.5	HC.5.23	—	HC.5.5	—
Chile	INDITECNOR	Cu Sn10 P	NCh248.of.68	—	—	—	—	—	—
France	NF	U-E9 P	—	A53-607	—	—	—	—	—
Germany	DIN	—	—	—	—	—	—	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN[b]	Cu-Sn9	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	Cu Sn10	—	37 103	—	37 103	—	—	—
Sweden	SIS	54 31	—	14 54 31	14 54 31	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States[c]	ASTM	No. 524	—	B 103 B 139	B 139	B 159	—	B 139	—
International Organization for Standardization	ISO	Cu Sn10	R 427	—	—	—	—	—	—

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

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE [*]

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 [a]
				%	gauge length	Brinell	Vickers		
Sheet Strip	Annealed	44	19	65	50 mm	95	100	33	0.2–3 mm thick
	Typical Cold Worked Tempers	70 83 88	64 80 85	17 3 —	50 mm 50 mm —	195 235 245	205 245 255	44 48 48	0.5–3 mm thick up to 1 mm thick up to 0.5 mm thick
Wire	Annealed	46	—	60	100 mm	—	—	34	0.2–1 mm diam.
	Typical Cold Drawn Temper	100	—	—	—	—	—	49	up to 1 mm diam.

[a] 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—SI and 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		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [b]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Strip	Annealed (grain size~0.03 mm)	43	28	17	11	70	50 mm (2 in.)	100	32	21	0.2–3 mm (0.008–0.125 in.) thick
	Cold Worked Extra Spring Hard	87	56	74	48	4	50 mm (2 in.)	250	48	31	0.2–0.5 mm (0.008–0.02 in.) thick

[a] The recognised temper designations used in the nearest British Standards are also given.

[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.

[*] 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, SI and 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.

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American standards. For British and other European countries' practices, see tables 5.1.2 and 5.1.1 respectively.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.
For a given temper, individual elongation values may show some variation above or below the typical values indicated.

Form	Temper	Tensile Strength psi	Yield Strength 0.5% extension under load psi	Elongation %	Elongation gauge length	Rockwell Hardness F	Rockwell Hardness B	Rockwell Hardness 30 T	Shear Strength psi	Typical Size Related to Properties Shown [a]
Flat Products (Plate, Sheet, Strip and Bar)	Annealed (grain size 0.025 mm)	65 000	28 000	68	2 in.	84	—	—	48 000	0.040 in. thick
	Cold Worked									
	Half Hard	83 000	60 000	34	2 in.	—	91	74	57 000	0.040 in. thick
	Hard	100 000	79 000	12	2 in.	—	96	80	64 000	"
	Spring	121 000	93 000	4	2 in.	—	101	83	68 000	"
	Extra Spring	128 000	—	3	2 in.	—	103	84	70 000	"
Wire	Annealed	66 000	—	—	—	—	—	—	48 000	0.080 in. diam.
	Cold Worked									
	Quarter Hard	93 000	—	—	—	—	—	—	61 000	0.080 in. diam.
	Half Hard	118 000	—	—	—	—	—	—	67 000	"
	Hard	146 000	—	—	—	—	—	—	70 000	"

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Impact Properties

Form	Temper	Testing Temperature		Impact Strength	
		°C	°F	kg m/cm²	ft lb
Rod (1) (a)	Cold Worked 37%	23 —78 —196 —246	73 —108 —321 —411	8.3 (b) 4.8 (b) 3.1 (b) 3.5 (b)	**48** (b) **28** (b) **18** (b) **20** (b)

(a) Form not reported in original document, but probably rod.

(b) Standard Charpy specimen, V-notch; cross-sectional area at the notch 0.8 cm².

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

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

— Data not available: Tensile strength,
Proof stress, 0.2% and 0.1% 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 (3) (a)	Annealed (b)	25 75 125 175 225 275 325	77 167 257 347 437 527 617	41.5 42 43 42 — 27.5 22.5	26.5 27 27 27 — 17.5 14.5	**59 000** **60 000** **61 000** **60 000** — **39 000** **32 000**	**64** **68** **70** **68** **36** **17** **10**
Rod (2)	Cold Worked (c)	27 149 260 371	80 300 500 700	74 71.5 64.5 33.5	47 45.5 41 21.5	**105 000** **102 000** **92 000** **48 000**	**18.0** **18.0** **10.0** **22.0**
Wire (4) 6.35 mm diam. 0.25 in. diam.	Cold Worked (c)	16 100 125 150 185 200 225 250 300 350 400 500 600	61 212 257 302 365 392 437 482 572 662 752 932 1 112	69.5 68.5 69 68 68 68 67.5 66 61.5 53.5 45 17 8	**44.21** **43.35** **43.93** **43.30** **43.21** **43.21** **42.98** **41.94** **38.96** **33.86** **28.71** **10.73** **5.14**	99 000 97 000 98 500 97 000 97 000 97 000 96 500 94 000 87 500 76 000 64 500 24 000 11 500	**22** **14.5** **17** **20** **19** **18** **20** **18** **12** **7** **6.5** **73** **52**

(a) Form not reported in original document, but probably rod.

