Cu Zn40

Common names: 60/40 Brass (Lead-Free)
Muntz Metal
Yellow Metal

A copper–zinc alloy with a duplex alpha-plus-beta phase structure and excellent hot-working properties. Service environment must be considered to predict corrosion behaviour. Cu Zn40 has somewhat better cold-working and joining properties, but is less readily machined, than the similar low-leaded alloy Cu Zn40 Pb. The most commonly used wrought forms are plate, rod and sections/shapes.

COMPOSITION (weight %)

Cu	59.0–62.0
Zn	rem.

1 SOME TYPICAL USES

Architectural

Extruded sections including angles, channels and trim; heavy-gauge panels and sheets.

Chemical and Marine

Condenser and heat exchanger tubeplates.

Mechanical

Hot forgings and "upset" products requiring limited cold bending or riveting.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.40 g/cm³	0.305 lb/in³
2.2	Melting range	895–900 °C	1 645–1 650 °F
2.3	Coefficient of thermal expansion (linear) at:		
	20 to 100 °C *68 to 212 °F*	0.000 020 per °C	0.000 011 per °F
	20 to 300 °C *68 to 572 °F*	0.000 021 " "	0.000 012 " "
2.4	Specific heat (thermal capacity) at:		
	20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
2.5	Thermal conductivity at:		
	—200 °C *—328 °F*	0.15 cal cm/cm² s °C	37 Btu ft/ft² h °F
	20 °C *68 °F*	0.30 "	73 "
	200 °C *392 °F*	0.34 "	82 "
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (annealed)	16 m/ohm mm²	28 % IACS
	200 °C *392 °F* (")	12 "	21 "
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (annealed)	0.062 ohm mm²/m 6.2 microhm cm	37 ohms (circ mil/ft) 2.4 microhm in
	200 °C *392 °F* (")	0.082 ohm mm²/m 8.2 microhm cm	49 ohms (circ mil/ft) 3.2 microhm in
2.8	Temperature coefficient of electrical resistance at:		
	20 °C *68 °F* (annealed)	0.002 0 per °C (28% IACS)	0.001 1 per °F (28% IACS)
	applicable over range from 0 to 100 °C *32 to 212 °F*		
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	10 400 kg/mm²	14 800 000 lb/in²
	cold worked	9 600–10 400 kg/mm²	13 650 000–14 800 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*		
	annealed	3 900 kg/mm²	5 550 000 lb/in²
	cold worked	3 500–3 900 kg/mm²	5 000 000–5 550 000 lb/in²

N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition range involved, are based on selected literature references.

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

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DATA SHEET No. D 8
Cu Zn40

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	1 010–1 050 °C	1 850–1 920 °F
3.2	Annealing temperature range	450– 650 °C	840–1 200 °F
	Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3	Hot working temperature range	650– 750 °C	1 200–1 380 °F
3.4	Hot formability	Excellent	
3.5	Cold formability	Limited	
3.6	Cold reduction between anneals	40% max.	
3.7	Machinability :	See General Data Sheet No. 2	
	Machinability rating (free-cutting brass = 100)	45	
3.8	Joining methods :	See General Data Sheet No. 3.4	
	Soldering	Excellent	
	Brazing	Good	
	Oxy-acetylene welding	Good	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Fair	
	Coated metal-arc welding	Not recommended	
	Resistance welding: spot and seam	Fair	
	butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS
and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	—	—	—	—	—	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	INDITECNOR	Cu Zn40	247 n./68	—	—	—	—	—	—
France	NF	U-Z40	EN A 53-013	A 53-603	A 53-303	—	A 53-503	A 53-303	—
Germany	DIN	Cu Zn40 (2.0360)	17 660	17 670	17 672	17 672	17 671	—	17 673
India	IS	Cu Zn40	—	410 422	4170	—	—	—	—
Italy	UNI	P-Cu Zn40	4891	4891	4891	4891	4891	4891	4891
Japan	JIS	BsP3 BsBF BsW3 BsR3 BsT3	—	H 3201 H 3321	—	H 3521	H 3631	H 3423	—
Netherlands	N or NEN[b]	Cu-Zn40	NEN 6030	NEN 6033	—	—	N 1130	—	—
South Africa	SABS	Cu Zn40	474	—	—	—	—	—	—
Spain	UNE	Cu Zn40	37.103	37.103 37.104	—	—	—	37.103 37.108	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Zn40	10 822	11 855	11 854	—	11 857	11 854	—
United Kingdom	BS	CZ109	—	—	1949 2872 2874	—	—	1949 2874	1949 2872
United States[c]	ASTM	No. 280	—	—	—	—	B 111 B 135 B 395	—	—
International Organization for Standardization	ISO	Cu Zn40	R 426	—	—	—	—	—	—

