Cu Zn38 Sn1

Common name: Naval Brass

A copper-zinc alloy with a duplex alpha-plus-beta phase structure, and containing tin; a small amount of lead may also be added to improve machinability. The alloy has good hot-working properties and the presence of tin improves corrosion resistance in marine and other mildly aggressive environments. The wrought material is generally supplied as plate, sheet or rod.

COMPOSITION (weight %)*

Cu . . .	59.5–63.5
Sn . . .	0.5– 1.5
Zn . . .	rem.

*Leaded alloys containing up to about 2% Pb are also covered by this data sheet. In American practice, Cu Zn38 Sn1 may be inhibited with arsenic, antimony or phosphorus (0.02-0.10%).

1 SOME TYPICAL USES

Marine and Mechanical

Condenser and heat exchanger tubeplates; bolts, nuts, rivets and other hardware for underwater applications; forged and machined components for marine equipment.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.40 [(a)] g/cm³ 8.45 [(b)] ,,	0.305 [(a)] lb/in³ 0.305 [(b)] ,,
2.2 Melting range	885–915 °C	1 625–1 680 °F
2.3 Coefficient of thermal expansion (linear) at: 20 to 100 °C *68 to 212 °F* 20 to 300 °C *68 to 572 °F*	 0.000 020 per °C 0.000 022 ,, ,,	 0.000 011 per °F 0.000 012 ,, ,,
2.4 Specific heat (thermal capacity) at: 20 °C *68 °F*	 0.09 cal/g °C	 0.09 Btu/lb °F
2.5 Thermal conductivity at: 20 °C *68 °F* 200 °C *392 °F*	 0.28 cal cm/cm² s °C 0.32 ,,	 68 Btu ft/ft² h °F 77 ,,
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed) 200 °C *392 °F* (,,)	 15 m/ohm mm² 12 ,,	 26 % IACS 20 ,, ,,
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed)	 0.066 ohm mm²/m 6.6 microhm cm	 40 ohms (circ mil/ft) 2.6 microhm in
200 °C *392 °F* (,,)	0.086 ohm mm²/m 8.6 microhm cm	52 ohms (circ mil/ft) 3.4 microhm in
2.8 Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	 0.001 8 per °C (26% IACS)	 0.001 0 per °F (26% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*: annealed	103000 N/mm² 10 500 kg/mm²	 15 000 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*: annealed	3 900 kg/mm² 38 300 N/mm²	5 500 000 lb/in²

(a) Non-leaded alloy.
(b) Leaded alloy containing about 2% Pb.
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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Distributed by
COPPER DEVELOPMENT ASSOCIATION
Orchard House, Mutton Lane, POTTERS BAR, Herts

DATA SHEET No. F3
Cu Zn38 Sn1
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3 FABRICATION PROPERTIES

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

	Metric Units	English Units
3.1 Casting temperature range	1 000–1 050 °C	1 830–1 920 °F
3.2 Annealing temperature range	450– 600 °C	840–1 110 °F
Stress relieving temperature range	225– 325 °C	435– 615 °F
3.3 Hot working temperature range	650– 750 °C	1 200–1 380 °F
3.4 Hot formability	Excellent[a] Good[b]	
3.5 Cold formability	Fair	
3.6 Cold reduction between anneals	40%[a] 25%[b]	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	40 [a] 70 [b]	
3.8 Joining methods:	See General Data Sheet No. 3.6	
Soldering	Excellent	
Brazing	Good	
Oxy-acetylene welding	Good [a] Not recommended [b]	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair [a] Not recommended [b]	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair [a] Not recommended [b]	
butt	Good [a] Fair [b]	

(a) Non-leaded alloy.
(b) Leaded alloy containing about 2% Pb.

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.

The properties quoted are typical for alloys containing up to about 0.5%Pb, as encountered in normal commercial practice; free-machining alloys of higher lead content are likely to have somewhat lower mechanical properties, especially in respect of elongation and shear strength values.

