PHOSPHORUS-DEOXIDISED ARSENICAL COPPER

Cu-DPA

Phosphorus-deoxidised copper containing arsenic, either as an intentional alloying element or occurring naturally in the metal. Arsenic raises the softening temperature and enhances corrosion resistance in specific environments.

COMPOSITION (weight %)

Cu (+ Ag) + As	99.7 min.
P	0.013–0.050
As	0.15–0.50

1 SOME TYPICAL USES

Chemical

Plant, equipment and piping for relatively non-corrosive liquids and gases, operating at moderately elevated temperatures.

Mechanical

Heat-exchange equipment including condenser tubes and tube plates using clean, fresh water; steam locomotive fireboxes, staybolts and rivets; steam, lubrication and other pipes; stills, vats, kettles, autoclaves and general coppersmithing where welding or brazing is involved.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.9 g/cm³	0.321 lb/in³
2.2 Melting range	1 053–1 082 °C	1 927–1 980 °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*	 0.000 017 per °C 0.000 018 „ „	 0.000 009 3 per °F 0.000 009 8 „ „
2.4 Specific heat (thermal capacity) at: 20 °C *68 °F*	0.092 cal/g °C	0.092 Btu/lb °F
2.5 Thermal conductivity at: 20 °C *68 °F* [(a)]	0.35–0.45 [(b)] cal cm/cm² s °C	85–110 [(b)] Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	20–26 [(c)] m/ohm mm²	35–45 [(c)] % IACS
2.7 Electrical resistivity (volume) at: 20 °C *68 °F* (annealed or cold worked)	0.049–0.038 ohm mm²/m 4.9–3.8 microhm cm	30–23 ohms (circ mil/ft) 1.9–1.5 microhm in
2.8 Temperature coefficient of electrical resistance at: [(d)] 20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	 0.001 4 per °C (35 % IACS) 0.001 8 „ „ (45 % IACS)	 0.000 8 per °F (35 % IACS) 0.001 0 „ „ (45 % IACS)

continued overleaf

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

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Cu-DPA
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2 PHYSICAL PROPERTIES (continued)

	Metric Units		English Units	
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*:				
annealed	12 000	kg/mm²	17 000 000	lb/in²
cold worked	12 000–13 500	"	17 000 000–19 000 000	"
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:				
annealed	4 500	kg/mm²	6 400 000	lb/in²
cold worked	4 500 – 5 000	"	6 400 000 – 7 000 000	"

(a) Deduced from electrical conductivity values.

(b) The range shown is typical; a wider range (0.28–0.56 cal cm/cm² s °C *56–110 Btu ft/ft² h °F*) is possible.

(c) The range shown is typical; a wider range (30–60 % IACS *17–35 m/ohm mm²*) is possible.

(d) — The temperature coefficients of resistance given can be used for calculating resistances within the temperature range shown, but these relate only to calculations based on a reference temperature of 20 °C (*68 °F*).
— The temperature coefficient of resistance of copper can be assumed to be directly proportional to the conductivity value and the figures given above have been calculated on the basis that copper of 100 % IACS conductivity at 20 °C (*68 °F*) has a temperature coefficient of resistance of 0.003 93 per °C (*0.002 18 per °F*). Temperature coefficients of resistance for copper with a conductivity value within the range shown above may be calculated in the same manner.

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.

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	1 140–1 200 °C	2 080–2 190 °F
3.2 Annealing temperature range	375– 650 °C	700–1 200 °F
Stress relieving temperature range	225– 275 °C	440– 530 °F
3.3 Hot working temperature range	750– 900 °C	1 400–1 650 °F
3.4 Hot formability	Good	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	85 % max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	25	
3.8 Joining methods:	See General Data Sheet No. 3.2	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Good	
Gas-shielded arc welding	Excellent	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

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	—	—	AS - H17	—	—	B158 B159 B160	—	—
Belgium	NBN	Cu As P	—	266.02	266.02	—	266.02	—	—
Canada	CSA	Cu-DPA 142	—	—	—	—	HC.7.1 HC.7.3 HC.7.4	—	—
Chile	INDITECNOR	CuAs$\overline{DH}$ P	245 n.68	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	SB-Cu (2.0150)	1708 1787	—	—	—	1785 17 671	—	—
Italy	UNI	Cu-DPA	5649	3310 [b]	3310 [b]	—	3310 [b]	3310 [b]	—
Netherlands	N or NEN [c]	Cu-DPA	NEN 6023	—	—	—	NEN 2263	—	—
South Africa	SABS	—	405	—	—	—	460 461 462 463 464 465	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu-DPA	10826	11852	11852	—	11852	—	—
United Kingdom	BS	C107	1174	24 (Part 5) 899 1569 2027 2870 2875	24 (Part 5)	—	24 (Part 5) 61 (Part 1) 378 659 1306 (Part 2) 1386 2017 2871 3931	—	—
United States [d]	ASTM	No. 142 or DPA	—	B11	B12	—	B75 B111 B359 B395	—	—

(a) Applicable when the chemical composition is not given in the specifications for wrought forms.
(b) Under revision.
(c) Older specifications bear prefix N; for new specifications the NEN prefix is used.
(d) 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 (Tipper notched tensile test)	see table 5.2.1
Impact properties	„ „ 5.2.1
Navy tear test	„ „ 5.2.2

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 [a]

5.1.1 Typical Tensile Properties and Hardness Values - Metric Units

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 [b]
				%	gauge length	Brinell	Vickers		
Plate Sheet Strip	Annealed	22	5	48	$5.65\sqrt{S_o}$	45	50	16	—
	Hot Rolled [c]	23	8	40	$5.65\sqrt{S_o}$	55	60	16	—
	Typical Cold Worked Tempers	27	18	25	$5.65\sqrt{S_o}$	75	80	18	0.2–10 mm thick
		32	27	12	$5.65\sqrt{S_o}$	90	100	19	0.2– 6 mm thick
		38	34	6	$5.65\sqrt{S_o}$	105	115	20	0.2– 1.5 mm thick
Rod	Annealed	22	5	45	$5.65\sqrt{S_o}$	45	50	16	—
	Typical Cold Worked Tempers	28	19	20	$5.65\sqrt{S_o}$	75	80	18	6–40 mm diam. or equivalent area
		34	28	10	$5.65\sqrt{S_o}$	95	105	19	6–20 mm diam. or equivalent area
Tube	Annealed	**24**	**6**	**45**	$5.65\sqrt{S_o}$	**45**	**50**	**16**	—
	Typical Cold Drawn Tempers [d]	**27**	**18**	**30**	$5.65\sqrt{S_o}$	**75**	**80**	**18**	10–200 mm O.D. up to 10 mm wall
		32	**27**	**15**	$5.65\sqrt{S_o}$	**90**	**100**	**19**	10–100 mm O.D. up to 6 mm wall
		35	30	8	$5.65\sqrt{S_o}$	100	110	20	10– 50 mm O.D. up to 2 mm wall
		38	35	6	$5.65\sqrt{S_o}$	105	115	20	up to 25 mm O.D. up to 1 mm wall

(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, English and American units respectively, are not directly comparable. This is because the properties quoted reflect to some extent the metalworking techniques and specification practices of the countries concerned.

(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.

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

5.1.2 Typical Tensile Properties and Hardness Values - English Units

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 ton/in²	Proof Stress 0.1 % offset ton/in²	Elongation		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown [a]
				%	gauge length			
Plate Sheet Strip	Annealed	14	3	50	2 in.	50	10	—
	Hot Rolled [b]	15	6	45	2 in.	65	10	—
	Typical Cold Worked Tempers	16 17 23	9 14 20	45 30 10	2 in. 2 in. 2 in.	75 85 110	11 11 13	0.006–0.5 in. thick 0.006–0.25 in. thick 0.006–0.1 in. thick
Rod	Annealed	14	3	50	$5.65\sqrt{S_o}$	50	10	—
	Typical Cold Worked Tempers	17 20	13 16	30 17	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	85 105	11 12	0.25–1 in. diam. or equivalent area "
Tube	Annealed	15	5	50	2 in.	50	10	—
	Typical Cold Drawn Tempers [c]	17 20 **18** **24**	10 17 **12** **21**	45 20 **30** **10**	2 in. 2 in. 2 in. 2 in.	80 100 **85** **110**	11 12 **12** **13**	4–8 in. O.D. up to 0.5 in. wall " 0.5–4 in. O.D. up to 0.2 in. 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 of the product.

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

5.1.3 Typical Tensile Properties and Hardness Values - American Units

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 psi	Yield Strength 0.5 % extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [b]
				%	gauge length	F	B	30 T		
Flat Products (Plate, Sheet, Strip and Bar)	As Hot Rolled	34 000	10 000	45	2 in.	45	—	—	23 000	0.040 in. thick
	Annealed	32 000	10 000	45	2 in.	40	—	—	22 000	0.040 in. thick
	Cold Worked									
	Hard	50 000	45 000	6	2 in.	90	50	57	28 000	0.040 in. thick
	Hard	50 000	45 000	12	2 in.	90	50	—	28 000	0.250 in. thick
	Hard	45 000	40 000	20	2 in.	85	45	—	26 000	1.0 in. thick
Rod	As Hot Rolled	32 000	10 000	55	2 in.	40	—	—	22 000	1.0 in. diam.
	Soft	32 000	10 000	55	2 in.	40	—	—	22 000	1.0 in. diam.
	Cold Worked									
	Hard	48 000	44 000	16	2 in.	87	47	—	27 000	1.0 in. diam.
Tube	Annealed	32 000	10 000	45	2 in.	40	—	—	22 000	1.0 in. O.D. × 0.065 in. wall
	Cold Worked [c]									
	Light Drawn	**40 000**	**32 000**	**25**	2 in.	**77**	**35**	**45**	**26 000**	1.0 in. O.D. × 0.065 in. wall
	Drawn	42 000	35 000	17	2 in.	85	—	—	27 000	,,
	Hard Drawn	**55 000**	**50 000**	**8**	2 in.	**95**	**60**	**63**	**29 000**	,,

(a) The tempers listed are those referred to in ASTM and other American Standards.

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

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties - Impact Properties

Form	Temper	Testing Temperature		Tensile Strength [a]			Elongation %	Reduction of Area	Impact Strength [b]	
		°C	°F	kg/mm²	ton/in²	psi	on 2 in.	%	kg m/cm²	ft lb
Plate [1] 12.7–19 mm 0.5–0.75 in.	Annealed	+ 20	+ 68	25	**15.9**	35 500	**35**	**59**	19.4	**112**
		– 50	– 58	—	—	—	—	—	20.7	**120**
		– 100	– 148	—	—	—	—	—	22.1	**128**
		– 120	– 184	30.5	**19.5**	43 500	**36**	**53.5**	—	—
		– 150	– 238	32	**20.4**	45 500	**37**	**54.5**	22.1	**128**
		– 196	– 321	40	**25.4**	57 000	**38**	**53.5**	21.4	**124**

(a) Tipper notched tensile test; section of notch 19.3 × 15.5 mm (0.760 × 0.610 in.).
(b) Charpy test; 10 × 10 × 100 mm specimen; 45° V-notch, 2 mm deep; cross-sectional area 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.
— Data not available:
Proof Stress 0.1 % and 0.2 % offset,
Yield Strength 0.5 % extension under load.

