WROUGHT MATERIALS | **HIGH-COPPER ALLOYS**

Cu Si3 Mn1

Common names: Silicon Bronze
High-Silicon Bronze A
Silicon-Manganese Bronze

A copper alloy containing silicon and manganese, and with an alpha phase structure. The material has good hot and cold-working properties relatively high strength at ordinary and elevated temperatures, good corrosion resistance in a wide variety of chemical environments and is readily weldable. It is used in chemical, mechanical and marine engineering, where advantage can be taken of this desirable combination of properties, and also for decorative applications. The most commonly used wrought forms are plate, sheet, strip, rod, wire, tube and forgings.

COMPOSITION (weight %)

Si	2.7–3.5
Mn	0.7–1.5
Cu	rem.

1 SOME TYPICAL USES

Chemical
Components of processing equipment including stills, vats and autoclaves; drains for corrosive liquids; ducts and fans for corrosive vapours; pickling and copper recovery equipment; reservoir and sewage plant; paper-mill machinery; woven-wire filter screens; electrical conduit for mildly corrosive environments.

Marine
Pipes and pipe fittings for seawater; yacht frames; boat fittings; propeller shafts; miscellaneous hardware.

Mechanical
Fasteners for outdoor electrical equipment; bolts, nuts, nails, rivets and screws (especially for outdoor and underwater construction); pressure vessels; hydraulic pressure lines; springs; pressurised hot-water storage tanks.

Plumbing
Domestic water heaters.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.55 g/cm³	0.310 lb/in³
2.2	Melting range	910–1 030 °C	1 670–1 885 °F
2.3	Coefficient of thermal expansion (linear) at:		
	—183 to 0 °C *—297 to 32 °F*	0.000 014 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*	0.085 cal cm/cm² s °C	21 Btu ft/ft² h °F
	200 °C *392 °F*	0.11 „	27 „
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	4 m/ohm mm²	7% IACS
	200 °C *392 °F* (annealed or cold worked)	3.5 „	6 „ „
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	0.25 ohm mm²/m 25 microhm cm	150 ohms (circ mil/ft) 10 microhm in
	200 °C *392 °F* (annealed or cold worked)	0.29 ohm mm²/m 29 microhm cm	170 ohms (circ mil/ft) 11 microhm in
2.8	Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 3 per °C (7% IACS)	0.000 2 per °F (7% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F:* annealed or cold worked	102 970 N/mm² 10 500 kg/mm²	15 000 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F:* annealed or cold worked	3 900 kg/mm² 38 246 N/mm²	5 600 000 lb/in²

N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition range involved, are based on selected literature references; the melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted.

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	1 080–1 150 °C	1 975–2 100 °F
3.2	Annealing temperature range	475– 700 °C	885–1 290 °F
	Stress relieving temperature range	250– 380 °C	480– 715 °F
3.3	Hot working temperature range	700– 875 °C	1 290–1 605 °F
3.4	Hot formability	Good	
3.5	Cold formability	Good	
3.6	Cold reduction between anneals	75% max.	
3.7	Machinability:	See General Data Sheet No. 2	
	Machinability rating (free cutting brass = 100)	30%	
3.8	Joining methods:	See General Data Sheet No. 3.3	
	Soldering	Good	
	Brazing	Excellent	
	Oxy-acetylene welding	Good	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Good	
	Coated metal-arc welding	Fair	
	Resistance welding: spot and seam	Excellent	
	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.S3	—	HC.4.7 HC.4.8	HC.5.6	HC.5.24	—	HC.5.6	—
Chile	NCh (INDITECNOR)	Cu Si3 Mn Pb	252 of. 68	—	—	—	259 of. 70	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	CuSi3Mn	17 666	17670	17 672	17 677	17 671	17 674	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	Cu Si3 Mn1	—	2528	2528	—	2528	2528	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN (b)	Cu-Si3 Mn1	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	CS101	—	2870 2875	2872 2874	2873	—	2874	2872
United States (c)	ASTM	Nos. 655 and 658	—	B96 B97 B98 B100 B124	B 98 B 124	B 99	B 315	B 98 B 124	B 283
International Organisation for Standardization	ISO	Cu Si3 Mn1	R 1187	—	—	—	—	—	—

