Cu Zn20 Al2

Common name: Aluminium Brass

A copper-zinc alloy with an alpha phase structure, containing aluminium and a small amount of arsenic which is added as an inhibitor against dezincification. The presence of aluminium imparts to the alloy very good corrosion and erosion resistance in clean and slightly polluted waters, including seawater, either stagnant or relatively fast moving (up to about 3 m/s). The most commonly used wrought form is condenser and heat exchanger tube.

COMPOSITION (weight %)

Cu	76.0 – 79.0
Al	1.8 – 2.5
As	0.02 – 0.06
Zn	rem.

1 SOME TYPICAL USES

Chemical

Evaporator, distillation and heat-exchange equipment, including desalination plant and sugar refineries.

Marine

Tubes, fittings and other components for seawater condensers; seawater trunking; oil tanker heating coils.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.35 g/cm³	0.300 lb/in³
2.2 Melting range	935 – 1 010 °C	1 715 – 1 850 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 018 per °C	0.000 010 per °F
20 to 200 °C *68 to 392 °F*	0.000 019 „ „	0.000 011 „ „
20 to 300 °C *68 to 572 °F*	0.000 020 „ „	0.000 011 „ „
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.24 cal cm/cm² s °C	58 Btu ft/ft² h °F
200 °C *392 °F*	0.30 „	73 „
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	13 m/ohm mm²	23 % IACS
200 °C *392 °F* („)	10 „	18 „ „
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.075 ohm mm²/m 7.5 microhm cm	45 ohms (circ mil/ft) 3.0 microhm in
200 °C *392 °F* („)	0.096 ohm mm²/m 9.6 microhm cm	58 ohms (circ mil/ft) 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*	0.001 3 per °C (23 % IACS)	0.000 7 per °F (23 % IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F* annealed	111900 N/mm² 11 200 kg/mm²	16 000 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F* annealed	40 200 N/mm² 4 100 kg/mm²	5 900 000 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.

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (*see page 10*); *INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE*

Prepared by
CONSEIL INTERNATIONAL POUR LE DEVELOPPEMENT DU CUIVRE (CIDEC)
100, rue du Rhône- 1204 GENEVE

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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	1 050–1 100 °C	1 920–2 010 °F
3.2 Annealing temperature range	450– 650 °C	840–1 200 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	700– 830 °C	1 290–1 525 °F
3.4 Hot formability	Fair	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	80% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	30	
3.8 Joining methods	See General Data Sheet No. 3.6	
Soldering	Fair	
Brazing	Good	
Oxy-acetylene welding	Fair	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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	36	14	55	$5.65\sqrt{S_o}$	70	74	27	—
	Hot Rolled	38	16	45	$5.65\sqrt{S_o}$	85	89	29	20–60 mm thick
Tube[b]	Annealed (grain size 0.030 mm)	38	14	60	$5.65\sqrt{S_o}$	75	79	28	15–30 mm O.D. 0.8–2 mm wall
	Annealed (grain size 0.020 mm)	43	22	50	$5.65\sqrt{S_o}$	95	100	32	15–30 mm O.D. 0.8–2 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) Tubes for condensers and heat exchangers are generally supplied in the annealed tempers whose representative mechanical properties are shown.

5.1.2 Typical Tensile Properties and Hardness Values—SI and English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 and 5.1.3, respectively.

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

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

Form	Temper[a]	Tensile Strength		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties shown[b]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Plate	Annealed	34	22	12	8	55	$5.65\sqrt{S_o}$	75	26	17	—
	Hot Rolled	36	23	14	9	50	$5.65\sqrt{S_o}$	90	27	17	12–50 mm (0.5–2 in.) thick
Sheet Strip	Annealed	34	22	12	8	60	50 mm (2 in.)	75	26	17	—
	Hot Rolled	39	25	15	10	50	50 mm (2 in.)	100	29	19	3–10 mm (0.125–0.375 in.) thick
Tube[c]	Annealed (grain size ~ 0.03 mm)	**36**	**23**	**14**	**9**	**60**	$5.65\sqrt{S_o}$	**75**	**27**	**17**	—
	Cold Drawn or Temper Annealed										
	Temper Annealed	37	24	19	12	45	$5.65\sqrt{S_o}$	90	28	18	50–255 mm (2–10 in.) O.D.
	As-Drawn	51	33	36	23	25	$5.65\sqrt{S_o}$	140	38	25	2–5 mm (0.08–0.2 in.) wall
	Temper Annealed	**37**	**24**	**19**	**12**	**50**	$5.65\sqrt{S_o}$	**90**	**28**	**18**	
	Temper Annealed	**43**	**28**	**32**	**21**	**35**	$5.65\sqrt{S_o}$	**135**	**32**	**21**	6–50 mm (0.25–2 in.) O.D.
	As-Drawn	**56**	**36**	**46**	**30**	**20**	$5.65\sqrt{S_o}$	**165**	**42**	**25**	0.5–2 mm (0.02–0.08 in.) wall
	As-Drawn	62	40	49	32	10	$5.65\sqrt{S_o}$	190	47	30	