5.2.2 Navy Tear Test

Form	Temper	Testing Temperature		Maximum Load			Corrected Energy Values: initiation		propagation		total		Reduction of Plate Thickness at Fracture		
		°C	°F	kg	ton	lb	kg m	ft lb	kg m	ft lb	kg m	ft lb	mm	in.	%
Plate [1] 12.7–19 mm 0.5–0.75 in.	Annealed	+ 20	+ 68	9 500	**9.5**	**21 500**	**54**	**392**	309	**2 236**	363.5	**2 628**	10.03	**0.395**	**52.5**
		– 150	– 238	12 000	**11.85**	**26 500**	**99.5**	**721**	326.5	**2 362**	426	**3 083**	8.64	**0.340**	**45.5**
		– 196	– 321	14 000	**13.55**	**30 500**	**89**	**644**	441.5	**3 193**	530.5	**3 837**	8.13	**0.320**	**42.2**

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation % on 2 in.
		°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	
Plate (2) **14 mm 0.56 in.**	Annealed	20	68	24	**15.1**	34 000	—	—	—	**57**
		200	392	20	**12.71**	28 500	—	—	—	**47.75**
		300	572	18	**11.49**	25 500	—	—	—	**38**
		400	752	15.5	**9.92**	22 000	—	—	—	**36**
		500	932	12.5	**7.85**	17 500	—	—	—	**36**
Plate (3)	Annealed	20	68	26	**16.6**	37 000	12.9 (a)	**7.8**	—	**49**
		65	150	24	**15.1**	34 000	12.8 (a)	**7.5**	—	**51**
		121	250	22.5	**14 2**	32 000	12.4 (a)	**7.3**	—	**47**
		177	350	20.5	**13.1**	29 500	11.7 (a)	**6.8**	—	**44**
		204	400	20.5	**12.9**	29 000	11.7 (a)	**7.0**	—	**45**
	Hot Rolled	20	68	22.5	**14.2**	32 000	9.92 (a)	**6.0**	—	**57**
		65	150	22.5	**14.2**	32 000	9.92 (a)	**6.0**	—	**57**
		121	250	21	**13.2**	29 500	9.76 (a)	**6.0**	—	**57**
		177	350	19	**12.2**	27 500	9.76 (a)	**5.8**	—	**52**
		204	400	18.5	**11.9**	26 500	9.13 (a)	**5.4**	—	**52**
	Half Hard (b)	20	68	29	**18.4**	41 000	26.3 (a)	**15.8**	—	**29**
		65	150	27	**17.0**	38 000	25.2 (a)	**15.0**	—	**27**
		121	250	26	**16.5**	37 000	24.6 (a)	**14.7**	—	**22**
		177	350	25	**15.8**	35 500	23.5 (a)	**14.2**	—	**17**
		204	400	23.5	**14.9**	33 500	22.4 (a)	**13.5**	—	**16**
	Hard (c)	20	68	35	**22.3**	50 000	31.7 (a)	**18.6**	—	**15**
		65	150	32.5	**20.8**	46 500	31.0 (a)	**18.1**	—	**11**
		121	250	31.5	**20.0**	45 000	29.8 (a)	**17.1**	—	**9**
		177	350	30	**18.9**	42 500	28.2 (a)	**16.8**	—	**9**
		204	400	29	**18.4**	41 000	27.4 (a)	**16.2**	—	**9**
Sheet (4) **2 mm 0.08 in.**	Annealed (grain size 0.030 mm)	20	68	25	**15.9**	35 500	—	**3.3**	—	**50**
		100	212	23.5	**14.8**	33 000	—	**3.2**	—	**45**
		200	392	21.5	**13.8**	31 000	—	**3.1**	—	**42**
		300	572	19	**12.0**	27 000	—	**2.8**	—	**41**
		400	752	15	**9.5**	21 500	—	**2.5**	—	**42**
		500	932	9.5	**6.1**	13 500	—	**1.9**	—	**53**
Rod (5) **3.2 mm diam. 0.125 in. diam.**	Annealed (grain size 0.045 mm)	24	75	24.5	15.5	**35 000**	3.66 (d)	—	**6 100**	**49.0**
		149	300	—	—	—	—	—	**5 300**	—
		204	400	—	—	—	—	—	**5 000**	—
		260	500	—	—	—	—	—	**4 800**	—

(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 'half hard' in original document, but amount of cold work not defined.
(c) Quoted as 'hard' in original document, but amount of cold work not defined.
(d) 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.

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 1 000 h	Total Extension % [a]	Intercept %	Min. Creep Rate % per 1 000 h
Rod [5] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.045 mm)	149	300	2	1	**3 000**	**6.50**	**0.055**	**0.013**	**< 0.000 1**
				3.5	2	**5 200**	**6.40**	**0.580**	**0.085**	**0.002 35**
				5	3	**7 200**	**6.40**	**1.236**	**0.122**	**0.006 2**
				5.5	3.5	**7 950**	**6.50**	**1.560**	**0.185**	**0.008 5**
				7	4.5	**10 250**	**6.40**	**2.537**	**0.275**	**0.019**
		204	400	1	0.9	**2 050**	**6.50**	**0.037**	**0.007**	**< 0.001**
				2	1	**3 050**	**6.00**	**0.119**	**0.040**	**0.002 3**
				2.5	1.5	**4 000**	**6.50**	**0.433**	**0.158**	**0.006 2**
				3.5	2	**5 600**	**6.00**	**1.055**	**0.295**	**0.014**
				4.5	3	**7 100**	**6.00**	**1.648**	**0.365**	**0.022**
		260	500	0.7	0.4	**1 000**	**6.50**	**0.027**	**0.014**	**0.000 5**
				1	0.9	**2 050**	**6.86**	**0.107**	**0.049**	**0.005 5**
				2	1.5	**3 550**	**6.86**	**0.678**	**0.335**	**0.024**
				4	2.5	**6 250**	**6.00**	**2.584**	**0.700**	**0.152**
	Cold Worked 84 %	149	300	8.5	5.5	**12 400**	**6.40**	**0.089**	**0.017**	**0.000 24**
				14	8.5	**20 150**	**6.50**	**0.153**	**0.033**	**0.000 5**
				21	13	**30 100**	**6.50**	**0.282**	**0.089**	**0.001 6**
				28	17.5	**40 000**	**6.00**	**0.426**	**0.114**	**0.008 75**
				28	17.5	**40 000**	**9.45**	**0.452**	**0.118**	**0.007 8**
				33	21	**47 200**	**0.50**	**0.750**	**0.160**	**0.42**
				33	21	**47 200**	**0.75**	**0.910**	—	—
		204	400	3.5	2	**5 050**	**6.50**	**0.044**	**0.008**	**0.000 1**
				6	3.5	**8 950**	**6.00**	**0.097**	**0.032**	**0.000 5**
				10.5	6.5	**15 250**	**6.00**	**0.175**	**0.058**	**0.001 9**
				14	8.5	**20 100**	**6.50**	**0.226**	**0.070**	**0.002 7**
				21	13.5	**30 500**	**6.00**	**0.517**	**0.208**	**0.016**
				28	17.5	**40 000**	**0.36**	**0.968**	**0.252**	**1.18**
				28	17.5	**40 000**	**1.85**	**5.058**	—	—
		260	500	1	0.6	**1 550**	**6.00**	**0.029**	**0.001 5**	**0.001 45**
				1	0.9	**2 050**	**6.00**	**0.075**	**−0.012**	**0.012** [b]
				2	1.5	**3 550**	**7.30**	**0.605**	**−0.187**	**0.105** [b]
				3.5	2	**5 000**	**6.50**	**0.933**	**−0.672**	**0.24** [b]

[a] Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
[b] Accelerating creep rate.
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
Rod [5] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.045 mm)	149	300	2.5	1.5	**4 000** [a]	5.5	3.5	**8 400**	> 7	> 4	**>10 000**
		204	400	1.5	0.9	**2 200**	3.5	2	**5 200**	> 4.5	> 3	**> 7 000**
		260	500	0.8	0.5	**1 250**	1.5	1	**2 600**	3.5	2	**5 500**
	Cold Worked 84 %	149	300	18	11.5	**26 000**	28	17.5	**40 000**	32	20.5	**46 000**
		204	400	8.5	5.5	**12 800**	19	12	**27 500**	24.5	15.5	**35 500**
		260	500	1	0.6	**1 500**	1	0.8	**2 000**	2.5	1.5	**3 750**

[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 × 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
Tube [6] **19 mm O.D. 1.25 mm wall** **0.75 in. O.D. 0.049 in. wall**	Annealed	20	26	10.5 [a]	16.5	6.5 [a]	**37 000**	**15 000** [a]

[a] Rotating-beam test.

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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Printed in England by Impress (Worcester) Ltd.

SILVER-BEARING TOUGH-PITCH COPPER

(Low Silver)

Cu-LSTP

Common name: Silver Copper

A high-conductivity oxygen-bearing copper containing silver either naturally or as an added alloying element. The material has greater resistance to softening and creep than unalloyed high-conductivity copper at moderately elevated temperatures.

COMPOSITION (weight %)

Cu (+ Ag) . . .	99.90 min.
Ag	0.02–0.12

1 SOME TYPICAL USES

Electrical

Windings, including hollow conductors for large generators and other heavy-duty rotating machines; commutator segments; busbars; contacts and switches; induction coils; integrated circuit lead frames.

Mechanical

Strip for automobile radiators and other heat exchangers; photogravure printing plates.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.9 g/cm³	0.321 lb/in³
2.2 Melting point	1 082 [a] °C	1 980 [a] °F
2.3 Coefficient of thermal expansion (linear) at:		
− 183 °C *− 297 °F*	0.000 009 5 per °C	0.000 005 28 per °F
− 191 to 16 °C *− 312 to 61 °F*	0.000 014 1 „ „	0.000 007 83 „ „
20 to 100 °C *68 to 212 °F*	0.000 016 8 „ „	0.000 009 33 „ „
20 to 300 °C *68 to 572 °F*	0.000 017 7 „ „	0.000 009 83 „ „
2.4 Specific heat (thermal capacity) at:		
− 150 °C *− 238 °F*	0.069 cal/g °C	0.069 Btu/lb °F
− 50 °C *− 58 °F*	0.087 „	0.087 „
20 °C *68 °F*	0.092 „	0.092 „
100 °C *212 °F*	0.094 „	0.094 „
200 °C *392 °F*	0.097 „	0.097 „
2.5 Thermal conductivity at:		
− 200 °C *− 328 °F*	1.37 cal cm/cm² s °C	330 Btu ft/ft² h °F
− 183 °C *− 297 °F*	1.13 „	270 „
− 100 °C *− 148 °F*	1.04 „	252 „
20 °C *68 °F*	0.94 „	227 „
100 °C *212 °F*	0.92 „	223 „
200 °C *392 °F*	0.91 „	220 „
300 °C *572 °F*	0.90 „	217 „
2.6 Electrical conductivity (volume) at:		
− 200 °C *− 328 °F* (annealed) [b]	460 [a] m/ohm mm²	800 [a] % IACS
− 100 °C *− 148 °F* („) [b]	110 [a] „	190 [a] „ „
20 °C *68 °F* („)	57.4–58.6 „	99–101 „ „
100 °C *212 °F* („) [b]	44 „	76 „ „
200 °C *392 °F* („) [b]	34 „	58 „ „
20 °C *68 °F* (fully cold worked) [b]	56.3 „	97 „ „

continued overleaf

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

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DATA SHEET No. B 2
Cu-LSTP
© 1968 Edition