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

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

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

5.2 Mechanical properties at low temperature

Tensile properties	see table 5.2.1
Impact properties	" " 5.2.1
Navy tear test	" " 5.2.2

5.3 Mechanical properties at elevated temperature

Short-time tensile properties	see table 5.3.1
Impact properties	" " 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

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

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

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

Form	Temper	Tensile Strength kg/mm²	Proof Stress 0.2% offset kg/mm²	Elongation		Hardness		Shear Strength kg/mm²	Typical Size Related to Properties Shown[b]
				%	gauge length	Brinell	Vickers		
Plate Sheet Strip	Annealed	38	16	40	$5.65\sqrt{S_o}$	85	89	29	—
	Hot Rolled	38	16	30	$5.65\sqrt{S_o}$	85	89	29	30–80 mm thick
	Typical Cold Worked Tempers	45 52	32 45	25 8	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	125 145	130 150	32 34	0.5–20 mm thick 0.5– 5 mm thick
Rod	Annealed	38	16	40	$5.65\sqrt{S_o}$	85	89	29	—
	Hot Worked	38	16	30	$5.65\sqrt{S_o}$	85	89	29	10–80 mm diam. or equivalent area
	Typical Cold Worked Tempers	43 50	32 45	28 10	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	120 135	125 140	30 33	6–40 mm diam. or equivalent area 6–12 mm diam. or equ valent area
Wire	Annealed	42	—	35	100 mm	—	—	32	1.5–6 mm diam.
	Typical Cold Drawn Tempers	48 60	— —	15 4	100 mm 100 mm	— —	— —	31 33	1.5–6 mm diam. "
Tube	Annealed	40	18	40	$5.65\sqrt{S_o}$	85	89	30	—
	Typical Cold Drawn Tempers	45 50	33 40	20 8	$5.65\sqrt{S_o}$ $5.65\sqrt{S_o}$	125 140	130 145	32 33	10–50 mm O.D. over 2 mm wall up to 25 mm O.D. up to 2 mm wall
Sections / Shapes	Annealed	38	16	40	$5.65\sqrt{S_o}$	85	89	29	—
	Hot Worked[c]	38	16	30	$5.65\sqrt{S_o}$	85	89	29	—
	Typical Cold Worked Temper[c]	42	25	28	$5.65\sqrt{S_o}$	100	105	29	—
Forgings	Hot Worked[c]	38	16	30	$5.65\sqrt{S_o}$	85	89	29	—

(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, specification practices, and testing procedures in the countries concerned, and in view of the different sizes of products referred to in these tables. Individual manufacturers of semi-fabricated products can, however, normally meet the requirements of any national standard.

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

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

5.1.2 Typical Tensile Properties and Hardness Values—English Units

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

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

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

Form	Temper[a]	Tensile Strength 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[b]
Rod	Annealed	23	8	45	$5.65\sqrt{S_o}$	90	17	—
	Hot Worked	24	9	40	$5.65\sqrt{S_o}$	100	18	0.5–2 in. diam. or equivalent area
	Cold Worked							
		25	10	40	$5.65\sqrt{S_o}$	110	19	1–2 in. diam. or equivalent area
	As Manufactured	27	14	35	$5.65\sqrt{S_o}$	125	20	0.375–1in. diam. or equivalent area
		30	18	25	$5.65\sqrt{S_o}$	140	21	0.125–0.375 in. diam. or equivalent area
Sections (extruded)	Hot Worked[c]	24	9	40	$5.65\sqrt{S_o}$	100	18	—
	Cold Drawn As Manufactured[c]	26	12	35	$5.65\sqrt{S_o}$	120	19	—
Forgings	Hot Worked[c]	24	9	40	$5.65\sqrt{S_o}$	100	18	—

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

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

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

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American Standards. For British and other European countries' practices, see tables 5.1.2 and 5.1.1, respectively.

