UDC 669.35'6'779

WROUGHT MATERIALS

COPPER-TIN ALLOYS
Tin Bronzes
Phosphor Bronzes

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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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 54 66 72	28 44 56 62	38 14 5 2	$5.65\sqrt{S_o}$ 50 mm 50 mm 50 mm	120 165 185 205	125 175 195 215	31 35 38 39	over 1 mm thick 0.5–3 mm thick 0.2–1.5 mm thick 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 65	28 55	38 5	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	120 190	125 200	31 38	5–40 mm diam. or equivalent area 3–6 mm diam. or equivalent area
Wire	Annealed	37	—	50	100 mm	—	—	28	0.5–3 mm diam.
	Typical Cold Drawn Tempers	66 73 82 95	— — — —	3 — — —	100 mm — — —	— — — —	— — — —	38 39 40 41	0.5–3 mm diam. 0.5–2 mm diam. up to 1 mm diam. 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 43	27 28	26 31	17 20	40 30	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	130 145	32 33	20 21	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)	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 36	22 23	— —	— —	53 50	100 mm (4 in.) 100 mm (4 in.)	— —	24 27	16 17	2.5–6 mm (0.10–0.25 in.) diam. 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**	$11.3\sqrt{S_0}$
		77	171	**50**	31.5	71 000	—	—	**48**	$11.3\sqrt{S_0}$
		127	261	**60**	38	85 500	—	—	**73**	$11.3\sqrt{S_0}$
		177	351	**64**	40.5	91 000	—	—	**79**	$11.3\sqrt{S_0}$
		227	441	**55**	35	78 500	—	—	**63**	$11.3\sqrt{S_0}$
		277	531	**38**	24	54 000	—	—	**29**	$11.3\sqrt{S_0}$
		327	621	**28**	18	40 000	—	—	**26**	$11.3\sqrt{S_0}$
		377	711	**24**	15	34 000	—	—	**26**	$11.3\sqrt{S_0}$
		427	801	**18**	11.5	25 500	—	—	**26.5**	$11.3\sqrt{S_0}$
		477	891	**12**	7.5	17 000	—	—	**27**	$11.3\sqrt{S_0}$
Rod (5) 6.35 mm diam. 0.25 in. diam.	Cold Worked (c)	20	68	56.5	**36.0**	80 500	—	—	**27**	$4\sqrt{S_0}$
		100	212	54.5	**34.6**	77 500	—	—	**25**	$4\sqrt{S_0}$
		200	392	63.5	**40.2**	90 000	—	—	**30**	$4\sqrt{S_0}$
		300	572	39.5	**25.2**	56 500	—	—	**5**	$4\sqrt{S_0}$
		400	752	34.5	**21.8**	49 000	—	—	**11**	$4\sqrt{S_0}$
		500	932	16.5	**10.5**	23 500	—	—	**56**	$4\sqrt{S_0}$
		600	1 112	10	**6.4**	14 500	—	—	**49**	$4\sqrt{S_0}$
		700	1 292	5.5	**3.4**	7 500	—	—	**45**	$4\sqrt{S_0}$
		800	1 472	3	**1.8**	4 000	—	—	**35**	$4\sqrt{S_0}$
		900	1 652	2	**1.4**	3 000	—	—	**24**	$4\sqrt{S_0}$
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**	$4\sqrt{S_0}$
		150	302	35	22.5	**50 000**	**11.8** (b)	—	**84**	$4\sqrt{S_0}$
		260	500	28.5	18	**40 300**	**10.2** (b)	—	**34**	$4\sqrt{S_0}$
		350	662	21	13.5	**30 000**	**9.45** (b)	—	**25**	$4\sqrt{S_0}$
		500	932	14.5	9	**20 400**	**6.61** (b)	—	**6**	$4\sqrt{S_0}$
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 °C	Testing Temperature °F	Stress kg/mm²	Stress ton/in²	Stress psi	Duration h	Total extension % [a]	Intercept %	Min. Creep Rate % per 1 000 h
Rod [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 $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Strip [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]
	Cold Worked	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:-

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