(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 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

Tensile properties	see tables 5.1.1/2/3
Hardness	,, ,, 5.1.1/2/3
Shear strength	,, ,, 5.1.1/2/3
Modulus of elasticity (tension)	see 2.9
Modulus of rigidity (torsion)	,, 2.10

5.2 Mechanical properties at low temperature

Tensile properties	see table 5.2.1
Impact properties	,, ,, 5.2.1

5.3 Mechanical properties at elevated temperature

Short-time tensile properties	see table 5.3.1
Impact properties	see table 5.3.1
Creep properties	see tables 5.3.2.1/2

5.4 Fatigue properties

Fatigue strength at room temperature	see table 5.4.1

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE [a]

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

The values 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 variation above or below the typical values indicated.

Form	Temper	Tensile Strength kg/mm²	Proof Stress 0.2% offset kg/mm²	Elongation %	Elongation gauge length	Hardness Brinell	Hardness Vickers	Shear Strength kg/mm²	Typical Size Related to Properties Shown [b]
Plate Sheet Strip	Annealed [c]	40	16	55	$5.65\sqrt{S_o}$	75	79	30	—
	Hot Rolled	42	17	45	$5.65\sqrt{S_o}$	80	84	31	—
	Typical Cold Worked Tempers	50	35	30	$5.65\sqrt{S_o}$	130	135	35	0.5–15 mm thick
		55	42	20	$5.65\sqrt{S_o}$	150	160	36	0.5–10 mm thick
		65	60	10	50 mm	180	190	39	0.5–2 mm thick
Rod [d]	Annealed	39	14	55	$5.65\sqrt{S_o}$	75	79	29	—
	Hot Worked	42	17	45	$5.65\sqrt{S_o}$	80	84	31	—
	Typical Cold Worked Tempers	55	42	20	$5.65\sqrt{S_o}$	150	160	35	5–40 mm diam. or equivalent area
		65	60	10	$5.65\sqrt{S_o}$	180	190	39	5–25 mm diam. or equivalent area
		75	72	5	$5.65\sqrt{S_o}$	200	210	42	1–5 mm diam. or equivalent area
Wire	Annealed	40	16	45	100 mm	—	—	30	—
	Typical Cold Drawn Temper	55	42	13	100 mm	—	—	32	2–5 mm diam.
		70	66	3	100 mm	—	—	36	0.8–2 mm diam.
		88	86	—	—	—	—	44	up to 0.8 mm diam
Tube	Annealed	40	16	55	$5.65\sqrt{S_o}$	75	79	30	—
	Typical Cold Drawn Temper	55	42	25	$5.65\sqrt{S_o}$	150	160	36	10–50 mm O.D., up to 5 mm wall
Forgings [d]	Hot Worked	42	17	40	$5.65\sqrt{S_o}$	85	89	31	—

(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 standards.

(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) Common average grain size 0.035 mm.

(d) 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 variations 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	37	24	11	7	60	$5.65\sqrt{S_o}$	75	25	16	—
	Hot Rolled As Manufactured	39	25	14	9	55	$5.65\sqrt{S_o}$	85	26	17	12–50 mm (0.5–2 in.) thick
Sheet Strip	Annealed	39	25	14	9	60	50 mm (2 in.)	85	26	17	—
	Hot Worked As Manufactured	42	27	23	15	55	50 mm (2 in.)	120	29	19	3–10 mm (0.125–0.375 in.) thick
	Typical Cold Worked Tempers	48	31	32	21	40	50 mm (2 in.)	160	32	21	0.2–3 mm (0.008–0.125 in.) thick
		56	36	42	27	25	50 mm (2 in.)	180	37	24	,,
		65	42	49	32	15	50 mm (2 in.)	200	42	27	,,
Rod [c]	Annealed	37	24	11	7	60	$5.65\sqrt{S_o}$	75	25	16	—
	Hot Worked	39	25	14	9	55	$5.65\sqrt{S_o}$	85	26	17	12–50 mm (0.5–2 in.) diam. or equivalent area
	Cold Worked As Manufactured	48	31	31	20	35	$5.65\sqrt{S_o}$	140	32	21	40–70 mm (1.6–2.8 in.) diam. or equivalent area
		51	33	36	23	30	$5.65\sqrt{S_o}$	150	34	22	20–40 mm (0.8–1.6 in.) diam. or equivalent area
		59	38	43	28	20	$5.65\sqrt{S_o}$	175	39	25	6–20 mm (0.25–0.8 in.) diam. or equivalent area
Wire	Annealed	42	27	—	—	50	100 mm (4 in.)	—	29	19	—
	Typical Cold Drawn Tempers	54	35	—	—	20	100 mm (4 in.)	—	31	20	0.5–5 mm (0.02–0.2 in.) diam.
		68	44	—	—	10	100 mm (4 in.)	—	36	23	,,
		87	56	—	—	5	100 mm (4 in.)	—	43	28	0.5–2 mm (0.02–0.08 in.) diam.
Forgings [c]	Hot Worked As Manufactured	40	26	15	10	45	$5.65\sqrt{S_o}$	90	28	18	—

