WROUGHT MATERIALS

COPPER-ALUMINIUM ALLOYS
Aluminium Bronzes

Cu Al5

Common names: 95/5 Aluminium Bronze
5% Aluminium Bronze
Aluminium Bronze, A

A copper-aluminium alloy with an alpha phase structure. The alloy may contain small amounts of arsenic, nickel and/or manganese, which are added to improve corrosion resistance and strength. It has good corrosion resistance in most environments and good cold-working properties. The most commonly used wrought forms are plate, sheet, strip and tube.

COMPOSITION (weight %)

Al	4.0–6.5
As	0 –0.4
Ni	0 –0.8
Mn	0 –0.5
Cu	rem.

1 SOME TYPICAL USES

Chemical and Mechanical
Components in contact with acid waters and saline solutions, including concentrated brine; tubes for condensers, evaporators and heat exchangers; papermaking equipment; valve spindles; waterboxes and storage tanks.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.2 g/cm³	0.295 lb/in³
2.2 Melting range	1 050–1 080 °C	1 920–1 975 °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*	0.10 cal/g °C	0.10 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.18–0.20 cal cm/cm² s °C	44–48 Btu ft/ft² h °F
200 °C *392 °F*	0.26 [(a)] ,,	63 [(a)] ,,
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed or cold worked)	8.7–10 m/ohm mm²	15–18% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed or cold worked)	0.11–0.10 ohm mm²/m 11–10 microhm cm	69–58 ohms (circ mil/ft) 4.5–3.8 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 8 per °C (15% IACS) 0.000 9 ,, ,, (18% IACS)	0.000 4 per °F (15% IACS) 0.000 5 ,, ,, (18% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	12 850 kg/mm²	18 300 000 lb/in²
cold worked	11 800 kg/mm²	16 800 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	4 750 kg/mm²	6 800 000 lb/in²
cold worked	4 350 kg/mm²	6 200 000 lb/in²

(a) Approximate value.

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 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	1 120–1 180 °C	2 050–2 155 °F
3.2 Annealing temperature range	550– 750 °C	1 020–1 380 °F
Stress relieving temperature range	300– 400 °C	570– 750 °F
3.3 Hot working temperature range	800– 900 °C	1 470–1 650 °F
3.4 Hot formability	Fair	
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. 3.8	
Soldering	Not recommended	
Brazing (with special fluxes)	Fair	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Good	
Resistance welding: spot and seam	Good	
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 Al5	—	266.22	266.22	—	266.22	266.22	—
Canada	CSA	HC.A6 606	—	—	—	—	HC.7.3 HC.7.4	—	—
Chile	NCh (INDITECNOR)	Cu Al5	—	NCh 249 of. 68	—	—	NCh 249 of. 68	—	—
France	NF	U-A 6	—	NF A53-609	—	—	—	—	—
Germany	DIN	Cu Al5 Cu Al5 As	17 665 1785	17 670 —	17 672 —	17 672 —	17 671 1785	— —	— —
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	P Cu Al5	—	2512	2512	2512	2512	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN [(b)]	Cu Al5	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	Cu Al5	—	37 103	—	37 103	37 103	37 103	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Al5 As	—	—	—	—	10 802 11 557	—	—
United Kingdom	BS	CA101	—	2870	—	—	—	—	—
United States[(c)]	ASTM	Nos. 606 and 608	—	B169	—	—	B 111 B 359 B 395	—	—
International Organisation for Standardization	ISO	Cu Al5	R 428	—	—	—	—	—	—

(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 is 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	no data

5.3 Mechanical properties at elevated temperature

Short-time tensile 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 (*)

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		
Plate Sheet Strip	Annealed	38	15	55	$5.65\sqrt{S_0}$	85	89	29	2–20 mm thick
	Typical Cold Worked Tempers	45	30	25	$5.65\sqrt{S_0}$	115	120	32	2–15 mm thick
		53	45	15	$5.65\sqrt{S_0}$	140	145	34	2–10 mm thick
Tube	Annealed	42	18	50	$5.65\sqrt{S_0}$	95	100	32	15–30 mm O.D., 1.5–3 mm wall

(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	
Sheet Strip	Annealed	37	24	14	9	65	50 mm (2 in.)	90	28	18	—
	Cold Worked										
	Half Hard	53	34	40	26	30	50 mm (2 in.)	150	37	24	1–6 mm (0.04–0.25 in.) thick
	Hard	65	42	54	35	15	50 mm (2 in.)	190	42	27	1–3 mm (0.04–0.125 in.) thick

(a) The recognised temper designations used in 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		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown[a]
				%	gauge length	F	B	30 T		
Tube	Annealed [b]	**60 000**	**27 000**	**55**	2 in.	**77**	—	—	**45 000**	1.0 in. O.D. × 0.065 in. wall

(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) Tubes for condensers and heat exchangers are generally supplied only to the temper whose representative mechanical properties are printed in **bold type**.

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] **8–10 mm diam. 0.3–0.4 in. diam.**	(a)	17	63	**42**	26.5	59 500	**61**	(b)	**74**
		—196	—321	**58**	37	82 500	**84**	(b)	**76**
		—253	—423	**65**	41.5	92 500	**83**	(b)	**72**

(a) Temper not stated in original document.

(b) Test bar: 3 mm diam x 30 mm gauge length.

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,
Impact Strength.

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
Flat Products [2] (Bar) **12 mm** **0.5 in.**	Hot Rolled	20	68	**40**	25.5	57 000	—	**62**	$5.65\sqrt{S_0}$
		200	392	**32.5**	20.5	46 000	—	**52**	$5.65\sqrt{S_0}$
		400	752	**23**	14.5	32 500	—	**22.5**	$5.65\sqrt{S_0}$
		600	1 112	**10**	6.5	14 000	—	**40**	$5.65\sqrt{S_0}$
		800	1 472	**3.5**	2	5 000	—	**95**	$5.65\sqrt{S_0}$
Plate [3] [4]	Annealed	20	68	**43.5**	27.5	62 000	**16.5**	**62**	50 mm
		100	212	**39**	25	55 500	**16**	**61**	50 mm
		150	302	**39**	25	55 500	**15.5**	**59**	50 mm
		200	392	**38**	24	54 000	**14.5**	**50**	50 mm
		250	482	**35.5**	22.5	50 500	**14.5**	**35**	50 mm
		300	572	**32**	20.5	45 500	**14.0**	**29**	50 mm
		350	662	**28**	18	40 000	**14.0**	**45**	50 mm
		400	752	**23**	14.5	32 500	**13.5**	**60**	50 mm
		450	842	**18**	11.5	25 500	**13.0**	**68**	50 mm
		500	932	**14**	9	20 000	**11.5**	**70**	50 mm
		600	1 112	**8**	5	11 500	**6**	**62**	50 mm
Rod [5]	Annealed	20	68	43	**27.3**	61 000	—	**81**	$4\sqrt{S_0}$
		400	752	15	**9.4**	21 000	—	**21**	$4\sqrt{S_0}$
	Cold Drawn 50%	20	68	73	**46.4**	104 000	—	**20**	$4\sqrt{S_0}$
		400	752	15	**9.4**	21 000	—	**33**	$4\sqrt{S_0}$
Rod [6] [a]	Rolled [b]	38	100	45.5	29	**64 500**	—	**65**	2 in.
		93	200	43	27	**61 000**	—	**56**	2 in.
		149	300	41.5	26.5	**59 000**	—	**45**	2 in.
		204	400	38.5	24.5	**55 000**	—	**37**	2 in.
		260	500	36	23	**51 500**	—	**28**	2 in.
		316	600	32.5	20.5	**46 000**	—	**25**	2 in.
		371	700	29	18.5	**41 500**	—	**19**	2 in.
		427	800	24.5	15.5	**35 000**	—	**15**	2 in.
		482	900	19	12	**27 000**	—	**15**	2 in.
Tube [7] **19 mm O.D.** **1.24 mm wall** **0.75 in. O.D.** **0.049 in. wall**	Cold Worked [c]	20	68	46.5	29.5	**66 000**	—	**59**	2 in.
		93	200	45	28.5	**64 000**	—	**55**	2 in.
		149	300	42	27	**60 000**	—	**53**	2 in.
		204	400	41	26	**58 000**	—	**52**	2 in.
		260	500	33	21	**47 000**	—	**41**	2 in.
		316	600	26.5	17	**38 000**	—	**32**	2 in.
		371	700	22	14	**31 000**	—	**44**	2 in.
		427	800	14	9	**20 000**	—	**47**	2 in.
		482	900	10	6.5	**14 000**	—	**42**	2 in.
		538	1 000	7.5	5	**11 000**	—	**42**	2 in.
Tube [3]	Annealed	20	68	**38**	24	54 000	**15**	**~60**	50 mm
		100	212	**38**	24	54 000	**15**	—	—
		150	302	**37**	23.5	52 500	**14**	—	—
		200	392	**35**	22	50 000	**11.5**	—	—
		250	482	**24.5**	15.5	35 000	**6.5**	—	—
		275	527	**20**	12.5	28 500	**3.5**	—	—

(a) Alloy containing 6.7% Al.

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

(c) Quoted as "hard drawn, relief annealed" 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:

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- 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

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				
Strip [(8)] [(f)] **2.5 mm 0.1 in.**	Annealed [(b)]	300	572	7.9 12.6	**5** **8**	11 200 17 900	**300** **300**	**0.32** **3.5**	— —	**0.55** **5.9**
		500	932	1.6	**1**	2 200	**300**	**1.1**	—	**2.7**
	Annealed [(c)]	300	572	7.9 12.6	**5** **8**	11 200 17 900	**300** **300**	**0.33** **6.8**	— —	**0.30** **11**
		500	932	1.6	**1**	2 200	**300**	**0.31**	—	**0.60**
Plate [(4)] [(3)]	Annealed	200 300	392 572	**11.0** **3.4**	7.0 2.2	15 600 4 800	**3 000** **2 000**	**0.2** **0.2**	— —	**0.000 07** **0.000 1**
Rod [(7)] **19 mm diam. 0.75 in. diam.**	Cold [(g)] Drawn	500	932	3.5	2.2	**5 000**	**0.82** [(d)]	**10.8** [(e)]	**0.246**	**6 140**
		550	1 022	1.8 3.5	1.1 2.2	**2 500** **5 000**	**5.8** [(d)] **0.52** [(d)]	**7.5** [(e)] **5.7** [(e)]	**0.035** **0.62**	**640** **8 340**
		600	1 112	0.70 1.8 3.5	0.45 1.1 2.2	**1 000** **2 500** **5 000**	**85.3** [(d)] **2.9** [(d)] **0.14** [(d)]	**23.5** [(e)] **8.5** [(e)] **8.0** [(e)]	**0.090** **0.316** **0**	**79** **1 250** **23 500**

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Grain size 15–20 mm.
(c) Grain size 6–8 mm.
(d) Rupture test.
(e) Total elongation.
(f) Alloy containing 6.51 % Al.
(g) Quoted as "Rockwell hardness 92B" in original document, but amount of cold work not defined.
N.B.: Original values are printed in **bold type**; other values are converted.

5.3.2.2 Stress for Rupture

Form	Temper	Testing Temperature		Stress for Rupture in 100 h		
		°C	°F	kg/mm²	ton/in²	psi
Rod [(7)] **19 mm diam. 0.75 in. diam.**	Cold Drawn [(a)]	600	1 112	0.60	0.38	**850**

(a) Quoted as "Rockwell hardness 92B" in original document, but amount of cold work not defined.
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 x10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Plate [3] [4]	Annealed	20	**43**	**16** [a]	27.5	10 [a]	61 000	23 000 [a]
Rod [9] **25 mm diam. 1 in. diam.**	Rolled	100	50.5	13.5 [b]	32	8.5 [b]	**71 900**	**19 000** [b]
Condenser [10] **Tube**	Annealed	100	**40**	**11**	25.5	7	57 000	15 500

(a) Rotating bending test.

(b) Rotating-cantilever test.

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

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

(10) Data sheet from Kabelmetall, Osnabrück, Germany.

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Cu Al8

Common names: 92/8 Aluminium Bronze
8% Aluminium Bronze
Aluminium Bronze, C

A copper-aluminium alloy with a duplex phase structure and possibly containing a small amount of nickel or manganese at the manufacturer's option. The alloy has good oxidation and corrosion resistance and hot working properties. The most commonly used wrought forms are plate, sheet, strip and rod.

COMPOSITION (weight %)

Al	8.0–9.0
Ni	0 –0.8
Mn	0 –0.5
Cu	rem.

1 SOME TYPICAL USES

Chemical
Components in contact with acid waters and saline solutions, including concentrated brine; tubes and tubeplates for condensers, evaporators and heat exchangers; papermaking equipment; processing vessels and autoclaves; cryogenic equipment; pickling chains and hooks; fractionating tower parts (bubble caps and risers); sewage-handling equipment; perforated screen plates; diaphragms; waterboxes and storage tanks.

Decorative
Coins, medallions and jewellery.

Marine
Non-magnetic components and instruments (e.g. gyro compasses); protective sheathing; seawater pipework.

Mechanical
Electrode materials for joining and overlaying; fasteners; valve spindles.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	7.8 g/cm³	0.280 lb/in³
2.2 Melting range	1 035–1 045 °C	1 895–1 915 °F
2.3 Coefficient of thermal expansion (linear) at:		
−183 °C *−297 °F*	0.000 009 per °C	0.000 005 per °F
− 93 °C *−135 °F*	0.000 013 ,, ,,	0.000 007 ,, ,,
20 to 100 °C *68 to 212 °F*	0.000 016 ,, ,,	0.000 009 ,, ,,
20 to 300 °C *68 to 572 °F*	0.000 017 ,, ,,	0.000 009 ,, ,,
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.10 cal/g °C	0.10 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.15–0.17 cal cm/cm² s °C	36–41 Btu ft/ft² h °F
200 °C *392 °F*	0.20 [a] ,,	48 [a] ,,
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed or cold worked)	7.5–8.7 m/ohm mm²	13–15% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed or cold worked)	0.13–0.11 ohm mm²/m 13–11 microhm cm	80–69 ohms (circ mil/ft) 5.2–4.5 microhm in
2.8 Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range 0 to 100 °C *32 to 212 °F*	0.000 8 per °C (13%–15% IACS)	0.000 4 per °F (13%–15% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*:		
annealed	12 600 kg/mm²	17 900 000 lb/in²
cold worked	11 350 kg/mm²	16 100 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:		
annealed	4 650 kg/mm²	6 600 000 lb/in²
cold worked	4 200 kg/mm²	6 000 000 lb/in²

(a) Approximate value.

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 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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3 FABRICATION PROPERTIES

Fabrication characteristics, corrosion resistance and mechanical properties of this copper–aluminium alloy are markedly influenced by composition and by heat treatment which is usually performed by the metal manufacturer.
If thermal treatment, including hot forming and joining processes, is to be undertaken by the end user, the advice of the metal supplier should be requested.

