Cu Zn28
Cu Zn30

This data sheet covers both Cu Zn28 and Cu Zn30, since these alloys have very similar compositions and properties.

Common names: 70/30 Brass
Cartridge Brass
Deep-Drawing Brass

Two copper–zinc alloys with an alpha phase structure. The alloys exhibit the optimum combination of strength and ductility in the copper-zinc series and are commonly used whenever extreme cold deformation is involved. Cu Zn28 is produced only in some European countries for applications for which American and British industrial practice would specify Cu Zn30. Service environment for both alloys must be considered to predict corrosion behaviour. A typical application of these alloys is for deep-drawn components such as cartridge cases. Cu Zn30 also includes the inhibited variety containing arsenic, which is generally used for heat-exchanger tubes.

COMPOSITION (weight %)

Cu Zn28		**Cu Zn30***	
Cu . .	71.0–73.0	Cu . .	68.5–71.5
Zn . .	rem.	Zn . .	rem.

*Arsenic is sometimes added as a corrosion inhibitor.

1 SOME TYPICAL USES

Chemical

Heat-exchanger tubes handling fresh, clean water; sugar evaporators and juice heaters; fire-extinguisher bodies.

Electrical

Lamp caps and lampholder components.

Hardware

Chain, eyelets, fasteners, hinges, locks, fingerplates, wire cloth, wire brushes.

Mechanical

Wide variety of deep-drawn and spun components, including cartridge cases and musical instruments; automobile radiator tanks and tubes; carburettor parts; wire reinforcements in brake and clutch linings; general industrial pressings formed from sheet and strip; torch and flashlight cases; reflectors; cold-headed or "upset" products such as rivets, pins and screws.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.55 g/cm³	0.310 lb/in³
2.2 Melting range	910–965 °C	1 670–1 770 °F
2.3 Coefficient of thermal expansion (linear) at:		
−128 to 20 °C *−200 to 68 °F*	0.000 009 per °C	0.000 005 per °F
20 to 100 °C *68 to 212 °F*	0.000 019 ,, ,,	0.000 010 ,, ,,
20 to 300 °C *68 to 572 °F*	0.000 020 ,, ,,	0.000 011 ,, ,,
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
200 °C *392 °F*	0.11 ,,	0.11 ,,
2.5 Thermal conductivity at:		
−200 °C *−328 °F*	0.12 cal cm/cm² s °C	30 Btu ft/ft² h °F
20 °C *68 °F*	0.29 ,,	70 ,,
200 °C *392 °F*	0.35 ,,	85 ,,
2.6 Electrical conductivity (volume) at:		
−196 °C *−321 °F* (annealed)	24 m/ohm mm²	41 % IACS
20 °C *68 °F* (,,)	16 ,,	28 ,, ,,
200 °C *392 °F* (,,)	13 ,,	22 ,, ,,
−196 °C *−321 °F* (fully cold worked)	18 ,,	31 ,, ,,
20 °C *68 °F* (,, ,, ,,)	13 ,,	22 ,, ,,

continued overleaf

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

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

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DATA SHEET No. D 5
Cu Zn28 — Cu Zn30

2 PHYSICAL PROPERTIES (continued)

	Metric Units	English Units
2.7 Electrical resistivity (volume) at:		
−196 °C *−321 °F* (annealed)	0.042 ohm mm²/m 4.2 microhm cm	25 ohms (circ mil/ft) 1.7 microhm in
20 °C *68 °F* (,,)	0.062 ohm mm²/m 6.2 microhm cm	37 ohms (circ mil/ft) 2.4 microhm in
200 °C *392 °F* (,,)	0.079 ohm mm²/m 7.9 microhm cm	47 ohms (circ mil/ft) 3.1 microhm in
−196 °C *−321 °F* (fully cold worked)	0.056 ohm mm²/m 5.6 microhm cm	33 ohms (circ mil/ft) 2.2 microhm in
20 °C *68 °F* (,, ,, ,,)	0.078 ohm mm²/m 7.8 microhm cm	47 ohms (circ mil/ft) 3.1 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 5 per °C (28% IACS)	0.000 8 per °F (28% IACS)
20 °C *68 °F* (fully cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 2 ,, ,, (22% IACS)	0.000 7 ,, ,, (22% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	11 700 kg/mm²	16 600 000 lb/in²
cold worked	9 900–11 700 kg/mm²	14 100 000–16 600 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	4 150 kg/mm²	5 900 000 lb/in²
cold worked	3 700–4 150 kg/mm²	5 250 000–5 900 000 lb/in²