(b) Temper not reported in original document but probably annealed.

(c) Amount of cold work not defined in original document.

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

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

— Further data can be obtained from the following papers:-

- Köster, W. and Speidel, M. O. Der Einfluss der Temperatur und der Korngrösse auf die ausgeprägte Streckgrenze von Kupferlegierungen. Z. Metallkunde, vol. 56 (1965), pp. 585–598.
- Crowe, C. H. Properties of Some Copper Alloys at Elevated Temperatures. ASTM Bulletin, No. 250, December, (1960), pp. 30–31.

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 Tensile Strength	Metric Units kg/mm² Fatigue Strength	English Units ton/in² Tensile Strength	English Units ton/in² Fatigue Strength	American Units psi Tensile Strength	American Units psi Fatigue Strength
Strip [5] 1 mm 0.04 in.	Annealed							
	(grain size 0.035 mm)	100	44.5	17.5 [a]	28	11 [a]	**63 000**	**25 000** [a]
	(grain size 0.015 mm)	100	48.5	22.5 [a]	31	14.5 [a]	**69 000**	**32 000** [a]
	Cold Worked 21% [b]	100	57.5	20.5 [a]	36.5	13 [a]	**82 000**	**29 000** [a]
	Cold Worked 21% [c]	100	60	22.5 [a]	38	14.5 [a]	**85 000**	**32 000** [a]
	Cold Worked 37% [b]	100	69.5	22 [a]	44	14 [a]	**99 000**	**31 000** [a]
	Cold Worked 37% [c]	100	71	22 [a]	45	14 [a]	**101 000**	**31 000** [a]
	Cold Worked 50% [b]	100	75	20.5 [a]	48	13 [a]	**107 000**	**29 000** [a]
	Cold Worked 50% [c]	100	77.5	21 [a]	49	13.5 [a]	**110 000**	**30 000** [a]
	Cold Worked 60.5% [b]	100	81	21 [a]	51.5	13.5 [a]	**115 000**	**30 000** [a]
	Cold Worked 60.5% [c]	100	82.5	21 [a]	52	13.5 [a]	**117 000**	**30 000** [a]
	Cold Worked 69% [b]	100	85	20.5 [a]	54	13 [a]	**121 000**	**29 000** [a]
	Cold Worked 69% [c]	100	86.5	20.5 [a]	55	13 [a]	**123 000**	**29 000** [a]
Rod [6] 13 mm diam. 0.5 in. diam.	Annealed							
	(grain size 0.016 mm)	1 000	48	24.5 [d]	30.5	15.5 [d]	**68 000**	**35 000** [d]
	(grain size 0.065/0.070 mm)	1 000	43.5	17.5 [d]	28	11 [d]	**62 200**	**25 000** [d]
	Cold Worked 15.2%	1 000	54	21 [d]	34	13.5 [d]	**76 600**	**30 000** [d]
	Cold Worked 30.1%	1 000	65	15 [d]	41	9.5 [d]	**92 100**	**21 000** [d]
	Cold Worked 50.1%	1 000	89.5	16 [d]	57	10.5 [d]	**127 500**	**23 000** [d]
Rod [7] 25.4 mm diam. 1 in. diam.	Annealed	100 [f]	45	14 [d]	28.5	9 [d]	**64 300**	**20 000** [d]
	Cold Worked and Stress Relieved [e]	100 [f]	61	12 [d]	38.5	7.5 [d]	**86 700**	**17 000** [d]
		100 [f]	64	12 [d]	41	7.5 [d]	**91 300**	**17 000** [d]
Rod [8]	Annealed	30	47.5	19 [d]	30	12 [d]	**67 500**	**27 000** [d]
	Cold Worked [g]	15	58.5	19 [d]	37	12 [d]	**83 000**	**27 000** [d]

(a) Reversed-bending test.
(b) Ready-to-finish grain size 0.035 mm.
(c) Ready-to-finish grain size 0.015 mm.
(d) Rotating-beam test.
(e) Stress relieved 3h at 204°C *(400°F)* and furnace-cooled.
(f) Extrapolated value.
(g) Amount of cold work not defined in original document.
N.B.: Original values are printed in **bold type**; other values are converted.

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