PHYSICAL PROPERTIES (continued)	Metric Units	English Units
2.7 Electrical resistivity (volume) at:		
− 200 °C *− 328 °F* (annealed)[b]	0.002 2[a] ohm mm^2/m 0.22[a] microhm cm	1.3[a] ohms (circ mil/ft) 0.085[a] microhm in
− 100 °C *− 148 °F* („)[b]	0.009 1[a] ohm mm^2/m 0.91[a] microhm cm	5.5[a] ohms (circ mil/ft) 0.36[a] microhm in
20 °C *68 °F* („)	0.017 4–0.017 1 ohm mm^2/m 1.74–1.71 microhm cm	10.5–10.3 ohms (circ mil/ft) 0.686–0.672 microhm in
100 °C *212 °F* („)[b]	0.022 7 ohm mm^2/m 2.27 microhm cm	13.6 ohms (circ mil/ft) 0.89 microhm in
200 °C *392 °F* („)[b]	0.029 5 ohm mm^2/m 2.95 microhm cm	17.7 ohms (circ mil/ft) 1.16 microhm in
20 °C *68 °F* (fully cold worked)[b]	0.017 8 ohm mm^2/m 1.78 microhm cm	10.7 ohms (circ mil/ft) 0.700 microhm in
2.8 Temperature coefficient of electrical resistance at:[c]		
20 °C *68 °F* (annealed) applicable over range from − 100 to 200 °C *− 148 to 392 °F*	0.003 93 per °C (100% IACS)	0.002 18 per °F (100% IACS)
20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.003 81 „ „ (97% IACS)	0.002 12 „ „ (97% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F:*		
annealed	12 000 kg/mm^2	17 000 000 lb/in^2
cold worked	12 000–13 500 „	17 000 000–19 000 000 „
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F:*		
annealed	4 500 kg/mm^2	6 400 000 lb/in^2
cold worked	4 500 – 5 000 „	6 400 000 – 7 000 000 „

(a) Approximate value.

(b) Based on annealed copper having a conductivity of 100% IACS (58.00 m/ohm mm^2) at 20 °C *(68 °F)*.

(c) —The temperature coefficients of resistance given can be used for calculating resistances within the temperature range shown, but these relate only to calculations based on a reference temperature of 20 °C *(68 °F)*. If it is more convenient to base calculations upon some other reference temperature, different temperature coefficients of resistance must be applied; for example, in the case of annealed copper (100% IACS), the temperature coefficient of resistance at 20 °C *(68 °F)* is 0.003 93 per °C *(0.002 18 per °F)* whereas at 0 °C *(32 °F)* the value is 0.004 265 per °C *(0.002 37 per °F)*.

—The change in resistance of annealed copper with temperature is essentially linear over a very wide range of temperature. Thus, although a range of only 0 to 100 °C *(32 to 212 °F)* is usually quoted for the temperature coefficient at 20 °C *(68 °F)*, the same coefficient may be used for calculations within the wider range of −100 to 200 °C *(−148 to 392 °F)* without introducing an error greater than 1%.

—Comparatively little information is available on the resistance/temperature relationship for cold-worked copper and there is, therefore, less justification for extending the range for its coefficient beyond 0 to 100 °C *(32 to 212 °F)*.

—The temperature coefficient of resistance of copper can be assumed to be directly proportional to the conductivity value. Thus, for copper of 101% IACS conductivity, the coefficient can be deduced by adding 1% to the value relating to copper of 100% IACS conductivity, i.e. the temperature coefficient corresponding to 101% IACS conductivity can be taken to be 0.003 97 per °C *(0.002 20 per °F)*. However, as the use of this modified coefficient changes the calculated value of resistance at 100 °C *(212 °F)* by less than 0.5%, adjustment of the temperature coefficient to take account of minor variations in conductivity is rarely considered to be worth while.

N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition range involved, are based partially on selected literature references and also upon values for Cu-ETP (electrolytic 'tough-pitch' copper).

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 [(a)]	1 120–1 200 °C	2 050–2 190 °F
3.2 Annealing temperature range [(b)]	350– 650 °C	660–1 200 °F
Stress relieving temperature range [(b)]	225– 275 °C	440– 530 °F
3.3 Hot working temperature range [(b)]	750– 950 °C	1 400–1 750 °F
3.4 Hot formability [(b)]	Good	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	90 % max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	20	
3.8 Joining methods [(b)]:	See General Data Sheet No. 3.2	
Soldering	Excellent	
Brazing	Good	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Not recommended	
butt	Good	

(a) Optimum casting temperature range 1 120–1 150 °C (*2 050–2 100 °F*).
(b) Embrittlement will occur if this material is heated in atmospheres containing an excess of hydrogen.

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

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	Cu Ag	—	266.02	266.02	266.02	—	266.02	—
Canada	CSA	Cu-STP 114	—	HC.4.1	—	—	—	—	—
Chile	INDITECNOR	CuAg TP	245 n.68	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	E-CuAg (2.1202)	17 666	40 500, Bl.1	40 500, Bl.3	40 500, Bl.4	—	—	—
Italy	UNI	Cu-STP	5649	—	—	—	—	—	—
Netherlands	N or NEN [b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	14 50 30	—	—	—	—	—	—	—
Switzerland	VSM	Cu-LSTP	10826	11852	11852	11852	—	11852	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States [c]	ASTM	Nos. 113, 114 115, 116 or STP	—	B48 B124 B133 B152 B187 B272	B49 B124 B133 B152 B187	B1 B2 B3 B33 B47 B48	B188	B124 B133 B187	—

(a) Applicable when the chemical composition is not given in the specifications for wrought forms.
(b) Older specifications bear prefix N; for new specifications the NEN prefix is used.
(c) In the United States bar and flat wire are covered under the Plate-Sheet-Strip column.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

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

5.2 Mechanical properties at low temperature

Tensile properties	no data traced
Impact properties	„ „ „

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 [(a)]

5.1.1 Typical Tensile Properties and Hardness Values - Metric Units

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 [(b)]
				%	gauge length	Brinell	Vickers		
Plate Sheet Strip	Annealed	22	5	48	$5.65\sqrt{S_o}$	45	50	16	—
	Hot Rolled [(c)]	23	8	40	$5.65\sqrt{S_o}$	55	60	16	—
	Typical Cold Worked Tempers	27	18	25	$5.65\sqrt{S_o}$	75	80	18	0.2 – 10 mm thick
		32	27	12	$5.65\sqrt{S_o}$	90	100	19	0.2 – 6 mm thick
		38	34	6	$5.65\sqrt{S_o}$	105	115	20	0.2 – 1.5 mm thick
Rod	Annealed	22	5	45	$5.65\sqrt{S_o}$	45	50	16	—
	Typical Cold Worked Tempers	28	19	20	$5.65\sqrt{S_o}$	75	80	18	6–40 mm diam. or equivalent area
		34	28	10	$5.65\sqrt{S_o}$	95	105	19	6–20 mm diam. or equivalent area
Wire	Annealed	23	—	37	200 mm	—	—	16	over 3 mm diam.
		24	—	35	200 mm	—	—	16	1–3 mm diam.
		26	—	28	200 mm	—	—	17	0.5–1 mm diam.
		—	—	26	200 mm	—	—	—	0.2–0.5 mm diam.
	Typical Cold Drawn Tempers	38	—	—	—	—	—	20	over 6 mm diam.
		42	—	—	—	—	—	22	3–6 mm diam.
		45	—	—	—	—	—	23	up to 3 mm diam.
Tube	Annealed	24	6	45	$5.65\sqrt{S_o}$	45	50	16	—
	Typical Cold Drawn Tempers	27	18	30	$5.65\sqrt{S_o}$	75	80	18	10–200 mm O.D. up to 10 mm wall
		32	27	15	$5.65\sqrt{S_o}$	90	100	19	10–100 mm O.D. up to 6 mm wall
		35	30	8	$5.65\sqrt{S_o}$	100	110	20	10– 50 mm O.D. up to 2 mm wall
		38	35	6	$5.65\sqrt{S_o}$	105	115	20	up to 25 mm O.D. up to 1 mm wall
Sections / Shapes	Hot Worked [(c)]	24	8	35	$5.65\sqrt{S_o}$	50	55	16	—
	Typical Cold Worked Tempers [(c)]	27	18	20	$5.65\sqrt{S_o}$	75	80	18	—
		32	27	10	$5.65\sqrt{S_o}$	90	100	19	—

(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, English and American units respectively, are not directly comparable. This is because the properties quoted reflect to some extent the metalworking techniques and specification practices of the countries concerned.

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

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

5.1.2 Typical Tensile Properties and Hardness Values - English Units

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 ton/in²	Proof Stress 0.1 % offset ton/in²	Elongation %	Elongation gauge length	Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown [(a)]
Plate Sheet Strip	Annealed	14	3	50	2 in.	50	10	—
	Hot Rolled [(b)]	15	6	45	2 in.	65	10	—
	Typical Cold Worked Tempers	16	9	45	2 in.	75	11	0.006–0.5 in. thick
		17	14	30	2 in.	85	11	0.006–0.25 in. thick
		23	20	10	2 in.	110	13	0.006–0.1 in. thick
Rod	Annealed	14	3	50	$5.65\sqrt{S_o}$	50	10	—
	Typical Cold Worked Tempers	17	13	30	$5.65\sqrt{S_o}$	85	11	0.25–1 in. diam. or equivalent area
		20	16	17	$5.65\sqrt{S_o}$	105	12	"
Wire	Annealed	14	—	35	10 in.	—	10	over 0.05 in. diam.
		15	—	30	10 in.	—	10	over 0.036 up to 0.05 in. diam.
		16	—	25	10 in.	—	11	over 0.02 up to 0.036 in. diam.
		—	—	20	10 in.	—	—	over 0.005 up to 0.02 in. diam.
	Typical Cold Drawn Tempers	26	—	—	—	—	14	over 0.104 in. diam.
		29	—	—	—	—	15	over 0.064 up to 0.104 in. diam.
		30	—	—	—	—	15	up to 0.064 in. diam.
Tube	Annealed	15	5	50	2 in.	50	10	—
	Typical Cold Drawn Tempers	17	10	45	2 in.	80	11	4–8 in. O.D. up to 0.5 in. wall
		20	17	20	2 in.	100	12	"
		18	12	30	2 in.	85	12	0.5–4 in. O.D. up to 0.2 in. wall
		24	21	10	2 in.	110	13	"
Sections (extruded)	Typical Cold Drawn Tempers [(b)]	16	11	27	$5.65\sqrt{S_o}$	80	10	—
		20	16	15	$5.65\sqrt{S_o}$	105	12	—

(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.