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

	Metric Units	English Units
3.1 Casting temperature range	1 120–1 180 °C	2 050–2 155 °F
3.2 Annealing temperature range Stress relieving temperature range	550– 750 °C 300– 400 °C	1 020–1 380 °F 570– 750 °F
3.3 Hot working temperature range	800– 900 °C	1 470–1 650 °F
3.4 Hot formability	Good	
3.5 Cold formability	Fair	
3.6 Cold reduction between anneals	30% max.	
3.7 Machinability: Machinability rating (free cutting brass = 100)	See General Data Sheet No. 2 20	
3.8 Joining methods:	See General Data Sheet No. 3.8	
Soldering	Not recommended	
Brazing (with special fluxes)	Fair	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Good	
Resistance welding: spot and seam	Good	
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 Al8	—	266.22	266.22	—	—	—	266.22
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Al8	—	NCh 249 of. 68	—	—	NCh 249 of. 68	—	—
France	NF	U-A8	—	NF A53-609	—	—	—	—	—
Germany	DIN	Cu Al8	17 665	17 670	17 672	17 672	17 671	—	17 673
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	P Cu Al9	—	2512	2512	2512	2512	—	2512
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN[b]	Cu Al8	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	Cu Al10	—	37 103	—	37 103	37 103	37 103	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Al8	—	10 802	10 802	—	10 802	—	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States	ASTM	—	—	—	—	—	—	—	—
International Organisation for Standardization	ISO	Cu Al8	R 428	—	—	—	—	—	—

[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.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

Tensile properties	see tables 5.1.1/2
Hardness	„ „ 5.1.1/2
Shear strength	„ „ 5.1.1/2
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	no data

5.3 Mechanical properties at elevated temperature

Short-time tensile 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 ‡

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

This table is representative of practice in many European countries. For British practice, see table 5.1.2.

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

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

Form	Temper	Tensile Strength kg/mm²	Proof Stress 0.2% offset kg/mm²	Elongation %	Elongation gauge length	Hardness Brinell	Hardness Vickers	Shear Strength kg/mm²	Typical Size Related to Properties Shown[(a)]
Plate Sheet Strip	Annealed	42	17	45	$5.65\sqrt{S_o}$	90	95	32	3–20 mm thick
	Typical Cold Worked Tempers	50	35	20	$5.65\sqrt{S_o}$	130	135	35	3–15 mm thick
		57	43	15	$5.65\sqrt{S_o}$	150	160	37	3–10 mm thick
Rod[(b)]	Annealed	42	17	45	$5.65\sqrt{S_o}$	90	95	32	10–60 mm diam. or equivalent area
	Hot Worked	45	18	40	$5.65\sqrt{S_o}$	95	100	34	15–80 mm diam. or equivalent area
	Typical Cold Worked Tempers	52	37	20	$5.65\sqrt{S_o}$	135	140	36	5–30 mm diam. or equivalent area
		58	43	15	$5.65\sqrt{S_o}$	160	170	38	5–20 mm diam. or equivalent area
Tube	Annealed	45	20	40	$5.65\sqrt{S_o}$	95	100	34	15–30 mm O.D., 1.5–3 mm wall

(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.

(b) 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 countries, see table 5.1.1.

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 hbar	Tensile Strength ton/in²	Proof Stress 0.1% offset hbar	Proof Stress 0.1% offset ton/in²	Elongation %	Elongation gauge length	Vickers Hardness	Shear Strength hbar	Shear Strength ton/in²	Typical Size Related to Properties Shown[(b)]
Plate	Hot Rolled As Manufactured	48	31	20	13	40	$5.65\sqrt{S_o}$	130	36	23	12–50 mm (0.5–2 in.) thick
Sheet Strip	Annealed	43	28	17	11	60	50 mm (2 in.)	100	32	21	—
	Hot Rolled As Manufactured	51	33	25	16	35	50 mm (2 in.)	140	36	23	3–10 mm (0.125–0.375in.) thick
	Cold Worked Half Hard	56	36	39	25	25	50 mm (2 in.)	160	39	25	1–6 mm (0.04–0.25 in.) thick
	Cold Worked Hard	66	43	51	33	10	50 mm (2 in.)	210	43	28	1–3 mm (0.04–0.125 in.) thick
Tube	Annealed	45	29	17	11	55	$5.65\sqrt{S_o}$	100	34	22	—
	Cold Drawn As Drawn (Half Hard)	57	37	34	22	30	$5.65\sqrt{S_o}$	140	40	26	12–50 mm (0.5–2 in.) O.D. up to 5 mm (0.2 in.) wall
	As Drawn (Hard)	70	45	57	37	7	$5.65\sqrt{S_o}$	190	45	29	

(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.

* Copper-aluminium alloys in this composition range (Al: 8.0—9.0%; Cu: rem.) are not included in British Standard specifications for wrought copper-base materials. Plate, sheet, strip and tube products containing 7.5—8% Al are, however, manufactured in British practice, with typical properties as shown above. The properties of plate and tube materials designated CA 102 (Al: 6.0—7.5%; Fe+Ni+Mn: 1.0—2.5% total, optional; Cu: rem.) in British Standards 2875 and 2871 respectively are also similar to those given for these forms in this table.

‡ It will be noted that tables 5.1.1 and 5.1.2, giving typical tensile properties and hardness values in Metric, and SI and English 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

Tensile properties and hardness values in American units are omitted from this data sheet, since alloys within the composition range concerned are not supplied by American manufacturers.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation		Reduction of Area %
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length	
(1) (a)	Cold Worked (d)	20 —78 —183	68 —108 —297	**54** **57** **65**	34.5 36 41.5	77 000 81 000 92 500	— — —	**33** **34** **29**	(b) (b) (b)	— — —
Rod (2) **3 mm diam.** **0.118 in. diam.**	Annealed (grain size 0.190 mm)	20 —196 —269	68 —321 —452	42 54 63.5	27 34 40	**60 000** **76 500** **90 000**	**9.56** (c) **14.1** (c) **15.5** (c)	— — —	— — —	**79** **79** **80**
Rod (3) (e) **76 mm diam.** **3 in. diam.**	Annealed (grain size 0.016 mm)	25 —196	77 —321	43 57	27 36	**61 000** **81 000**	**11.2** (c) **13.7** (c)	**107** **77**	(b) (b)	**75** **60**

(a) Form not stated in original document.

(b) Gauge length not stated in original document.

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

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

(e) Alloy containing 7.9% Al.

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.

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	%	gauge length
Flat Products[4] (Rectangular Rod) **12 mm thick** **0.5 in. thick**	Hot Rolled	20	68	**42**	26.5	59 500	—	**72**	$5.65\sqrt{S_0}$
		200	392	**35**	22	50 000	—	**60**	$5.65\sqrt{S_0}$
		400	752	**26**	16.5	37 000	—	**20**	$5.65\sqrt{S_0}$
		600	1 112	**9**	5.5	13 000	—	**55**	$5.65\sqrt{S_0}$
		800	1 472	**2**	1.5	3 000	—	**85**	$5.65\sqrt{S_0}$
Rod[5] **14 mm diam.** **0.55 in. diam.**	Cold Worked[a]	20	68	**53.5**	34	76 000	**36.5**	**40**	$5.65\sqrt{S_0}$
		100	212	**50**	31.5	71 000	**36**	**37**	$5.65\sqrt{S_0}$
		200	392	**49**	31	69 500	**33**	**45**	$5.65\sqrt{S_0}$
		300	572	**47.5**	30	67 500	**29.5**	**38**	$5.65\sqrt{S_0}$
		400	752	**36**	23	51 000	**26**	**15**	$5.65\sqrt{S_0}$
		500	932	**21**	13.5	30 000	**15**	**20**	$5.65\sqrt{S_0}$
		600	1 112	**11**	7	15 500	**10**	**14**	$5.65\sqrt{S_0}$
		700	1 292	**6**	4	8 500	**2.5**	**36**	$5.65\sqrt{S_0}$
		800	1 472	**2**	1.5	3 000	**1**	**31**	$5.65\sqrt{S_0}$
Rod[6]	Cold Worked 10%	20	68	**58.5**	37	83 000	**38**	**37**	$5.65\sqrt{S_0}$
		100	212	**58.5**	37	83 000	**34**	**38**	$5.65\sqrt{S_0}$
		200	392	**58**	37	82 500	**32**	**39**	$5.65\sqrt{S_0}$
		300	572	**56**	35.5	79 500	**30**	**38**	$5.65\sqrt{S_0}$
		400	752	**51**	32.5	72 500	**28**	**35**	$5.65\sqrt{S_0}$
		500	932	**38**	24	54 000	**24**	**35**	$5.65\sqrt{S_0}$
		600	1 112	**23**	14.5	32 500	**13**	**44**	$5.65\sqrt{S_0}$
Rod[7]	Extruded	20	68	**50**	31.5	71 000	**30**	**55**	$5.65\sqrt{S_0}$
		100	212	**48**	30.5	68 500	**26**	**44**	$5.65\sqrt{S_0}$
		200	392	**45**	28.5	64 000	**17**	**48**	$5.65\sqrt{S_0}$
		300	572	**42**	26.5	60 000	**7**	**31**	$5.65\sqrt{S_0}$
		400	752	**37**	23.5	52 500	**2**	**39**	$5.65\sqrt{S_0}$
		500	932	**15**	9.5	21 500	**1**	**58**	$5.65\sqrt{S_0}$
[5] [b]	Hot Worked	20	68	**47.5**	30	67 500	—	**59**	$11.3\sqrt{S_0}$
		100	212	**45**	28.5	64 000	—	**64**	$11.3\sqrt{S_0}$
		200	392	**44**	28	62 500	—	**64**	$11.3\sqrt{S_0}$
		300	572	**42.5**	27	60 500	—	**58**	$11.3\sqrt{S_0}$
		400	752	**32**	20.5	45 500	—	**33**	$11.3\sqrt{S_0}$
		500	932	**14**	9	20 000	—	**28**	$11.3\sqrt{S_0}$
		600	1 112	**7**	4.5	10 000	—	**28**	$11.3\sqrt{S_0}$
		700	1 292	**4**	2.5	5 500	—	**31**	$11.3\sqrt{S_0}$
		800	1 472	**2.5**	1.5	3 500	—	**19**	$11.3\sqrt{S_0}$

[a] Quoted as "1/4 hard" in original document, but amount of cold work not defined.

[b] Form not stated in original document.

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 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.

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
Square Tube[8] [c] 38 mm side 1.625 mm wall 1.5 in. side 0.064 in. wall	Annealed grain size 0.037 mm	500	932	7.0	4.5	**10 000**	**7** [b]	**17**	—	—
				5.6	3.6	**8 000**	**25** [b]	**13**	—	—
				4.2	2.7	**6 000**	**92** [b]	**9**	—	—
				2.8	1.8	**4 000**	**376**	**6.5**	**0.08**	**4.0**
				2.5	1.6	**3 500**	**624**	**6.5**	**0.05**	**2.8**
				2.1	1.3	**3 000**	**1 400**	**5**	**0.06**	**0.9**
				1.8	1.1	**2 500**	**3 072**	**6**	**0.11**	**0.4**
				1.4	0.89	**2 000**	**7 420**	**11**	**0.07**	**0.2**
	Cold Worked 25%	500	932	7.0	4.5	**10 000**	**18** [b]	**1**	—	—
				5.6	3.6	**8 000**	**80** [b]	**2**	—	—
				4.2	2.7	**6 000**	**268** [b]	**2**	—	—
				3.5	2.2	**5 000**	**691**	**2**	**0.12**	**1.1**
				3.2	2.0	**4 500**	**1 173**	**2.5**	**0.10**	**0.6**
				2.8	1.8	**4 000**	**1 636** [b]	**2**	—	—
				2.5	1.6	**3 500**	**3 432**	**1.23** [d]	**0.08**	**0.3**
				2.1	1.3	**3 000**	**7 776**	**3**	**0.07**	**0.3**

[a] Total elongation (rupture).
[b] Rupture test.
[c] The chemical composition of this material is: Al 7.07; Fe0.83; Ni0.80; Mn0.30; Cu: rem (%).
[d] Total extension (creep).
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	0.001% per 1 000 h kg/mm²	0.001% per 1 000 h ton/in²	0.001% per 1 000 h psi	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
Square Tube [8] [a] 38 mm side 1.625 mm wall 1.5 in. side 0.064 in. wall	Annealed grain size 0.037 mm	500	932	0.47	0.30	**670**	0.70	0.45	**1 000**	1.3	0.80	**1 800**
	Cold Worked 25%	500	932	—	—	—	—	—	—	1.7	1.1	**2 400**

[a] The chemical composition of this material is: Al 7.07; Fe0.83; Ni0.80; Mn0.30; Cu: rem (%).
N.B.: Original values are printed in **bold type**; other values are converted.
* This data has been included for information only, since none has been traced for alloys within the exact composition range of Cu Al8.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles x10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod [9] [(a)] **19 mm diam. 0.75 in. diam.**	Extruded Light Drawn	52.52 [(b)]	56	22 [(c)]	**35.7**	**14** [(c)]	80 000	31 500 [(c)]
Rod [10] [(f)] **25 mm diam. 1 in. diam.**	Rolled	100	61	17 [(d)]	39	11 [(d)]	**86 800**	**24 500** [(d)]
Rod [6] **42 mm diam. 1.7 in. diam.**	Forged	50	**52.5**	**18.5** [(d)]	33.5	11.5 [(d)]	74 500	26 500 [(d)]
Rod [11] [(i)]	Cold Worked 11.5%	300	68.5	15.5 [(c)]	43.5	10 [(c)]	**97 500**	**22 000** [(c)]
Wire [3] [(g)]	Annealed (grain size 0.16 mm)	10 [(b)]	43	16 [(h)]	27	10 [(h)]	**61 000**	**22 700** [(h)]

(a) Alloy containing 1.4% Zn.
(b) Unbroken specimen.
(c) Rotating beam test.
(d) Rotating cantilever test.
(f) Alloy containing 9.10% Al.
(g) Alloy containing 7.9% Al.
(h) Push-pull test.
(i) Alloy containing 0.64% Fe; 0.51% Ni; 0.38% Sn.

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

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MECHANICAL PROPERTIES (SECTION 5)

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WROUGHT MATERIALS

COPPER-ALUMINIUM ALLOYS
Aluminium Bronzes

Cu Al8 Fe3

Common names: Aluminium Bronze (Alloy D)
Aluminium Bronze, D

A copper-aluminium-iron alloy with a duplex phase structure. Iron is added to inhibit grain growth and to improve strength; the alloy may also contain small amounts of nickel and/or manganese. The material has good corrosion resistance in most environments and good hot-working properties. The most commonly used wrought forms are plate, sheet and rod.

COMPOSITION (weight %)

Al	6.0–8.0
Fe	2.0–3.5
Ni	0 –1.0
Mn	0 –0.8
Cu	rem.