(a) The recognised temper designations used in the relevant 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.

(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 Flat Wire)	Annealed									
	grain size 0.070 mm	54 000	21 000	68	2 in.	40	—	—	42 000	0.040 in. thick
	grain size 0.035 mm	60 000	25 000	60	2 in.	62	—	—	43 000	"
	grain size 0.015 mm	63 000	30 000	55	2 in.	66	—	—	45 000	"
	Soft	58 000	21 000	60	2 in.	—	40	—	43 000	1 in. thick
	Cold Worked									
	Quarter Hard	68 000	35 000	30	2 in.	—	75	67	47 000	0.040 in. thick
	Half Hard	78 000	45 000	17	2 in.	—	87	75	50 000	"
	Hard	94 000	58 000	8	2 in.	—	93	78	57 000	"
	Extra Hard	104 000	60 000	6	2 in.	—	96	80	60 000	"
	Spring	110 000	62 000	4	2 in.	—	97	81	63 000	"
	Extra Spring	125 000	68 000	2	2 in.	—	99	83	70 000	"
Rod [b]	Annealed									
	grain size 0.085 mm	60 000	16 000	68	2 in.	—	44	—	43 000	0.50 in. diam.
	Soft	55 000	20 000	65	2 in.	—	35	—	42 000	1 in. diam.
	grain size 0.050 mm	58 000	23 000	60	2 in.	—	60	—	43 000	"
	Cold Worked									
	Quarter Hard	67 000	45 000	49	2 in.	—	84	—	47 000	0.40 in. diam.
	Half Hard	75 000	49 000	37	2 in.	—	89	—	49 000	"
	Hard	97 000	64 000	13	2 in.	—	101	—	58 000	0.50 in. diam.
	Half Hard	78 000	45 000	35	2 in.	—	85	—	52 000	1 in. diam.
	Hard	92 000	55 000	22	2 in.	—	90	—	58 000	"
	Extra Hard	108 000	60 000	13	2 in.	—	95	—	62 000	"
Wire	Annealed									
	grain size 0.035 mm	60 000	25 000	60	2 in.	—	—	—	43 000	0.080 in. diam.
	Cold Worked									
	Eighth Hard	70 000	40 000	35	2 in.	—	—	—	48 000	0.080 in. diam.
	Quarter Hard	80 000	48 000	20	2 in.	—	—	—	52 000	"
	Half Hard	98 000	57 000	8	2 in.	—	—	—	58 000	"
	Hard	125 000	65 000	5	2 in.	—	—	—	65 000	"
	Spring	145 000	70 000	3	2 in.	—	—	—	70 000	"
Tube	Annealed									
	grain size 0.050 mm	57 000	20 000	70	2 in.	—	45	—	42 000	1 in. O.D. × 0.065 in. wall
	Cold Worked									
	Hard	93 000	55 000	22	2 in.	—	92	78	57 000	1 in. O.D. × 0.065 in. wall
Forgings [b]	As Forged	60 000	20 000	75	2 in.	—	35	—	43 000	—
	Cold Worked									
	Struck	68 000	35 000	60	2 in.	—	70	—	47 000	—