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

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

Form	Temper	Tensile Strength psi	Yield Strength 0.5% extension under load psi	Elongation		Rockwell Hardness			Shear Strength psi	Typical Size Related to Properties Shown[a]
				%	gauge length	F	B	30 T		
Flat Products (Plate, Sheet Strip and Bar)	As Hot Rolled	54 000	21 000	45	2 in.	85	—	49	40 000	0.040 in. thick
	Annealed-Soft	54 000	21 000	45	2 in.	80	—	46	40 000	0.040 in. thick
	Cold Worked									
	Eighth Hard	60 000	35 000	30	2 in.	—	55	54	42 000	0.040 in. thick
	Half Hard	70 000	50 000	10	2 in.	—	75	67	44 000	"
Rod	As Extruded	52 000	20 000	52	2 in.	78	—	—	39 000	1.0 in. diam.
	Annealed-Soft	54 000	21 000	50	2 in.	80	—	—	40 000	1.0 in. diam.
	Cold Worked									
	Quarter Hard	72 000	50 000	25	2 in.	—	78	—	45 000	1.0 in. diam.
Tube	Annealed	56 000	23 000	50	2 in.	82	—	47	39 000	1.0 in. O.D. × 0.065 in. wall
	Cold Worked									
	Hard Drawn (30%)	74 000	55 000	10	2 in.	—	80	—	46 000	1.0 in. O.D. × 0.065 in. wall
Shapes	As Extruded[b]	52 000	20 000	52	2 in.	78	—	—	39 000	—
	Annealed-Soft[b]	54 000	21 000	50	2 in.	80	—	—	40 000	—
	Cold Worked[b]									
	Quarter Hard	72 000	50 000	25	2 in.	—	78	—	45 000	—
Forgings	As Forged[b]	53 000	21 000	40	2 in.	78	—	—	39 000	—

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

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation		Reduction of Area	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length	%	kg m/cm²	ft lb
Plate[1]	—[a]	20	68	29.5[b]	**18.6**[b]	41 500[b]	**14**	2 in.	**26.5**	6.0[c]	**34.5**[c]
		− 50	− 58	—	—	—	—	—	—	6.6[c]	**38**[c]
		−100	−148	—	—	—	—	—	—	6.6 [c]	**38**[c]
12.7—19 mm		−120	−184	33.5[b]	**21.4**[b]	48 000[b]	**15**	2 in.	**27.0**	—	—
0.5—0.75 in.		−150	−238	35.5[b]	**22.5**[b]	50 500[b]	**15**	2 in.	**26.5**	6.3[c]	**36.5**[c]
		−196	−321	39[b]	**24.9**[b]	56 000[b]	**14**	2 in.	**24.5**	6.7[c]	**39**[c]
Rod[2]	Annealed	20	68	**40.5**	25.5	57 500	**51.3**	$11.3\sqrt{S_o}$	**75.5**	**8.55**[d]	30.9[d]
		− 78	−108	**43.0**	27.5	61 000	**53.0**	$11.3\sqrt{S_o}$	**74.6**	**8.57**[d]	31.0[d]
		−183	−297	**53.3**	34	76 000	**55.3**	$11.3\sqrt{S_o}$	**71.0**	**8.30**[d]	30.0[d]
	Cold Worked 17%	20	68	—	—	—	—	—	—	**5.08**[d]	18.4[d]
		− 78	−108	—	—	—	—	—	—	**5.29**[d]	19.1[d]
		−183	−297	—	—	—	—	—	—	**5.27**[d]	19.0[d]
	Cold Worked 25%	20	68	**56.0**	35.5	79 500	**19.8**	$11.3\sqrt{S_o}$	**65.5**	—	—
		− 78	−108	**58.3**	37	83 000	**21.0**	$11.3\sqrt{S_o}$	**67.7**	—	—
		−183	−297	**69.2**	44	98 500	**24.4**	$11.3\sqrt{S_o}$	**64.1**	—	—
—[3][e]	Annealed	20	68	**36**	23	51 000	**51**	$5.65\sqrt{S_o}$	—	—	—
		− 80	−112	**38**	24	54 000	**53**	$5.65\sqrt{S_o}$	—	—	—
		−195	−319	**47**	30	67 000	**55**	$5.65\sqrt{S_o}$	—	—	—
	Cold Worked[f]	20	68	**50**	31.5	71 000	**20**	$5.65\sqrt{S_o}$	—	—	—
		− 80	−112	**52**	32.5	72 500	**21**	$5.65\sqrt{S_o}$	—	—	—
		−195	−319	**61**	38.5	87 000	**24**	$5{\cdot}65\sqrt{S_o}$	—	—	—

[a] Temper not stated in original document; probably annealed.