1 SOME TYPICAL USES

Chemical
Tubeplates for condensers, evaporators and heat exchangers; cryogenic equipment; waterboxes and storage tanks; processing vessels; pickling equipment.

Marine
Tubeplates for condensers, evaporators and heat exchangers; seawater storage tanks and pipework.

Mechanical
Fasteners; pump components.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	7.8 g/cm³	0.280 lb/in³
2.2 Melting range	1 045–1 110 °C	1 915–2 030 °F
2.3 Coefficient of thermal expansion (linear) at:		
–200 to 20 °C *–328 to 68 °F*	0.000 014 [(a)] per °C	0.000 008 [(a)] per °F
20 to 100 °C *68 to 212 °F*	0.000 016 " "	0.000 009 " "
20 to 300 °C *68 to 572 °F*	0.000 017 " "	0.000 009 " "
2.4 Specific heat (thermal capacity) at: 20 °C *68 °F*	0.10 cal/g °C	0.10 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.14–0.17 cal cm/cm² s °C	34–41 Btu ft/ft² h °F
200 °C *392 °F*	0.20 [(a)] "	48 [(a)] "
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	7.0–8.1 m/ohm mm²	12–14% IACS
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	0.14–0.12 ohm mm²/m 14–12 microhm cm	86–74 ohms (circ mil/ft) 5.7–4.8 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 8 per °C (12%–14% IACS)	0.000 4 per °F (12%–14% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*: annealed	12 250 kg/mm²	17 400 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*: annealed	4 550 kg/mm²	6 500 000 lb/in²

(a) Approximate value.

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 8); *INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE*

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3 FABRICATION PROPERTIES

Fabrication characteristics, corrosion resistance and mechanical properties of this copper-aluminium alloy are markedly influenced by composition and by heat treatment which is usually performed by the metal manufacturer.
If thermal treatment, including hot forming and joining processes, is to be undertaken by the end user, the advice of the metal supplier should be requested.

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

		Metric Units	English Units
3.1	Casting temperature range	1 140–1 200 °C	2 085–2 190 °F
3.2	Annealing temperature range Stress relieving temperature range	650– 800 °C 300– 400 °C	1 200–1 470 °F 570– 750 °F
3.3	Hot working temperature range	800– 925 °C	1 470–1 695 °F
3.4	Hot formability	Good	
3.5	Cold formability	Fair	
3.6	Cold reduction between anneals	25% max.	
3.7	Machinability: Machinability rating (free cutting brass = 100)	See General Data Sheet No. 2 30	
3.8	Joining methods:	See General Data Sheet No. 3.8	
	Soldering	Not recommended	
	Brazing (with special fluxes)	Fair	
	Oxy-acetylene welding	Not recommended	
	Carbon-arc welding	Fair	
	Gas-shielded arc welding	Fair	
	Coated metal-arc welding	Fair	
	Resistance welding: spot and seam	Good	
	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	—	—	—	—	—	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Al8 Fe3	—	NCh 249 of. 68	—	—	—	—	NCh 249 of. 68
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	Cu Al8 Fe	17 665	17 670	17 672	—	17 671	—	17 673
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN [b]	Cu Al8 Fe3	—	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Al8 Fe3	—	10 802	—	—	—	—	—
United Kingdom	BS	CA106	—	1541 2875	2872 2874	—	[redacted]	[redacted]	2872
United States [c]	ASTM	No. 614	—	B150 B169 B171	B150 —	—	—	B150	—
International Organisation for Standardization	ISO	Cu Al8 Fe3	R428	—	—	—	—	—	—

(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 is 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 *

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		
Plate Sheet	Annealed	48	25	40	$5.65\sqrt{S_o}$	115	120	36	3–30 mm thick
	Hot Rolled	52	27	35	$5.65\sqrt{S_o}$	130	135	39	10–40 mm thick
	Typical Cold Worked Tempers	55	35	30	$5.65\sqrt{S_o}$	140	145	39	3–20 mm thick
		63	45	20	$5.65\sqrt{S_o}$	160	170	41	3–10 mm thick
Rod [b]	Annealed	48	25	40	$5.65\sqrt{S_o}$	115	120	36	10–60 mm diam. or equivalent area
	Hot Worked	55	28	30	$5.65\sqrt{S_o}$	140	145	41	15–80 mm diam. or equivalent area
	Typical Cold Worked Temper	65	47	20	$5.65\sqrt{S_o}$	165	175	42	10–40 mm diam. or equivalent area

(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.

(b) 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 Sheet	Hot Rolled As Manufactured	54	35	23	15	40	$5.65\sqrt{S_o}$	150	43	28	12–50 mm (0.5–2 in.) thick
		57	37	25	16	40	50 mm (2 in.)	160	45	29	3–10 mm (0.125–0.375 in.) thick
Rod [c]	Annealed	48	31	20	13	45	$5.65\sqrt{S_o}$	120	36	23	—
	Hot or Hot & Cold Worked As Manufactured	51	33	20	13	42	$5.65\sqrt{S_o}$	130	36	23	50–100 mm (2–4 in.) diam. or equivalent area
		53	34	22	14	40	$5.65\sqrt{S_o}$	140	37	24	25–50 mm (1–2 in.) diam. or equivalent area
		57	37	25	16	38	$5.65\sqrt{S_o}$	160	40	26	10–25 mm (0.375–1 in.) diam. or equivalent area
		62	40	31	20	35	$5.65\sqrt{S_o}$	180	43	28	" "
Forgings [c]	Hot Worked As Manufactured	53	34	22	14	40	$5.65\sqrt{S_o}$	140	37	24	—

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

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

* 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		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown[(a)]
				%	gauge length	F	B	30 T		
Flat products (plate, sheet)	Annealed	75 000	42 000	40	2 in.	—	75	—	45 000	0.125 in. thick
		72 000	38 000	40	2 in.	—	74	—	42 000	0.312 in. thick
		72 000	32 000	42	2 in.	—	71	—	40 000	0.500 in. thick
		70 000	30 000	45	2 in.	—	69	—	40 000	1.0 in. thick
	Hard	85 000	55 000	32	2 in.	—	84	—	58 000	0.125 in. thick
		80 000	50 000	35	2 in.	—	83	—	55 000	0.312 in. thick
		75 000	45 000	38	2 in.	—	80	—	52 000	0.500 in. thick
		70 000	40 000	40	2 in.	—	78	—	50 500	1.0 in. thick
Rod[(b)]	Hard	80 000	40 000	35	2 in.	—	91	—	48 000	0.500 in. diam.
		75 000	35 000	35	2 in.	—	90	—	45 000	1.0 in. diam.
		70 000	32 000	35	2 in.	—	88	—	40 000	2.0 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			Yield Strength 0.5% ext. under load psi	Elongation		Reduction of Area %	Impact Strength[(a)]	
		°C	°F	kg/mm²	ton/in²	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	58.5	37	**83 200**	**59 400** [(b)]	**40**	$4.52\sqrt{S_o}$	**66**	19.0	**110**
		— 78	—108	63	40	**89 500**	**64 800** [(b)]	**45**	$4.52\sqrt{S_o}$	**71**	17.3	**100**
		—197	—323	74.5	47	**105 800**	**69 500** [(b)]	**52**	$4.52\sqrt{S_o}$	**64**	12.4	**72**
		—253	—423	89	56.5	**126 400**	**80 600** [(b)]	**48**	$4.52\sqrt{S_o}$	**58**	11.4	**66**
		—269	—452	94.5	60	**134 500**	**82 400** [(b)]	**52**	$4.52\sqrt{S_o}$	**59**	—	—
Rod [(2) (3)] **41 mm diam. 1.6 in. diam.**	Annealed (grain size 0.025 mm)	20	68	59.5	37.5	**84 600**	**41 800**	**45**	2 in.	**56**	12.6	**73**
		— 29	— 20	61	39	**87 100**	**43 900**	**44**	·2 in.	**56**	12.6	**73**
		— 59	— 75	62	39.5	**88 400**	**44 300**	**47**	2 in.	**57**	13.0	**75**
		—182	—295	72	46	**102 600**	**50 300**	**52**	2 in.	**51**	11.1	**64**
	Cold Worked 0.3%	20	68	60	38	**85 500**	**46 100**	**42**	2 in.	**59**	12.6	**73**
		— 29	— 20	62	39	**87 900**	**49 200**	**44**	2 in.	**58**	13.5	**78**
		— 59	— 75	62.5	39.5	**88 600**	**48 700**	**45**	2 in.	**55**	13.1	**76**
		—182	—295	73	46.5	**104 100**	**57 600**	**50**	2 in.	**49**	12.1	**70**

(a) Charpy test, V notch, cross-sectional area at the notch 0.8 cm².

(b) Quoted as yield point, but offset strain not defined.

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

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

—The 0.1% and 0.2% offset proof stress values are not available.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Impact [d] 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 [4] 25 mm 1 in.	Forged	20	68	**62**	39.5	88 000	**35**	—	—	**38**	$5.65\sqrt{S_o}$	—	—
		100	212	**60**	38	85 500	**33**	—	—	**36**	$5.65\sqrt{S_o}$	—	—
		200	392	**57**	36	81 000	**33.5**	—	—	**34**	$5.65\sqrt{S_o}$	—	—
		250	482	**56**	35.5	79 500	**33.5**	—	—	**38**	$5.65\sqrt{S_o}$	—	—
		300	572	**50**	31.5	71 000	**33.5**	—	—	**37**	$5.65\sqrt{S_o}$	—	—
		350	662	**45**	28.5	64 000	**32**	—	—	**36**	$5.65\sqrt{S_o}$	—	—
		400	752	**33.5**	21.5	47 500	**29**	—	—	**35**	$5.65\sqrt{S_o}$	—	—
Plate [5]	As received [b] (grain size 0.05 mm)	20	68	58.5	**37**	83 000	—	—	—	**59**	$5.65\sqrt{S_o}$	—	—
		100	212	53.5	**34**	76 000	—	—	—	**52**	$5.65\sqrt{S_o}$	—	—
		200	392	50.5	**32**	71 500	—	—	—	**55**	$5.65\sqrt{S_o}$	—	—
		300	572	42.5	**27**	60 500	—	—	—	**20**	$5.65\sqrt{S_o}$	—	—
		400	752	31.5	**20**	45 000	—	—	—	**30**	$5.65\sqrt{S_o}$	—	—
		500	932	15.5	**10**	22 500	—	—	—	**62**	$5.65\sqrt{S_o}$	—	—
		600	1 112	12	**7.5**	17 000	—	—	—	**30**	$5.65\sqrt{S_o}$	—	—
		700	1 292	8	**5**	11 000	—	—	—	**39**	$5.65\sqrt{S_o}$	—	—
		800	1 472	6.5	**4**	9 000	—	—	—	**30**	$5.65\sqrt{S_o}$	—	—
		900	1 652	0	**0**	0	—	—	—	**20**	$5.65\sqrt{S_o}$	—	—
Plate [6]	Annealed	20	68	57.5	**36.5**	82 000	**25.4** [c]	**15.5**	—	**49**	2 in.	—	—
		66	150	55.5	**35.3**	79 000	**24.6** [c]	**14.9**	—	**44**	2 in.	—	—
		121	250	51	**32.5**	73 000	**24.4** [c]	**15.0**	—	**27**	2 in.	—	—
		177	350	47	**30.0**	67 000	**24.7** [c]	**15.0**	—	**22**	2 in.	—	—
		232	450	43.5	**27.5**	61 500	**24.3** [c]	**14.7**	—	**18**	2 in.	—	—
		288	550	38.5	**24.3**	54 500	**25.7** [c]	**15.1**	—	**9**	2 in.	—	—
		343	650	34.5	**21.8**	49 000	**23.3** [c]	**13.8**	—	**9**	2 in.	—	—
		371	700	31.5	**20.1**	45 000	**22.1** [c]	**13.1**	—	**9**	2 in.	—	—
Rod [2] [3] 41 mm diam. 1.6 in. diam.	Annealed (grain size 0.025 mm)	20	68	59.5	38	**84 600**	—	—	**41 800**	**45**	2 in.	13	**73**
		204	400	53	34	**75 700**	—	—	**40 100**	**34**	2 in.	10	**62**
		316	600	43.5	27.5	**62 000**	—	—	**37 100**	**30**	2 in.	10	**58**
		427	800	18	11.5	**25 300**	—	—	**17 800**	**60**	2 in.	7.3	**42**
		538	1 000	9.5	6	**13 300**	—	—	**9 900**	**36**	2 in.	4.8	**28**
	Cold Worked 0.3%	20	68	60	38	**85 500**	—	—	**46 100**	**42**	2 in.	13	**73**
		204	400	54.5	34.5	**77 200**	—	—	**43 300**	**35**	2 in.	11	**66**
		316	600	44	28	**62 600**	—	—	**39 300**	**22**	2 in.	10	**62**
		427	800	17.5	11	**24 600**	—	—	**15 200**	**52**	2 in.	7.4	**43**
		538	1 000	9	5.5	**12 800**	—	—	**10 300**	**27**	2 in.	5.2	**30**
Rod [8] 51 mm diam. 2 in. diam.	[e]	27	80	60	38	**85 000**	—	—	—	**42.0**	2 in.	—	—
		149	300	56	35.5	**80 000**	—	—	—	**39.0**	2 in.	—	—
		260	500	50	31.5	**71 000**	—	—	—	**27.0**	2 in.	—	—
		371	700	30	19	**43 000**	—	—	—	**38.0**	2 in.	—	—

(b) Alloy composition: Cu 89.47%; Al 7.75%; Fe 2.73%; Mn 0.010%; Ni 0.04%.

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

(d) Charpy test; V notch; cross-sectional area at the notch 0.8 cm².

(e) Temper not stated in original document.

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

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

—Further information on elevated-temperature tensile properties of hot-rolled rod is given in reference [5].

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension % (a)	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi			
Strip (7) (b) 2.54 mm 0.10 in.	Solution Treated	300	572	6.3	**4**	9 000	**300**	**0.57**	**0.55**
	Aged to Maximum Hardness	300	572	6.3	**4**	9 000	**300**	**0.30**	**0.40**

(a) Total extension = Initial extension + Total Creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Alloy containing: Al 6.16%; Fe 1.52%; Cu rem.
N.B.:—Original values are printed in **bold type**; other values are converted.
—The intercept values are not available.
—Further data: creep tests at 450°C (842°F) are reported in the following paper:
■ Dennison, J. P. Some Creep Characteristics of a Group of Precipitation-Hardening Alloys based on the Alpha-Copper-Aluminium Phase. J. Inst. Metals, Vol. 82. (1953-54) pp. 117-128.