5.1.3 Typical Tensile Properties and Hardness Values - American Units

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 psi	Yield Strength 0.5 % extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [b]
				%	gauge length	F	B	30 T		
Flat Products (Plate, Sheet, Strip, Bar and Flat Wire)	As Hot Rolled	34 000	10 000	45	2 in.	45	—	—	23 000	0.040 in. thick
	Annealed	32 000	10 000	45	2 in.	40	—	—	22 000	0.040 in. thick
	Cold Worked									
	Light Cold Rolled	36 000	28 000	30	2 in.	60	10	25	25 000	0.040 in. thick
	Half Hard	42 000	36 000	14	2 in.	84	40	50	26 000	"
	Hard	50 000	45 000	6	2 in.	90	50	57	28 000	"
	Spring	55 000	50 000	4	2 in.	94	60	63	29 000	"
	Extra Spring	57 000	53 000	4	2 in.	95	62	64	29 000	"
	Light Cold Rolled	36 000	28 000	40	2 in.	60	10	—	25 000	0.250 in. thick
	Hard	50 000	45 000	12	2 in.	90	50	—	28 000	"
	Hard	45 000	40 000	20	2 in.	85	45	—	26 000	1.0 in. thick
Rod	As Hot Rolled	32 000	10 000	55	2 in.	40	—	—	22 000	1.0 in. diam.
	Soft	32 000	10 000	55	2 in.	40	—	—	22 000	1.0 in. diam.
	Cold Worked									
	Hard	48 000	44 000	16	2 in.	87	47	—	27 000	1.0 in. diam.
Wire	Annealed - Soft	40 000	—	17	10 in.	—	—	—	—	0.008–0.020 in. diam.
		38 000	—	23	10 in.	—	—	—	—	0.021–0.039 in. diam.
		35 000	—	27	10 in.	—	—	—	—	0.040–0.118 in. diam.
		35 000	—	33	10 in.	—	—	—	—	over 0.118 in. diam.
	Cold Worked									
	Medium Hard Drawn	56 000	—	1	60 in.	—	—	—	—	0.008–0.039 in. diam.
	Hard Drawn	67 000	—	1	60 in.	—	—	—	—	"
	Medium Hard Drawn	54 000	—	1.5	60 in.	—	—	—	—	0.040–0.118 in. diam.
	Hard Drawn	65 000	—	1	60 in.	—	—	—	—	"
	Medium Hard Drawn	49 000	—	2.5	10 in.	—	—	—	—	over 0.118 in. diam.
	Hard Drawn	57 000	—	2	10 in.	—	—	—	—	"
Tube	Annealed	32 000	10 000	45	2 in.	40	—	—	22 000	1.0 in. O.D. × 0.065 in. wall
	Cold Worked									
	Light Drawn	40 000	32 000	25	2 in.	77	35	45	26 000	1.0 in. O.D. × 0.065 in. wall
	Drawn	42 000	35 000	17	2 in.	85	—	—	27 000	"
	Hard Drawn	55 000	50 000	8	2 in.	95	60	63	29 000	"
Shapes	As Hot Rolled	32 000	10 000	50	2 in.	40	—	—	22 000	0.50 in. thick
	Annealed - Soft	32 000	10 000	50	2 in.	40	—	—	22 000	0.50 in. thick
	Cold Worked									
	Hard	40 000	32 000	30	2 in.	—	35	—	26 000	0.50 in. thick
Forgings	As Forged [c]	33 000	11 000	45	2 in.	37	—	—	23 000	—

(a) The tempers listed are those referred to in ASTM and other American Standards.

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

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

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 % on 2 in.
		°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	
Sheet (1) 2 mm 0.08 in.	Annealed (grain size 0.030 mm)	20	68	23	**14.7**	33 000	—	**3.1**	—	**53**
		100	212	21	**13.4**	30 000	—	**3.0**	—	**49**
		200	392	18.5	**11.8**	26 500	—	**2.9**	—	**47**
		300	572	16.5	**10.5**	23 500	—	**2.9**	—	**45**
		400	752	15	**9.5**	21 500	—	**2.4**	—	**44**
		500	932	11	**6.9**	15 500	—	**2.1**	—	**42**
Strip (2)	Cold Worked (a)	20	68	35	22.5	**50 000**	**33.0** (b)	—	—	**8.5**
		288	550	24.5	15.5	**35 000**	**19.7** (b)	—	—	**12.1**
Rod (3) 3.2 mm diam. 0.125 in. diam.	Cold Worked 84 %	24	75	41.5	26.5	**59 300**	—	—	**54 100**	**8.5**
		149	300	—	—	—	—	—	**47 000**	—

(a) Quoted as 'cold rolled to RB 61' hardness, in original document, but amount of cold work not defined.
(b) 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.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration 1 000 h	Total Extension % [a]	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Strip [4] 2.5 mm 0.1 in.	Annealed (grain size 0.030 mm)	130	266	14	8.5	20 000	2.40	15.8	14.7	1.05
		175	347	9.5 14	6 8.5	14 000 20 000	2.60 2.40	7.0 27.4	6.7 23.2	0.35 1.85
		225	437	4 9.5	2.5 6	6 000 14 000	3.00 2.50	0.9 10.6	0.6 8.0	0.02 1.1
	Cold Worked 10 %	130	266	5.5 9.5 14	3.5 6 8.5	8 000 14 000 20 000	4.75 9.80 7.20	0.09 0.17 0.325	0.08 0.145 0.29	0.000 4 0.002 4 0.007
		175	347	5.5 9.5 14	3.5 6 8.5	8 000 14 000 20 000	4.85 12.90 4.90	0.13 0.28 0.565	0.11 0.22 0.43	0.006 5 0.008 2 0.03
		225	437	5.5 9.5	3.5 6	8 000 14 000	8.90 12.90	0.26 0.865	0.175 0.34	0.009 8 0.037
	Cold Worked 25 %	130	266	5.5 9.5 14	3.5 6 8.5	8 000 14 000 20 000	4.75 10.20 7.20	0.08 0.18 0.26	0.075 0.16 0.24	0.002 0.004 0.005
		175	347	5.5 9.5 14	3.5 6 8.5	8 000 14 000 20 000	4.90 12.90 10.30	0.16 0.25 0.43	0.14 0.18 0.33	0.003 0.005 0.011
		225	437	5.5 9.5 14	3.5 6 8.5	8 000 14 000 20 000	8.90 11.50 9.87	0.21 0.56 1.7 [b]	0.14 0.38 0.43	0.006 4 0.017 0.105
	Cold Worked 50 %	130	266	5.5 9.5 14	3.5 6 8.5	8 000 14 000 20 000	4.55 11.40 7.25	0.09 0.20 0.29	0.08 0.185 0.265	0.001 5 0.001 5 0.004
		175	347	5.5 9.5 14	3.5 6 8.5	8 000 14 000 20 000	6.90 12.90 3.70	0.135 0.285 0.39	0.115 0.25 0.315	0.004 0.006 0.021
		225	437	5.5 9.5 14	3.5 6 8.5	8 000 14 000 20 000	8.90 12.90 3.00	0.26 0.795 0.825	0.15 0.335 0.525	0.011 0.029 0.10
Strip [2]	Cold Worked [c]	288	550	21 17.5 15 10.5	13 11 9.5 6.5	30 000 25 000 22 000 15 000	0.001 05 [b] 0.020 [b] 0.040 [b] 0.170 [b]	— — — —	— — — —	— — — —
Rod [3] 3.2 mm diam. 0.125 in. diam.	Cold Worked 84 %	149	300	6.5 10.5 14 17.5 21 28	4 6.5 8.5 11 13 17.5	9 900 15 000 19 950 24 950 30 000 40 000	7.25 7.25 7.08 7.08 6.00 6.00	0.079 9 0.112 0.181 0.224 0.305 0.870	0.016 9 0.013 8 0.043 6 0.051 5 0.089 8 0.268	<0.000 1 0.000 3 0.001 0.001 6 0.002 9 0.055

continued overleaf

5.3.2.1 Original Creep Data (continued)

Form	Temper	Testing Temperature		Stress			Duration 1 000 h	Total Extension % [a]	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Square Wire [5] 6.5 mm 0.257 in.	Cold Worked 5 %	300	572	5	3	**7 500**	**1.440** [d]	**0.345**	—	**6.3** [f]
				8.5	5.5	**12 500**	**1.440** [d]	**0.755**	—	**19.2** [f]
				5	3	**7 500**	**1.240** [d]	**0.35**	—	**4.7** [g]
				7	4	**10 000**	**1.275** [d]	**0.48**	—	**7.8** [g]
				5	3	**7 500**[e]	**1.410** [d]	**0.43**	—	**5.4** [g]
				7	4	**10 000**[e]	**1.340** [d]	**0.45**	—	**7.8** [g]
				5	3	**7 500**	**1.400** [d]	**0.40**	—	**5.7** [g]
				7	4	**10 000**	**1.250** [d]	**0.465**	—	**9.6** [g]
				5	3	**7 500**[e]	**1.200** [d]	**0.39**	—	**6.0** [g]
				7	4	**10 000**[e]	**1.340** [d]	**0.625**	—	**10.2** [g]
	Cold Worked 20 %	300	572	5	3	**7 500**	**1.395** [d]	**0.420**	—	**10.0** [f]
				8.5	5.5	**12 500**	**1.415** [d]	**0.870**	—	**24.6** [f]
				12	7.5	**17 500**	**0.315** [d]	**1.060**	—	— [f]
				8.5	5.5	**12 500**	**1.440** [d]	**1.075**	—	**30.0** [g]
	Cold Worked 30 %	300	572	5	3	**7 500**	**1.370** [d]	**0.370**	—	**9.4** [f]
				8.5	5.5	**12 500**	**1.380** [d]	**0.940**	—	**22.0** [f]
	Cold Worked 40 %	300	572	5	3	**7 500**	**1.400** [d]	**0.405**	—	**12.5** [f]
				8.5	5.5	**12 500**	**1.400** [d]	**0.970**	—	**27.2** [f]
				8.5	5.5	**12 500**	**1.340** [d]	**1.050**	—	**31.0** [g]

(a) Total extension = Initial extension + Total Creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Rupture test. (c) Quoted as 'cold rolled to RB 61' hardness in original document, but amount of cold work not defined.
(d) Duration in 1 000 minutes. (e) Compression test. (f) Creep tests performed on material containing 0.063% Ag. (g) Creep tests performed on material containing 0.072% Ag.

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

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 [3] 3.2 mm diam. 0.125 in. diam.	Cold Worked 84 %	149	300	15	9.5	**22 000**	25	16	**36 000**	28.5	18	**41 000**

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

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

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Mechanical Properties of Copper. Imperial Metal Industries Ltd., England, July 1965.
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(3) 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).
(4) Benson, N.D., McKeown, J. and Mends, D. N. The Creep and Softening Properties of Copper for Alternator Rotor Windings. J. Inst. Metals, Vol. 80 (1951-52), pp. 131-142.
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SILVER-BEARING OXYGEN-FREE COPPER

Cu-OFS

Common name: Silver Copper

A high-conductivity copper made by remelting of cathodes and containing silver as an added alloying element. Melting and casting take place under conditions which ensure freedom from oxide and deoxidants. The material has greater resistance to softening and creep than unalloyed high-conductivity copper at moderately elevated temperatures and is not embrittled when heated in a reducing atmosphere.