(a) The recognised temper designations used in the relevant or nearest British Standards are also given to clarify the cold-worked tempers shown.
(b) It is possible to obtain sizes outside the ranges given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.
(c) Intermediate tube tempers are generally obtained by temper annealing. Drawn tubes are usually stress relieved after the final draw. Tubes for condensers and heat exchangers are mainly supplied in the tempers whose representative mechanical properties are printed in **bold type**.
* 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 designation shown is 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[b]	Annealed grain size 0.025 mm	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 the one 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 in the annealed tempers whose representative mechanical properties are shown.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	%	gauge length
Sheet[1] 2 mm diam. 0.08 in. diam.	Annealed	20	68	42	26.8	60 000	—	9.1	—	51	2 in.
		100	212	41	26.0	58 000	—	8.7	—	50	2 in.
		200	392	37.5	23.9	53 500	—	8.3	—	50	2 in.
		300	572	35.5	22.5	50 500	—	8.2	—	42	2 in.
		400	752	28	17.9	40 000	—	7.8	—	23	2 in.
		500	932	13	8.4	19 000	—	2.4	—	35	2 in.
Plate[2] 18 to 60 mm thick 0.71 to 2.4 in. thick	Hot Rolled	20	68	40.5	25.5	57 500	34.5	—	—	27	$11.3\sqrt{S_o}$
		100	212	39.5	25	56 000	34.0	—	—	25	$11.3\sqrt{S_o}$
		200	392	37.5	24	53 500	32.5	—	—	22	$11.3\sqrt{S_o}$
		300	572	35.0	22	50 000	31.5	—	—	17	$11.3\sqrt{S_o}$
		350	662	32.0	20.5	45 500	28.0	—	—	9	$11.3\sqrt{S_o}$
Sheet[3] 18 to 60 mm thick 0.71 to 2.4 in. thick	Hot Rolled	20	68	35.6	22.5	50 500	13.8	—	—	65	$11.3\sqrt{S_o}$
		200	392	31.6	20	45 000	10.0	—	—	60	$11.3\sqrt{S_o}$
		300	572	28.6	18	40 500	6.5	—	—	39	$11.3\sqrt{S_o}$
		400	752	21.9	14	31 000	5.0	—	—	10	$11.3\sqrt{S_o}$
Plate[1] 89 mm thick 3.5 in. thick	Hot Rolled	20	68	35	22.7	51 000	10.7 [a]	6.7	—	73	$4\sqrt{S_o}$
		150	302	32.5	21.1	47 500	10.1 [a]	6.2	—	76	$4\sqrt{S_o}$
		200	392	32.5	21.0	47 000	10.1 [a]	6.3	—	79	$4\sqrt{S_o}$
		250	482	32	20.6	46 000	10.6 [a]	6.3	—	73	$4\sqrt{S_o}$
		300	572	27.5	17.9	40 000	9.92[a]	6.2	—	44	$4\sqrt{S_o}$
Plate[1] 137 mm thick 5.4 in. thick	Hot Rolled	20	68	29	18.4	41 000	8.98[a]	5.5	—	63	$4\sqrt{S_o}$
		150	302	25	16.0	36 000	7.56[a]	4.6	—	66	$4\sqrt{S_o}$
		200	392	25	16.0	36 000	7.56[a]	4.6	—	69	$4\sqrt{S_o}$
		250	482	25.5	16.2	36 500	8.51[a]	5.3	—	62	$4\sqrt{S_o}$
		300	572	22	13.9	31 000	8.66[a]	5.4	—	38	$4\sqrt{S_o}$
Plate[4]	Cold Worked[b]	21	70	59.5	37.7	84 500	53.7 [a]	30.6	—	9	2 in.
		66	150	58	36.7	82 000	53.7 [a]	31.9	—	8	2 in.
		121	250	56.5	36.0	80 500	50.7 [a]	29.2	—	7	2 in.
		177	350	55	35.0	78 500	—	30.2	—	7	2 in.
		232	450	53	33.8	75 500	44.7 [a]	26.9	—	4	2 in.
Rod[5] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.015 mm)	24	75	42.5	27	60 600	—	—	27 500	47.0	2 in.
		149	300	—	—	—	—	—	29 400	—	—
		204	400	—	—	—	—	—	28 000	—	—
		260	500	—	—	—	—	—	24 200	—	—
	Annealed (grain size 0.030 mm)	24	75	40.5	26	58 100	—	—	23 700	53.0	2 in.
		149	300	—	—	—	—	—	28 500	—	—
		204	400	—	—	—	—	—	23 600	—	—
		260	500	—	—	—	—	—	21 300	—	—
	Cold Worked 37%	24	75	61.5	39	87 800	—	—	67 000	11.5	2 in.
		149	300	—	—	—	—	—	66 000	—	—
		204	400	—	—	—	—	—	62 500	—	—
		260	500	—	—	—	—	—	49 500	—	—