[b] Tipper notched tensile test; section of notch 19 × 15 mm (0.750 × 0.610 in.). [c] Charpy test; 10 × 10 × 100 mm specimen; 45° V-notch, 2 mm deep; cross-sectional area at the notch 0.8 cm². [d] Charpy test; 10 × 8 × 100 mm specimen; 45° V-notch, 3 mm deep; cross-sectional area at the notch 0.5 cm². [e] Form not stated in original document. [f] Quoted as "hard" in original document but amount of cold work not defined.

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

—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 (and vice versa) 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						Reduction of Plate Thickness at Fracture		
							initiation		propagation		total				
		°C	°F	kg	ton	lb	kg m	ft lb	kg m	ft lb	kg m	ft lb	mm	in.	%
Plate[1]	—[a]	20	68	9 195	**9.05**	20 270	15.5	**112**	80.5	**582**	95.9	**694**	3.8	**0.150**	**20.0**
		−120	−184	10 975	**10.8**	24 190	30.1	**218**	94.7	**685**	124.8	**903**	4	**0.160**	**21.5**
12.7 − 19 mm		−196	−321	13 410	**13.2**	29 570	33.7	**244**	117.7	**851**	151.4	**1 095**	3.8	**0.150**	**20.0**
0.5 − 0.75 in.															

[a] Temper not stated in original document; probably annealed.

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—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% extension under load psi	%	gauge length	kg m / cm²	ft lb
Plate[4]	Annealed	20	68	34	**21.5**	48 000	**10.1**[a]	**6.2**	—	**62**	2 in.	—	—
		66	150	34.5	**21.8**	49 000	**10.1**[a]	**6.2**	—	**65**	2 in.	—	—
		121	250	32	**20.2**	45 000	**10.1**[a]	**6.2**	—	**62**	2 in.	—	—
		177	350	30.5	**19.4**	43 500	**10.5**[a]	**6.5**	—	**63**	2 in.	—	—
		204	400	30	**19.2**	43 000	**11.2**[a]	**6.8**	—	**62**	2 in.	—	—
Rod[5] **3.2 mm diam. 0.125 in. diam.**	Annealed	24	75	38.5	24.5	**54 700**	**13.1**[b]	—	**18 600**	**51.0**	2 in.	—	—
		149	300	—	—	—	**12.9**[b]	—	**18 500**	—	—	—	—
		204	400	—	—	—	**12.9**[b]	—	**18 500**	—	—	—	—
		260	500	—	—	—	**12.4**[b]	—	**17 900**	—	—	—	—
Rod[2]	Annealed	19	66	—	—	—	—	—	—	—	—	**8.55**[c]	30.9[c]
		20	68	**40.5**	25.5	57 500	—	—	—	**51.3**	$11.3\sqrt{S_o}$	—	—
		51	124	—	—	—	—	—	—	—	—	**8.26**[c]	29.9[c]
		55	131	**39.7**	25	56 500	—	—	—	**51.0**	$11.3\sqrt{S_o}$	—	—
		100	212	**38.8**	24.5	55 000	—	—	—	**50.8**	$11.3\sqrt{S_o}$	**7.56**[c]	27.3[c]
		151	304	—	—	—	—	—	—	—	—	**6.94**[c]	25.0[c]
		154	309	**35.2**	22.5	50 000	—	—	—	**50.3**	$11.3\sqrt{S_o}$	—	—
		200	392	—	—	—	—	—	—	—	—	**6.27**[c]	22.7[c]
		206	403	**34.4**	22	49 000	—	—	—	**49.8**	$11.3\sqrt{S_o}$	—	—
		250	482	**31.5**	20	45 000	—	—	—	**48.7**	$11.3\sqrt{S_o}$	**5.17**[c]	18.7[c]
		283	541	**30.6**	19.5	43 500	—	—	—	**47.8**	$11.3\sqrt{S_o}$	—	—
		300	572	—	—	—	—	—	—	—	—	**2.38**[c]	8.6[c]
		327	621	—	—	—	—	—	—	—	—	**2.13**[c]	7.7[c]
		336	637	**26.9**	17	38 500	—	—	—	**33.2**	$11.3\sqrt{S_o}$	—	—
		351	664	—	—	—	—	—	—	—	—	**1.08**[c]	3.9[c]
		355	671	**25.3**	16	36 000	—	—	—	**37.2**	$11.3\sqrt{S_o}$	—	—
		400	752	**21.2**	13.5	30 000	—	—	—	**41.6**	$11.3\sqrt{S_o}$	**0.81**[c]	2.9[c]
		450	842	—	—	—	—	—	—	—	—	**0.92**[c]	3.3[c]
		454	849	**16.7**	10.5	23 500	—	—	—	**34.7**	$11.3\sqrt{S_o}$	—	—
		500	932	**9.6**	6	13 500	—	—	—	**33.3**	$11.3\sqrt{S_o}$	**0.77**[c]	2.8[c]
		550	1022	—	—	—	—	—	—	—	—	**1.14**[c]	4.1[c]
		599	1110	—	—	—	—	—	—	—	—	**1.37**[c]	5.0[c]
		650	1202	—	—	—	—	—	—	—	—	**7.18**[c][d]	26.0[c][d]
		704	1299	—	—	—	—	—	—	—	—	**4.82**[c][d]	17.4[c][d]
	Cold Worked 17%	19	66	—	—	—	—	—	—	—	—	**5.08**[c]	18.4[c]
		53	127	—	—	—	—	—	—	—	—	**5.09**[c]	18.4[c]
		100	212	—	—	—	—	—	—	—	—	**4.85**[c]	17.7[c]
		152	306	—	—	—	—	—	—	—	—	**4.41**[c]	17.4[c]
		201	394	—	—	—	—	—	—	—	—	**4.11**[c]	14.9[c]
		250	482	—	—	—	—	—	—	—	—	**3.27**[c]	11.8[c]
		301	574	—	—	—	—	—	—	—	—	**2.06**[c]	7.5[c]
		351	664	—	—	—	—	—	—	—	—	**1.06**[c]	3.8[c]
		400	752	—	—	—	—	—	—	—	—	**0.96**[c]	3.5[c]
		450	842	—	—	—	—	—	—	—	—	**1.68**[c]	6.1[c]
		500	932	—	—	—	—	—	—	—	—	**1.59**[c]	5.8[c]
		550	1022	—	—	—	—	—	—	—	—	**2.07**[c]	7.5[c]
		600	1112	—	—	—	—	—	—	—	—	**2.84**[c]	10.3[c]
		650	1202	—	—	—	—	—	—	—	—	**7.93**[c][d]	28.7[c][d]
		700	1292	—	—	—	—	—	—	—	—	**5.10**[c][d]	18.4[c][d]