(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] **3 mm 0.125 in.**	Cold Worked 11%	27	80	45.5	29	**65 000**	**28.1** [a]	**50**	2 in.	—	—	—
		—78	—108	50.5	32	**72 000**	**29.5** [a]	**58**	2 in.	—	—	—
		—197	—323	64	40.5	**91 000**	**34.4** [a]	**65**	2 in.	—	—	—
		—253	—424	75	48	**107 000**	**38.0** [a]	**64**	2 in.	—	—	—
Rod [2] **19 mm diam. 0.75 in. diam.**	Annealed	22	72	43	27.5	**61 400**	**17.0** [a]	**66**	$4.52\sqrt{S_o}$	**79**	19.4 [b]	**112** [b]
		—78	—108	49	31	**69 900**	**18.8** [a]	**68**	$4.52\sqrt{S_o}$	**79**	19.4 [b]	**112** [b]
		—197	—323	62.5	39.5	**89 000**	**22.4** [a]	**71**	$4.52\sqrt{S_o}$	**69**	19.7 [b]	**114** [b]
		—253	—423	76.5	48.5	**108 900**	**26.4** [a]	**72**	$4.52\sqrt{S_o}$	**69**	20.0 [b]	**116** [b]
		—269	—452	71	45	**101 200**	**25.9** [a]	**71**	$4.52\sqrt{S_o}$	**70**	—	—
Rod [3] **19 mm diam. 0.75 in. diam.**	Annealed	20	68	—	—	—	—	—	—	—	18.4 [c]	**66.4** [c]
		3	37	—	—	—	—	—	—	—	20.3 [c]	**73.3** [c]
		—18	0	—	—	—	—	—	—	—	22.1 [c]	**80.1** [c]
		—30	—22	—	—	—	—	—	—	—	20.6 [c]	**74.6** [c]
		—50	—58	—	—	—	—	—	—	—	20.2 [c]	**73.1** [c]
		—80	—112	—	—	—	—	—	—	—	19.1 [c]	**69.2** [c]
		—115	—175	—	—	—	—	—	—	—	17.8 [c]	**64.5** [c]
Rod [3] **13 mm diam. 0.5 in. diam.**	Cold Worked 42%	25	77	52	33	**74 150**	—	**39.8**	2 in.	**75.1**	—	—
		0	32	53.5	34	**76 200**	—	**31.2**	2 in.	**70.4**	—	—
		—80	—112	58.5	37	**82 900**	—	**31.7**	2 in.	**72.4**	—	—
		—190	—310	70.5	45	**100 500**	—	**36.2**	2 in.	**72.5**	—	—
Rod [4]	Cold Worked [d]	20	68	—	—	—	—	—	—	—	13	**74** [b]
		—80	—112	—	—	—	—	—	—	—	12	**69** [b]
		—197	—323	—	—	—	—	—	—	—	10	**60** [b]
		—253	—423	—	—	—	—	—	—	—	9	**52** [b]

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

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

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

(d) Quoted as "hard, Rockwell B=91" in original document, but amount of cold work not defined.