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate 0.01% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi
Plate (9)	Annealed (grain size 0.025)	260	500	7.0	4.5	**10 000**

N.B.:—Original values are printed in **bold type**; other values are converted.
—The stresses for 0.001% per 1 000h and 0.1% per 1 000h creep rate values are not available.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles x10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Flat Products (10) 3 mm 0.125 in.	Annealed (a)	100	57.5	21	36.5	13.5	**82 000**	**30 000**
Flat Products (11) 3 mm 0.125 in.	Cold Worked (b)	100	60	21	38	13.5	**85 000**	**30 000**
Flat Products (10) 8 mm 0.312 in.	Annealed (a)	100	56	19.5	35.5	12.5	**80 000**	**28 000**
Flat Products (11) 8 mm 0.312 in.	Cold Worked (b)	100	56	19.5	35.5	12.5	**80 000**	**28 000**
Flat Products (10) 12 mm 0.5 in.	Annealed (a)	100	55	18.5	35	11.5	**78 000**	**26 000**
Flat Products (10) 25 mm 1 in.	Annealed (a)	100	53.5	17.5	34	11	**76 000**	**25 000**
Flat Products (11) 25 mm 1 in.	Cold Worked (b)	100	49	15	31.5	9.5	**70 000**	**21 000**

(a) Quoted as "soft" in original document.
(b) Quoted as "hard" in original document, but amount of cold work not defined.
N.B.: —Original values are printed in **bold type**; other values are converted.
—Further information can be obtained from the following paper:-
■ Williams, W. L. Aluminium Bronzes for Marine Applications. J. Amer. Soc. Naval Engineers, Vol. 69 (1957), pp. 453-461.

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(3) Ramsey, R.H., Jaffee, R.I. and Nekervis, R.J. Report on the Mechanical and Physical Properties of Certain Aluminium-Bronze Alloys over a Temperature Range of —295°F to 1000°F. Battelle Memorial Institute (20 May, 1946). 46 pp.

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(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) 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. 82.

(11) Metals Handbook, Vol. 1, 8th ed. American Society for Metals, Cleveland, Ohio (1961), p. 1034.

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WROUGHT MATERIALS

COPPER-ALUMINIUM ALLOYS
Aluminium Bronzes

Cu Al9 Mn2

A copper–aluminium–manganese alloy with an alpha-plus-beta phase structure. Manganese is added to improve hot-working properties and weldability; the alloy may also contain small amounts of iron and/or nickel. The most commonly used wrought forms are plate, sheet, rod and forgings.

COMPOSITION (weight %)

Al	8.0–10.0
Mn	1.5– 3.0
Fe	0 – 1.5
Ni	0 – 0.8
Cu	rem.

1 SOME TYPICAL USES

Chemical
Cryogenic equipment; strainers, screens and perforated plates; components for food machinery.

Mechanical
Worm gears; fasteners; machine slides; moulding dies for plastics; slow-moving bearings (e.g. lock gates and sluices); shafts.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	7.6 g/cm³	0.275 lb/in³
2.2 Melting range	1 045–1 100 °C	1 915–2 010 °F
2.3 Coefficient of thermal expansion (linear) at: 20 to 100 °C *68 to 212 °F*	0.000 016 per °C	0.000 009 per °F
20 to 300 °C *68 to 572 °F*	0.000 017 „ „	0.000 009 „ „
2.4 Specific heat (thermal capacity) at: 20 °C *68 °F*	0.10 cal/g °C	0.10 Btu/lb °F
2.5 Thermal conductivity at: 20 °C *68 °F*	0.14–0.16 cal cm/cm² s °C	34–39 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	7.0–8.1 m/ohm mm²	12–14% IACS
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	0.14–0.12 ohm mm²/m 14–12 microhm cm	86–74 ohms (circ mil/ft) 5.7–4.8 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 8 per °C (12%–14% IACS)	0.000 4 per °F (12%–14% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*: annealed or cold worked	10 500 kg/mm²	14 900 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*: annealed or cold worked	3 900 kg/mm²	5 500 000 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 6); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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3 FABRICATION PROPERTIES

Fabrication characteristics, corrosion resistance and mechanical properties of this copper–aluminium alloy are markedly influenced by composition and by heat treatment which is usually performed by the metal manufacturer.
If thermal treatment, including hot forming and joining processes, is to be undertaken by the end user, the advice of the metal supplier should be requested.

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

	Metric Units	English Units
3.1 Casting temperature range	1 140–1 200 °C	2 085–2 190 °F
3.2 Annealing temperature range Stress relieving temperature range	600– 800 °C 300– 400 °C	1 110–1 470 °F 570– 750 °F
3.3 Hot working temperature range	800– 925 °C	1 470–1 695 °F
3.4 Hot formability	Good	
3.5 Cold formability	Fair	
3.6 Cold reduction between anneals	25% max.	
3.7 Machinability: Machinability rating (free cutting brass = 100)	See General Data Sheet No. 2 20	
3.8 Joining methods:	See General Data Sheet No. 3.8	
Soldering	Not recommended	
Brazing (with special fluxes)	Fair	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Good	
Resistance welding: spot and seam	Good	
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	—	—	—	—	—	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Al9 Mn2	NCh 249 of. 68	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	Cu Al9 Mn	17 665	—	17 672	—	17 671	—	17 673
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN[b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States	ASTM	—	—	—	—	—	—	—	—
International Organisation for Standardization	ISO	Cu Al9 Mn2	R428	—	—	—	—	—	—

(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.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

Tensile properties	see table 5.1.1
Hardness	" " 5.1.1
Shear strength	" " 5.1.1
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
Creep properties	see table 5.3.2.2

5.4 Fatigue properties

Fatigue strength at room temperature	see table 5.4.1

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.

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		
Plate Sheet	Annealed	50	20	35	$5.65\sqrt{S_o}$	120	125	38	3–30 mm thick
Rod[b]	Hot Worked	52	25	25	$5.65\sqrt{S_o}$	130	135	39	15–80 mm diam. or equivalent area
	Typical Cold Worked Temper	65	40	15	$5.65\sqrt{S_o}$	160	170	42	10–40 mm diam. or equivalent area
Forgings[b]	Hot Worked	55	28	25	$5.65\sqrt{S_o}$	135	140	41	—

(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.

(b) 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

Tensile properties and hardness values in SI and English units are omitted from this data sheet, since alloys within the composition range concerned are not normally produced by British manufacturers.

5.1.3 Typical Tensile Properties and Hardness Values—American Units

Tensile properties and hardness values in American units are omitted from this data sheet, since alloys within the composition range concerned are not supplied by American manufacturers.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm²	Elongation		Impact Strength [a]
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length	kg m/cm²
Plate [1] [2] **5 mm 0.2 in.**	Annealed	20 —165	68 —265	**54.6** **64**	34.5 40.5	77 500 91 000	**23.3** —	**35.5** **40**	[c] [c]	**9.2–11.0** **9.2–11.0**
[3] [b]	Annealed	20 — 78 —183	68 —108 —297	**53** **55** **63**	33.5 35 40	75 500 78 000 89 500	— — —	**36** **36** **33**	[c] [c] [c]	— — —

[a] Charpy test; KUF specimen; cross-sectional area at the notch not stated in original document, therefore impossible to give conversion from kg m/cm² to ft. lb.

[b] Form not stated in original document.

[c] 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, 0.1% offset,

Yield Strength, 0.5% extension under load.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength*			Proof Stress 0.2% offset kg/mm²	Elongation	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length
Flat Products [4] (Bar) **12 mm 0.5 in.**	Hot Rolled	20 600 800	68 1 112 1 472	**42** **9** **0.8**	26.5 5.5 0.5	59 500 13 000 1 000	— — —	**25** **17** **70**	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$
Rod [5] **25 mm diam. 1 in. diam.**	Forged	20 100 200 300 400	68 212 392 572 752	**56** **52** **51** **51** **38**	35.5 33 32.5 32.5 24	79 500 74 000 72 500 72 500 54 000	**35** **32** **32** **31** **28**	**40** **30** **40** **36** **55**	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$

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 paper:

- Rosenhain, W. and Lantsberry, F.C.A.H. On the Properties of Some Alloys of Copper, Aluminium and Manganese. Excerpt Minutes Proc. Inst. Mech. Engrs., London (1910), pp. 119-286.

5.3.2 Creep Properties

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate		
				1% per 1000 h		
		°C	°F	kg/mm²	ton/in²	psi
(6) (a)	(b)	300	572	**9.8**	6.2	13 900
		350	662	**4.6** (c)	2.9 (c)	6 500 (c)

(a) Form not stated in original document.
(b) Temper not stated in original document.
(c) Extrapolated value.
N.B.—Original values are printed in **bold type**; other values are converted.
—The stresses for 0.001%, 0.01% and 0.1% 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 × 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
Plate (5)	Forged	40	**52**	**>12** (a)	33	> 7.5 (a)	74 000	>17 000 (a)
Rod (5) **25 to 50 mm diam. 1 to 2 in. diam.**	Cold Worked	50	**65.5**	**>24** (a)	41.5	>15 (a)	93 000	>34 000 (a)
Rod (5) **50 mm diam. 2 in. diam.**	Forged	50	**74**	**26** (a)	47	16.5 (a)	105 500	37 000 (a)
Rod (5) **80 mm diam. 3.2 in. diam.**	Forged	20 20	**55** **50**	**19** (a) **18** (a)	35 31.5	12 (a) 11.5 (a)	78 500 71 000	27 000 (a) 25 500 (a)

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

- Heubner, U., Jung-König, W. and Wincierz, P. Beitzag zur Biegewechselfestigkeit und Kerbempfindlichkeit von Kupferlegierungen — Teil 2. Metall, Vol. 21 (1967), pp. 1250-1254.
- Rosenhain, W. and Lantsberry, F.C.A.H. On the Properties of Some Alloys of Copper, Aluminium and Manganese. Excerpt Minutes Proc. Inst. Mech. Engrs., London (1910), pp. 119-286.

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(2) Weill-Couly, M. P. I Cupro Allumini e le Bassissime Temperature-Scelta di una Gradazione Criogenica – Comportamento di questi Materiali e loro Applicazioni. Simposio ATI, Milano (Dicembre, 1963).
(3) Propriétés des Alliages Cuivreux aux Basses Températures (The Properties of Copper Alloys at Low Temperatures). Cuivre, Laitons, Alliages, No. 74 (1963), July-August, pp. 41-43.
(4) Luzhnikov, L. P. Werkstoffe in Maschinenbau – Vol. 1: NE – Metalle und Legierungen. Izdatelstvo Mashinostroenie, Moskva (1967), 304 pp.
(5) Private communication from Fürstlich Hohenzollernsche Hüttenverwaltung Laucherthal, Hohenzollern, Germany.
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WROUGHT MATERIALS

COPPER-ALUMINIUM ALLOYS
Aluminium Bronzes

Cu Al10 Fe3

Common name: Iron-Aluminium Bronze

A copper–aluminium–iron alloy with an alpha-plus-beta phase structure. Iron is added to inhibit grain growth and to improve strength; the alloy may also contain nickel and/or manganese. It presents a combination of high corrosion and oxidation resistance, and good hot-working properties; the material retains its strength at moderately elevated temperatures. The most commonly used wrought forms are rod, sections and forgings.

COMPOSITION (weight %)

Al	8.5–10.0
Fe	2.0– 4.0
Ni	0 – 1.0
Mn	0 – 2.0
Cu	rem.

1 SOME TYPICAL USES

Chemical
Cryogenic equipment; pickling equipment; pump components.

Marine
Fittings and fasteners.

Mechanical
Non-sparking tools for gas, oil, coal, mining, chemical and explosives industries; bushings and bearings; machine slides; gears; fasteners; wear-resistant components; hot-stamped accessories for electrical lines and machines; valve spindles; moulding dies for plastics; deep-drawing tools and dies.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	7.6 g/cm³	0.275 lb/in³
2.2 Melting range	1 045–1 090 °C	1 915–1 995 °F
2.3 Coefficient of thermal expansion (linear) at:		
—200 to 20 °C *—328 to 68 °F*	0.000 014 [a] per °C	0.000 008 [a] per °F
20 to 100 °C *68 to 212 °F*	0.000 016 ,, ,,	0.000 009 ,, ,,
20 to 300 °C *68 to 572 °F*	0.000 017 ,, ,,	0.000 009 ,, ,,
2.4 Specific heat (thermal capacity) at: 20 °C *68 °F*	0.10 cal/g °C	0.10 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.14–0.16 cal cm/cm² s °C	34–39 Btu ft/ft² h °F
200 °C *392 °F*	0.20 [a] ,,	48 [a] ,,
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	7.0–8.1 m/ohm mm²	12–14% IACS
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	0.14–0.12 ohm mm²/m 14–12 microhm cm	86–74 ohms (circ mil/ft) 5.7–4.8 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 8 per °C (12%–14% IACS)	0.000 4 per °F (12%–14% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*: annealed	12 000 kg/mm²	17 000 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*: annealed	4 450 kg/mm²	6 300 000 lb/in²

(a) Approximate value.

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 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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3 FABRICATION PROPERTIES

Fabrication characteristics, corrosion resistance and mechanical properties of this copper–aluminium alloy are markedly influenced by composition and by heat treatment which is usually performed by the metal manufacturer.
If thermal treatment, including hot forming and joining processes, is to be undertaken by the end user, the advice of the metal supplier should be requested.

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

		Metric Units	English Units
3.1	Casting temperature range	1 140–1 200 °C	2 085–2 190 °F
3.2	Annealing temperature range Stress relieving temperature range	650– 800 °C 300– 400 °C	1 200–1 470 °F 570– 750 °F
3.3	Hot working temperature range	800– 950 °C	1 470–1 740 °F
3.4	Hot formability	Good	
3.5	Cold formability	Limited	
3.6	Cold reduction between anneals	15% max.	
3.7	Machinability: Machinability rating (free cutting brass = 100)	See General Data Sheet No. 2 30	
3.8	Joining methods:	See General Data Sheet No. 3.8	
	Soldering	Not recommended	
	Brazing (with special fluxes)	Fair	
	Oxy-acetylene welding	Not recommended	
	Carbon-arc welding	Fair	
	Gas-shielded arc welding	Good	
	Coated metal-arc welding	Good	
	Resistance welding: spot and seam	Good	
	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	—	—	—	—	—	—	—	—
Canada	CSA	HC.AS72 637		—	HC.5.7	—	—	HC.5.7	—
Chile	NCh (INDITECNOR)	Cu Al9 Fe4 Cu Al10 Fe3	—		—		—	—	NCh 249 of. 68
France	NF	—		—	—	—		—	—
Germany	DIN	Cu Al10 Fe	17 665	—	17 672	—	17 671	—	17 673
India	IS	—	—		—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	ABP 1 ABB 1	—	H3208	H3441	—	—	—	—
Netherlands	N or NEN [b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Al10 Fe	—	10 802	10 802	—	—	—	—
United Kingdom	BS	CA 103	—		2032 2872 2874	—		2032 2874	2872
United States [c]	SAE	No. 623	—	J461b	J461b	—	—	J461b	J461b
International Organisation for Standardization	ISO	Cu Al10 Fe3	R 428		—		—	—	—

(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 is 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 *

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		
Rod[b]	Hot Worked	62	32	18	$5.65\sqrt{S_0}$	160	170	47	20–80 mm diam. or equivalent area
	Typical Cold Worked Temper	70	45	10	$5.65\sqrt{S_0}$	180	190	46	10–40 mm diam. or equivalent area
Sections[b] / Shapes	Hot Worked	62	30	15	$5.65\sqrt{S_0}$	160	170	47	—
Forgings[b]	Hot Worked	65	35	15	$5.65\sqrt{S_0}$	170	180	49	—

(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.