COMPOSITION (weight %)

Cu (+ Ag) . .	99.95 min.
Ag . . .	0.02–0.12

1 SOME TYPICAL USES

Electrical

Glass-to-metal seals in electronic equipment; transistor and rectifier bases; windings, including hollow conductors, for large generators and other heavy-duty rotating machines; commutator segments; busbars; contacts and switches.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.9 g/cm³	0.321 lb/in³
2.2 Melting point	1 082[(a)] °C	1 980[(a)] °F
2.3 Coefficient of thermal expansion (linear) at:		
−183 °C *−297 °F*	0.000 009 5 per °C	0.000 005 28 per °F
−191 to 16 °C *−312 to 61 °F*	0.000 014 1 ,, ,,	0.000 007 83 ,, ,,
20 to 100 °C *68 to 212 °F*	0.000 016 8 ,, ,,	0.000 009 33 ,, ,,
20 to 300 °C *68 to 572 °F*	0.000 017 7 ,, ,,	0.000 009 83 ,, ,,
2.4 Specific heat (thermal capacity) at:		
−150 °C *−238 °F*	0.069 cal/g °C	0.069 Btu/lb °F
− 50 °C *− 58 °F*	0.087 ,,	0.087 ,,
20 °C *68 °F*	0.092 ,,	0.092 ,,
100 °C *212 °F*	0.094 ,,	0.094 ,,
200 °C *392 °F*	0.097 ,,	0.097 ,,
2.5 Thermal conductivity at:		
−200 °C *−328 °F*	1.25 cal cm/cm² s °C	300 Btu ft/ft² h °F
−183 °C *−297 °F*	1.13 ,,	270 ,,
−100 °C *−148 °F*	1.04 ,,	252 ,,
20 °C *68 °F*	0.94 ,,	227 ,,
100 °C *212 °F*	0.92 ,,	223 ,,
200 °C *392 °F*	0.91 ,,	220 ,,
300 °C *572 °F*	0.90 ,,	217 ,,
2.6 Electrical conductivity (volume) at:		
−200 °C *−328 °F* (annealed) [(b)]	460 [(a)] m/ohm mm²	800 [(a)] % IACS
−100 °C *−148 °F* (,,) [(b)]	110 [(a)] ,,	190 [(a)] ,, ,,
20 °C *68 °F* (,,)	57.4–58.6 ,,	99–101 ,, ,,
100 °C *212 °F* (,,) [(b)]	44 ,,	76 ,, ,,
200 °C *392 °F* (,,) [(b)]	34 ,,	58 ,, ,,
20 °C *68 °F* (fully cold worked) [(b)]	56.3 ,,	97 ,, ,,

continued overleaf

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 8): INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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Cu-OFS
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2 PHYSICAL PROPERTIES (continued)

	Metric Units		English Units	
2.7 Electrical resistivity (volume) at:				
−200 °C *−328 °F* (annealed) [b]	0.002 2 [a] 0.22 [a]	ohm mm^2/m microhm cm	1.3 [a] 0.085 [a]	ohms (circ mil/ft) microhm in
−100 °C *−148 °F* („) [b]	0.009 1 [a] 0.91 [a]	ohm mm^2/m microhm cm	5.5 [a] 0.36 [a]	ohms (circ mil/ft) microhm in
20 °C *68 °F* („)	0.017 4–0.017 1 1.74–1.71	ohm mm^2/m microhm cm	10.5–10.3 0.686–0.672	ohms (circ mil/ft) microhm in
100 °C *212 °F* („) [b]	0.022 7 2.27	ohm mm^2/m microhm cm	13.6 0.89	ohms (circ mil/ft) microhm in
200 °C *392 °F* („) [b]	0.029 5 2.95	ohm mm^2/m microhm cm	17.7 1.16	ohms (circ mil/ft) microhm in
20 °C *68 °F* (fully cold worked) [b]	0.017 8 1.78	ohm mm^2/m microhm cm	10.7 0.700	ohms (circ mil/ft) microhm in
2.8 Temperature coefficient of electrical resistance at: [c] 20 °C *68 °F* (annealed) applicable over range from −100 to 200 °C *−148 to 392 °F*	0.003 93 per °C (100% IACS)		0.002 18 per °F (100% IACS)	
20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.003 81 „ „ (97% IACS)		0.002 12 „ „ (97% IACS)	
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*:				
annealed	12 000	kg/mm^2	17 000 000	lb/in^2
cold worked	12 000–13 500	„	17 000 000–19 000 000	„
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:				
annealed	4 500	kg/mm^2	6 400 000	lb/in^2
cold worked	4 500–5 000	„	6 400 000–7 000 000	„

(a) Approximate value.

(b) Based on annealed copper having a conductivity of 100% IACS (58.00 m/ohm mm^2) at 20 °C *(68 °F)*.

(c) — The temperature coefficients of resistance given can be used for calculating resistances within the temperature range shown, but these relate only to calculations based on a reference temperature of 20 °C *(68 °F)*. If it is more convenient to base calculations upon some other reference temperature, different temperature coefficients of resistance must be applied; for example, in the case of annealed copper (100% IACS), the temperature coefficient of resistance at 20 °C *(68 °F)* is 0.003 93 per °C *(0.002 18 per °F)* whereas at 0 °C *(32 °F)* the value is 0.004 265 per °C *(0.002 37 per °F)*.

— The change in resistance of annealed copper with temperature is essentially linear over a very wide range of temperature. Thus, although a range of only 0 to 100 °C *(32 to 212 °F)* is usually quoted for the temperature coefficient at 20 °C *(68 °F)*, the same coefficient may be used for calculations within the wider range of −100 to 200 °C *(−148 to 392 °F)* without introducing an error greater than 1%.

— Comparatively little information is available on the resistance/temperature relationship for cold-worked copper and there is, therefore, less justification for extending the range for its coefficient beyond 0 to 100 °C *(32 to 212 °F)*.

— The temperature coefficient of resistance of copper can be assumed to be directly proportional to the conductivity value. Thus, for copper of 101% IACS conductivity, the coefficient can be deduced by adding 1% to the value relating to copper of 100% IACS conductivity, i.e. the temperature coefficient corresponding to 101% IACS conductivity can be taken to be 0.003 97 per °C *(0.002 20 per °F)*. However, as the use of this modified coefficient changes the calculated value of resistance at 100 °C *(212 °F)* by less than 0.5%, adjustment of the temperature coefficient to take account of minor variations in conductivity is rarely considered to be worth while.

N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition range involved, are based partially on selected literature references and also upon values for Cu-OF (oxygen-free copper).

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 [a]	1 120–1 200 °C	2 050–2 190 °F
3.2 Annealing temperature range	350– 650 °C	660–1 200 °F
Stress relieving temperature range	225– 275 °C	440– 530 °F
3.3 Hot working temperature range	750– 950 °C	1 400–1 750 °F
3.4 Hot formability	Good	
3.5 Cold formability	Excellent	
3.6 Cold reduction between anneals	95% 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. 3.2	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Fair	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Not recommended	
butt	Good	

(a) Optimum casting temperature range 1 120–1 150 °C *(2 050–2 100 °F)*.

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

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	Cu Ag	—	266.02	266.02	266.02	—	266.02	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	INDITECNOR	CuAg OF	245 n.68	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	SE–CuAg	40 500	40 500, Bl.1	40 500, Bl.3	40 500, Bl.4	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Netherlands	N or NEN (b)	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States (c)	ASTM	Nos. 104, 105, and 107 or OFS	—	B152 B187	B187	—	B188	B187	—

(a) Applicable when the chemical composition is not given in the specifications for wrought forms.
(b) Older specifications bear prefix N; for new specifications, the NEN prefix is used.
(c) In the United States bar and flat wire are covered under the Plate-Sheet-Strip column.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

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

5.2 Mechanical properties at low temperature

Tensile properties	No data traced
Impact properties	" " "

5.3 Mechanical properties at elevated temperature

Short-time tensile properties	see table 5.3.1
Creep properties	" " 5.3.2

5.4 Fatigue properties

Fatigue strength at room temperature	see table 5.4.1

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE [a]

5.1.1 Typical Tensile Properties and Hardness Values - Metric Units

The values 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 [b]
				%	gauge length	Brinell	Vickers		
Plate Sheet Strip	Annealed	22	5	48	$5.65\sqrt{S_o}$	45	50	16	—
	Hot Rolled [c]	23	8	40	$5.65\sqrt{S_o}$	55	60	16	—
	Typical Cold Worked Tempers	27 32 38	18 27 34	25 12 6	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	75 90 105	80 100 115	18 19 20	0.2–10 mm thick 0.2– 6 mm thick 0.2– 1.5 mm thick
Rod	Annealed	22	5	45	$5.65\sqrt{S_o}$	45	50	16	—
	Typical Cold Worked Tempers	28 34	19 28	20 10	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	75 95	80 105	18 19	6–40 mm diam. or equivalent area 6–20 mm diam. or equivalent area
Wire	Annealed	23 24 26 —	— — — —	37 35 28 26	200 mm 200 mm 200 mm 200 mm	— — — —	— — — —	16 16 17 —	over 3 mm diam. 1–3 mm diam. 0.5–1 mm diam. 0.2–0.5 mm diam.
	Typical Cold Drawn Tempers	38 42 45	— — —	— — —	— — —	— — —	— — —	20 22 23	over 6 mm diam. 3–6 mm diam. up to 3 mm diam.
Tube	Annealed	24	6	45	$5.65\sqrt{S_o}$	45	50	16	—
	Typical Cold Drawn Tempers	27 32 35 38	18 27 30 35	30 15 8 6	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	75 90 100 105	80 100 110 115	18 19 20 20	10–200 mm O.D. up to 10 mm wall 10–100 mm O.D. up to 6 mm wall 10– 50 mm O.D. up to 2 mm wall up to 25 mm O.D. up to 1 mm wall
Sections / Shapes	Hot Worked [c]	24	8	35	$5.65\sqrt{S_o}$	50	55	16	—
	Typical Cold Worked Tempers [c]	27 32	18 27	20 10	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	75 90	80 100	18 19	— —

(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, English and American units respectively, are not directly comparable. This is because the properties quoted reflect to some extent the metalworking techniques and specification practices of the countries concerned.