Form	Temper	Tensile Strength kg/mm²	Proof Stress 0.2% offset kg/mm²	Elongation		Hardness		Shear Strength kg/mm²	Typical Size Related to Properties Shown[b]
				%	gauge length	Brinell	Vickers		
Plate Sheet	Annealed	39	16	40	$5.65\sqrt{S_o}$	90	95	29	—
	Hot Rolled	42	20	35	$5.65\sqrt{S_o}$	100	105	32	20–60 mm thick
	Typical Cold Worked Temper	48	32	24	$5.65\sqrt{S_o}$	130	135	34	3–12 mm thick
Rod	Annealed [c]	40	18	40	$5.65\sqrt{S_o}$	90	95	30	—
	Hot Worked[c]	42	20	35	$5.65\sqrt{S_o}$	100	105	32	10-80 mm diam. or equiv. area
	Typical Cold Worked Tempers[c]	46	30	30	$5.65\sqrt{S_o}$	115	120	33	50-80 mm diam. or equiv. area
		48	33	25	$5.65\sqrt{S_o}$	130	135	34	25-50 mm diam. or equiv. area
		52	39	20	$5.65\sqrt{S_o}$	145	150	36	5-25 mm diam. or equiv. area
Forgings	Hot Worked[c]	42	20	32	$5.65\sqrt{S_o}$	100	105	32	—

(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 of the product.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress		Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	Yield Strength 0.5% ext. under load psi	%	gauge length		kg m/cm²	ft lb
Rod[1] **19 mm diam. 0.75 in. diam.**	Annealed (grain size 0.036 mm)	22	72	44.5	28.5	**63 300**	**21.8**[a]	—	**37**	$4.52\sqrt{S_0}$	**52**	6.6[b]	**38** [b]
		−78	−108	47.5	30	**67 400**	**23.8**[a]	—	**37**	$4.52\sqrt{S_0}$	**54**	7.3[b]	**42** [b]
		−197	−323	56.5	36	**80 400**	**26.7**[a]	—	**44**	$4.52\sqrt{S_0}$	**48**	6.6[b]	**38** [b]
		−253	−423	74	47	**105 200**	**33.5**[a]	—	**41**	$4.52\sqrt{S_0}$	**42**	6.0[b]	**35** [b]
		−269	−452	70	44.5	**99 600**	**30.7**[a]	—	**40**	$4.52\sqrt{S_0}$	**48**	—	—
Rod[2] **19 mm diam. 0.75 in. diam.**	Annealed	20	68	45.5	29	**64 600**	—	**35 000**	**41.0**	2 in.	—	4.45[c]	**16.1**[c]
		3	37	—	—	—	—	—	—	—	—	4.45[c]	**16.1**[c]
		−18	0	—	—	—	—	—	—	—	—	4.87[c]	**17.6**[c]
		−30	−22	—	—	—	—	—	—	—	—	5.06[c]	**18.3**[c]
		−50	−58	—	—	—	—	—	—	—	—	5.00[c]	**18.1**[c]
		−80	−112	—	—	—	—	—	—	—	—	4.95[c]	**17.9**[c]
		−115	−175	—	—	—	—	—	—	—	—	4.67[c]	**16.9**[c]
Rod[4]	Rolled[e]	20	68	40	25.5	**57 100**	—	**28 800**	**47.4**	2 in.	**50.5**	—	—
		−183	−297	57	36	**81 100**	—	**37 200**	**48.3**	2 in.	**48.4**	—	—
—[d][3]	Annealed	27	81	—	—	—	—	—	—	—	—	7.5[c]	**27** [c]
		−78	−108	—	—	—	—	—	—	—	—	9.4[c]	**34** [c]
		−197	−323	—	—	—	—	—	—	—	—	7.7[c]	**28** [c]
—[d][3]	Cold Worked 27%	27	81	—	—	—	—	—	—	—	—	4.4[c]	**16** [c]
		−78	−108	—	—	—	—	—	—	—	—	5.3[c]	**19** [c]
		−197	−323	—	—	—	—	—	—	—	—	5.0[c]	**18** [c]

(a) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.
(b) Charpy specimen, V-notch; cross sectional area at the notch 0.8 cm².
(c) Charpy specimen, keyhole-notch; cross sectional area at the notch 0.5 cm².
(d) Form not stated in original document.
(e) Amount of cold working not defined in original document.