N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition ranges 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	1 070–1 110 °C	1 960–2 030 °F
3.2 Annealing temperature range	450– 680 °C	840–1 255 °F
Stress relieving temperature range	250– 350 °C	480– 660 °F
3.3 Hot working temperature range	750– 870 °C	1 380–1 600 °F
3.4 Hot formability	Fair	
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)	30	
3.8 Joining methods:	See General Data Sheet No. 3.4	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	Good	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Fair	
Coated metal-arc welding	Not recommended	
Resistance welding: spot and seam	Fair	
butt	Good	

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
				Cu Zn28					
Belgium	NBN	Lt 72	—	266.11	266.11	266.11	—	—	—
Chile	INDITECNOR	Cu Zn28	247 n./68	—	—	—	—	—	—
France	NF	U-Z28	EN A 53–013	A 53-603	—	—	—	—	—
Germany	DIN	Cu Zn28 (2.0261)	17 660	17 670	17 672	17 672 17 689	17 671	—	—
Italy	UNI	P-Cu Zn28	4896	4896	4896	4896	4896	—	—
Spain	UNE	Cu Zn28	37.103	37.103	—	37.103	37.103	—	—
Switzerland	VSM	Cu Zn28	10 822	11 855	11 854	11 858	11 857	11 854	—
				Cu Zn30					
Australia	SAA	—	—	H7	—	—	H15	—	—
Belgium	NBN	Lt 70	—	—	—	—	266.11	—	—
Canada	CSA	HC.Z30 (or 260)	—	HC.4.2	—	HC.5.21	HC.7.2	—	—
Chile	INDITECNOR	Cu Zn30	247 n./68	—	—	—	—	—	—
France	NF	U-Z30	EN A 53-013	—	—	—	A 53-503		—
Germany	DIN	Cu Zn30 (2.0265)	17 660	17 670	17 672	17 672	1785 17 671	—	—
India	IS	Cu Zn30	—	410 3168	4170	4413	407	—	—
Italy	UNI	P-Cu Zn30	4895	4895	4895	4895	4895	—	—
Japan	JIS	BsP1 BsW1 BsR1 BsT1	—	H 3201 H 3321	—	H 3521	H 3631	—	—
Netherlands	N or NEN[(b)]	Cu-Zn30	NEN 6030	NEN 6033	—	—	N 1130	—	—
South Africa	SABS	Cu Zn30	—	—	—	—	466 467	—	—
Spain	UNE	Cu Zn30	37.103	37.103 37.104	—	37.103	37.103 37.107	37.103 37.108	—
Sweden	SIS	14 51 22	—	14 51 22	—	—	—	—	—
Switzerland	VSM	Cu Zn30	10 822	11 855	11 854	11 858	11 557 11 857	11 854	—
United Kingdom	BS	CZ105	—	2875	—	—	378 885 1464 2871 2579 (Part 1)	—	—
		CZ106	—	267 2870 2875	2874	2873	—	—	—
United States[(c)]	ASTM	No. 260	—	B19 B36 B134	—	B 134	B135	B129	—
International Organization for Standardization	ISO	Cu Zn30	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 and flat wire are covered under the Plate-Sheet-Strip column.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

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

5.2 Mechanical properties at low temperature

Tensile properties	see table 5.2.1
Impact properties	" " 5.2.1

5.3 Mechanical properties at elevated temperature

Short-time tensile properties	see table 5.3.1
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								
	grain size 0.035 mm	33	12	60	$5.65\sqrt{S_o}$	65	68	25	0.2–5 mm thick
	grain size 0.025 mm	35	14	57	50 mm	80	84	26	0.2–2.5 mm thick
	grain size 0.015 mm	37	15	55	50 mm	85	89	28	0.2–1.5 mm thick
	Typical Cold Worked Tempers	38	23	40	50 mm	95	100	27	0.2–3 mm thick
		42	32	32	50 mm	120	125	28	"
		48	40	18	50 mm	135	140	30	0.2–2 mm thick
		52	47	10	50 mm	145	150	31	"
		57	54	6	50 mm	155	160	32	0.2–1.5 mm thick
		60	—	—	—	160	170	33	0.2–1 mm thick
Rod	Annealed	32	12	62	$5.65\sqrt{S_o}$	65	68	24	—
	Typical Cold Worked Tempers	36	20	45	$5.65\sqrt{S_o}$	80	84	26	—
		40	30	35	$5.65\sqrt{S_o}$	110	115	28	6–40 mm diam. or equivalent area
		46	39	20	$5.65\sqrt{S_o}$	125	130	30	6–12 mm diam. or equivalent area
Wire	Annealed	36	—	48	100 mm	—	—	26	1.5–6 mm diam.
		38	—	38	100 mm	—	—	27	0.5–1.5 mm diam.
		42	—	22	100 mm	—	—	28	up to 0.5 mm diam.
	Typical Cold Drawn Tempers	40	—	35	100 mm	—	—	27	1.5–6 mm diam.
		55	—	10	100 mm	—	—	30	"
		65	—	—	—	—	—	35	1.5–3 mm diam.
		78	—	—	—	—	—	39	"
		44	—	18	100 mm	—	—	29	0.5–1.5 mm diam.
		58	—	3	100 mm	—	—	32	"
		70	—	—	—	—	—	35	"
		85	—	—	—	—	—	43	"
Tube[c]	Annealed								
	—[d]	33	13	58	$5.65\sqrt{S_o}$	65	68	25	—
	grain size 0.030 mm	**34**	**13**	**55**	$5.65\sqrt{S_o}$	**65**	**68**	**26**	15—30 mm O.D. 0.8— 2 mm wall
	grain size 0.020 mm	**37**	**18**	**45**	$5.65\sqrt{S_o}$	**75**	**79**	**27**	"
	Typical Cold Drawn Tempers	40	32	30	$5.65\sqrt{S_o}$	110	115	28	10–50 mm O.D. over 2 mm wall
		48	42	15	$5.65\sqrt{S_o}$	135	140	31	up to 25 mm O.D. up to 2 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, 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) Tubes for heat exchangers and condensers are generally supplied only to the tempers whose representative mechanical properties are printed in **bold type.**