continued on opposite page

5.3.1. Short-Time Tensile Properties (continued)

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	%	gauge length
Rod[7] **27 mm diam.** **1.1 in. diam.**	Annealed	20	68	43.5	**27.6**	62 000	**20.0** (a)	**12.7**	—	**62**	$4\sqrt{S_o}$
		100	212	41	**26.0**	58 000	**18.6** (a)	**11.7**	—	**56**	$4\sqrt{S_o}$
		200	392	39	**24.7**	55 500	**18.9** (a)	**12.0**	—	**58**	$4\sqrt{S_o}$
		250	482	38	**24.1**	54 000	**18.4** (a)	**11.4**	—	**53**	$4\sqrt{S_o}$
		300	572	33.5	**21.3**	47 500	**18.0** (a)	**10.8**	—	**34**	$4\sqrt{S_o}$
Rod[6]	Cold Worked 45%	25	77	56.5	36	**80 100**	—	—	—	**10**	2 in.
		325	617	32	20.5	**45 500**	—	—	—	**2**	2 in.
		500	932	9.5	6	**13 400**	—	—	—	**31**	2 in.
		625	1 157	4.5	3	**6 200**	—	—	—	**42**	2 in.
		745	1 373	2.5	1.5	**3 700**	—	—	—	**72**	2 in.
		900	1 652	0.9	0.6	**1 300**	—	—	—	**89**	2 in.
Tube[3] **10 mm O.D., 1 mm wall** **to** **30 mm O.D., 2 mm wall**	Annealed	20	68	**35.5**	22.5	50 500	**8.9**	—	—	**63.8**	$11.3\sqrt{S_o}$
		200	392	**31.5**	20	45 000	**6.5**	—	—	**67.8**	$11.3\sqrt{S_o}$
		300	572	**25.4**	16	36 000	**6.0**	—	—	**36.6**	$11.3\sqrt{S_o}$
		400	752	**16.0**	10	23 000	**5.5**	—	—	**14.5**	$11.3\sqrt{S_o}$
0.39 in. O.D., 0.04 in. **wall to** **1.2 in. O.D., 0.08 in. wall**	Annealed	20	68	**40.5**	25.5	57 500	**16.8**	—	—	**53.8**	$11.3\sqrt{S_o}$
		200	392	**36.6**	23	52 000	**13.5**	—	—	**47.9**	$11.3\sqrt{S_o}$
		300	572	**32.6**	20.5	46 500	**12.5**	—	—	**38.5**	$11.3\sqrt{S_o}$
		400	752	**23.7**	15	33 500	**11.0**	—	—	**15.1**	$11.3\sqrt{S_o}$
		500	932	**11.5**	7.5	16 500	**6.0**	—	—	**13.3**	$11.3\sqrt{S_o}$
Tube[8] **10 mm O.D., 1 mm wall** **to** **30 mm O.D., 2 mm wall** **0.39 in. O.D., 0.04 in.** **wall to** **1.2 in. O.D., 0.08 in. wall**	Annealed	20	68	**42.0**	26.5	59 500	**20.0**	—	—	**50**	$11.3\sqrt{S_o}$
		200	392	**38.0**	24	54 000	**18.0**	—	—	**51**	$11.3\sqrt{S_o}$
		300	572	**33.0**	21	47 000	**17.0**	—	—	**47**	$11.3\sqrt{S_o}$
		400	752	**26.0**	16.5	37 000	**16.0**	—	—	**37**	$11.3\sqrt{S^{\circ}}$
Tube[9] **10 mm O.D., 1 mm wall** **to** **30 mm O.D., 2 mm wall** **0.39 in. O.D., 0.04 in. wall** **to** **1.2 in. O.D., 0.08 in. wall**	Annealed	20	68	**40**	25.5	57 000	**14**	—	—	**56**	$11.3\sqrt{S_o}$
		100	212	**37.5**	24	53 500	**15**	—	—	**54**	$11.3\sqrt{S_o}$
		200	392	**38.0**	24	54 000	**16**	—	—	**51**	$11.3\sqrt{S_o}$
		300	572	**32.5**	20.5	46 500	**13.5**	—	—	**38**	$11.3\sqrt{S_o}$
		400	752	**21.5**	13.5	30 500	**13**	—	—	**10.5**	$11.3\sqrt{S_o}$

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

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 1000 h
Wire[(10)] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.015 mm)	149	300	3.5	2.2	**5 000**	**6 500**	**0.031**	**0.001**	**0.000 5**
				7.0	4.5	**10 000**	**6 500**	**0.133**	**0.034**	**0.003 1**
				14.0	8.9	**19 850**	**6 500**	**0.509**	**0.183**	**0.027**
				17.6	11.2	**25 000**	**11 100**	**1.660**	**0.655**	**0.072**
		204	400	1.4	0.92	**2 050**	**6 500**	**0.073**	**0.030**	**0.004 65**
				3.6	2.3	**5 050**	**6 500**	**0.342**	**0.094**	**0.033 5**
				7.1	4.5	**10 100**	**6 500**	**1.640**	**0.143**	**0.22**
		260	500	1.1	0.69	**1 550**	**3 170**	**0.368**	**0.111**	**0.076**
	Annealed (grain size 0.030 mm)	149	300	4.1	2.6	**5 900**	**5 500**	**0.037 5**	**0.002**	**0.001 0**
				7.0	4.4	**9 900**	**6 500**	**0.099**	**0.024**	**0.003 8**
				14.0	8.9	**19 900**	**6 500**	**0.450**	**0.146**	**0.029**
				15.5	9.8	**22 000**	**9 450**	**0.979**	**0.367**	**0.051**
		204	400	1.4	0.89	**2 000**	**6 500**	**0.074**	**0.028**	**0.004 3**
				3.5	2.2	**5 000**	**6 500**	**0.186**	**—0.007**	**0.023 5**
				7.0	4.5	**10 000**	**6 500**	**1.285**	**0.035**	**0.18**
		260	500	0.39	0.25	**550**	**6 860**	**0.097**	**0.043**	**0.007 1**
				0.74	0.47	**1 050**	**6 860**	**0.298**	**0.082**	**0.030**
				1.1	0.69	**1 550**	**6 500**	**0.524**	**0.128**	**0.059**
	Cold Worked 37%	149	300	13.5	8.5	**19 150**	**6 400**	**0.208**	**0.074**	**0.002 8**
				21.2	13.4	**30 100**	**6 500**	**0.349**	**0.128**	**0.006 3**
				28.1	17.8	**39 900**	**11 100**	**0.590**	**0.233**	**0.010**
				35.2	22.3	**50 000**	**6 500**	**1.169**	**0.498**	**0.054**
		204	400	10.6	6.7	**15 000**	**6 000**	**0.248**	**0.118**	**0.003 3**
				14.1	9.0	**20 100**	**6 500**	**0.403**	**0.206**	**0.007 7**
				21.3	13.5	**30 300**	**6 000**	**1.280**	**0.480**	**0.097**
				24.8	15.7	**35 200**	**4 130**	**2.840**	**0.485**	**0.51**
		260	500	0.74	0.47	**1 050**	**6 000**	**0.159**	**0.081**	**0.012**
				1.4	0.92	**2 050**	**6 000**	**0.577**	**0.197**	**0.061**
				2.1	1.4	**3 050**	**6 000**	**1.243**	**0.117**	**0.184**
				3.6	2.3	**5 050**	**3 480**	**2.322**	**—0.181**	**0.71**