N.B.:—Original values are printed in **bold type**; other values are converted.
—All converted values for impact strength are to be taken as indicative only; the impact energy has been converted from ft lb into kg m/cm² taking into account the actual cross-sectional area of the specimen at the notch.
—Data not available:
Proof Stress, 0.1% offset,
Yield Strength, 0.5% extension under load.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	%	gauge length	kg m/cm²	ft lb
Plate (5)	Annealed	21	70	36.5	**23.2**	52 000	**11.5** (a)	**6.8**	—	**69**	2 in.	—	—
		66	150	34.5	**22.0**	49 500	**10.6** (a)	**6.4**	—	**71**	2 in.	—	—
		121	250	33.5	**21.2**	47 500	**10.2** (a)	**6.2**	—	**68**	2 in.	—	—
		177	350	32.5	**20.5**	46 000	**10.2** (a)	**6.1**	—	**67**	2 in.	—	—
Strip (6) (b) 1.9 mm 0.075 in.	Annealed	20	68	38	**24.0**	54 000	—	**6.75**	—	**66**	2 in.	—	—
		100	212	34.5	**22.0**	49 500	—	**6.09**	—	**59**	2 in.	—	—
		200	392	31.5	**20.0**	45 000	—	**6.09**	—	**54**	2 in.	—	—
		300	572	28	**17.9**	40 000	—	**5.95**	—	**52**	2 in.	—	—
Strip (7) (c) 1.9–2.0 mm 0.075–0.080 in.	Annealed	20	68	39	**24.8**	55 500	—	**7.5**	—	**70**	2 in.	—	—
		100	212	36	**23.0**	51 500	—	**7.1**	—	**61**	2 in.	—	—
		200	392	33	**21.1**	47 500	—	**7.0**	—	**59**	2 in.	—	—
		300	572	29.5	**18.7**	42 000	—	**6.8**	—	**56**	2 in.	—	—
		310	590	26	**16.4**	36 500	—	**6.4**	—	**56**	2 in.	—	—
		320	608	22.5	**14.3**	32 000	—	**5.9**	—	**58**	2 in.	—	—
Rod (8) 10 mm diam. 0.375 in. diam.	Cold Worked	62	144	51	32.5	**72 650**	—	—	—	**43.5**	2 in.	—	—
		260	500	42.5	27	**60 200**	—	—	—	**33.0**	2 in.	—	—
		400	752	25.5	16	**35 930**	—	—	—	**25.5**	2 in.	—	—
		540	1 004	10	6.5	**14 480**	—	—	—	**18.0**	2 in.	—	—
Rod (9) 13 mm diam. 0.5 in. diam.	Annealed	25	77	47	29.5	**66 500**	**18.5** (d)	—	—	—	—	—	—
		300	572	31.5	20	**44 800**	**12.7** (d)	—	—	—	—	—	—
		500	932	10.5	6.5	**14 700**	**5.34** (d)	—	—	—	—	—	—
Rod (10) 14 mm diam. 0.56 in. diam.	Annealed	20	68	42.5	**26.9**	60 500	—	**8.0** (e)	—	**71**	$4\sqrt{S_o}$	19.7 (f)	**114** (f)
		200	392	—	—	—	—	—	—	—	—	17 (f)	**99** (f)
		250	482	—	—	—	—	—	—	—	—	17.5 (f)	**101** (f)
		300	572	—	—	—	—	—	—	—	—	12.8 (f)	**74** (f)
		350	662	—	—	—	—	—	—	—	—	7.6 (f)	**44** (f)
		400	752	18.5	**11.8**	26 500	—	**6.0** (e)	—	**90**	$4\sqrt{S_o}$	7.8 (f)	**45** (f)
		450	842	—	—	—	—	—	—	—	—	7.1 (f)	**41** (f)
		500	932	—	—	—	—	—	—	—	—	5.2 (f)	**30** (f)
		550	1 022	—	—	—	—	—	—	—	—	3.8 (f)	**22** (f)
		600	1 112	—	—	—	—	—	—	—	—	2.8 (f)	**16** (f)
Rod (11) 19 mm diam. 0.75 in. diam.	Annealed	27	80	40	25.5	**57 200**	—	—	**10 500**	**68.5**	2 in.	—	—
		149	300	37.5	23.5	**53 200**	—	—	**4 700**	**64.0**	2 in.	—	—
		288	550	29	18.5	**41 600**	—	—	**4 200**	**44.0**	2 in.	—	—
		427	800	18.5	11.5	**26 100**	—	—	**4 000**	**26.0**	2 in.	—	—
		538	1 000	11	7	**16 000**	—	—	**3 500**	**42.0**	2 in.	—	—
Rod (3) 19 mm diam. 0.75 in. diam.	Annealed	20	68	44	28	**62 400**	—	—	**29 900**	**65.5**	2 in.	18.4 (g)	**66.4** (g)
		65	149	—	—	—	—	—	—	—	—	16.5 (g)	**59.8** (g)
		120	248	—	—	—	—	—	—	—	—	15.2 (g)	**55.0** (g)
		205	401	—	—	—	—	—	—	—	—	13.9 (g)	**50.2** (g)
Rod (12) 19 mm diam. 0.75 in. diam.	Annealed (i)	29	85	49.5	31.5	**70 300**	—	—	**22 000** (h)	**53.0**	2 in.	—	—
		204	400	40	25.5	**57 100**	—	—	**14 375** (h)	**53.0**	2 in.	—	—
		288	550	34	21.5	**48 400**	—	—	**10 000** (h)	**60.0**	2 in.	—	—
	Cold Worked (l)	21	70	71.5	45.5	**102 000**	—	—	**86 500** (e)	**15.0**	2 in.	—	—
		149	300	66.5	42	**94 500**	—	—	**82 000** (e)	**13.0**	2 in.	—	—
		288	550	58.5	37	**82 900**	—	—	**71 600** (e)	**8.5**	2 in.	—	—
		427	800	34	21.5	**48 500**	—	—	**28 900** (e)	**13.0**	2 in.	—	—
		538	1 000	10.5	6.5	**15 000**	—	—	**7 000** (e)	**73.0**	2 in.	—	—
Rod (13) 27 mm diam. 1.1 in. diam.	Annealed	20	68	39.5	**25.1**	56 000	**12.1** (a)	**7.2**	—	**79**	$4\sqrt{S_o}$	—	—
		200	392	34.5	**22.0**	49 500	**11.3** (a)	**6.7**	—	**74**	$4\sqrt{S_o}$	—	—
		300	572	30.5	**19.3**	43 000	**11.3** (a)	**6.6**	—	**70**	$4\sqrt{S_o}$	—	—