N.B. — Original values are printed in **bold type**; other values are converted.
— All converted values for impact strength are to be taken as indicative only; the impact energy has been converted from ft lb into kg m/cm² taking into account the actual cross-sectional area of the specimen at the notch.
— The 0.1% proof stress values are not available.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	%	gauge length
Plate[6] 10 to 60 mm thick 0.4 to 2.4 in. thick	Hot Rolled (grain size 0.020 mm)	20	68	**43.0**	27.5	61 000	**29**	—	—	**22**	$11.3\sqrt{S_o}$
		100	212	**41.5**	26.5	59 000	**29**	—	—	**26**	$11.3\sqrt{S_o}$
		200	392	**38.0**	24	54 000	**28**	—	—	**30**	$11.3\sqrt{S_o}$
		300	572	**33.0**	21	47 000	**22**	—	—	**31**	$11.3\sqrt{S_o}$
		350	662	**26.0**	16.5	37 000	**15**	—	—	**31**	$11.3\sqrt{S_o}$
Plate[5]	Annealed	21	70	36.5	**23.3**	52 000	**15.0[a]**	**9.1**	—	**47**	2 in.
		66	150	35.5	**22.7**	51 000	**13.9[a]**	**8.6**	—	**45**	2 in.
		121	250	35.5	**22.4**	50 000	**14.5[a]**	**8.6**	—	**46**	2 in.
		177	350	34	**21.7**	48 500	**14.0[a]**	**8.5**	—	**49**	2 in.
		204	400	33	**21.1**	47 500	**14.6[a]**	**8.7**	—	**38**	2 in.
Plate[7]	Forged (grain size 0.030 mm)	20	68	**47.7**	30.5	68 000	**27.5**	—	—	**40**	$5.65\sqrt{S_o}$
		100	212	**43.6**	27.5	62 000	**27**	—	—	**35**	$5.65\sqrt{S_o}$
		200	392	**32.0**	20.5	45 500	**19**	—	—	**45**	$5.65\sqrt{S_o}$
		300	572	**23.6**	15	33 500	**17.5**	—	—	**65**	$5.65\sqrt{S_o}$
		400	752	**10.2**	6.5	14 500	**7**	—	—	**70**	$5.65\sqrt{S_o}$
Plate[8] Sheet	Hot Rolled	20	68	**42.3**	27	60 000	**19.7**	—	—	**40**	$5.65\sqrt{S_o}$
		100	212	**41.0**	26	58 500	**20.4**	—	—	**39**	$5.65\sqrt{S_o}$
		200	392	**36.1**	23	51 500	**17.8**	—	—	**51**	$5.65\sqrt{S_o}$
		300	572	**25.2**	16	36 000	**15.5**	—	—	**40**	$5.65\sqrt{S_o}$
		350	662	**17.3**	11	24 500	**13.6**	—	—	**34**	$5.65\sqrt{S_o}$
		400	752	**10.3**	6.5	14 500	**9.8**	—	—	**32**	$5.65\sqrt{S_o}$
Rod[9] 3.2 mm diam. 0.125 in. diam.	Annealed	24	75	46.5	29.5	**66 000**	—	—	**31 200**	**40.0**	2 in.
		149	300	—	—	—	—	—	**32 800**	—	—
		204	400	—	—	—	—	—	**31 500**	—	—
		260	500	—	—	—	—	—	**24 000**	—	—
Rod[21] 19 mm diam. 0.75 in. diam.	Annealed (grain size 0.025 mm)	27	80	45	28.5	**64 000**	—	—	**12 000[b]**	**45**	2 in.
		204	400	36	23	**51 000**	—	—	**16 000[b]**	**55**	2 in.
		316	600	18.5	11.5	**26 000**	—	—	**4 000[b]**	**53**	2 in.
		427	800	7	4.5	**10 000**	—	—	**500[b]**	**35**	2 in.
	Annealed (grain size 0.045 mm)	27	80	44.5	28	**63 000**	—	—	**11 000[b]**	**47**	2 in.
		204	400	32.5	20.5	**46 000**	—	—	**10 500[b]**	**55**	2 in.
		316	600	16	10.5	**23 000**	—	—	**2 000[b]**	**80**	2 in.
		427	800	5.5	3.5	**7 500**	—	—	**500[b]**	**37**	2 in.
Rod[11] 19 mm diam. 0.75 in. diam.	Annealed	21	70	42.5	27	**60 300**	—	—	**15 700[c]**	**41.5**	2 in.
		149	300	35.5	22.5	**50 400**	—	—	**19 700[c]**	**50.5**	2 in.
		232	450	28.5	18	**40 500**	—	—	**21 300[c]**	**35.0**	2 in.
		288	550	22	14	**31 000**	—	—	**15 500[c]**	**45.5**	2 in.
		427	800	8	5	**11 500**	—	—	**4 500[c]**	**38.5**	2 in.
Rod[12] 19 mm diam. 0.75 in. diam.	Hot Worked (grain size 0.025 mm)	24	75	44	28	**62 750**	—	—	**11 000[b]**	**46.0**	2 in.
		204	400	32	20.5	**45 875**	—	—	**10 500[b]**	**54.0**	2 in.
		316	600	16	10.5	**23 050**	—	—	**1 750[b]**	**79.5**	2 in.
		427	800	5	3	**6 950**	—	—	**250[b]**	**39.0**	2 in.