(d) Grain size not defined.

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)]
Plate	Annealed	20	6	60	$5.65\sqrt{S_o}$	70	15	—
	Hot Rolled	21	7	55	$5.65\sqrt{S_o}$	85	16	0.5–2 in. thick
	Cold Rolled							
	Hard	23	14	45	$5.65\sqrt{S_o}$	100	17	0.625–1in. thick
		24	16	40	$5.65\sqrt{S_o}$	110	18	0.375–0.625 in. thick
Sheet Strip	Annealed							
	grain size 0.070 mm	20	6	70	2 in.	60	15	—
	grain size 0.050 mm	21	7	68	2 in.	65	16	—
	grain size 0.035 mm	21	7	65	2 in.	70	16	—
	grain size 0.025 mm	22	8	63	2 in.	80	17	—
	grain size 0.015 mm	23	9	60	2 in.	90	17	0.01–0.125 in. thick
	Cold Worked							
	Quarter Hard	22	14	55	2 in.	90	17	0.01–0.375 in. thick
	Half Hard	25	19	40	2 in.	120	18	0.01–0.25 in. thick
	Hard	29	24	22	2 in.	145	19	0.01–0.1 in. thick
	Extra Hard	35	30	10	2 in.	170	20	"
Rod	Annealed	20	7	60	$5.65\sqrt{S_o}$	70	15	—
	Cold Worked							
	As Manufactured	22	14	50	$5.65\sqrt{S_o}$	90	17	0.25–1 in. diam. or equivalent area
		24	18	40	$5.65\sqrt{S_o}$	110	18	
Wire	Annealed	21	—	70	2 in.	—	16	0.10–0.25 in. diam.
		22	—	65	2 in.	—	17	0.02–0.10 in. diam.
	Cold Drawn							
	Quarter Hard	26	—	35	2 in.	—	18	0.10–0.25 in. diam.
	Half Hard	34	—	12	2 in.	—	24	"
	Hard	42	—	—	—	—	27	"
	Half Hard	36	—	10	2 in.	—	25	0.02–0.10 in. diam.
	Hard	44	—	—	—	—	29	"
Tube[(c)]	Annealed							
	grain size 0.025 - 0.035 mm	**20**	**6**	**60**	$5.65\sqrt{S_o}$	**70**	**15**	—
	Cold Drawn or Temper Annealed							
	Temper Annealed	23	12	45	$5.65\sqrt{S_o}$	90	17	2–10 in. O.D., 0.08–0.2 in. wall
	As Drawn	26	20	25	$5.65\sqrt{S_o}$	130	19	"
	Temper Annealed	**23**	**12**	**50**	$5.65\sqrt{S_o}$	**90**	**17**	0.25–2 in. O.D., 0.02–0.08 in. wall
	Temper Annealed	**26**	**18**	**35**	$5.65\sqrt{S_o}$	**135**	**19**	"
	As Drawn	**30**	**25**	**20**	$5.65\sqrt{S_o}$	**165**	**21**	"
	As Drawn	36	30	10	$5.65\sqrt{S_o}$	185	25	"