continued on opposite page

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

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength 0.5% extension under load psi	%	gauge length	kg m / cm²	ft lb
Rod[2]	Cold Worked 25%	21	70	**56.0**	35.5	79 500	—	—	—	**19.8**	$11.3\sqrt{S_o}$	—	—
		50	122	**54.2**	34.5	77 000	—	—	—	**19.6**	$11.3\sqrt{S_o}$	—	—
		100	212	**53.0**	33.5	75 500	—	—	—	**19.4**	$11.3\sqrt{S_o}$	—	—
		156	313	**49.3**	31.5	70 000	—	—	—	**19.2**	$11.3\sqrt{S_o}$	—	—
		194	381	**45.1**	28.5	64 000	—	—	—	**20.0**	$11.3\sqrt{S_o}$	—	—
		253	487	**43.2**	27.5	61 500	—	—	—	**19.6**	$11.3\sqrt{S_o}$	—	—
		296	565	**38.4**	24.5	54 500	—	—	—	**16.5**	$11.3\sqrt{S_o}$	—	—
		325	617	**36.7**	23.5	52 000	—	—	—	**14.2**	$11.3\sqrt{S_o}$	—	—
		365	689	**22.7**	14.5	32 500	—	—	—	**14.7**	$11.3\sqrt{S_o}$	—	—
		396	745	**20.7**	13	29 500	—	—	—	**23.4**	$11.3\sqrt{S_o}$	—	—
		450	842	**13.6**	8.5	19 500	—	—	—	**32.5**	$11.3\sqrt{S_o}$	—	—
		505	941	**5.5**	3.5	8 000	—	—	—	**31.8**	$11.3\sqrt{S_o}$	—	—
Rod[6]	Hot Worked (grain size 0.020 mm)	24	75	39	24.5	**55 350**	—	—	—	**51.0**	2 in.	—	—
19 mm diam.		204	400	33.5	21.5	**45 750**	—	—	—	**50.5**	2 in.	—	—
0.75 in. diam.		316	600	17.5	11	**25 150**	—	—	—	**40.0**	2 in.	—	—
		427	800	6	4	**8 700**	—	—	—	**18.0**	2 in.	—	—
Tube[7]	Annealed	Room	Room	28	18	**40 000**	—	—	**20 000**	—	—	—	—
		66	150	28	18	**40 000**	—	—	**20 000**	—	—	—	—
		121	250	31.5	20	**45 000**	—	—	**20 000**	—	—	—	—
		149	300	30	19	**43 000**	—	—	**20 000**	—	—	—	—
		177	350	28	18	**40 000**	—	—	**20 000**	—	—	—	—
		204	400	26	16.5	**37 000**	—	—	**20 000**	—	—	—	—
		232	450	24	15	**34 000**	—	—	**18 000**	—	—	—	—