(a) This value was originally reported in ton/in²; in this table it is given in kg/mm² to 3 significant figures.
(b) Alloy containing 3.61% Si, 1.05% Mn, 0.22% Zn.
(c) Alloy containing 2.67% Si, 1.26% Mn, 0.45% Zn.
(d) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.
(e) Yield point.
(f) Charpy-type test on Izod machine, Izod notch, cross-sectional area at the notch 0.8 cm².
(g) Charpy, keyhole-notch specimen; cross-sectional area at the notch 0.5 cm².
(h) Proportional limit.
(i) Alloy containing 2.84% Si; 1.25% Mn.
(l) Alloy containing 3.40% Si; 1.21% Mn.

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.

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 (12) 19 mm diam. 0.75 in. diam.	Annealed (b)	204	400	8.8 10.5	5.6 6.7	**12 500** **15 000**	**995** **1 000**	**0.255 0** **0.306 0**	**0.120 0** **0.136 0**	**0.065** **0.084**
		288	550	3.5 4.2 5.3 7.0	2.2 2.7 3.3 4.5	**5 000** **6 000** **7 500** **10 000**	**1 000** **1 000** **1 000** **1 000**	**0.124 0** **0.290 0** **0.531 0** **1.182 0**	**0.063 0** **0.166 0** **0.284 0** **0.455 0**	**0.035** **0.080** **0.190** **0.650**
	Cold Worked (d)	316	600	7.0	4.5	**10 000**	**250**	**0.033** (c)	**0.033**	**0**
		371	700	2.1 7.0	1.3 4.5	**3 000** **10 000**	**250** **750**	**0.045** (c) **0.468** (c)	**0.034** **0.075**	**0.044** **0.526**
		427	800	0.70 2.1	0.45 1.3	**1 000** **3 000**	**250** **250**	**0.051** (c) **0.760** (c)	**0.029** **0**	**0.088** **3.0**
		482	900	0.70	0.45	**1 000**	**500**	**0.780** (c)	**0**	**1.56**
		538	1 000	0.70	0.45	**1 000**	**250**	**8.700** (c)	**—0.270**	**36.0**

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

(b) Alloy containing 2.84% Si, 1.25% Mn.

(c) Total creep = Total extension — Initial extension.

(d) Alloy containing 3.40% Si, 1.21 % Mn.