(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								
		°C	°F	0.001% per 1 000 h			0.01% per 1 000 h			0.1% per 1 000 h		
				kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Plate[4] **89 mm thick** **3.5 in. thick**	Hot Rolled	200	392	—	—	—	15.8[a]	**10.0[a]**	22 400[a]	17.8	**11.3**	25 300
		250	482	—	—	—	6.3	**4.0**	9 000	8.5	**5.4**	12 100
		300	572	—	—	—	4.7	**3.0**	6 700	6.3	**4.0**	9 000
Plate[1] **137 mm thick** **5.4 in. thick**	Hot Rolled	200	392	—	—	—	9.9	**6.3**	14 100	11.8	**7.5**	16 800
		250	482	—	—	—	8.0	**5.1**	11 400	9.3	**5.9**	13 200
		300	572	—	—	—	5.7	**3.6**	8 100	7.1	**4.5**	10 100
Rod[7]	Annealed	200	392	—	—	—	5.0	**3.2**	7 200	9.9	**6.3**	14 100
		250	482	—	—	—	1.6	**1.0**	2 200	4.3	**2.7**	6 000
		300	572	—	—	—	0.47[a]	**0.3[a]**	670[a]	1.7	**1.1**	2 500
Wire[10] **3.2 mm diam.** **0.125 in diam.**	Annealed (grain size 0.015 mm)	149	300	4.7	3.0	**6 700**	10.1	6.4	**14 300**	18.6	11.8	**26 500**
		204	400	0.63[a]	0.40[a]	**900[a]**	2.0	1.3	**2 900**	5.4	3.4	**7 700**
		260	500	—	—	—	0.42[a]	0.27[a]	**600[a]**	1.2[a]	0.78[a]	**1 750[a]**
	Annealed (grain size 0.030 mm)	149	300	4.1	2.6	**5 900**	9.4	6.0	**13 400**	18.6	11.8	**26 500**
		204	400	0.63[a]	0.40[a]	**900[a]**	2.3	1.4	**3 200**	5.9	3.8	**8 400**
		260	500	0.14[a]	0.09[a]	**200[a]**	0.46	0.29	**650**	1.4[a]	0.89[a]	**2 000[a]**
	Cold Worked 37%	149	300	7.0[a]	4.5[a]	**10 000[a]**	24.6	15.6	**35 000**	38.0[a]	24.1[a]	**54 000[a]**
		204	400	6.3[a]	4.0[a]	**9 000[a]**	14.8	9.4	**21 000**	21.4	13.6	**30 500**
		260	500	—	—	—	0.70	0.45	**1 000**	1.7	1.1	**2 400**

(a) Extrapolated value.

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 $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod[11]	Cold Worked 20-25% and Stress Relieved	20	**45**	**10**[(a)]	28.5	6.5[(a)]	64 000	14 000[(a)]

(a) Reversed-bending test.
N.B.: Original values are printed in **bold type**; other values are converted.

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Private communication from Imperial Metal Industries Ltd., England.
(2) Private communication from Kabel- und Metallwerke Gutehoffnungshütte AG, Germany.
(3) Private communication from Vereinigte Deutsche Metallwerke AG, Germany.
(4) Ashbolt, D. and Bowers, J. E. The Properties of Copper and Copper Alloys at Elevated Temperatures. BNFMRA Research Report A 1550 (1965), July.
(5) 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).
(6) Price, W.B. Properties of Copper and Some of its Important Industrial Alloys at Elevated Temperatures. ASTM-ASME Symposium on Effect of Temperature on the Properties of Metals (1931), pp. 340-367.
(7) Bearham, J. H. and Parker, R. J. Elevated Temperature Tensile, Stress-Rupture and Creep Data for Six Copper-Base Materials. Metallurgia, Vol. 78 (1968) pp. 9-14.
(8) Private communication from R. & G. Schmöle Metallwerke Germany.
(9) Private communication from Wieland-Werke AG, Germany.
(10) Burghoff, H.L. and Blank, A.I. The Creep Characteristics of Copper and Some Copper Alloys at 300, 400 and 500 F. Proc. ASTM, Vol. 47 (1947), pp. 725-754.
(11) Private communication from Fürstlich Hohenzollernsche Hüttenverwaltung Laucherthal, Germany.

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Cu Zn28 Sn1

Common names: Admiralty Brass
Inhibited Admiralty

A copper-zinc alloy with an alpha phase structure, containing tin and a small amount of arsenic which is added as an inhibitor against dezincification. The presence of tin imparts to the alloy good corrosion resistance in moderately polluted river water and clean seawater, either stagnant or slow moving (up to about 2 m/s). The most commonly used wrought forms are tube and plate for heat-exchange equipment.

COMPOSITION (weight %)

Cu	70.0 –73.0
Sn	0.9 – 1.3
As*	0.02– 0.06
Zn	rem.

* Arsenic is the preferred inhibitor, but antimony or phosphorus is sometimes used in the USA

1 SOME TYPICAL USES

Chemical and Mechanical

Condenser tubes, tubeplates and other heat-exchange components, principally for oil refineries and power stations.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.55 g/cm³	0.310 lb/in³
2.2 Melting range	890–970 °C	1 635–1 780 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212°F*	0.000 019 per °C	0.000 011 per °F
20 to 300 °C *68 to 572 °F*	0.000 020 ,, ,,	0.000 011 ,, ,,
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.26 cal cm/cm² s °C	63 Btu ft/ft² h °F
200 °C *392 °F*	0.33 ,,	80 ,,
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	14 m/ohm mm²	25% IACS
200 °C *392 °F* (,,)	12 ,,	20 ,, ,,
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.069 ohm mm²/m 6.9 microhm cm	41 ohms (circ mil/ft) 2.7 microhm in
200 °C *392 °F* (,,)	0.086 ohm mm²/m 8.6 microhm cm	52 ohms (circ mil/ft) 3.4 microhm in
2.8 Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 3 per °C (25% IACS)	0.000 7 per °F (25% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*: annealed	111 900 N/mm² 11 200 kg/mm²	16 000 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F* annealed	40 200 N/mm² 4 100 kg/mm²	5 900 000 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.

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 11)*; 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	1 030–1 080 °C	1 885–1 975 °F
3.2 Annealing temperature range	450– 650 °C	840–1 200 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	680– 780 °C	1 255–1 435 °F
3.4 Hot formability	Fair	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	80% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	30	
3.8 Joining methods:	See General Data Sheet No. 3.6	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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	34	13	60	$5.65\sqrt{S_o}$	65	68	25	—
	Hot Rolled	36	15	50	$5.65\sqrt{S_o}$	80	84	27	20–60 mm thick
Tube [b]	Annealed (grain size 0.030 mm)	36	13	65	$5.65\sqrt{S_o}$	70	74	27	15–30 mm O.D. 0.8– 2 mm wall
	Annealed (grain size 0.020 mm)	40	18	57	$5.65\sqrt{S_o}$	85	89	30	15–30 mm O.D. 0.8– 2 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) Tubes for condensers and heat exchangers are generally supplied in the annealed tempers whose representative mechanical properties are shown.