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

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

5.1.2 Typical Tensile Properties and Hardness Values - English Units

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 ton/in²	Proof Stress 0.1 % offset ton/in²	Elongation %	Elongation gauge length	Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown (a)
Plate Sheet Strip	Annealed	14	3	50	2 in.	50	10	—
	Hot Rolled (b)	15	6	45	2 in.	65	10	—
	Typical Cold Worked Tempers	16	9	45	2 in.	75	11	0.006–0.5 in. thick
		17	14	30	2 in.	85	11	0.006–0.25 in. thick
		23	20	10	2 in.	110	13	0.006–0.1 in. thick
Rod	Annealed	14	3	50	$5.65\sqrt{S_o}$	50	10	—
	Typical Cold Worked Tempers	17	13	30	$5.65\sqrt{S_o}$	85	11	0.25–1 in. diam. or equivalent area
		20	16	17	$5.65\sqrt{S_o}$	105	12	"
Wire	Annealed	14	—	35	10 in.	—	10	over 0.05 in. diam.
		15	—	30	10 in.	—	10	over 0.036 up to 0.05 in. diam.
		16	—	25	10 in.	—	11	over 0.02 up to 0.036 in. diam.
		—	—	20	10 in.	—	—	over 0.005 up to 0.02 in. diam.
	Typical Cold Drawn Tempers	26	—	—	—	—	14	over 0.104 in. diam.
		29	—	—	—	—	15	over 0.064 up to 0.104 in. diam.
		30	—	—	—	—	15	up to 0.064 in. diam.
Tube	Annealed	15	5	50	2 in.	50	10	—
	Typical Cold Drawn Tempers	17	10	45	2 in.	80	11	4–8 in. O.D. up to 0.5 in. wall
		20	17	20	2 in.	100	12	"
		18	12	30	2 in.	85	12	0.5–4 in. O.D. up to 0.2 in. wall
		24	21	10	2 in.	110	13	"
Sections (extruded)	Typical Cold Drawn Tempers (b)	16	11	27	$5.65\sqrt{S_o}$	80	10	—
		20	16	15	$5.65\sqrt{S_o}$	105	12	—

(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.

5.1.3 Typical Tensile Properties and Hardness Values - American Units

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 psi	Yield Strength 0.5 % extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [(b)]
				%	gauge length	F	B	30 T		
Flat Products (Plate, Sheet, Strip, Bar and Flat Wire)	As Hot Rolled	34 000	10 000	45	2 in.	45	—	—	23 000	0.040 in. thick
	Annealed	32 000	10 000	45	2 in.	40	—	—	22 000	0.040 in. thick
	Cold Worked									
	Light Cold Rolled	36 000	28 000	30	2 in.	60	10	25	25 000	0.040 in. thick
	Half Hard	42 000	36 000	14	2 in.	84	40	50	26 000	"
	Hard	50 000	45 000	6	2 in.	90	50	57	28 000	"
	Spring	55 000	50 000	4	2 in.	94	60	63	29 000	"
	Extra Spring	57 000	53 000	4	2 in.	95	62	64	29 000	"
	Light Cold Rolled	36 000	28 000	40	2 in.	60	10	—	25 000	0.250 in. thick
	Hard	50 000	45 000	12	2 in.	90	50	—	28 000	"
	Hard	45 000	40 000	20	2 in.	85	45	—	26 000	1.0 in. thick
Rod	As Hot Rolled	32 000	10 000	55	2 in.	40	—	—	22 000	1.0 in. diam.
	Soft	32 000	10 000	55	2 in.	40	—	—	22 000	1.0 in. diam.
	Cold Worked									
	Hard	48 000	44 000	16	2 in.	87	47	—	27 000	1.0 in. diam.
	Annealed-Soft	40 000	—	17	10 in.	—	—	—	—	0.008–0.020 in. diam.
		38 000	—	23	10 in.	—	—	—	—	0.021–0.039 in. diam.
		35 000	—	27	10 in.	—	—	—	—	0.040–0.118 in. diam.
		35 000	—	33	10 in.	—	—	—	—	over 0.118 in. diam.
Wire	Cold Worked									
	Medium Hard Drawn	56 000	—	1	60 in.	—	—	—	—	0.008–0.039 in. diam.
	Hard Drawn	67 000	—	1	60 in.	—	—	—	—	"
	Medium Hard Drawn	54 000	—	1.5	60 in.	—	—	—	—	0.040–0.118 in. diam.
	Hard Drawn	65 000	—	1	60 in.	—	—	—	—	"
	Medium Hard Drawn	49 000	—	2.5	10 in.	—	—	—	—	over 0.118 in. diam.
	Hard Drawn	57 000	—	2	10 in.	—	—	—	—	"
Tube	Annealed	32 000	10 000	45	2 in.	40	—	—	22 000	1.0 in. O.D. × 0.065 in. wall
	Cold Worked									
	Light Drawn	40 000	32 000	25	2 in.	77	35	45	26 000	1.0 in. O.D. × 0.065 in. wall
	Drawn	42 000	35 000	17	2 in.	85	—	—	27 000	"
	Hard Drawn	55 000	50 000	8	2 in.	95	60	63	29 000	"
Shapes	As Hot Rolled	32 000	10 000	50	2 in.	40	—	—	22 000	0.50 in. thick
	Annealed-Soft	32 000	10 000	50	2 in.	40	—	—	22 000	0.50 in. thick
	Cold Worked									
	Hard	40 000	32 000	30	2 in.	—	35	—	26 000	0.50 in. thick

(a) The tempers listed are those referred to in ASTM and other American Standards.

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

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 % on 2 in.
		°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	
Sheet [1] 2 mm 0.08 in.	Annealed (grain size 0.030 mm)	20 100 200 300 400 500	68 212 392 572 752 932	23 21 18.5 16.5 15 11	**14.7** **13.4** **11.8** **10.5** **9.5** **6.9**	33 000 30 000 26 500 23 500 21 500 15 500	— — — — — —	**3.1** **3.0** **2.9** **2.9** **2.4** **2.1**	— — — — — —	**53** **49** **47** **45** **44** **42**
Strip [2]	Cold Worked [a]	20 288	68 550	35 24.5	22.5 15.5	**50 000** **35 000**	**33.0** [b] **19.7** [b]	— —	— —	**8.5** **12.1**
Rod [3] 3.2 mm diam. 0.125 in. diam.	Cold Worked 84 %	24 149	75 300	41.5 —	26.5 —	**59 300** —	— —	— —	**54 100** **47 000**	**8.5** —

(a) Quoted as 'cold rolled to RB 61' hardness in original document, but amount of cold work not defined.
(b) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.

N.B.:— The values shown in this table were obtained using Cu-LSTP (silver-bearing 'tough-pitch' copper) test specimens; it is assumed that Cu-OFS exhibits the same short-time tensile properties at elevated temperature.
— Original values are printed in **bold type**; other values are converted.

5.3.2 Creep Properties

Form	Temper	Testing Temperature		Stress			Duration 1 000 h	Total Extension % [a]	Intercept %	Min.Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Strip [4] 2.5 mm 0.1 in.	Cold Worked 10 %	130	266	14	8.5	**20 000**	**0.75**	**0.215**	**0.201**	0.001 5
		225	437	9.5	6	**14 000**	**1.05**	**0.253**	**0.143**	0.041
	Cold Worked 25 %	130	266	9.5 14	6 8.5	**14 000** **20 000**	**1.55** **1.05**	**0.15** **0.22**	**0.138** **0.195**	0.02 0.06
		225	437	5.5 9.5 14	3.5 6 8.5	**8 000** **14 000** **20 000**	**3.15** **3.10** **5.00**	**0.16** **0.40** **2.56**	**0.108** **0.228** **0.426**	0.016 0.048 0.31
	Cold Worked 50 %	130	266	14	8.5	**20 000**	**0.75**	**0.175**	**0.155**	0.003
		225	437	9.5	6	**14 000**	**3.25**	**0.283**	**0.193**	0.019
Rod [5] [6] 4 mm diam. 0.16 in. diam.	Annealed (water quenched)	250	482	**13.1** **14.0** **16.1** **20.4**	8 8.5 10 12.5	18 500 19 500 22 500 29 000	**0.050** [b] **0.023** [b] **0.002** [b] **0.000 1** [b]	— — — —	— — — —	— — — —
	Annealed (furnace cooled)	250	482	**14.9** **16.1** **17.1** **18.0** **22.3**	9 10.5 10.5 11 14	21 000 22 500 24 000 25 500 31 500	**0.065** [b] **0.013 5** [b] **0.002** [b] **0.001 3** [b] **0.000 1** [b]	— — — — —	— — — — —	— — — — —

Continued overleaf

5.3.2 Creep Properties—Continued

Form	Temper	Testing Temperature		Stress			Duration 1 000 h	Total Extension % [a]	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Wire [7] 2 mm diam. 0.08 in. diam.	Annealed	110	230	17.5	11	**25 000**	**5.00**	**0.38** [c]	—	**0.025**
		121	250	17.5	11	**25 000**	**4.20**	**1.00** [c]	—	**0.090** [d]
		149	300	14 17.5	8.5 11	**20 000** **25 000**	**1.10** **1.10**	**0.750** [c] **0.880** [c]	— —	**0.21** **0.25**
	Cold Worked 10 %	121	250	17.5	11	**25 000**	**5.00**	**0.170** [c]	—	**0.013**
	Cold Worked 37 %	121	250	17.5	11	**25 000**	**4.80**	**0.10** [c]	—	**0.004 0**
	Cold Worked 84 %	115	240	17.5	11	**25 000**	**4.80**	**0.033** [c]	—	**0.003 2**
		149	300	17.5	11	**25 000**	**1.00**	**0.066** [c]	—	**0.045**
Square Wire [7] 6.5 mm 0.257 in.	Cold Worked 5 %	300	572	5 8.5	3 5.5	**7 500** **12 500**	**1.440** [e] **1.440** [e]	**0.215** **0.340**	— —	**1.4** [g] **4.5** [g]
				5 7 8.5	3 4 5.5	**7 500** **10 000** **12 500**	**1.400** [e] **1.415** [e] **1.205** [e]	**0.22** **0.25** **0.36**	— — —	**1.0** [h] **1.6** [h] **7.9** [h]
				5.5 7 8.5	3.5 4.5 5.5	**7 870** [f] **10 600** [f] **12 500** [f]	**1.505** [e] **1.455** [e] **1.540** [e]	**0.31** **0.36** **0.56**	— — —	**2.1** [h] **5.1** [h] **8.9** [h]
	Cold Worked 20 %	300	572	5 8.5 12	3 5.5 7.5	**7 500** **12 500** **17 500**	**1.360** [e] **1.440** [e] **1.430** [e]	**0.25** **0.45** **0.945**	— — —	**5.2** [g] **10.0** [g] **23.0** [g]
	Cold Worked 30 %	300	572	5 8.5	3 5.5	**7 500** **12 500**	**1.375** [e] **1.355** [e]	**0.20** **0.48**	— —	**4.9** [g] **11.0** [g]
	Cold Worked 40 %	300	572	5 8.5	3 5.5	**7 500** **12 500**	**1.440** [e] **1.440** [e]	**0.20** **0.48**	— —	**5.2** [g] **7.4** [g]

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration). (b) Rupture test.
(c) Total creep strain = Total extension — Initial extension. (d) Decreasing creep rate. (e) Duration in 1 000 minutes. (f) Compression test.
(g) Creep tests performed on material containing 0.054% Ag. (h) Creep tests performed on material containing 0.076% Ag.

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

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
Strip [8] 1 mm 0.04 in.	Cold Worked 50 %	—	36.5–41	10.5 [a]	23–26	6.5 [a]	**52 000–58 000**	**15 000** [a]

(a) Reversed-bending test.

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

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Printed in England by Impress (Worcester) Ltd.

COPPER-SULPHUR

Cu S

Common name: Sulphur Copper

A free-machining copper with a small sulphur addition. The material is oxygen-free or deoxidised, has relatively high conductivity and is free from risk of hydrogen embrittlement.