continued on opposite page

5.3.1 Short-Time Tensile Properties (continued)

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	%	gauge length
Rod[(11)] 19 mm diam. 0.75 in. diam.	Hot Worked	21	70	49.5	31.5	**70 300**	—	—	**49 500[(c)]**	**31.0**	2 in.
		149	300	44	28	**62 900**	—	—	**45 500[(c)]**	**34.5**	2 in.
		232	450	38	24	**54 100**	—	—	**25 000[(c)]**	**39.0**	2 in.
		288	550	30	19	**43 000**	—	—	**16 500[(c)]**	**45.0**	2 in.
		427	800	8.5	5.5	**11 850**	—	—	**4 000[(c)]**	**43.0**	2 in.
Rod[(13)] 25.4 mm diam. 1 in. diam.	Cold Worked 28%	21	70	58.5	37	**83 000**	—	—	—	**20**	2 in.
		38	100	57.5	36.5	**82 000**	—	—	—	**21**	2 in.
		93	200	55.5	35.5	**79 000**	—	—	—	**25**	2 in.
		149	300	52.5	33.5	**74 500**	—	—	—	**26**	2 in.
		204	400	47.5	30	**67 500**	—	—	—	**29**	2 in.
		260	500	33.5	21.5	**48 000**	—	—	—	**39**	2 in.
		316	600	18.5	11.5	**26 000**	—	—	—	**57**	2 in.
		371	700	8.5	5.5	**12 000**	—	—	—	**65**	2 in.
		427	800	4.5	3	**6 500**	—	—	—	**52**	2 in.
Rod[(10)]	Annealed	23	73	42.5	27	**60 600**	—	—	—	**46**	2 in.
		250	482	31	20	**44 300**	—	—	—	**65**	2 in.
		400	752	6.5	4	**9 000**	—	—	—	**51**	2 in.
		500	932	1.5	0.9	**2 100**	—	—	—	**27**	2 in.
		600	1 112	0.7	0.5	**1 000**	—	—	—	**38**	2 in.
		675	1 247	0.4	0.3	**600**	—	—	—	**74**	2 in.
		750	1 382	0.2	0.1	**240**	—	—	—	**118**	2 in.
		825	1 517	0.1	0.08	**170**	—	—	—	**168**	2 in.

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

(b) Proportional limit.

(c) Yield Point.

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

— Values for impact strength up to 205 °C are given in reference (2).