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	
Tube for Condensers and Heat Exchangers [c]	Annealed (grain size 0.03 mm)	**32**	**21**	**11**	**7**	**60**	$5.65\sqrt{S_o}$	**75**	**24**	**16**	—
	Cold Drawn or Temper Annealed										
	Temper Annealed	**37**	**24**	**23**	**15**	**50**	$5.65\sqrt{S_o}$	**90**	**28**	**18**	6 –50 mm (0.25-2in.) O.D. 0.5– 2 mm (0.02–0.08in.) wall
	Temper Annealed	**42**	**27**	**31**	**20**	**35**	$5.65\sqrt{S_o}$	**135**	**32**	**20**	
	As-Drawn	**46**	**30**	**39**	**25**	**20**	$5.65\sqrt{S_o}$	**165**	**35**	**23**	
	As-Drawn	56	36	46	30	10	$5.65\sqrt{S_o}$	190	42	27	

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

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

(c) Intermediate tube tempers are generally obtained by temper annealing. Drawn tubes are usually stress relieved after the final draw. Tubes for condensers and heat exchangers are mainly supplied in the tempers whose representative mechanical properties are printed in **bold type.**

* 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 semifabricated products, can, however, normally meet the requirements of any national standard.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress		Elongation		Reduction of Area	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	Yield Strength 0.5% ext. under load psi	%	gauge length	%	kg m/cm²	ft lb
Rod (1) 19 mm diam. 0.75 in. diam.	Annealed (grain size 0.144 mm)	22	72	31.5	20	**44 800**	**7.45** (a)	—	**86**	$4.52\sqrt{S_o}$	**81**	19.4 (b)	**112** (b)
		−78	−108	35	22	**49 600**	**8.86** (a)	—	**91**	$4.5^2\sqrt{S_o}$	**79**	19.5 (b)	**113** (b)
		−197	−323	45.5	29	**64 600**	**13.1** (a)	—	**98**	$4.52\sqrt{S_o}$	**73**	19.7 (b)	**114** (b)
		−253	−423	54	34.5	**76 800**	**14.6** (a)	—	**99**	$4.52\sqrt{S_o}$	**68**	19.7 (b)	**114** (b)
		−269	−452	55.5	35	**78 600**	**14.8** (a)	—	**92**	$4.52\sqrt{S_o}$	**72**	—	—
Rod (2) 19 mm diam. 0.75 in. diam.	Annealed	20	68	32.5	21	**46 500**	—	**13 300**	**83.5**	2 in.	—	16.8 (c)	**60.8** (c)
		3	37	—	—	—	—	—	—	—	—	16.8 (c)	**60.6** (c)
		−18	0	—	—	—	—	—	—	—	—	16.3 (c)	**58.8** (c)
		−30	−22	—	—	—	—	—	—	—	—	16.8 (c)	**60.8** (c)
		−50	−58	—	—	—	—	—	—	—	—	16.3 (c)	**58.9** (c)
		−80	−112	—	—	—	—	—	—	—	—	17.0 (c)	**61.5** (c)
		−115	−175	—	—	—	—	—	—	—	—	16.4 (c)	**59.2** (c)
—(3) (d)	Annealed	22	72	—	—	—	—	—	—	—	—	17 (c)	**61** (c)
		−78	−108	—	—	—	—	—	—	—	—	19 (c)	**69** (c)
		−197	−323	—	—	—	—	—	—	—	—	23 (c)	**84** (c)
	Cold Worked 27%	22	72	—	—	—	—	—	—	—	—	10 (c)	**37** (c)
		−78	−108	—	—	—	—	—	—	—	—	11 (c)	**40** (c)
		−197	−323	—	—	—	—	—	—	—	—	11 (c)	**39** (c)

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

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

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

(d) Form not stated in original document.