(b) 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[d]		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown[b]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Rod[c]	Hot or Hot + ColdWorked										
	As Manufactured	57	37	26	17	30	$5.65\sqrt{S_0}$	150	40	26	50–100 mm (2–4 in.) diam. or equivalent area
		59	38	28	18	28	$5.65\sqrt{S_0}$	160	42	27	10–50 mm (0.375–2 in.) diam. or equivalent area
		65	42	34	22	22	$5.65\sqrt{S_0}$	190	45	29	" "
Sections[c] (extruded)	Hot Worked As Manufactured	59	38	23	15	25	$5.65\sqrt{S_0}$	160	42	27	—
Forgings[c]	Hot Worked As Manufactured	57	37	23	15	25	$5.65\sqrt{S_0}$	150	40	26	—

(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.

(d) Elongation values for this alloy can be increased, above the typical values quoted, by appropriate heat treatment.

* 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		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown[(a)]
				%	gauge length	F	B	30 T		
Rod [(b)]	Hot Worked	75 000	35 000	35	2 in.	—	80	—	56 500	3.0 in. diam.
	Cold Worked Hard	98 000 95 000	52 000 50 000	22 25	2 in. 2 in.	— —	89 88	— —	63 500 64 000	0.5 in. diam. 1.0 in. diam.
Sections [(b)] / Shapes	Hot Worked	85 000	35 000	25	2 in.	—	80	—	64 000	3.0 in. diam.
Forgings [(b)]	Hot Worked	85 000	35 000	25	2 in.	—	80	—	64 000	3.0 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			Yield Strength 0.5% ext. under load psi	Elongation		Reduction of Area %	Impact Strength [(a)]	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Rod [(1)] [(2)] 49 mm diam. 1.9 in. diam.	Annealed	20 — 29 — 59 —182	68 — 20 — 75 —295	63.5 66 67.5 77.5	40 42 43 49.5	**90 000** **93 800** **96 300** **110 500**	**42 600** **46 900** **47 900** **54 700**	**32** **31** **33** **35**	2 in. 2 in. 2 in. 2 in.	**39** **38** **39** **38**	2.8 2.4 2.2 1.7	**16** **14** **13** **10**
	Cold Worked 0.4%	20 — 29 — 59 —182	68 — 20 — 75 —295	66.5 67.5 69.5 79.5	42 43 44 50.5	**94 500** **96 200** **98 900** **112 800**	**46 400** **47 300** **49 300** **56 500**	**34** **34** **34** **37**	2 in. 2 in. 2 in. 2 in.	**44** **44** **41** **41**	6.0 5.9 5.9 4.7	**35** **34** **34** **27**
[(3)] [(b)]	Forged	20 —192	68 —314	62.5 79	39.5 50	**88 900** **112 500**	**47 900** [(c)] **84 900** [(c)]	**45.2** **38.4**	2 in. 2 in.	**46.9** **42.1**	— —	— —

(a) Charpy test, V notch, cross-sectional area at the notch 0.8 cm².

(b) Form not stated in original document.

(c) Quoted as "yield point" in original document, but offset strain not defined.

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

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

—The 0.1% and 0.2% offset proof stress values are not available.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—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	Yield Strength 0.5% ext. under load psi	%	gauge length	kg m/cm²	ft lb
Flat Products [4] 12 mm 0.5 in.	Hot Rolled	20	68	**55**	35	78 000	**26**	—	**20**	$5.65\sqrt{S_0}$	—	—
		200	392	**53.5**	34	76 000	—	—	**17**	$5.65\sqrt{S_0}$	—	—
		400	752	**43**	27.5	61 000	—	—	**28**	$5.65\sqrt{S_0}$	—	—
		600	1 112	**18**	11.5	25 500	—	—	**32**	$5.65\sqrt{S_0}$	—	—
		800	1 472	**2**	1.5	3 000	—	—	**45**	$5.65\sqrt{S_0}$	—	—
Rod [1] [2] 49 mm diam. 1.9 in. diam.	Annealed	20	68	63.5	40	**90 000**	—	**42 600**	**32**	2 in.	2.8 [b]	**16** [b]
		204	400	54.5	34.5	**77 500**	—	**43 800**	**20**	2 in.	3.3 [b]	**19** [b]
		316	600	45.5	29	**65 000**	—	**41 800**	**10**	2 in.	3.3 [b]	**19** [b]
		427	800	21.5	13.5	**30 500**	—	**22 200**	**46**	2 in.	1.2 [b]	**7** [b]
		538	1 000	9.5	6	**13 600**	—	**12 200**	**27**	2 in.	1.4 [b]	**8** [b]
	Cold Worked 0.4 %	20	68	66.5	42	**94 500**	—	**46 400**	**34**	2 in.	6.0 [b]	**35** [b]
		204	400	56	35.5	**79 800**	—	**43 000**	**22**	2 in.	6.0 [b]	**35** [b]
		316	600	47.5	30	**67 500**	—	**43 000**	**10**	2 in.	5.7 [b]	**33** [b]
		427	800	20	12.5	**28 500**	—	**20 000**	**32**	2 in.	1.2 [b]	**7** [b]
		538	1 000	10.5	6.5	**15 000**	—	**13 300**	**18**	2 in.	1.4 [b]	**8** [b]
Rod [6] 51 mm diam. 2 in. diam.	[d]	27	80	67	42.5	**95 000**	—	—	**34.0**	2 in.	—	—
		149	300	60.5	38.5	**86 000**	—	—	**28.0**	2 in.	—	—
		260	500	53.5	34	**76 000**	—	—	**14.0**	2 in.	—	—
		371	700	36	23	**51 000**	—	—	**21.0**	2 in.	—	—
Rod [7]	Annealed [e]	20	68	67.5	**42.7**	95 500	—	—	**26**	$4\sqrt{S_0}$	4.6 [c]	**27** [c]
		200	392	—	—	—	—	—	—	—	4.8 [c]	**28** [c]
		250	482	—	—	—	—	—	—	—	5.9 [c]	**34** [c]
		300	572	—	—	—	—	—	—	—	6.2 [c]	**36** [c]
		350	662	—	—	—	—	—	—	—	4.8 [c]	**28** [c]
		400	752	26.5	**16.8**	37 500	—	—	**77**	$4\sqrt{S_0}$	2.6 [c]	**15** [c]
		450	842	—	—	—	—	—	—	—	1.4 [c]	**8** [c]
		500	932	—	—	—	—	—	—	—	1.7 [c]	**10** [c]
		550	1 022	—	—	—	—	—	—	—	3.6 [c]	**21** [c]
		600	1 112	—	—	—	—	—	—	—	7.9 [c]	**46** [c]
	Hot Forged [f]	20	68	62.5	**39.7**	89 000	—	—	**32**	$4\sqrt{S_0}$	2.2 [c]	**13** [c]
		200	392	—	—	—	—	—	—	—	2.6 [c]	**15** [c]
		250	482	—	—	—	—	—	—	—	2.9 [c]	**17** [c]
		300	572	—	—	—	—	—	—	—	3.5 [c]	**20** [c]
		350	662	—	—	—	—	—	—	—	3.3 [c]	**19** [c]
		400	752	25.5	**16.1**	36 000	—	—	**73**	$4\sqrt{S_0}$	2.4 [c]	**14** [c]
		450	842	—	—	—	—	—	—	—	2.1 [c]	**12** [c]
		500	932	—	—	—	—	—	—	—	2.4 [c]	**14** [c]
		550	1 022	—	—	—	—	—	—	—	3.1 [c]	**18** [c]
		600	1 112	—	—	—	—	—	—	—	6.6 [c]	**38** [c]
	Extruded [e]	20	68	74	**46.9**	105 000	—	—	**17**	$4\sqrt{S_0}$	—	—
		400	752	30.5	**19.4**	43 500	—	—	**51**	$4\sqrt{S_0}$	—	—

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

(c) Charpy-type test on Izod machine; Izod notch, cross-sectional area at the notch 0.8 cm².

(d) Temper not stated in original document.

(e) Alloy containing 10.13% Al, 2.80% Fe, Cu rem.

(f) Alloy containing 9.95% Al, 4.1% Fe, Cu rem.

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% offset proof stress values are not available.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension % [(a)]	Intercept %	Min. Creep Rate %per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod [(5) (b)] 19 mm diam. 0.75 in. diam.	Extruded	316	600	7.0	4.5	**10 000**	**5 760**	**0.46**	**0.217**	**0.041**
		371	700	7.0 21.1	4.5 13.4	**10 000** **30 000**	**1 368** **3.2** [(c)]	**0.539** **20.8** [(d)]	**0.195** **0.390**	**0.25** **1 960**
		427	800	2.1	1.3	**3 000**	**2 640**	**0.531**	**0.160**	**0.121**
		482	900	2.1	1.3	**3 000**	**1 152**	**0.971**	**0.290**	**0.38**
Rod [(7) (h)]	Extruded and Normalised [(i)]	250	482	1.6 7.9 13.4 31.5	**1** **5** [(e)] **8.5** **20** [(f)]	2 200 11 200 19 000 44 800	**816** **960** **1 344** **1 920**	**0.022** [(g)] **0.121** [(g)] **0.352** [(g)] **11.7** [(g)]	— — — —	<**0.004 2** [(k)] **0.020** [(k)] **0.087 5** [(k)] —

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

(b) Alloy containing 0.27% Si.

(c) Rupture test.

(d) Total elongation.

(e) Following 1 ton/in².

(f) Following 8.5 ton/in².

(g) After 960 hours (0.022% by extrapolation).

(h) Alloy containing 10.13% Al, 2.80% Fe.

(i) Normalising treatment: 1 h at 825°C (1517°F), cooled in air.

(k) After 960 hours, or minimum if earlier (< 0.004 2% by extrapolation).

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 0.01% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi
[(5) (a)]	Hot Worked	316 371 427 482	600 700 800 900	5.1 3.2 1.1 0.98	3.2 2.1 0.71 0.63	**7 200** **4 600** **1 600** **1 400**

(a) Form not stated in original document; alloy containing 0.27% Si.

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

—The stresses for 0.001% per 1 000 h and 0.1% per 1 000 h creep rate values are not available.

—Further data can be obtained from the following paper:

■Reference (7), Table VII.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles x10^6	Metric Units kg/mm^2		English Units ton/in^2		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod [8] [(d)] **14 mm diam. 0.565 in. diam.**	Drawn 10%	100	65.5	20 [(b)]	41.5	12.5 [(b)]	**93 000**	**28 500** [(b)]
Rod [9] [(c)] **25 mm diam. 1 in. diam.**	Rolled	100	69.5	24.5 [(a)]	44	15.5 [(a)]	**99 000**	**35 000** [(a)]

(a) Rotating cantilever test.

(b) Rotating-beam test.

(c) Alloy containing 10.40% Al, 2.92% Fe.

(d) Alloy containing 9.65% Al, 1.95% Fe, 0.52% Te.

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

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WROUGHT MATERIALS

COPPER-ALUMINIUM ALLOYS
Aluminium Bronzes

Cu Al10 Fe5 Ni5

Common name: Nickel-Iron-Aluminium Bronze

A copper–aluminium–iron–nickel alloy with a predominantly alpha-plus-kappa phase structure and of fairly constant aluminium content and iron/nickel ratio in different countries; the alloy may also contain a small amount of manganese. The addition of nickel and iron provides a good combination of corrosion and oxidation resistance, with high strength and fatigue and wear resistance. The material also has good hot-working properties and retains its strength at moderately elevated temperatures. The most commonly used wrought forms are rod and forgings.

COMPOSITION (weight %)

Al	9.0–11.0
Fe	4.0– 6.0
Ni	4.0– 6.0
Mn	0 – 2.0
Cu	rem.

1 SOME TYPICAL USES

Chemical
Tubeplates for condensers, evaporators and heat exchangers; pickling equipment; fans for acid vapours; valves and spindles; valve yoke sleeves; sewage-handling equipment; flowmeter parts; components for service in industrial atmospheres; waterboxes and storage tanks.

Marine
Underwater fittings; shipboard fittings and fasteners; pump and valve components; propeller shafts (for shallow-draft vessels); forgings for marine assemblies; fans for exhaust gases.

Mechanical
Fasteners and high-tensile bolts; higher-pressure valve bodies; wear-resistant components and weld overlays; welder jaws; forming dies; rolling mill bearings and screwdown nuts; conveyor links and hinge bolts; gears; bushings and bearings; non-sparking tools for gas, oil, coal, mining, chemical and explosives industries; shafts; bridge bearing plates and lock gate bearings; moulding dies for plastics.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	7.6 g/cm³	0.275 lb/in³
2.2 Melting range	1 060–1 075 °C	1 940–1 965 °F
2.3 Coefficient of thermal expansion (linear) at:		
—200 to 20 °C *—328 to 68 °F*	0.000 015 [a] per °C	0.000 008 [a] per °F
20 to 100 °C *68 to 212 °F*	0.000 015 " "	0.000 008 " "
20 to 300 °C *68 to 572 °F*	0.000 017 " "	0.000 009 " "
2.4 Specific heat (thermal capacity) at: 20 °C *68 °F*	0.10 cal/g °C	0.10 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.09–0.11 cal cm/cm² s °C	22–27 Btu ft/ft² h °F
200 °C *392 °F*	0.13 [a] "	31 [a] "
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	4.1–5.2 m/ohm mm²	7–9% IACS
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	0.25–0.19 ohm mm²/m 25–19 microhm cm	150–120 ohms (circ mil/ft) 9.7–7.5 microhm in
2.8 Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 5 per °C (7%–9% IACS)	0.000 3 per °F (7%–9% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*:		
Solution annealed	13 000–13 350 kg/mm²	18 500 000–19 000 000 lb/in²
Lightly cold worked	12 800–13 100 kg/mm²	18 200 000–18 500 000 lb/in²
Heat Treated	13 400–14 000 kg/mm²	19 000 000–19 900 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:		
Solution annealed	4 800–4 950 kg/mm²	6 800 000–7 000 000 lb/in²
Lightly cold worked	4 750–4 850 kg/mm²	6 700 000–6 900 000 lb/in²
Heat Treated	4 950–5 200 kg/mm²	7 100 000–7 400 000 lb/in²

(a) Approximate value.

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

Fabrication characteristics, corrosion resistance and mechanical properties of this copper-aluminium alloy are markedly influenced by composition and by heat treatment which is usually performed by the metal manufacturer.
If thermal treatment, including hot forming and joining processes, is to be undertaken by the end user, the advice of the metal supplier should be requested.