COMPOSITION (weight %)

Cu (+ Ag) + S	99.90 min.
S	0.20–0.50

1 SOME TYPICAL USES

Electrical

Transformer and circuit-breaker terminals; contacts, connectors (including crimped types), clamps and other high-conductivity current-carrying components requiring free-machining properties.

Mechanical

Bolts, nuts, studs and a wide variety of other components requiring free-machinability and in most cases good conductivity, often for production on automatic screw machines.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.9 g/cm³	0.321 lb/in³
2.2 Melting range	1 067–1 079 °C	1 953–1 975 °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 3 per °F
20 to 300 °C *68 to 572 °F*	0.000 018 „ „	0.000 009 8 „ „
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.092 cal/g °C	0.092 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F* [a]	0.89 cal cm/cm² s °C	215 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	55.1 m/ohm mm²	95 % IACS
20 °C *68 °F* (fully cold worked)	53.9 „	93 „ „
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.018 1 ohm mm²/m 1.81 microhm cm	10.9 ohms (circ mil/ft) 0.714 microhm in
20 °C *68 °F* (fully cold worked)	0.018 5 ohm mm²/m 1.85 microhm cm	11.2 ohms (circ mil/ft) 0.730 microhm in
2.8 Temperature coefficient of electrical resistance at: [b]		
20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.003 7 per °C (95 % IACS)	0.002 1 per °F (95 % IACS)
20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.003 6 „ „ (93 % IACS)	0.002 0 „ „ (93 % IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*:		
annealed	12 000 kg/mm²	17 000 000 lb/in²
cold worked	12 000–13 500 „	17 000 000–19 000 000 „
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:		
annealed	4 500 kg/mm²	6 400 000 lb/in²
cold worked	4 500–5 000 „	6 400 000–7 000 000 „

(a) Deduced from electrical conductivity value for annealed material.

(b) —The temperature coefficients of resistance given can be used for calculating resistances within the temperature range shown, but these relate only to calculations based on a reference temperature of 20°C (*68°F*).

—The temperature coefficient of resistance of this low-alloyed copper can be assumed to be directly proportional to the conductivity value and the figures given above have been calculated on the basis that copper of 100% IACS conductivity at 20°C (*68°F*) has a temperature coefficient of resistance of 0.003 93 per °C (*0.002 18 per °F*).

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

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DATA SHEET No. B 4
Cu S

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	1 140–1 200 °C	2 080–2 190 °F
3.2 Annealing temperature range	400– 650 °C	750–1 200 °F
Stress relieving temperature range	225– 275 °C	440– 530 °F
3.3 Hot working temperature range	750– 870 °C	1 400–1 600 °F
3.4 Hot formability	Good	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	70 % max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	75	
3.8 Joining methods:	See General Data Sheet No. 3.2	
Soldering	Excellent	
Brazing	Good	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Not recommended	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Not recommended	
butt	Fair	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

At the date of publication of this sheet, the only known national specification is British Standard 2874 in which copper-sulphur rod material is designated as C111.

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	no data traced
Impact properties	" " "

5.3 Mechanical properties at elevated temperature

Short-time tensile properties	see table 5.3.1
Creep properties	no data traced

5.4 Fatigue properties

Fatigue strength at room temperature	no data traced

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE [a]

5.1.1 Typical Tensile Properties and Hardness Values - Metric Units

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 [b]
				%	gauge length	Brinell	Vickers		
Rod	Annealed	23	6	40	$5.65\sqrt{S_o}$	50	55	14	—
	Typical Cold Worked Tempers	27	23	15	$5.65\sqrt{S_o}$	80	85	17	6–40 mm diam. or equivalent area
		32	29	8	$5.65\sqrt{S_o}$	90	100	18	6–20 mm diam. or equivalent area
		35	32	5	$5.65\sqrt{S_o}$	100	110	19	up to 6 mm diam. or equivalent area

(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, English and American units respectively, are not directly comparable. This is because the properties quoted reflect to some extent the metalworking techniques and specification practices of the countries concerned.

(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.

5.1.2 Typical Tensile Properties and Hardness Values - English Units

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 ton/in²	Proof Stress 0.1 % offset ton/in²	Elongation		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown [(a)]
				%	gauge length			
Rod	Annealed	14	3	45	$5.65\sqrt{S_o}$	50	9	—
	Typical Cold Worked Tempers	18 20	15 17	20 10	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	85 100	11 12	0.25–1 in. diam. or equivalent area "
Forgings	Hot Worked [(b)]	15	6	30	$5.65\sqrt{S_o}$	60	10	—

(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.

5.1.3 Typical Tensile Properties and Hardness Values - American Units

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 psi	Yield Strength 0.5 % extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [b]
				%	gauge length	F	B	30 T		
Flat Products (Bar)	As Hot Rolled [c]	34 000	10 000	40	2 in.	50	—	—	23 000	—
	Annealed	34 000	10 000	42	2 in.	52	—	—	23 000	—
	Cold Worked									
	Half Hard	42 000	40 000	15	2 in.	77	35	50	25 000	0.125–0.250 in. thick
	Hard	50 000	48 000	10	2 in.	83	45	54	29 000	"
	Quarter Hard	35 000	31 000	30	2 in.	72	25	45	24 000	0.250–0.50 in. thick
	Half Hard	42 000	40 000	15	2 in.	77	35	50	26 000	"
	Hard	50 000	48 000	10	2 in.	83	45	54	29 000	"
	Half Hard	40 000	35 000	20	2 in.	75	32	48	25 000	over 0.50 in. thick
	Hard	46 000	43 000	15	2 in.	81	42	53	27 000	"
Rod	As Hot Rolled [c]	34 000	10 000	40	2 in.	50	—	—	23 000	—
	Annealed	34 000	10 000	42	2 in.	52	—	—	23 000	—
	Cold Worked									
	Hard	52 000	50 000	10	2 in.	85	50	57	30 000	0.125 in. diam.
	Quarter Hard	35 000	31 000	30	2 in.	72	25	45	24 000	0.250 in. diam.
	Half Hard	42 000	40 000	15	2 in.	77	35	50	26 000	"
	Hard	50 000	48 000	10	2 in.	83	45	54	29 000	"
	Quarter Hard	35 000	31 000	30	2 in.	72	25	45	24 000	0.50 in. diam.
	Half Hard	42 000	40 000	15	2 in.	77	35	50	26 000	"
	Hard	50 000	48 000	10	2 in.	83	45	54	29 000	"
	Half Hard	41 000	38 000	20	2 in.	76	33	49	25 000	1.0 in. diam.
	Hard	48 000	46 000	15	2 in.	82	43	53	28 000	"
	Half Hard	40 000	37 000	20	2 in.	75	32	48	25 000	2.0 in. diam.
	Hard	46 000	43 000	15	2 in.	81	42	52	27 000	"
Shapes	As Hot Rolled [c]	34 000	10 000	40	2 in.	50	—	—	23 000	—
	Annealed [c]	34 000	10 000	42	2 in.	52	—	—	23 000	—
	Cold Worked [c]									
	Half Hard	42 000	38 000	20	2 in.	77	35	50	26 000	—
	Hard	50 000	48 000	15	2 in.	83	45	54	29 000	—
Forgings	As Forged [c]	30 000	10 000	40	2 in.	52	—	—	21 000	—

(a) The tempers listed are those referred to in ASTM and other American Standards.

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

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

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 0.1 % offset ton/in²	Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi		
Rod [1] 25.4 mm diam. 1 in. diam.	Cold Worked	20	68	30.5	**19.5**	43 500	**16.0**	**20.0**
		100	212	27.5	**17.5**	39 000	—	**19.5**
		200	392	24	**15.0**	34 000	—	**18.5**
		300	572	18	**11.5**	25 500	—	**23.0**
		400	752	11	**7.0**	16 000	—	**53.0**
		500	932	9.5	**6.0**	13 500	—	**50.0**

N.B.: — Original values are printed in **bold type**; other values are converted.
— Data not available:
Proof Stress 0.2 % offset.
Yield Strength 0.5 % extension under load.

5.3.2 Creep Properties

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

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

REFERENCE

MECHANICAL PROPERTIES (SECTION 5)

(1) Copper-Sulphur — Boltomet 917. Thomas Bolton & Sons Ltd., England. TBS 127. August, 1965.

Printed in England by Impress (Worcester) Ltd.

COPPER-TELLURIUM

Cu Te

Common name: Tellurium Copper

A free-machining copper with a small tellurium addition. The material has relatively high conductivity and is available in both phosphorus-bearing and 'tough-pitch' varieties, the first being free from risk of hydrogen embrittlement.

COMPOSITION (weight %)

Cu (+ Ag) + Te	99.90 min.
Te	0.30–0.80

1 SOME TYPICAL USES

Electrical

Transformer and circuit-breaker terminals; contacts, connectors, clamps and other high-conductivity current-carrying components requiring free-machining properties.

Mechanical

Bolts, nuts, studs and a wide variety of other components requiring free-machinability and in most cases good conductivity, often for production on automatic screw machines.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.9 g/cm³	0.321 lb/in³
2.2 Melting range	870–1 081 °C [a] 1 051–1 081 °C [b]	1 600–1 978 °F [a] 1 924–1 978 °F [b]
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C *68 to 212 °F*	0.000 017 per °C	0.000 009 3 per °F
20 to 300 °C *68 to 572 °F*	0.000 018 ,, ,,	0.000 009 8 ,, ,,
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.092 cal/g °C	0.092 Btu/lb °F
2.5 Thermal conductivity at:		
–240 °C *–400 °F*	1.9 [b] cal cm/cm² s °C	462 [b] Btu ft/ft² h °F
–173 °C *–280 °F*	0.98 [b] ,,	237 [b] ,,
20 °C *68 °F* [c]	0.91 [a] ,, 0.88 [b] ,,	220 [a] ,, 214 [b] ,,
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed)	56.8 [a] m/ohm mm² 54.5 [b] ,,	98 [a] % IACS 94 [b] ,, ,,
20 °C *68 °F* (fully cold worked)	55.7 [a] ,, 53.4 [b] ,,	96 [a] ,, ,, 92 [b] ,, ,,
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed)	0.017 6 [a] ohm mm²/m 1.76 [a] microhm cm 0.018 3 [b] ohm mm²/m 1.83 [b] microhm cm	10.6 [a] ohms (circ mil/ft) 0.693 [a] microhm in 11.0 [b] ohms (circ mil/ft) 0.722 [b] microhm in
20 °C *68 °F* (fully cold worked)	0.018 0 [a] ohm mm²/m 1.80 [a] microhm cm 0.018 7 [b] ohm mm²/m 1.87 [b] microhm cm	10.8 [a] ohms (circ mil/ft) 0.707 [a] microhm in 11.3 [b] ohms (circ mil/ft) 0.738 [b] microhm in

continued overleaf

INDEX NUMBERS RELATE TO LITERATURE REFERENCES (see page 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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DATA SHEET No. B 5
Cu Te

2 PHYSICAL PROPERTIES (continued)

	Metric Units	English Units
2.8 Temperature coefficient of electrical resistance at: [d] 20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.003 9 [a] per °C (98 % IACS) 0.003 7 [b] „ „ (94 % IACS)	0.002 1 [a] per °F (98 % IACS) 0.002 0 [b] „ „ (94 % IACS)
20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.003 8 [a] „ „ (96 % IACS) 0.003 6 [b] „ „ (92 % IACS)	0.002 1 [a] „ „ (96 % IACS) 0.002 0 [b] „ „ (92 % IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*:		
annealed	12 000 kg/mm²	17 000 000 lb/in²
cold worked	12 000–13 500 „	17 000 000–19 000 000 „
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:		
annealed	4 500 kg/mm²	6 400 000 lb/in²
cold worked	4 500– 5 000 „	6 400 000– 7 000 000 „

(a) Oxygen-bearing ('tough-pitch') tellurium copper.
(b) Phosphorus-deoxidised tellurium copper.
(c) Deduced from electrical conductivity values for annealed material.
(d)—The temperature coefficients of resistance given can be used for calculating resistances within the temperature range shown, but these relate only to calculations based on a reference temperature of 20°C *(68°F)*.
—The temperature coefficient of resistance of this low-alloyed copper can be assumed to be directly proportional to the conductivity value and the figures given above have been calculated on the basis that copper of 100% IACS conductivity at 20°C *(68°F)* has a temperature coefficient of resistance of 0.003 93 per °C *(0.002 18 per °F)*.