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation	
		°C	°F	kg/mm^2	ton/in^2	psi	0.2% offset kg/mm^2	0.1% offset ton/in^2	Yield Strength 0.5% ext. under load psi	%	gauge length
Sheet [4] 2 mm thick 0.08 in. thick	Annealed	20	68	41	26.0	58 000	—	9.1	—	55	2 in.
		100	212	41	26.1	58 500	—	9.1	—	55	2 in.
		200	392	38.5	24.3	54 500	—	8.9	—	56	2 in.
		300	572	36	23.0	51 500	—	8.5	—	63	2 in.
		400	752	27	17.0	38 000	—	7.9	—	63	2 in.
		500	932	11	6.9	15 500	—	3.8	—	53	2 in.
Plate Sheet [5] 18 to 60 mm thick 0.71 to 2.4 in. thick	Hot Rolled	20	68	38	24	54 000	28.5	—	—	35	$11.3\sqrt{S_o}$
		100	212	37.5	24	53 500	28.5	—	—	34	$11.3\sqrt{S_o}$
		200	392	36	23	51 000	28	—	—	33	$11.3\sqrt{S_o}$
		300	572	34	21.5	48 500	26.5	—	—	25	$11.3\sqrt{S_o}$
		350	662	32	20.5	45 500	24	—	—	18	$11.3\sqrt{S_o}$
Sheet [6] 18 to 60 mm thick 0.71 to 2.4 in. thick	Hot Rolled	20	68	33.4	21	47 500	10	—	—	67	$5.65\sqrt{S_o}$
		100	212	33.0	21	47 000	9.2	—	—	72	$5.65\sqrt{S_o}$
		200	392	32.6	20.5	46 500	8.9	—	—	65	$5.65\sqrt{S_o}$
		300	572	30.2	19	43 000	8.9	—	—	52	$5.65\sqrt{S_o}$
		350	662	24.6	15.5	35 000	8.7	—	—	46	$5.65\sqrt{S_o}$
		400	752	19.4	12.5	27 500	8.5	—	—	35	$5.65\sqrt{S_o}$
		450	842	13.2	8.5	19 000	8.3	—	—	32	$5.65\sqrt{S_o}$
		500	932	8.5	5.5	12 000	7.4	—	—	35	$5.65\sqrt{S_o}$
Plate [7]	Annealed	21	70	31.5	20.1	45 000	8.35 [a]	5.1	—	89	2 in.
		66	150	30.5	19.3	43 500	8.35 [a]	4.8	—	92	2 in.
		121	250	30.5	19.5	43 500	8.19 [a]	5.0	—	93	2 in.
		177	350	30	19.0	42 500	7.72 [a]	4.8	—	90	2 in.
		232	450	29	18.3	41 000	7.56 [a]	4.7	—	77	2 in.
Rod [8] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.018 mm)	24	75	40	25.5	57 000	—	—	26 000	52.0	2 in.
		260	500	—	—	—	—	—	23 000	—	—
Rod [9] 16 mm diam. 0.625 in. diam.	Cold Worked 30%	24	75	48	30.5	68 500	—	—	31 750 [b]	35.0	2 in.
		204	400	46.5	29.5	65 950	—	—	29 000 [b]	24.0	2 in.
		316	600	39	25	55 800	—	—	15 000 [b]	14.5	2 in.
		427	800	18.5	12	26 400	—	—	8 000 [b]	57.5	2 in.
		538	1 000	6.5	4	9 250	—	—	1 500 [b]	33.0	2 in.
Rod [8] 19 mm diam. 0.75 in. diam.	Annealed	27	80	40.5	25.5	57 250	18.3 [c]	—	—	58.0	2 in.
		204	400	40.5	26	57 800	17.2 [c]	—	—	63.5	2 in.
		260	500	35	22.5	49 900	16.8 [c]	—	—	94.0	2 in.
		316	600	24.5	15.5	34 500	14.8 [c]	—	—	64.0	2 in.
		371	700	—	—	—	5.62 [c]	—	—	—	—
		427	800	—	—	—	2.11 [c]	—	—	—	—
Rod [10]	Cold Worked 35%	23	73	50.5	32	71 800	—	—	—	10	2 in.
		250	480	47.5	30.5	67 900	—	—	—	6	2 in.
		390	735	20	13	28 800	—	—	—	21	2 in.
		500	930	5	3	6 900	—	—	—	47	2 in.
		600	1 110	2	1.5	3 200	—	—	—	31	2 in.
		750	1 380	1	0.7	1 600	—	—	—	23	2 in.
		800	1 470	0.6	0.4	910	—	—	—	23	2 in.
		825	1 515	0.5	0.3	710	—	—	—	9	2 in.

continued overleaf

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

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% ext. under load psi	%	gauge length
Tube [6] **10 mm O.D., 1 mm wall to 30 mm O.D., 2 mm wall 0.39 in. O.D., 0.04 in. wall to 1.2 in. O.D., 0.08 in. wall**	Annealed (grain size 0.050 mm)	20	68	**39.8**	25.5	56 500	**17.2**	—	—	**58**	$11.3\sqrt{S_o}$
		200	392	**36.9**	23.5	52 500	**14.9**	—	—	**58**	$11.3\sqrt{S_o}$
		300	572	**34.5**	22	49 000	**15.2**	—	—	**55**	$11.3\sqrt{S_o}$
		400	752	**22.9**	14.5	32 500	**13.2**	—	—	**48**	$11.3\sqrt{S_o}$
		500	932	**9.9**	6.5	14 000	**7.5**	—	—	**45**	$11.3\sqrt{S_o}$
Tube [11] **10 mm O.D., 1 mm wall to 30 mm O.D., 2 mm wall 0.39 in. O.D., 0.04 in. wall to 1.2 in. O.D., 0.08 in. wall**	Annealed	20	68	**41**	26	58 500	**20**	—	—	**53**	$11.3\sqrt{S_o}$
		200	392	**39.5**	25	56 000	**17**	—	—	**58**	$11.3\sqrt{S_o}$
		300	572	**38.0**	24	54 000	**17**	—	—	**52**	$11.3\sqrt{S_o}$
		400	752	**28.0**	18	40 000	**16**	—	—	**42**	$11.3\sqrt{S_o}$

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

(b) Proportional limit.

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

N.B.: —Original values are printed in **bold type**; other values are converted.
—Values for impact strength up to 205°C are given in reference (2).