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

		Metric Units	English Units
3.1	Casting temperature range	1 140–1 200 °C	2 085–2 190 °F
3.2	Annealing temperature range Stress relieving temperature range	650– 850 °C 300– 400 °C	1 200–1 560 °F 570– 750 °F
3.3	Hot working temperature range	850– 975 °C	1 560–1 785 °F
3.4	Hot formability	Good	
3.5	Cold formability	Limited	
3.6	Cold reduction between anneals	10% max.	
3.7	Machinability: Machinability rating (free cutting brass = 100)	See General Data Sheet No. 2 20	
3.8	Joining methods:	See General Data Sheet No. 3.8	
	Soldering	Not recommended	
	Brazing (with special fluxes)	Fair	
	Oxy-acetylene welding	Not recommended	
	Carbon-arc welding	Fair	
	Gas-shielded arc welding	Good	
	Coated metal-arc welding	Good	
	Resistance welding: spot and seam	Good	
	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	—	—	—	—	—	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Al10 Fe5 Ni5	NCh 249 of. 68	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	Cu Al10 Ni Cu Al11 Ni	17 665	17 670	17 672	—	17 671	—	17 673
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	ABP 5	—	H 3208	—	—	—	—	—
Netherlands	N or NEN [(b)]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Al10 Fe5 Ni5	—	—	10 802	—	—	—	—
United Kingdom	BS	CA104	—	—	2033 2872 2874	—	—	2033 2874	2872
United States	MIL	No. 632	—	—	—	—	—	—	MIL-B-16 166
International Organisation for Standardization	ISO	Cu Al10 Fe5 Ni5	R 428	—	—	—	—	—	—

(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.

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 *

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		
Rod[(b)]	Hot Worked	75	42	15	$5.65\sqrt{S_o}$	180	190	56	20–80 mm diam. or equivalent area
	Typical Cold Worked Temper	80	50	12	$5.65\sqrt{S_o}$	215	225	56	10–40 mm diam. or equivalent area
Forgings[(b)]	Hot Worked	75	40	15	$5.65\sqrt{S_o}$	185	195	56	—

(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.

(b) 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	Hot Rolled As Manufactured	77	50	39	25	15	$5.65\sqrt{S_o}$	200	59	38	12–50 mm (0.5–2 in.) thick
Sheet		80	52	42	27	15	50 mm (2 in.)	210	60	39	3–10 mm (0.125–0.375 in.) thick
Rod[(c)]	Hot or Hot + Cold Worked As Manufactured	74	48	39	25	20	$5.65\sqrt{S_o}$	200	56	36	50–100 mm (2–4 in.) diam. or equivalent area
		76	49	42	27	18	$5.65\sqrt{S_o}$	210	57	37	25–50 mm (1–2 in.) diam. or equivalent area
		79	51	45	29	15	$5.65\sqrt{S_o}$	230	59	38	10–25 mm (0.375–1 in.) diam. or equivalent area
Sections[(c)] (extruded)	Hot Worked As Manufactured	76	49	37	24	17	$5.65\sqrt{S_o}$	190	59	38	—
Forgings[(c)]	Hot Worked As Manufactured	74	48	36	23	17	$5.65\sqrt{S_o}$	190	56	36	—

‡ The tensile properties and hardness of this alloy are increased considerably as the Al content is raised within the composition range defined. The values given above are typical for material manufactured in accordance with the relevant BS specifications in Section 4.

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

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

* 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		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown[a]
				%	gauge length	F	B	30 T		
Forgings [b]	Hot Worked	110 000	60 000	12	2 in.	—	92	—	82 500	—

[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 [a]	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Plate [1] **100 mm. 4 in.**	Hot Worked	20	68	**70**	44.5	99 500	**36**	**12**	$5.65\sqrt{S_o}$	**17**	**2.4**	12.1
		—196	—321	**82**	52	116 500	**41**	**7**	$5.65\sqrt{S_o}$	**10**	**1.4**	7.1
Rod [1] **30 mm. diam. 1.2 in. diam.**	Cold Worked 10%	20	68	**76**	48	108 000	**46**	**12**	$5.65\sqrt{S_o}$	**14**	**2.8**	14.2
		—196	—321	**91**	58	129 500	**60**	**4**	$5.65\sqrt{S_o}$	**6**	**1.2**	6.1

[a] Charpy test, V notch, cross sectional area at the notch 0.7 cm².

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

—All converted values for impact strength are to be taken as indicative only; the impact energy has been converted from kg m/cm² into ft lb 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	%	gauge length	kg m/cm²	ft lb
Flat Products [2] (Bar) 12 mm 0.5 in.	Hot Rolled	20	68	65	41.5	92 500	—	—	10–15	$5.65\sqrt{S_o}$	—	—
		200	392	65	41.5	92 500	—	—	18	$5.65\sqrt{S_o}$	—	—
		400	752	40	25.5	57 000	—	—	18	$5.65\sqrt{S_o}$	—	—
		600	1 112	17	11	24 000	—	—	18	$5.65\sqrt{S_o}$	—	—
		800	1 472	1.8	1	2 500	—	—	38	$5.65\sqrt{S_o}$	—	—
Plate [3] 13 mm 0.52 in.	Annealed (grain size 0.01 mm)	20	68	76.5	48.6	109 000	48.8 [a]	29.9	20	$4\sqrt{S_o}$	—	—
		250	482	63	40.1	90 000	44.0 [a]	26.7	8	$4\sqrt{S_o}$	—	—
		350	662	58	36.8	82 500	33.8 [a]	18.1	13	$4\sqrt{S_o}$	—	—
		450	842	33	21.1	47 500	15.4 [a]	8.8	63	$4\sqrt{S_o}$	—	—
		550	1 022	22	14.0	31 500	9.44 [a]	4.9	67	$4\sqrt{S_o}$	—	—
Plate [4]	Annealed	20	68	78	49.4	110 500	54.9 [a]	32.2	8	2 in.	—	—
		66	150	74	47.1	105 500	54.0 [a]	32.3	6	2 in.	—	—
		121	250	71	45.2	101 000	52.4 [a]	31.3	7	2 in.	—	—
		177	350	69	43.7	98 000	50.5 [a]	29.9	6	2 in.	—	—
		232	450	64.5	41.0	92 000	47.7 [a]	27.6	4	2 in.	—	—
		288	550	62	39.3	88 000	44.4 [a]	25.7	4	2 in.	—	—
		343	650	54	34.2	76 500	35.5 [a]	17.9	2	2 in.	—	—
		371	700	48	30.4	68 000	26.6 [a]	14.2	4	2 in.	—	—
Rod [1] 19 mm diam. 0.75 in. diam.	Annealed	20	68	83	52.5	118 000	58	—	18	$5.65\sqrt{S_o}$	—	—
		100	212	81	51.5	115 000	54.5	—	15	$5.65\sqrt{S_o}$	—	—
		200	392	78	49.5	111 000	50.5	—	12	$5.65\sqrt{S_o}$	—	—
		250	482	71.5	45.5	101 500	44.5	—	10	$5.65\sqrt{S_o}$	—	—
		300	572	62	39.5	88 000	44.5	—	5	$5.65\sqrt{S_o}$	—	—
		350	662	50	31.5	71 000	38	—	12	$5.65\sqrt{S_o}$	—	—
		400	752	42	26.5	59 500	22	—	36	$5.65\sqrt{S_o}$	—	—
		450	842	22	14	31 500	12	—	64	$5.65\sqrt{S_o}$	—	—
		500	932	17	11	24 000	8	—	63	$5.65\sqrt{S_o}$	—	—
Rod [1] 20 mm diam. 0.8 in. diam.	Cold Drawn 10%	20	68	82	52	116 500	60	—	14	$5.65\sqrt{S_o}$	—	—
		200	392	76	48	108 000	50	—	10	$5.65\sqrt{S_o}$	—	—
		300	572	79	50	112 500	50	—	11	$5.65\sqrt{S_o}$	—	—
		400	752	72	45.5	102 500	44	—	5	$5.65\sqrt{S_o}$	—	—
		500	932	50	31.5	71 000	32	—	7	$5.65\sqrt{S_o}$	—	—
		600	1 112	25	16	35 500	15	—	25	$5.65\sqrt{S_o}$	—	—
	Forged	20	68	97	61.5	138 000	88	—	10	$5.65\sqrt{S_o}$	—	—
		100	212	93	59	132 500	80	—	10	$5.65\sqrt{S_o}$	—	—
		200	392	88	56	125 000	70	—	11	$5.65\sqrt{S_o}$	—	—
		250	482	89	56.5	126 500	70	—	11	$5.65\sqrt{S_o}$	—	—
		300	572	70	44.5	99 500	55	—	6	$5.65\sqrt{S_o}$	—	—
		350	662	58	37	82 500	45	—	23	$5.65\sqrt{S_o}$	—	—
		400	752	42	26.5	59 500	25.5	—	47	$5.65\sqrt{S_o}$	—	—
		450	842	20	12.5	28 500	13	—	108	$5.65\sqrt{S_o}$	—	—
		500	932	15	9.5	21 500	7.5	—	117	$5.65\sqrt{S_o}$	—	—
Rod [1] 22 mm diam. 0.9 in. diam.	Cold Worked and Stress Relieved	20	68	79	50	112 500	53	—	18	$5.65\sqrt{S_o}$	—	—
		100	212	75	47.5	106 500	49.5	—	17	$5.65\sqrt{S_o}$	—	—
		200	392	70	44.5	99 500	45.5	—	15	$5.65\sqrt{S_o}$	—	—
		250	482	69	44	98 000	39	—	8	$5.65\sqrt{S_o}$	—	—
		300	572	62	39.5	88 000	32.5	—	5	$5.65\sqrt{S_o}$	—	—
		350	662	53	33.5	75 500	25.5	—	7	$5.65\sqrt{S_o}$	—	—
		400	752	43	27.5	61 000	25.5	—	12	$5.65\sqrt{S_o}$	—	—
		450	842	23	14.5	32 500	20	—	51	$5.65\sqrt{S_o}$	—	—
		500	932	21	13.5	30 000	18	—	55	$5.65\sqrt{S_o}$	—	—

continued on opposite page

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

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress		Elongation		Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	%	gauge length	kg m/cm²	ft lb
Rod [5] 25 mm diam. 1 in. diam.	Hot Rolled [c]	20	68	86.5	**55**	123 000	—	**37**	**18**	[d]	1.9 [b]	**11** [b]
		100	212	85	**54**	121 000	—	**38**	**17**	[d]	2.0 [b]	**12** [b]
		200	392	82	**52**	116 500	—	**38**	**15**	[d]	2.4 [b]	**14** [b]
		300	572	71	**45**	101 000	—	**35**	**14**	[d]	2.7 [b]	**16** [b]
		400	752	31.5	**20**	45 000	—	**16**	**37**	[d]	2.2 [b]	**13** [b]
		500	932	19	**12**	27 000	—	**9**	**24**	[d]	1.7 [b]	**10** [b]
		600	1 112	12.5	**8**	18 000	—	**4**	**13**	[d]	2.0 [b]	**12** [b]
		700	1 292	6.5	**4**	9 000	—	**2**	**20**	[d]	3.4 [b]	**20** [b]
		800	1 472	3	**2**	4 500	—	**1**	—	[d]	5.5 [b]	**32** [b]
	Hot Rolled [e]	20	68	86.5	**55**	123 000	—	**36**	**17**	[d]	1.2 [b]	**7** [b]
		100	212	86.5	**55**	123 000	—	**35**	**18**	[d]	2.0 [b]	**12** [b]
		200	392	83.5	**53**	118 500	—	**33**	**18**	[d]	2.9 [b]	**17** [b]
		300	572	63	**40**	89 500	—	**28**	**17**	[d]	2.2 [b]	**13** [b]
		400	752	31.5	**20**	45 000	—	**17**	**35**	[d]	2.2 [b]	**13** [b]
		500	932	15.5	**10**	22 500	—	**8**	**25**	[d]	2.0 [b]	**12** [b]
		600	1 112	9.5	**6**	13 500	—	**3**	**23**	[d]	1.3 [b]	**8** [b]
		700	1 292	4.5	**3**	6 500	—	**1.5**	**31**	[d]	1.3 [b]	**8** [b]
		800	1 472	1.5	**1**	2 000	—	**1**	—	[d]	2.0 [b]	**12** [b]
	Hot Rolled [f]	20	68	86.5	**55**	123 000	—	**37**	**23**	[d]	2.2 [b]	**13** [b]
		100	212	82	**52**	116 500	—	**34**	**23**	[d]	3.5 [b]	**20** [b]
		200	392	77	**49**	110 000	—	**30**	**22**	[d]	4.2 [b]	**24** [b]
		300	572	66	**42**	94 000	—	**26**	**21**	[d]	4.0 [b]	**23** [b]
		400	752	36	**23**	51 500	—	**17**	**34**	[d]	4.3 [b]	**25** [b]
		500	932	20.5	**13**	29 000	—	**11**	**20**	[d]	3.3 [b]	**19** [b]
		600	1 112	12.5	**8**	18 000	—	**8**	**12**	[d]	3.5 [b]	**21** [b]
		700	1 292	9.5	**6**	13 500	—	**3**	**19**	[d]	7.2 [b]	**42** [b]
		800	1 472	4.5	**3**	6 500	—	**2**	**40**	[d]	9.1 [b]	**53** [b]
	Hot Rolled [g]	20	68	88	**56**	125 500	—	**32**	**8**	[d]	1.9 [b]	**11** [b]
		100	212	91.5	**58**	130 000	—	**34**	**10**	[d]	2.4 [b]	**14** [b]
		200	392	93	**59**	132 000	—	**36**	**12**	[d]	2.9 [b]	**17** [b]
		300	572	71	**45**	101 000	—	**37**	**14**	[d]	3.1 [b]	**18** [b]
		400	752	34.5	**22**	49 500	—	**20**	**59**	[d]	3.3 [b]	**19** [b]
		500	932	17.5	**11**	24 500	—	**8**	**32**	[d]	1.4 [b]	**8** [b]
		600	1 112	12.5	**8**	18 000	—	**5**	**24**	[d]	3.3 [b]	**19** [b]
		700	1 292	6.5	**4**	9 000	—	**2**	**26**	[d]	6.9 [b]	**40** [b]
		800	1 472	3	**2**	4 500	—	**1**	**40**	[d]	8.8 [b]	**51** [b]
Rod [1] [h] 41 mm 1.6 in.	Cold Drawn 6%	20	68	**78**	49.5	111 000	**50**	—	**25**	$5.65\sqrt{S_o}$	—	—
		200	392	**75**	47.5	106 500	**43**	—	**12**	$5.65\sqrt{S_o}$	—	—
		300	572	**69**	44	98 000	**43**	—	**9**	$5.65\sqrt{S_o}$	—	—
		400	752	**56**	35.5	79 500	**43**	—	**5**	$5.65\sqrt{S_o}$	—	—
		500	932	**43**	27.5	61 000	**33**	—	**10**	$5.65\sqrt{S_o}$	—	—
		600	1 112	**17**	11	24 000	**8**	—	**12**	$5.65\sqrt{S_o}$	—	—
Rod [1] 90 mm diam. 3.5 in. diam.	Forged	20	68	**77**	49	109 500	**42**	—	**19**	$5.65\sqrt{S_o}$	—	—
		100	212	**73**	46.5	104 000	**40.5**	—	**16**	$5.65\sqrt{S_o}$	—	—
		200	392	**69**	44	98 000	**38.5**	—	**12**	$5.65\sqrt{S_o}$	—	—
		250	482	**67**	42.5	95 500	**38.5**	—	**13**	$5.65\sqrt{S_o}$	—	—
		300	572	**64**	40.5	91 000	**35.5**	—	**10**	$5.65\sqrt{S_o}$	—	—
		350	662	**54**	34.5	77 000	**32**	—	**11**	$5.65\sqrt{S_o}$	—	—
		400	752	**43**	27.5	61 000	**26**	—	**32**	$5.65\sqrt{S_o}$	—	—
		450	842	**30**	19	42 500	**16.5**	—	**60**	$5.65\sqrt{S_o}$	—	—
		500	932	**17**	11	24 000	**10**	—	**58**	$5.65\sqrt{S_o}$	—	—
Rod [6]	Cold Worked and Stress Relieved	20	68	**79**	50	112 500	**35.8**	—	**11**	$5.65\sqrt{S_o}$	—	—
		200	392	**66.5**	42	94 500	**37.2**	—	**8**	$5.65\sqrt{S_o}$	—	—
		300	572	**62**	39.5	88 000	**35.6**	—	**8**	$5.65\sqrt{S_o}$	—	—
	Cold Rolled 5%	20	68	**80**	51	114 000	**56**	—	**16**	$5.65\sqrt{S_o}$	—	—
		100	212	**66**	42	94 000	**49**	—	**10**	$5.65\sqrt{S_o}$	—	—
		200	392	**50**	31.5	71 000	**35**	—	**6**	$5.65\sqrt{S_o}$	—	—
		300	572	**36**	23	51 000	**14**	—	**3**	$5.65\sqrt{S_o}$	—	—
		400	752	**24**	15	34 000	**7**	—	**25**	$5.65\sqrt{S_o}$	—	—
		500	932	**13**	8.5	18 500	**3**	—	**60**	$5.65\sqrt{S_o}$	—	—