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration	Total Extension	Intercept	Min. Creep Rate
		°C	°F	kg/mm²	ton/in²	psi	h	%[a]	%	% per 1 000 h
Rod[9] 3.2 mm diam. 0.125 in. diam.	Annealed	260	500	0.28 0.91	0.18 0.58	**400** **1 300**	**5 400** **3 800**	**0.155** **2.546**	**0.047** **–0.615**	**0.020** **0.83**[b]
Rod[11] 19 mm diam. 0.75 in. diam.	Annealed	149	300	7.0	4.5	**10 000**	**250**	**0.033**[c]	**0.030**	**0.013**
		177	350	2.1 7.0	1.3 4.5	**3 000** **10 000**	**250** **500**	**0.025**[c] **0.159**[c]	**0.023** **0.062**	**0.009** **0.194**
		204	400	0.70 2.1 7.0	0.45 1.3 4.5	**1 000** **3 000** **10 000**	**250** **250** **250**	**0.035**[c] **0.070**[c] **0.474**[c]	**0.031** **0.023** **0**	**0.020** **0.185** **1.90**
		232	450	0.70 2.1	0.45 1.3	**1 000** **3 000**	**250** **250**	**0.061**[c] **0.198**[c]	**0.031** **0.030**	**0.121** **0.65**
		260	500	0.70	0.45	**1 000**	**250**	**0.054**[c]	**0.032**	**0.088**
		288	550	0.70	0.45	**1 000**	**250**	**0.037**[c]	**0.037**	**0**
		315	600	0.70	0.45	**1 000**	**250**	**0.062**[c]	**0**	**0.248**
		343	650	0.70	0.45	**1 000**	**250**	**0.110**[c]	**0**	**0.440**
		371	700	0.70	0.45	**1 000**	**250**	**0.165**[c]	**0.020**	**0.58**
		399	750	0.70	0.45	**1 000**	**250**	**1.200**[c]	**0**	**4.8**
	Hot Worked	288	550	0.70 2.1	0.45 1.3	**1 000** **3 000**	**250** **750**	**0.044**[c] **0.935**[c]	**0.044** **0.190**	**0** **1.00**
Wire[14] 3.2 mm diam. 0.125 in. diam.	Annealed	149	300	2.2 5.0 14.0	1.4 3.2 8.9	**3 100** **7 100** **20 000**	**5 600** **5 600** **6 050**	**0.028** **0.077** **0.456**	**0.007** **0.024** **—0.072**	**0.000 4** **0.001 2** **0.067 4**[b]
Wire[15] 3.2 mm diam. 0.125 in. diam.	Annealed	149	300	3.2 7.1 10.6	2.1 4.5 6.7	**4 600** **10 050** **15 100**	**4 750** **4 500** **4 500**	**0.057** **0.132** **0.228**	**0.015** **0.022** **0.048**	**0.002 6** **0.009 6** **0.017**
		204	400	0.81 1.1 2.0 2.9 4.2 9.1	0.51 0.70 1.3 1.9 2.7 5.8	**1 150** **1 575** **2 800** **4 180** **5 950** **12 900**	**5 000** **5 000** **3 630** **4 730** **4 820** **550**	**0.045** **0.075** **0.123** **0.387** **1.000** **2.090**	**0.019** **0.027** **0.025** **0.080** **0.035** —	**0.003 7** **0.007 5** **0.022** **0.061** **0.19** —
		260	500	0.51 1.4	0.33 0.88	**730** **1 980**	**2 180** **1 080**	**0.253** **0.822**	**0.059** **0.032**	**0.084** **0.71**
Wire[14] 3.2 mm diam. 0.125 in. diam.	Cold Worked 37%	149	300	0.70 1.4 5.6 17.5	0.45 0.92 3.6 11.1	**1 000** **2 050** **8 000** **24 900**	**5 600** **5 550** **6 000** **5 830**	**0.024** **0.060** **0.212** **1.273**	**0.012** **0.038** **0.124** **0.504**	**0.000 7** **0.001 1** **0.004 5** **0.098**
Wire[15] 3.2 mm diam. 0.125 in. diam.	Cold Worked 37%	149	300	3.2 10.6	2.0 6.7	**4 580** **15 050**	**4 750** **4 900**	**0.120** **0.497**	**0.059** **0.305**	**0.005 2** **0.015**
		204	400	0.81 1.1 2.0 4.2 9.6	0.51 0.70 1.3 2.6 6.1	**1 150** **1 570** **2 820** **5 920** **13 700**	**5 000** **5 000** **5 160** **4 820** **1 220**	**0.068** **0.086** **0.147** **0.426** **1.328**	**0.033** **0.040** **0.079** **0.220** **0.53**	**0.004 8** **0.005 9** **0.009 0** **0.031** **0.48**
		260	500	0.23 0.52 0.82 1.4	0.14 0.33 0.52 0.88	**320** **740** **1 160** **1 980**	**1 440** **2 160** **1 080** **900**	**0.095** **0.491** **0.496** **1.699**	— — — —	— — — —

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Accelerating creep rate.
(c) Total creep = Total extension — Initial extension.
N.B.: Original values are printed in **bold type**; other values are converted.