5.3.2 Creep Properties
5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature °C	Testing Temperature °F	Stress kg/mm²	Stress ton/in²	Stress psi	Duration h	Total Extension % [a]	Intercept %	Min. Creep Rate % per 1 000 h
Rod [8] 19 mm diam. 0.75 in. diam.	Annealed	204	400	5.6	3.6	**8 000**	**1 488**	**0.054**	**0.014**	**0.021**
		260	500	2.1	1.3	**3 000**	**1 152**	**0.096**	**0.024**	**0.063**
				5.6	3.6	**8 000**	**2 304**	**2.60**	**0.070**	**1.11**
		316	600	0.70	0.45	**1 000**	**2 064**	**0.060**	**0.006**	**0.027**
				2.1	1.3	**3 000**	**3 312**	**2.366**	**0.181**	**0.659**
		371	700	0.70	0.45	**1 000**	**1 560**	**1.360**	**0.113**	**0.800**
				5.6	3.6	**8 000**	**178**	**7.4**	**0**	**460**
		427	800	2.1	1.3	**3 000**	**26**	**1.60**	**0.220**	**61**
Wire [12] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.055 mm)	149	300	3.2	2.0	**4 540**	**4 500**	**0.029**	**0.013**	**<0.001**
				8.5	5.4	**12 050**	**3 380**	**0.090**	**0.023**	**0.001 4**
				10.7	6.8	**15 150**	**4 400**	**0.134**	**0.042**	**0.002 8**
		260	500	0.69	0.44	**980**	**4 980**	**0.026**	**0.003**	**0.003 7**
				1.4	0.88	**1 970**	**4 300**	**0.072**	**0.031**	**0.008 0**
				2.1	1.3	**3 000**	**4 980**	**0.149**	**0.034**	**0.021**
				3.2	2.0	**4 500**	**4 300**	**0.306**	**0.019**	**0.062** [b]
				4.3	2.7	**6 150**	**6 300**	**1.528**	**−0.350**	**0.295** [b]
	Cold Worked 60%	260	500	0.70	0.44	**990**	**2 950**	**0.425**	**0.090**	**0.11**
				2.1	1.3	**2 950**	**2 600**	**2.601**	**0.340**	**0.86**
Wire [13] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.018 mm)	149	300	1.4	0.88	**1 980**	**3 700**	**0.018**	**0.004**	**0.000 2**
				3.5	2.2	**5 000**	**5 100**	**0.057**	**0.018**	**0.000 9**
				6.9	4.4	**9 840**	**5 100**	**0.109**	**0.029**	**0.002 5**
				8.3	5.3	**11 800**	**5 200**	**0.141**	**0.044**	**0.003 3**
				10.5	6.7	**14 950**	**5 100**	**0.181**	**0.053**	**0.005 3**
				13.9	8.8	**19 750**	**5 100**	**0.259**	**0.073**	**0.010**
				17.6	11.2	**25 000**	**5 900**	**1.575**	**0.230**	**0.050**
		204	400	0.56	0.36	**800**	**5 100**	**0.027**	**0.009**	**0.002 6**
				1.4	0.88	**1 970**	**5 100**	**0.057**	**0.014**	**0.005 6**
				2.8	1.8	**4 000**	**5 100**	**0.166**	**0.047**	**0.017 4**
				4.9	3.1	**6 940**	**5 100**	**0.405**	**0.100**	**0.050**
				7.4	4.7	**10 500**	**5 100**	**0.770**	**0.055**	**0.125**
		260	500	0.34	0.21	**480**	**5 100**	**0.115**	**0.008**	**0.020**
				0.72	0.46	**1 020**	**5 000**	**0.408**	**0.080**	**0.064**
				1.4	0.89	**2 000**	**5 000**	**1.318**	**0.155**	**0.228**
				2.8	1.8	**4 000**	**5 000**	**2.275**	**0.045**	**0.440**
				4.1	2.6	**5 860**	**2 350**	**2.722**	**−0.66**	**1.43** [b]
	Annealed (grain size 0.055 mm)	204	400	1.4	0.88	**1 970**	**5 400**	**0.026**	**0.013**	**0.000 5**
				2.8	1.8	**4 000**	**5 400**	**0.046**	**0.019**	**0.001 4**
				4.1	2.6	**5 820**	**6 400**	**0.077**	**0.028**	**0.002 7**
				4.9	3.1	**6 920**	**5 200**	**0.082**	**0.022**	**0.003 8**
				7.0	4.4	**9 960**	**5 700**	**0.128**	**0.027**	**0.006 7**
				9.1	5.8	**13 000**	**6 600**	**0.255**	**0.044**	**0.018**
	Cold Worked 60%	149	300	8.8	5.6	**12 550**	**5 200**	**0.164**	**0.066**	**0.001 6**
				10.5	6.7	**15 000**	**6 500**	**0.203**	**0.078**	**0.002 7**
				12.1	7.7	**17 250**	**5 200**	**0.228**	**0.089**	**0.002 8**
				14.1	9.0	**20 100**	**5 400**	**0.287**	**0.116**	**0.005 2**
				21.3	13.5	**30 300**	**6 500**	**0.451**	**0.179**	**0.008 8**
				28.6	18.1	**40 650**	**5 200**	**0.685**	**0.307**	**0.018**
				35.3	22.4	**50 200**	**5 200**	**1.053**	**0.385**	**0.060**
		204	400	1.4	0.89	**2 000**	**5 750**	**0.066**	**—0.016**	**0.011 5** [b]
				2.8	1.8	**4 000**	**5 750**	**0.125**	**—0.017**	**0.019** [b]
				5.7	3.6	**8 100**	**5 750**	**0.306**	**—0.143**	**0.067** [b]
				6.9	4.4	**9 850**	**5 750**	**0.413**	**—0.278**	**0.106** [b]
		260	500	0.21	0.13	**300**	**5 750**	**0.088**	**0.052**	**0.005 5**
				0.34	0.22	**490**	**6 100**	**0.185**	**0.062**	**0.019 2**
				1.4	0.89	**2 000**	**5 300**	**2.481**	**0.160**	**0.435**

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Accelerating creep rate from third stage of 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		Stress for Designated Creep Rate								
				0.001% per 1 000 h			0.01% per 1 000 h			0.1% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod [15] **16 mm diam. 0.625 in. diam.**	Cold Worked 30%	204	400	—	—	—	9.1	5.8	**13 000**	13.4	8.5	**19 000**
		316	600	—	—	—	0.70	0.45	**1 000**	1.4	0.87	**1 950**
		427	800	—	—	—	0.04	0.02	**54**	0.11	0.07	**160**
Wire [12] **3.2 mm diam. 0.125 in. diam.**	Annealed (grain size 0.055 mm)	260	500	—	—	—	1.5	0.98	**2 200**	3.5	2.2	**5 000**
	Cold Worked 60%	260	500	—	—	—	—	—	—	0.63 [a]	0.40 [a]	**900** [a]
Wire [13] **3.2 mm diam. 0.125 in. diam.**	Annealed (grain size 0.018 mm)	149	300	3.8	2.4	**5 400**	13.4	8.5	**19 000**	17.9 [a]	11.4 [a]	**25 500** [a]
		204	400	—	—	—	2.0	1.3	**2 900**	6.7	4.3	**9 600**
		260	500	—	—	—	0.21 [a]	0.13 [a]	**300** [a]	0.95	0.60	**1 350**
	Annealed (grain size 0.055 mm)	149	300	9.3	5.9	**13 200**	13.7 [a]	8.7 [a]	**19 500** [a]	—	—	—
		204	400	2.2	1.4	**3 100**	7.7	4.9	**11 000**	>9.1	>5.8	> **13 000**
		260	500	0.7	0.4	**950**	1.5	0.96	**2 150**	3.2 [b]	2.1 [b]	**4 600** [b]
	Cold Worked 60%	149	300	7.0	4.5	**10 000**	22.5	14.3	**32 000**	36.6 [a]	23.2 [a]	**52 000** [a]
		204	400	—	—	—	1.1 [b]	0.67 [b]	**1 500** [b]	6.7 [b]	4.3 [b]	**9 600** [b]
		260	500	0.1 [a]	0.03 [a]	**150** [a]	0.27	0.17	**380**	0.74	0.47	**1 050**