continued overleaf

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

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress		Elongation		Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	%	gauge length	kg m/cm²	ft lb
Rod (7)	Hot Forged	20	68	83	**52.6**	118 000	—	—	**16**	$4\sqrt{S_o}$	2.2 (i)	**13** (i)
		200	392	—	—	—	—	—	—	—	2.8 (i)	**16** (i)
		250	482	—	—	—	—	—	—	—	3.5 (i)	**20** (i)
		300	572	—	—	—	—	—	—	—	3.8 (i)	**22** (i)
		350	662	—	—	—	—	—	—	—	3.1 (i)	**18** (i)
		400	752	38.5	**24.3**	54 500	—	—	**37**	$4\sqrt{S_o}$	3.1 (i)	**18** (i)
		450	842	—	—	—	—	—	—	—	2.9 (i)	**17** (i)
		500	932	—	—	—	—	—	—	—	2.4 (i)	**14** (i)
		550	1 022	—	—	—	—	—	—	—	2.1 (i)	**12** (i)
		600	1 112	—	—	—	—	—	—	—	2.4 (i)	**14** (i)

(a) This value was originally reported in ton/in²; in this table it is given in kg/mm² to 3 significant figures.
(b) Izod-test; cross-sectional area at the notch 0.8 cm².
(c) Alloy composition (%) Cu 80.51; Al 9.35; Ni 4.99; Fe 5.07; Mn 0.41.
(d) Gauge length not stated in original document.
(e) Alloy composition (%) Cu 79.92; Al 10.0; Ni 4.80; Fe 4.80; Mn 0.39.
(f) Alloy composition (%) Cu 80.47; Al 9.35; Ni 5.10; Fe 5.16.
(g) Alloy composition (%) Cu 79.45; Al 10.45; Ni 5.14; Fe 4.83.
(h) Hexagonal rod.
(i) Charpy-type test on Izod machine; Izod 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.
—The yield strength 0.5% extension under load values are not available.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension % (a)	Intercept %	Min. Creep Rate % per 1 000h
		°C	°F	kg/mm²	ton/in²	psi				
Strip (8) (9) 2.5 mm 0.1 in.	Hot Rolled 50%	300	572	9.4	**6**	13 400	**3 200**	**0.095** (c)	**0.058** (g)	**0.013** (g)
				11.0	**7**	15 700	**3 000**	**0.12** (c)	**0.080** (g)	**0.014** (g)
				12.6	**8**	17 900	**3 000**	**0.18** (c)	**0.100** (g)	**0.028** (g)
				14.2	**9**	20 200	**3 000**	**0.19** (c)	**0.121** (g)	**0.023** (g)
				6.3	**4**	9 000	**10 000**	**0.28** (b)	**0.118** (g)	**0.032** (g)
									0.204 (h)	**0.007** (h)
				7.9	**5**	11 200	**10 000**	**0.315** (b)	**0.130** (g)	**0.034** (g)
									0.225 (h)	**0.009** (h)
				9.4	**6**	13 400	**10 000**	**0.515** (b)	**0.217** (g)	**0.053** (g)
									0.357 (h)	**0.016** (h)
				11.0	**7**	15 700	**10 000**	**0.57** (b)	**0.243** (g)	**0.058** (g)
									0.404 (h)	**0.017** (h)
		400	752	4.7	**3**	6 700	**3 000**	**0.25** (c)	**0.150** (g)	**0.037** (g)
				6.3	**4**	9 000	**3 000**	**0.335** (c)	**0.190** (g)	**0.052** (g)
				7.9	**5**	11 200	**2 400**	**0.51** (c)	**0.266** (g)	**0.105** (g)
				3.1	**2**	4 500	**3 000**	**0.375** (b)	**0.232** (g)	**0.050** (g)
				4.7	**3**	6 700	**2 500**	**0.54** (b)	**0.321** (g)	**0.088** (g)
Rod (7)	Extruded	250	482	1.6	**1**	2 200	**1 176**	**0.016** (d)	—	<**0.004 2** (e)
				3.9	**2.5**	5 600	**1 176**	**0.051** (d)	—	<**0.004 2** (e)
				6.3	**4**	9 000	**1 176**	**0.068** (d)	—	<**0.004 2** (e)
				9.4	**6**	13 400	**1 440**	**0.123** (d)	—	**0.008 3** (e)
				14.2	**9**	20 200	**1 440**	**0.236** (d)	—	**0.031 7** (e)
				22.0	**14**	31 400	**1 272**	**0.622** (d)	—	**0.258 3** (e)
				31.5	**20**	44 800	**1 128**	**3.67** (d)	—	—
		400	752	4.7	**3**	6 700	**720**	**0.43** (f)	—	**0.237 5** (f)
				6.3	**4**	9 000	**720**	**0.76** (f)	—	**0.541 7** (f)
				7.9	**5**	11 200	**720**	**1.93** (f)	—	**1.375** (f)

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Alloy containing 10.6% Al.
(c) Alloy containing 9.1% Al.
(d) After 960 hours.
(e) After 960 hours, or minimum if earlier.
(f) After 960 hours, by extrapolation.
(g) At 2 000h.
(h) At 10 000h.

N.B.:—Original values are printed in **bold type**; other values are converted.
—Further data can be obtained from the following paper.
■Dies, K. and Jung-König, W. Zeitstandverhalten einiger technischer Kupferlegierungen in der Wärme. Metall. Vol. 16 (1962), pp. 1097-1102.

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate					
				0.01% per 1 000 h			0.1% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Plate (3) **13 mm** **0.52 in.**	Annealed	250 350 450 550	482 662 842 1022	12.6 4.7 1.7 0.32 (a)	**8.0** **3.0** **1.1** **0.2** (a)	17 900 6 700 2 500 450 (a)	17.0 8.8 3.3 1.3	**10.8** **5.6** **2.1** **0.8**	24 200 12 500 4 700 1 800

(a) Extrapolated value.

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

—The stresses for 0.001 % per 1 000 h creep rate values are not available.

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

■Dies, K. and Jung-König, W. Zeitstandverhalten einiger technischer Kupferlegierungen in der Wärme. Metall, Vol. 16 (1962), pp. 1097-1102. (Fig. 7).

■Macken, P.J. and Smith, A.A. The Aluminium Bronzes. CDA Publication No. 31 (1966). Copper Development Association, Potters Bar, England (see Table 25, p. 157).

■Reference (7), Table VII.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles x10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Flat Product (8) **6.4 mm** **0.25 in.**	Hot Rolled (e) 50%	50	—	28.5 (a)	—	**18** (a)	—	40 500 (a)
	Hot Rolled (f) 50%	50	—	30 (a)	—	**19** (a)	—	42 500 (a)
Rod (1) **15 mm diam.** **0.59 in. diam.**	Cold Drawn 15%	30	**83.8**	**31** (a)	53	19.5 (a)	119 000	44 000 (a)
Rod (1) **25 to 50 mm diam.** **1 to 2 in. diam.**	Forged	20	**90**	**33** (b)	57	21 (b)	128 000	47 000 (b)
Rod (1) **35 mm diam.** **1.4 in. diam.**	Cold Drawn 10%	30	**72.5**	**27** (a)	46	17 (a)	103 000	38 500 (a)
Rod (1) **45 mm diam.** **1.8 in. diam.**	Cold Drawn 5%	30	**75.2**	**29.5** (a)	47.5	18.5 (a)	107 000	42 000 (a)
Rod (1) **50 mm diam.** **2 in. diam.**	Forged	30	**73.7**	**29** (a)	47	18.5 (a)	105 000	41 000 (a)
Rod (6)	Annealed	40	**55**	**26** (b)	35	16.5 (b)	78 000	37 000 (b)
Rod (6)	Annealed	35	**72.5**	**28** (b)	46	18 (b)	103 000	40 000 (b)
Rod (1)	Forged	20	**75**	**30** (a)	47.5	19 (a)	106 500	42 500 (a)
	Cold Drawn 20%	20	**90**	**36** (a)	57	23 (a)	128 000	51 000 (a)
Rod (10)	Forged	56.8 (g)	81.5	35.5 (d)	**51.7**	**22.5** (d)	116 000	50 500 (d)
Rod (11)	Forged	20 20	**78** **83**	**30** (b) **34** (b)	49.5 52.5	19 (b) 21.5 (b)	111 000 118 000	42 500 (b) 48 500 (b)
— (1) (c)	Forged	57	**51.7**	**22.5** (d)	33	14.5 (d)	73 500	32 000 (d)

(a) Rotating-bending test.

(b) Rotating-cantilever test.

(c) Form not stated in original document.

(d) Rotating-beam test.

(e) Alloy containing 9% Al.

(f) Alloy containing 10.5% Al.

(g) Unbroken specimen.

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. 151-158.

■Roland, J.M., le Maître, F. and Bouchy, C. The Fatigue Strength of Alloys under Low-Frequency Cycling. Mem. Sci. Rev. Métall, Vol. 67 (1970), pp. 637-646.

■Dies, K. and Jung-König, W. Korrosionswechselfestigkeit von Kupfer und Kupferlegierungen, insbesondere von Mehrstoff-Aluminiumbronzen. Werkstoffe und Korrosion, Vol. 17 (1966), pp. 461-468.

■Heubner, U., Jung-König, W. und Wincierz, P. Beitrag zur Biegewechselfestigkeit und Kerbempfindlichkeit von Kupferlegierungen— Teil. 2. Metall, Vol. 21 (1967), pp. 1250-1254.

■Slocombe, T.A. The Fatigue Strength of Some Gas Turbine Compressor Blade Materials in Air, in Seawater Spray, and at 300°C. Admiralty Materials Laboratory, England. Report No. B/129 (S). (1955).

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MECHANICAL PROPERTIES (SECTION 5)

(1) Private communication from Fürstlich Hohenzollernsche Hüttenverwaltung Laucherthal, Hohenzollern, Germany.

(2) Luzhnikov, L.P. Werkstoffe in Maschinenbau—Vol. 1: NE—Metalle und Legierungen. Izdatelstvo Mashinostroenie, Moskva (1967). 304 pp.

(3) Bearham, J.H., and Parker, R.J. Elevated-Temperature Tensile, Stress-Rupture and Creep Data for Six Copper-Base Materials. Metallurgia, Manchr, Vol. 78, (1968), pp. 9–14.

(4) Ashbolt, D., and Bowers, J.E. The Properties of Copper and Copper Alloys at Elevated Temperatures. BNFMRA Research Report A1550 (1965).

(5) Tyler, D.E., and Goodwin, R.J. The Effect of Temperature upon the Mechanical Properties of Selected Cu-Al-Fe-Ni Aluminium Bronzes. J. Inst. Metals, Vol 96. (1968), pp. 314-319.

(6) Private communication from Vereinigte Deutsche Metallwerke AG, Germany.

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(8) McKeown, J., Mends, D.N., Bale, E.,S., and Michael, A.D. The Creep and Fatigue Properties of Some Wrought Complex Aluminium Bronzes. J. Inst. Metals, Vol. 83 (1954-1955) pp. 69-79.

(9) Private communication from BNFMRA, England.

(10) Gough, H.J. and Sopwith, D.G. The Resistance of Some Special Bronzes to Fatigue and Corrosion-Fatigue. J. Inst. Metals, Vol. 60 (1937), pp. 143-158.

(11) Private communication from Schwietzke Metallwerke, Germany.

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Cu Al9 Ni6 Fe3

Common names: Aluminium Bronze (Alloy E)
Aluminium Bronze, E

A copper-aluminium-nickel-iron alloy with a predominantly alpha-plus-kappa phase structure and of much more variable aluminium content and iron/nickel ratio than Cu Al10 Fe5 Ni5, in different countries; the alloy also contains a small amount of manganese. The addition of nickel and iron provides a good combination of corrosion and oxidation resistance with strength, and fatigue and wear resistance. The material also has good hot-working properties and retains its strength at moderately elevated temperatures. The most commonly used wrought forms are plate, rod and forgings.

COMPOSITION (weight %)

Al	8.0–11.0
Ni	4.0– 7.0
Fe	1.5– 3.5
Mn	0.5– 2.0
Cu	rem.

1 SOME TYPICAL USES

Chemical
Tubeplates and shells for heat exchangers; waterboxes and storage tanks; pickling equipment.

Marine
Tubeplates and shells for heat exchangers; fittings and fasteners; pump components.