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate								
				0.001% per 1 000 h			0.01% per 1 000 h			0.1% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod[22] 19 mm diam. 0.75 in. diam.	Hot Rolled (grain size 0.025 mm)	149	300	—	—	—	8.4	5.4	**12 000**	10.6	6.7	**15 000**
		204	400	—	—	—	2.5	1.6	**3 500**	4.0	2.5	**5 700**
Wire[14] 3.2 mm diam. 0.125 in. diam.	Annealed	149	300	3.4	2.1	**4 800**	8.4	5.4	**12 000**	>14.1[b]	>8.9[b]	**>20 000**[b]
		204	400	0.42[a]	0.27[a]	**600**[a]	1.3	0.85	**1 900**	3.5	2.2	**5 000**
		260	500	—	—	—	0.18[a]	0.11[a]	**250**[a]	0.53	0.33	**750**
	Cold Worked 37%	149	300	1.1	0.69	**1 550**	8.7	5.5	**12 400**	17.6	11.2	**25 000**
		204	400	—	—	—	2.1	1.3	**3 000**	6.3	4.0	**9 000**
		260	500	—	—	—	0.07[a]	0.04[a]	**100**[a]	0.28	0.18	**400**
Wire[15] 3.2 mm diam. 0.125 in. diam.	Annealed	149	300	—	—	—	7.4	4.7	**10 500**	—	—	—
		204	400	—	—	—	1.3	0.85	**1 900**	3.5	2.2	**5 000**
		260	500	—	—	—	0.18[a]	0.11[a]	**250**[a]	0.56	0.36	**800**
	Cold Worked 37%	149	300	—	—	—	6.3	4.0	**9 000**	—	—	—
		204	400	—	—	—	2.1	1.3	**3 000**	6.3	4.0	**9 000**

(a) Extrapolated value. (b) Produces accelerating creep rate.

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles × 10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod[16] 13 mm diam. 0.5 in. diam.	Cold Worked 9.4%	300	46.5	19.5[a]	30	12.5[a]	**66 300**	**28 000**[a]
Rod[17] 13 mm diam. 0.5 in. diam.	Rolled[d]	200	48	15.5[a]	30.5	10[a]	**68 200**	**22 000**[a]
Rod[18] 13 mm diam. 0.5 in. diam.	Cold Worked 24%[b]	100	61	23[a]	39	14.5[a]	**87 000**	**33 000**[a]
	Cold Worked 24%[c]	100	61.5	15[a]	39	9.5[a]	**87 300**	**21 000**[a]
Rod[18] 13.5 mm diam. 0.53 in. diam.	Cold Worked 27%[b]	100	61.5	22[a]	39	14[a]	**87 200**	**31 500**[a]
	Cold Worked 27%[c]	100	64.5	18.5[a]	41	12[a]	**91 400**	**26 500**[a]

continued overleaf

5.4.1. Fatigue Strength at Room Temperature (continued)

Form	Temper	Number of Cycles × 10^6	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod[19] **19 mm diam. 0.75 in. diam.**	Rolled[b]	300	48	15[a]	30.5	9.5[a]	**68 215**	**21 000**[a]
Rod[13] **25.4 mm diam. 1 in. diam.**	Annealed	—	41.5	15[a]	26.5	9.5[a]	**59 000**	**21 000**(()
		—	41.5	15.5[a]	26.5	10[a]	**59 000**	**22 000**[a]
Rod[20] **25.4 mm diam. 1 in. diam.**	Hot Rolled	100	41.5	13[a]	26.5	8.5[a]	**59 300**	**18 500**[a]
Rod[16] **25.4 mm diam. 1 in. diam.**	Cold Worked 11.5%	300	49	16.5[a]	31	10.5[a]	**69 600**	**23 700**[a]
		300	49	10.5[a]	31	6.5[a]	**69 600**	**15 000**[a]
		300	51	10.5[a]	32.5	6.5[a]	**72 300**	**15 000**[a]
Rod[13] **25.4 mm diam. 1 in. diam.**	Cold Worked 28%	—	60.5	18.5[a]	38.5	11.5[a]	**86 000**	**26 000**[a]
	Cold Worked 30%	—	60.5	19[a]	38.5	12[a]	**86 000**	**27 000** [a]

(a) Rotating-beam test.
(b) Fine grained.
(c) Coarse grained.
(d) Amount of work not defined in original document.