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.

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 [a]	1 120–1 200 °C	2 050–2 190 °F
3.2 Annealing temperature range [b]	425– 650 °C	800–1 200 °F
Stress relieving temperature range [b]	225– 275 °C	440– 530 °F
3.3 Hot working temperature range [b]	725– 825 °C	1 340–1 520 °F
3.4 Hot formability [b]	Good	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	70 % max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free-cutting brass = 100)	85	
3.8 Joining methods [b]	See General Data Sheet No. 3.2	
Soldering	Excellent	
Brazing [c]	Good	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Not recommended	
butt	Fair	

(a) Optimum casting temperature range for 'tough-pitch' variety 1 120–1 150 °C *(2 050–2 100 °F)*.
(b) Embrittlement will occur if the 'tough-pitch' variety is heated in atmospheres containing an excess of hydrogen.
(c) For 'tough-pitch' variety, care should be taken to avoid melting of ternary eutectic which occurs at 870 °C *(1 600 °F)*.

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

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	Cu Te	—	—	266.02	—	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	INDITECNOR	Cu-Te	245 n.68	—	—	—	—	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	E-CuTe (2.1545)	17 666	—	17 672	17 672	17 671	17 674	—
		SE-CuTe (2.1546)	17 666	—	17 672	17 672	17 671	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Netherlands	N or NEN [b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu-OFTE	10826	—	11852	—	—	—	—
United Kingdom	BS	C109	—	—	2874	—	—	2874	—
United States	ASTM	No. 145 or DPTE or OFTE or OFPTE	—	—	B301	—	—	—	—

(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 5.1.1/2/3
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	no data traced
Impact properties	„ „ „

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

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	Annealed	23	6	40	$5.65\sqrt{S_o}$	50	55	14	—
Rod	Typical Cold Worked Tempers	27	23	15	$5.65\sqrt{S_o}$	80	85	17	6–40 mm diam. or equivalent area
		32	29	8	$5.65\sqrt{S_o}$	90	100	18	6–20 mm diam. or equivalent area
		35	32	4	$5.65\sqrt{S_o}$	100	110	19	up to 6 mm diam. or equivalent area
Tube	Annealed	23	6	40	$5.65\sqrt{S_o}$	50	55	14	—
Tube	Typical Cold Drawn Tempers	27	23	15	$5.65\sqrt{S_o}$	80	85	17	10–50 mm O.D. up to 6 mm wall
		32	29	8	$5.65\sqrt{S_o}$	90	100	18	10–25 mm O.D. up to 2 mm wall
Sections / Shapes	Hot Worked (b)	23	6	40	$5.65\sqrt{S_o}$	55	60	15	—
Sections / Shapes	Typical Cold Worked Temper (b)	30	26	12	$5.65\sqrt{S_o}$	85	95	18	—

(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 - English Units

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 ton/in²	Proof Stress 0.1 % offset ton/in²	Elongation		Vickers Hardness	Shear Strength ton/in²	Typical Size Related to Properties Shown (a)
				%	gauge length			
Rod	Annealed	15	3	45	$5.65\sqrt{S_o}$	50	9	—
Rod	Typical Cold Worked Tempers	18	15	20	$5.65\sqrt{S_o}$	85	11	0.25–1 in. diam. or equivalent area
		20	17	10	$5.65\sqrt{S_o}$	100	12	"
Sections (extruded)	Typical Cold Drawn Temper (b)	18	15	20	$5.65\sqrt{S_o}$	85	11	—
Forgings	Hot Worked (b)	15	6	30	$5.65\sqrt{S_o}$	60	10	—

(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.

* 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, English and American units respectively, are not directly comparable. This is because the properties quoted reflect to some extent the metalworking techniques and specification practices of the countries concerned.

5.1.3 Typical Tensile Properties and Hardness Values - American Units

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 psi	Yield Strength, 0.5 % extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown [b]
				%	gauge length	F	B	30 T		
Flat Products (Bar)	As Hot Rolled [c]	33 000	8 000	45	2 in.	40	—	—	23 000	—
	Annealed	33 000	8 000	47	2 in.	32	—	—	23 000	—
	Cold Worked									
	Half Hard	42 000	38 000	20	2 in.	80	40	24	26 000	0.125–0.250 in. thick
	Hard	54 000	51 000	11	2 in.	85	50	31	29 000	"
	Quarter Hard	37 000	32 000	30	2 in.	72	25	13	24 000	0.250–0.50 in. thick
	Half Hard	42 000	38 000	20	2 in.	77	35	20	26 000	"
	Hard	50 000	47 000	15	2 in.	83	45	28	28 000	"
	Half Hard	42 000	36 000	25	2 in.	79	38	23	26 000	over 0.50 in. thick
	Hard	48 000	43 000	15	2 in.	85	50	32	27 000	"
Rod	As Hot Rolled [c]	33 000	8 000	45	2 in.	40	—	—	23 000	—
	Annealed-Soft	33 000	8 000	47	2 in.	32	—	—	23 000	—
	Cold Worked									
	Hard	54 000	50 000	9	2 in.	85	50	32	29 000	0.125 in. diam.
	Quarter Hard	37 000	32 000	30	2 in.	69	20	10	24 000	0.250 in. diam.
	Half Hard	43 000	38 000	20	2 in.	79	38	23	26 000	"
	Hard	53 000	49 000	10	2 in.	87	52	33	28 000	"
	Quarter Hard	37 000	32 000	30	2 in.	75	30	16	24 000	0.50 in. diam.
	Half Hard	42 000	38 000	20	2 in.	80	40	24	26 000	"
	Hard	48 000	45 000	15	2 in.	83	45	28	27 000	"
	Half Hard	42 000	36 000	25	2 in.	75	35	22	26 000	1.0 in. diam.
	Hard	48 000	42 000	15	2 in.	80	42	27	27 000	"
	Half Hard	41 000	35 000	30	2 in.	75	35	22	25 000	2.0 in. diam.
	Hard	46 000	40 000	20	2 in.	80	42	27	27 000	"
Shapes	As Hot Rolled [c]	33 000	8 000	45	2 in.	40	—	—	23 000	—
	Annealed [c]	33 000	8 000	47	2 in.	32	—	—	23 000	—
	Cold Worked [c]									
	Half Hard	42 000	36 000	25	2 in.	75	35	22	26 000	—
	Hard	48 000	42 000	15	2 in.	80	42	27	27 000	—
Forgings	As Forged [c]	33 000	8 000	40	2 in.	40	—	—	23 000	—

(a) The tempers listed are those referred to in ASTM and other American Standards.
(b) It is possible to obtain sizes different from those given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.
(c) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

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 % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi	0.2 % offset kg/mm²	Yield Strength 0.5 % ext. under load psi	
Rod [1] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.025 mm)	24	75	24.5	15.5	**34 800**	**5.35** [a]	**8 400**	**48**
		149	300	—	—	—	**4.50** [a]	**7 300**	—
		204	400	—	—	—	**4.22** [a]	**6 800**	—
		260	500	—	—	—	**4.07** [a]	**6 600**	—
	Cold Worked 37 %	24	75	34.5	22	**49 200**	**31.4** [a]	**45 000**	**8.5**
		149	300	—	—	—	**27.7** [a]	**40 000**	—
		204	400	—	—	—	**24.8** [a]	**36 000**	—
		260	500	—	—	—	**22.6** [a]	**32 800**	—
Rod [1] 19 mm diam. 0.75 in. diam.	Cold Worked 21 %	20	68	35.5	22.5	**50 400**	—	—	**12.5**
		260	500	28.5	18.5	**40 900**	—	—	**9**
		288	550	27	17	**38 600**	—	—	**9**
		315	600	25	16	**35 400**	—	—	**7**
		343	650	23	14.5	**32 700**	—	—	**8**
		371	700	22.5	14.5	**32 200**	—	—	**8**
		399	750	18	11.5	**25 600**	—	—	**8**
		426	800	15.5	10	**22 100**	—	—	**11**
	Cold Worked [b]	27	80	37	23.5	**52 400**	**35.6** [a]	—	**12.8**
		260	500	27	17	**38 600**	**27.1** [a]	—	**4.7**

(a) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.
(b) Quoted as 'Rockwell hardness 56B' in original document, but amount of cold work not defined.
N.B.: — Original values are printed in **bold type**; other values are converted.
— 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 1 000 h	Total Extension % (a)	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod (1) 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.025 mm)	149	300	2 3.5 6	1 2 3.5	**3 050** **5 200** **8 550**	**6.00** **6.00** **6.00**	**0.134 4** **0.251 5** **1.553**	**0.077** **0.121** **0.737**	**0.001 4** **0.007 8** **0.022 3**
	Cold Worked 37 %	149	300	4.5 7 10.5 14 20.5	3 4 6.5 8.5 13	**6 900** **10 000** **15 000** **19 950** **29 200**	**6.00** **6.00** **6.00** **6.00** **6.00**	**0.089 5** **0.149 4** **0.223 4** **0.390 5** **1.133**	**0.034 4** **0.068 1** **0.088** **0.155 5** **0.479**	**0.000 85** **0.001 9** **0.005 23** **0.011 5** **0.080**
Rod (1) 19 mm diam. 0.75 in. diam.	Cold Worked (b)	260 315	500 600	5.5 2	3.5 1	**8 000** **3 000**	**>4.368** **>3.60**	**0.420** **0.084**	**0.219** **0.065**	**0.046** **0.005**

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Quoted as 'Rockwell hardness 56B' 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 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 (1) 3.2 mm diam. 0.125 in. diam.	Cold Worked 37 %	149	300	5	3	**7 400**	13	8	**19 000**	21.5	13.5	**31 000**

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 × 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 [2] **7.6 mm diam. 0.3 in. diam.**	Cold Worked 17 %	100	28	11.5 [a]	17.5	7.5 [a]	**39 500**	**16 500** [a]
Rod [3]	Hot Worked	10	25	8.5 [a]	**16**	**5.5** [a]	36 000	12 500 [a]
	Cold Worked 25 %	10	31.5	11 [a]	**20**	**7** [a]	45 000	15 500 [a]

[a] Rotating-beam test.

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

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

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