Mechanical
Wear-resistant components and weld overlays; fasteners and high-tensile bolts; high-pressure valve bodies; welder jaws; forming dies; rolling mill bearings; conveyor links and hinge bolts; gears; heavy duty bushings and bearings; non-sparking tools for gas, oil, coal, mining, chemical and explosives industries; shafts; moulding dies for plastics.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	7.6 g/cm³	0.275 lb/in³
2.2	Melting range	1 050–1 070 °C	1 920–1 960 °F
2.3	Coefficient of thermal expansion (linear) at:		
	−200 to 20 °C *−328 to 68 °F*	0.000 015 [a] per °C	0.000 008 [a] per °F
	20 to 100 °C *68 to 212 °F*	0.000 016 " "	0.000 009 " "
	20 to 300 °C *68 to 572 °F*	0.000 017 " "	0.000 009 " "
2.4	Specific heat (thermal capacity) at:		
	20 °C *68 °F*	0.10 cal/g °C	0.10 Btu /lb °F
2.5	Thermal conductivity at:		
	20 °C *68 °F*	0.09–0.11 cal cm/cm² s °C	22–27 Btu ft/ft² h °F
	200 °C *392 °F*	0.13 [a] "	31 [a] "
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	4.1–5.2 m/ohm mm²	7–9 % IACS
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	0.25–0.19 ohm mm²/m 25–19 microhm cm	150–120 ohms (circ mil/ft) 9.7–7.5 microhm in
2.8	Temperature coefficient of electrical resistance at:		
	20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 5 per °C (7%–9% IACS)	0.000 3 per °F (7%–9% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*:		
	Solution annealed	13 000–13 350 kg/mm²	18 500 000–19 000 000 lb/in²
	Lightly cold worked	12 800–13 100 kg/mm²	18 200 000–18 600 000 lb/in²
	Heat treated	13 400–14 000 kg/mm²	19 000 000–19 900 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*:		
	Solution annealed	4 800–4 950 kg/mm²	6 800 000 –7 000 000 lb/in²
	Lightly cold worked	4 750–4 850 kg/mm²	6 700 000–6 900 000 lb/in²
	Heat treated	4 950–5 200 kg/mm²	7 100 000–7 400 000 lb/in²

[a] Approximate value.

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 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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3 FABRICATION PROPERTIES

Fabrication characteristics, corrosion resistance and mechanical properties of this copper–aluminium alloy are markedly influenced by composition and by heat treatment which is usually performed by the metal manufacturer.
If thermal treatment, including hot forming and joining processes, is to be undertaken by the end user, the advice of the metal supplier should be requested.

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

	Metric Units	English Units
3.1 Casting temperature range	1 140–1 200 °C	2 085–2 190 °F
3.2 Annealing temperature range	650– 850 °C	1 200–1 560 °F
Stress relieving temperature range	300– 400 °C	570– 750 °F
3.3 Hot working temperature range	850– 975 °C	1 560–1 785 °F
3.4 Hot formability	Good	
3.5 Cold formability	Limited	
3.6 Cold reduction between anneals	10% 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. 3.8	
Soldering	Not recommended	
Brazing (with special fluxes)	Fair	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Good	
Resistance welding: spot and seam	Good	
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	—	—	—	—	—	—	—	—
Canada	CSA	HC.AN 105F 630	—	—	HC.5.7	—	—	HC.5.7	—
Chile	NCh (INDITECNOR)	Cu Al10 Ni6 Fe3	—	NCh 249 of. 68	—	—	—	—	NCh 249 of. 68
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	—	—	—	—	—	—	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	ABP4	—	H 3208	—	—	—	—	—
Netherlands	N or NEN [b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Swoden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	CA105	—	1541 2875	—	—	—	—	—
United States [c]	ASTM	No. 628 and 630	—	B124 B150 B171	B124 B150	—	—	B124 B150	—
International Organisation for Standardization	ISO	—	—	—	—	—	—	—	—

[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 is 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 *

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		
Plate	Hot Rolled	65	38	15	$5.65\sqrt{S_o}$	165	175	49	10–50 mm thick
Rod[b]	Hot Worked	60	32	15	$5.65\sqrt{S_o}$	160	170	45	20–80 mm diam. or equivalent area
	Typical Cold Worked Temper	75	50	8	$5.65\sqrt{S_o}$	200	210	53	10–40 mm diam. or equivalent area
Forgings[b]	Hot Worked	62	35	15	$5.65\sqrt{S_o}$	165	175	47	—

(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.

(b) 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	Hot Rolled	71	46	29	19	20	$5.65\sqrt{S_o}$	190	54	35	12-50 mm (0.5–2in.) thick
Sheet	As Manufactured	74	48	32	21	20	50mm(2in)	200	56	36	3–10 mm (0.125–0.375 in.) thick
Rod[c]	Hot or Hot + Cold Worked As Manufactured	70	45	32	21	22	$5.65\sqrt{S_o}$	190	53	34	50–100 mm (2–4 in.) diam. or equivalent area
		73	47	36	23	20	$5.65\sqrt{S_o}$	200	54	35	25–50 mm (1-2in.) diam. or equivalent area
		77	50	40	26	17	$5.65\sqrt{S_o}$	220	59	38	10–25 mm (0.375-1in.) diam. or equivalent area
Forgings[c]	Hot Worked As Manufactured	66	43	26	17	22	$5.65\sqrt{S_o}$	180	49	32	—

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

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

* 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		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown[a]
				%	gauge length	F	B	30 T		
Flat products (bar)	As extruded	90 000	50 000	15	2 in.	—	96	—	67 500	1.0 in. thick
	Cold Worked	110 000	62 000	15	2 in.	—	97	—	77 000	1.0 in. thick
Rod [b]	As extruded	100 000	60 000	15	2 in.	—	96	—	62 000	4.0 in. diam.
	Cold Worked	118 000	75 000	15	2 in.	—	98	—	70 000	1.0 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			Yield Strength 0.5% ext. under load psi	Elongation		Reduction of Area %	Impact Strength [a]	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Rod [1] [2] 49 mm diam. 1.9 in. diam.	Annealed	20	68	78	49.5	**111 100**	**53 600**	**21**	2 in.	**21**	2.4	**14**
		— 29	— 20	79.5	50.5	**113 300**	**55 700**	**23**	2 in.	**23**	2.2	**13**
		— 59	— 75	80	51	**113 700**	**54 900**	**24**	2 in.	**26**	2.2	**13**
		—182	—295	88.5	56	**125 800**	**62 500**	**12**	2 in.	**12**	1.5	**9**
	Cold Worked 0.2%	20	68	79	50	**112 500**	**59 100**	**20**	2 in.	**21**	2.6	**15**
		— 29	— 20	80	51	**113 700**	**67 100**	**24**	2 in.	**29**	2.4	**14**
		— 59	— 75	79	50	**112 300**	**64 300**	**26**	2 in.	**28**	2.2	**13**
		—182	—295	86	54.5	**122 500**	**68 100**	**8**	2 in.	**10**	1.5	**9**
— [3] (b)	Annealed	20	68	**70**	44.5	99 500	—	**19**	(c)	—	—	—
		— 78	—108	**72**	45.5	102 500	—	**18**	(c)	—	—	—
		—150	—238	**80**	51	114 000	—	**16**	(c)	—	—	—

(a) Charpy test, V-notch, cross-sectional area at the notch 0.8 cm².

(b) Form not stated in original document.

(c) Gauge length not stated in original document.

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

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

—The 0.1% and 0.2% offset proof stress values are not available.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Impact Strength [a]	
		°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 [4] 25 mm 1 in	Forged	20	68	**69**	44	98 000	**27**	—	—	**9**	$5.65\sqrt{S_o}$	—	—
		100	212	**69**	44	98 000	**27**	—	—	**9**	$5.65\sqrt{S_o}$	—	—
		200	392	**63**	40	89 500	**26**	—	—	**9**	$5.65\sqrt{S_o}$	—	—
		250	482	**60**	38	85 500	**24**	—	—	**7**	$5.65\sqrt{S_o}$	—	—
		300	572	**57.5**	36.5	82 000	**23.5**	—	—	**7**	$5.65\sqrt{S_o}$	—	—
		350	662	**47**	30	67 000	**22**	—	—	**6**	$5.65\sqrt{S_o}$	—	—
		400	752	**36**	23	51 000	**18**	—	—	**24**	$5.65\sqrt{S_o}$	—	—
Plate [5]	Annealed	20	68	80	**50.9**	114 000	**55.1** [d]	**32.3**	—	**17**	2 in.	—	—
		66	150	77	**48.9**	109 500	**54.5** [d]	**32.5**	—	**17**	2 in.	—	—
		121	250	75	**47.7**	107 000	**53.0** [d]	**31.6**	—	**13**	2 in.	—	—
		177	350	74	**47.1**	105 500	**51.9** [d]	**30.9**	—	**13**	2 in.	—	—
		232	450	72.5	**46.0**	103 000	**50.2** [d]	**29.9**	—	**14**	2 in.	—	—
		288	550	67.5	**42.9**	96 000	**46.1** [d]	**26.7**	—	**11**	2 in.	—	—
		343	650	57	**36.1**	81 000	**37.0** [d]	**20.4**	—	**15**	2 in.	—	—
		371	700	48	**30.5**	68 500	**27.4** [d]	**15.0**	—	[c]	2 in.	—	—
Plate [6]	Hot Rolled	20	68	56.5	36	**80 500**	**21.5** [b]	—	—	**14**	2 in.	—	—
		121	250	57.5	36.5	**81 800**	**25.1** [b]	—	—	**19.5**	2 in.	—	—
		177	350	53.5	34	**75 900**	**24.3** [b]	—	—	**16**	2 in.	—	—
		260	500	49.5	31.5	**70 250**	**24.5** [b]	—	—	**15**	2 in.	—	—
		316	600	49.5	31.5	**70 250**	**25.8** [b]	—	—	**16**	2 in.	—	—
		371	700	41	26	**58 200**	**25.0** [b]	—	—	**12**	2 in.	—	—
Rod [1] [2] 49 mm diam. 1.9 in. diam.	Annealed	20	68	78	49.5	**111 100**	—	—	**53 600**	**21**	2 in.	2.4	**14**
		204	400	72	45.5	**102 400**	—	—	**50 400**	**16**	2 in.	2.6	**15**
		316	600	61.5	39	**87 700**	—	—	**48 900**	**10**	2 in.	1.4	**8**
		427	800	23.5	15	**33 700**	—	—	**22 900**	**41**	2 in.	1.2	**7**
		538	1 000	9.5	6	**13 700**	—	—	**11 300**	**39**	2 in.	1.2	**7**
	Cold Worked 0.2%	20	68	79	50	**112 500**	—	—	**59 100**	**20**	2 in.	2.6	**15**
		204	400	71	45	**100 700**	—	—	**58 500**	**13**	2 in.	2.9	**17**
		316	600	59.5	37.5	**84 400**	—	—	**54 100**	**8**	2 in.	1.4	**8**
		427	800	25	16	**35 500**	—	—	**24 100**	**51**	2 in.	1.4	**8**
		538	1 000	11	7	**15 500**	—	—	**12 800**	**41**	2 in.	1.5	**9**
Rod [7] 51 mm diam. 2 in. diam.	[e]	27	80	78.5	50	**112 000**	—	—	—	**20.0**	2 in.	—	—
		149	300	74	47	**105 000**	—	—	—	**15.0**	2 in.	—	—
		260	500	66	42	**94 000**	—	—	—	**10.0**	2 in.	—	—
		371	700	43.5	27.5	**62 000**	—	—	—	**32.0**	2 in.	—	—
Rod [6]	Annealed	20	68	85	54	**121 000**	**59.0** [b]	—	—	**15**	2 in.	—	—
		121	250	84	53.5	**119 500**	**64.3** [b]	—	—	**15**	2 in.	—	—
		177	350	81.5	52	**116 000**	**56.5** [b]	—	—	**15**	2 in.	—	—

(a) Charpy test; V notch; cross-sectional area at the notch 0.8 cm².

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

(c) Duplicate tests gave 38% and 50% elongation.

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

(e) Temper not stated in original document.

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

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

—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). Nov.
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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				
Plate [6]	Hot Rolled	316	600	7.0	4.5	**10 000**	**1 550**	**0.092**	**0.088**	**0.004**
				9.1	5.8	**13 000**	**1 000**	**0.16**	**0.14**	**0.017**
				12.3	7.8	**17 500**	**1 300**	**0.275**	**0.242**	**0.031**
		371	700	4.2	2.7	**6 000**	**1 150**	**0.08**	**0.07**	**0.006**
				4.6	2.9	**6 500**	**1 750**	**0.12**	**0.097**	**0.02**
				5.6	3.6	**8 000**	**1 300**	**0.11**	**0.09**	**0.016**
				7.0	4.5	**10 000**	**1 750**	**0.226**	**0.11**	**0.084**
Rod [6]	Annealed	121	250	15.1	9.6	**21 500**	**1 600**	**0.115**	**0.109**	**0.003 75**
		177	350	12.3	7.8	**17 500**	**1 600**	**0.108**	**0.105**	**0.001 8**
		260	500	7.0	4.5	**10 000**	**1 075**	**0.10**	**0.09**	**0.012**
				10.5	6.7	**15 000**	**1 100**	**0.22**	**0.17**	**0.053**
				14.1	8.9	**20 000**	**1 000**	**0.26**	**0.23**	**0.14**
				18.3	11.6	**26 000**	**1 100**	**0.73**	**0.48**	**0.21**

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

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

5.3.2.2. Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate					
				0.01% per 1 000 h			0.1% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Plate [6]	Hot Rolled	316	600	8.4	5.4	**12 000**	16.2	10.3	**23 000**
		371	700	4.2	2.7	**6 000**	7.5	4.7	**10 600**
Rod [6]	Annealed	121	250	15.1	9.6	**21 500**	—	—	—
		177	350	12.3	7.8	**17 500**	—	—	—
		260	500	8.4	5.4	**12 000**	16.2	10.3	**23 000**

N.B.: — Original values are printed in **bold type**; other values are converted.
— The stresses for 0.001% 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 x10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod [8] **13 mm diam. 0.5 in. diam.**	Cold Worked [a] 11.5%	300	87.5	22.5 [b]	55.5	14.5 [b]	**124 800**	**32 000** [b]
Rod [9] **16 mm diam. 0.625 in. diam.**	Heat Treated	100	82	~29.5 [b]	52	~18.5 [b]	**116 600**	**~42 000** [b]
— [10] [c]	Annealed	100	72.5	24.5 [d]	46	15.5 [d]	**103 300**	**35 000** [d]
— [11] [c]	— [e]	100	76.5	17.5 23 [f]	48.5	11 14.5 [f]	**109 000**	**25 000— 33 000** [f]

(a) Alloy containing 0.30% Zn.

(b) Rotating-beam test.

(c) Form not stated in original document.

(d) Rotating-cantilever test.

(e) Temper not stated in original document.

(f) Rotating-bending test.

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

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