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

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Reed, R.P. and Mikesell, R.P. Low-Temperature (295 to 4K) Mechanical Properties of Selected Copper Alloys. J. Materials, Vol. 2 (1967), No. 2, pp. 370-392.
(2) Smith, C.S. Mechanical Properties of Copper and its Alloys at Low Temperatures: A Review. Proc. ASTM, Vol. 39 (1939), pp. 642-648.
(3) Reed, R.P. and Mikesell, R.P. Low-Temperature Mechanical Properties of Copper and Selected Copper Alloys. US Dept. Commerce, Nat. Bureau of Standards Monograph 101 (1967).
(4) Strauss, J. Metals and Alloys for Industrial Applications Requiring Extreme Stability. Trans. ASST, Vol. 16 (1929), pp. 191-226.
(5) Ashbolt, D. and Bowers, J.E. The Properties of Copper and Copper Alloys at Elevated Temperatures. BNFMRA Research Report A1550 (1965), July.
(6) Private communication from Kabel-und Metallwerke Gutehoffnungshütte AG Germany.
(7) Private communication from Fürstlich Hohenzollernsche Hüttenverwaltung Laucherthal, Germany.
(8) Private communication from Vereinigte Deutsche Metallwerke AG, Germany.
(9) Upthegrove, C. and Burghoff, H.L. Elevated-Temperature Properties of Coppers and Copper-Base Alloys. American Society for Testing and Materials, Philadelphia, Pa. (1956) (ASTM Spec. Tech. Pub. No. 181).
(10) Price,W.B. Properties of Copper and Some of its Important Industrial Alloys at Elevated Temperatures. ASTM-ASME Symposium on the Effect of Temperature on the Properties of Metals (1931), pp. 340-367.
(11) Compilation of Available High-Temperature Creep Characteristics of Metals and Alloys. ASTM-ASME (1938).
(12) Clark, C.L. and White, A.E. Properties of Non-Ferrous Alloys at Elevated Temperatures. Trans ASME, Vol. 43 (1931), pp. 183-191.
(13) Wilkins, R.A. and Bunn, E.S. Copper and Copper-Base Alloys. McGraw-Hill Book Company, New York (1943).
(14) Burghoff, H.L., and Blank, A.I. The Creep Characteristics of Copper and Some Copper Alloys at 300, 400 and 500 F. Proc. ASTM, Vol. 47 (1947), pp. 725-754.
(15) Burghoff, H.L., Blank, A.I., and Maddigan, S.E. The Creep Characteristics of Some Copper Alloys at Elevated Temperatures. Proc. ASTM, Vol. 42 (1942) pp. 668-691.
(16) Anderson, A.R., and Smith, C.S. Fatigue Tests on Some Copper Alloys. Proc. ASTM, Vol. 41 (1941), pp. 849-858.
(17) Moore, H.F., and Jasper, T.M. An Investigation of the Fatigue of Metals. Bull. Univ. Illinois Enging. Expt. Stu., No. 152. (1925), Nov.
(18) Burghoff, H.L. and Blank, A.I. Fatigue Characteristics of Some Copper Alloys. Proc. ASTM, Vol. 47 (1947), pp. 695-712.
(19) Moore, R.R. Some Fatigue Tests on Non-Ferrous Metals, Proc ASTM, Vol. 25 (1925), Pt. 2, pp. 66-96.
(20) McAdam, D.J., Jr. Endurance Properties of Alloys of Nickel and of Copper-Part 1. Trans. ASST, Vol. 7 (1925), pp. 54-81.
(21) White, A.E. and Clark, C.L. Influence of Grain Size on the High-Temperature Characteristics of Ferrous and Non-Ferrous Alloys. Trans. ASM, Vol. 22 (1934), pp. 1069-1098.
(22) Clark, C.L. and White, A.E. Influence of Recrystallization Temperature and Grain Size on the Creep Characteristics of Non-Ferrous Alloys. Proc. ASTM Vol. 32 (1932), Part 2, pp. 492-516.

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