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

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

(c) Charpy test, 10 × 8 × 100 mm specimen, 45° V-notch, 3 mm deep; cross-sectional area at the notch 0.5 cm².

(d) Unbroken specimen.

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

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

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension %[a]	Intercept %	Minimum Creep Rate % per 1000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod[5] **3.2 mm diam. 0.125 in. diam.**	Annealed	149	300	3.5	2.2	**5 000**	**6 430**	**0.053 5**	**0.009 5**	**0.001 1**
				5.2	3.3	**7 450**	**6 430**	**0.099**	**0.029**	**0.002 3**
				7.0	4.4	**10 000**	**6 430**	**0.158**	**0.039**	**0.006**
				10.5	6.7	**15 000**	**6 430**	**0.313**	**0.084**	**0.011 5**
				14.0	8.9	**19 900**	**6 430**	**3.580**	**1.265**	**0.20**
		204	400	0.74	0.47	**1 050**	**7 700**	**0.048**	**0.013 2**	**0.002 9**
				1.4	0.92	**2 050**	**7 700**	**0.090**	**0.025**	**0.005 8**
				2.8	1.8	**4 050**	**2 280**	**0.18**	**0.010**	**0.022**
				4.3	2.7	**6 100**	**7 680**	**1.975**	**0.053**	**0.246**

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

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

5.3.2.2 Stress for Designated Creep Data

Form	Temper	Testing Temperature		Stress for Designated Creep Rate								
		°C	°F	0.001 % per 1 000 h			0.01 % per 1 000 h			0.1 % per 1 000 h		
				kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod[5] **3.2 mm diam. 0.125 in. diam.**	Annealed	149	300	3.3	2.1	**4 700**	9.7	6.2	**13 800**	13.6	8.6	**19 300**
Rod[8] **19 mm diam. 0.75 in. diam.**	Hot Rolled (alpha grain size 0.020 mm)	149	300	—	—	—	6.3	4.0	**9 000**	8.4	5.4	**12 000**
		204	400	—	—	—	1.4	0.89	**2 000**	3.3	2.1	**4 750**

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod[9] **19 mm diam. 0.75 in. diam.**	Annealed	50	42	15[a]	26.5	9.5[a]	**59 500**	**21 500**[a]
	Cold Worked 25%	50	54.5	19.5[a]	34.5	12.5[a]	**77 600**	**27 700**[a]
	Cold Worked 25% and Stress Relieved[e]	50	51.5	21.5[a]	32.5	13.5[a]	**73 200**	**30 400**[a]
Rod[10] **25.4 mm diam. 1 in. diam.**	Hot Worked[b]	100	54	11[a]	34	7[a]	**76 600**	**16 000**[a]
	Hot Worked[c]	100	55.5	13[a]	35.5	8.5[a]	**79 200**	**18 500**[a]
	Hot Worked[d]	100	46	12.5[a]	29.5	8[a]	**65 600**	**18 000**[a]

[a] Rotating-beam test. [b] Drawn at 249 °C (*480 °F*). [c] Drawn at 343 °C (*650 °F*). [d] Drawn at 450 °C (*840 °F*). [e] Stress relieved at 275 °C (*527 °F*).

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

—Further data can be obtained from the following paper:

■ Frost, N.E. and Greenan, A.F. Further Experiments on the Propagation of Edge Cracks in Plate Specimens. National Engineering Laboratory, East Kilbride, Glasgow: NEL Report No. 132 (1964), Feb.

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