(a) Extrapolated value.
(b) Produces accelerating creep rate.
N.B.: Original values are printed in **bold type**; other values are converted.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles × 10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod [14] **3.2 mm diam. 0.125 in. diam.**	Annealed (grain size 0.035 mm)	10	35.5	13.5 [a]	22.5	8.5 [a]	**50 800**	**19 000** [a]
	Annealed [b] (grain size 0.035 mm)	10	33.5	12 [a]	21.5	7.5 [a]	**47 800**	**17 000** [a]
	Annealed [c] (grain size 0.035 mm)	10	35.5	12.5 [a]	22.5	8 [a]	**50 500**	**18 000** [a]
	Annealed [d] (grain size 0.035 mm)	10	37.5	12 [a]	24	7.5 [a]	**53 500**	**17 000** [a]
Wire [15] **1.8 mm diam. 0.072 in. diam.**	Cold Worked 60%	100	75	16 [e]	47.5	10 [e]	**106 500**	**22 500** [e]
	Cold Worked 84%	100	93.5	18.5 [e]	59.5	12 [e]	**133 000**	**26 500** [e]

(a) Rotating-beam test
(b) Containing 0.03% As.
(c) Containing 0.033% Sb.
(d) Containing 0.034% P.
(e) Rotating-wire arc test.
N.B.: Original values are printed in **bold type**; other values are converted.

WROUGHT MATERIALS

SPECIAL COPPER-ZINC ALLOYS
Special Brasses

Cu Zn38 Sn1

Common name: Naval Brass

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

COMPOSITION (weight %)*

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

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

1 SOME TYPICAL USES

Marine and Mechanical

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

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.40 (a) g/cm³ 8.45 (b) ,,	0.305 (a) lb/in³ 0.305 (b) ,,
2.2 Melting range	885–915 °C	1 625–1 680 °F
2.3 Coefficient of thermal expansion (linear) at: 20 to 100 °C *68 to 212 °F* 20 to 300 °C *68 to 572 °F*	 0.000 020 per °C 0.000 022 ,, ,,	 0.000 011 per °F 0.000 012 ,, ,,
2.4 Specific heat (thermal capacity) at: 20 °C *68 °F*	 0.09 cal/g °C	 0.09 Btu/lb °F
2.5 Thermal conductivity at: 20 °C *68 °F* 200 °C *392 °F*	 0.28 cal cm/cm² s °C 0.32 ,,	 68 Btu ft/ft² h °F 77 ,,
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed) 200 °C *392 °F* (,,)	 15 m/ohm mm² 12 ,,	 26 % IACS 20 ,, ,,
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed)	0.066 ohm mm²/m 6.6 microhm cm	40 ohms (circ mil/ft) 2.6 microhm in
200 °C *392 °F* (,,)	0.086 ohm mm²/m 8.6 microhm cm	52 ohms (circ mil/ft) 3.4 microhm in
2.8 Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 8 per °C (26% IACS)	0.001 0 per °F (26% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*: annealed	103 000 N/mm² 10 500 kg/mm²	15 000 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*: annealed	3 900 kg/mm² 38 300 N/mm²	5 500 000 lb/in²

(a) Non-leaded alloy.
(b) Leaded alloy containing about 2% Pb.
N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition range involved, are based on selected literature references.

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 12); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

Prepared by
CONSEIL INTERNATIONAL POUR LE DEVELOPPEMENT DU CUIVRE (CIDEC)
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Cu Zn38 Sn1
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3 FABRICATION PROPERTIES

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

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

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

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE[a]

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

This table is representative of practice in many European countries. For British and American practices, see tables 5.1.2 and 5.1.3, respectively.

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

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

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

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

(a) It will be noted that tables 5.1.1, 5.1.2 and 5.1.3, giving typical tensile properties and hardness values in Metric, SI and English, and American units respectively, are not directly comparable. This is because the properties quoted reflect to some extent the metalworking techniques, specification practices, and testing procedures in the countries concerned, and in view of the different sizes of products referred to in these tables. Individual manufacturers of semi-fabricated products, can, however, normally meet the requirements of any national standard.

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

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

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

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

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

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

continued on opposite page

5.3.1 Short-Time Tensile Properties (continued)

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

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

(b) Proportional limit.

(c) Yield Point.

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

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

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

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

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

5.3.2.2 Stress for Designated Creep Rate

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

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

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod[16] 13 mm diam. 0.5 in. diam.	Cold Worked 9.4%	300	46.5	19.5[a]	30	12.5[a]	**66 300**	**28 000**[a]
Rod[17] 13 mm diam. 0.5 in. diam.	Rolled[d]	200	48	15.5[a]	30.5	10[a]	**68 200**	**22 000**[a]
Rod[18] 13 mm diam. 0.5 in. diam.	Cold Worked 24%[b]	100	61	23[a]	39	14.5[a]	**87 000**	**33 000**[a]
	Cold Worked 24%[c]	100	61.5	15[a]	39	9.5[a]	**87 300**	**21 000**[a]
Rod[18] 13.5 mm diam. 0.53 in. diam.	Cold Worked 27%[b]	100	61.5	22[a]	39	14[a]	**87 200**	**31 500**[a]
	Cold Worked 27%[c]	100	64.5	18.5[a]	41	12[a]	**91 400**	**26 500**[a]

continued overleaf

5.4.1. Fatigue Strength at Room Temperature (continued)

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

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

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

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