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 °C	Testing Temperature °F	0.01% per 1 000 h kg/mm²	0.01% per 1 000 h ton/in²	0.01% per 1 000 h psi	0.1% per 1 000 h kg/mm²	0.1% per 1 000 h ton/in²	0.1% per 1 000 h psi
Rod (12) 19 mm diam. 0.75 in. diam.	Annealed	204 288	400 550	5.7 2.6	3.6 1.7	**8 100** **3 750**	10.5 4.5	6.7 2.9	**14 900** **6 400**
Rod (13) 27 mm diam. 1.1 in. diam.	Annealed	200 300	392 572	18.7 5.8	**11.9** **3.7**	26 700 8 300	22.0 8.2	**14.0** **5.2**	31 400 11 600

N.B.:—Original values are printed in **bold type**; other values are converted.
—Data not available:
Stresses for creep rate of 0.001% per 1 000 h.
—Further data can be obtained from the following papers:
■Weaver, V. P. and Imperati, J. Copper and Copper Alloys for Pressure Vessels. Welding Research Council, New York. Bull. No. 73 (1961), 21 pp.
■Voce, E. The Mechanical Properties, Including Creep, of Aluminium Bronzes at Elevated Temperatures. Metallurgia (Manchr), Vol. 35 (1946), pp. 3-9.
■Copper Metals by Anaconda. Anaconda American Brass Co., Connecticut. Publication No. B-40 (1961), p. 38.

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
Sheet [14] 0.5 mm 0.02 in.	Annealed	100	41.5	11 [a]	26.5	7 [a]	**59 300**	**16 000** [a]
	Cold Worked 37%	100	66	16 [a]	42	10.5 [a]	**93 700**	**23 000** [a]
	Cold Worked 60.5%	100	56	16.5 [a]	35.5	10.5 [a]	**80 000**	**23 500** [a]
		100	75.5	14.5 [a]	48	9 [a]	**107 600**	**20 500** [a]
Rod [15] 25 mm diam. 1 in. diam.	Annealed (grain size 0.045–0.065 mm)	100	39	12.5 [b]	**24.9**	**8.0** [b]	56 000	18 000 [b]
	Cold Worked 25%	100	57	17.5 [b]	**36.3**	**11.1** [b]	81 500	25 000 [b]
	Cold Worked 50%	100	78	22 [b]	**49.5**	**13.9** [b]	111 000	31 000 [b]
Rod [16] 13 mm diam. 0.5 in. diam.	Annealed (grain size 0.085 mm)	300	42	13 [b]	26.5	8.5 [b]	**59 600**	**18 800** [b]
	Cold Worked 8%	300	47	22 [b]	29.5	14 [b]	**66 600**	**31 500** [b]
	Cold Worked 20%	300	52.5	21.5 [b]	33.5	13.5 [b]	**74 900**	**30 500** [b]
Rod [17] 13 mm diam. 0.5 in. diam.	Cold Worked 39% [c]	1 000	65.5	17 [b]	41.5	10.5 [b]	**93 500**	**24 000** [b]
	Cold Worked 39% [d]	1 000	67	19.5 [b]	42.5	12.5 [b]	**95 000**	**28 000** [b]
	Cold Worked 39% [d]	1 000	67	18 [b]	42.5	11.5 [b]	**95 300**	**25 500** [b]
	Cold Worked 39% [e]	1 000	68.5	23.5 [b]	43.5	15 [b]	**97 100**	**33 500** [b]
	Cold Worked 39% [f]	1 000	75	29 [b]	47.5	18.5 [b]	**106 900**	**41 000** [b]
	Cold Worked 39% [g]	1 000	75.5	27 [b]	48	17 [b]	**107 100**	**38 500** [b]
Wire [18] 2 mm diam. 0.080 in. diam.	Cold Worked 60%	100	88	20.5	56	13	**125 000**	**29 000**
	Cold Worked 80%	100	102	21	64.5	13.5	**145 000**	**30 000**

(a) Reversed-bending test.
(b) Rotating-beam test.
(c) Ready-to-finish grain size 0.300 mm.
(d) Ready-to-finish grain size 0.175 mm.
(e) Ready-to-finish grain size 0,110 mm.
(f) Ready-to-finish grain size 0,025 mm.
(g) Ready-to-finish grain size 0.015 mm.

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

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