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

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

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

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, Bar and Flat Wire)	Annealed									
	grain size 0.100 mm	44 000	11 000	66	2 in.	54	—	11	32 000	0.040 in. thick
	grain size 0.070 mm	46 000	14 000	65	2 in.	58	—	15	32 000	"
	grain size 0.050 mm	47 000	15 000	62	2 in.	64	—	26	33 000	"
	grain size 0.035 mm	49 000	17 000	57	2 in.	68	—	31	34 000	"
	grain size 0.025 mm	51 000	19 000	55	2 in.	72	—	36	34 000	"
	grain size 0.015 mm	53 000	22 000	54	2 in.	78	—	43	35 000	"
	Cold Worked									
	Quarter Hard	54 000	40 000	43	2 in.	—	55	54	36 000	0.040 in. thick
	Half Hard	62 000	52 000	23	2 in.	—	70	65	40 000	"
	Hard	76 000	63 000	8	2 in.	—	82	73	44 000	"
	Extra Hard	86 000	65 000	5	2 in.	—	88	76	46 000	"
	Spring	94 000	65 000	3	2 in.	—	91	77	48 000	"
	Extra Spring	99 000	65 000	3	2 in.	—	93	78	53 000	"
Rod	Annealed									
	grain size 0.050 mm	48 000	15 000	65	2 in.	65	—	—	34 000	1.0 in. diam.
	Cold Worked									
	Eighth Hard (6%)	55 000	40 000	48	2 in.	—	60	—	36 000	1.0 in. diam.
	Half Hard (20%)	70 000	52 000	30	2 in.	—	80	—	42 000	"
Wire	Annealed									
	grain size 0.050 mm	48 000	16 000	64	2 in.	—	—	—	33 000	0.080 in. diam.
	grain size 0.035 mm	50 000	18 000	60	2 in.	—	—	—	34 000	"
	grain size 0.025 mm	52 000	21 000	58	2 in.	—	—	—	35 000	"
	grain size 0.015 mm	54 000	23 000	56	2 in.	—	—	—	36 000	"
	Cold Worked									
	Eighth Hard	58 000	46 000	35	2 in.	—	—	—	38 000	0.080 in. diam.
	Quarter Hard	70 000	57 000	20	2 in.	—	—	—	42 000	"
	Extra Hard	124 000	—	4	2 in.	—	—	—	59 000	"
	Spring	130 000	—	3	2 in.	—	—	—	60 000	"
Tube	Annealed									
	grain size 0.050 mm	47 000	15 000	65	2 in.	64	—	26	33 000	1.0 in. O.D. × 0.065 in. wall
	grain size 0.025 mm	52 000	20 000	55	2 in.	75	—	40	35 000	"
	Cold Worked									
	Hard Drawn (35%)	78 000	64 000	8	2 in.	—	82	73	44 000	1.0 in. O.D. × 0.065 in. wall
Shapes	Annealed[b]	48 000	15 000	65	2 in.	65	—	—	34 000	—
	Cold Worked[b]									
	Eighth Hard (6%)	55 000	40 000	48	2 in.	—	60	—	36 000	—
	Half Hard (20%)	70 000	52 000	30	2 in.	—	80	—	42 000	—

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

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation		Reduction of Area	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	0.1% offset ton/in²	Yield Strength psi	%	gauge length	%	kg m/cm²	ft lb
Rod[1] 19 mm diam. 0.75 in. diam.	Cold Worked[a]	20	68	67	42.5	**95 200**	**42.8**[b]	—	—	**14.2**	$4.52\sqrt{S_0}$	**58.3**	2.7[c]	**15.5**[c]
		-78	-108	71	45	**100 800**	**45.2**[b]	—	—	**17.3**	$4.52\sqrt{S_0}$	**62.3**	2.7[c]	**15.5**[c]
		-197	-323	82.5	52	**117 000**	**48.2**[b]	—	—	**28.4**	$4.52\sqrt{S_0}$	**63.4**	2.7[c]	**15.5**[c]
		-253	-423	93	59	**132 500**	**51.6**[b]	—	—	**32.2**	$4.52\sqrt{S_0}$	**58.2**	—	—
Rod[2] 25.4 mm diam. 1.0 in. diam.	Annealed[d]	20	68	36	**22.8**	51 000	—	**12.57**	—	**49.4**	2 in.	**77.0**	11.3[e]	**65.5**[e]
		-10	14	37.5	**23.7**	53 000	—	**12.75**	—	**48.5**	2 in.	**77.0**	—	—
		-40	-40	38.5	**24.4**	54 500	—	**12.0**	—	**57.7**	2 in.	**77.0**	11.4[e]	**66.0**[e]
		-80	-112	40	**25.5**	57 000	—	**12.17**	—	**59.5**	2 in.	**79.0**	11.9[e]	**69.0**[e]
		-120	-184	43	**27.3**	61 000	—	**12.5**	—	**54.7**	2 in.	**77.5**	12.2[e]	**70.5**[e]
		-180	-292	51.5	**32.8**	73 500	—	**13.2**	—	**74.6**	2 in.	**73.0**	13.6[e]	**78.5**[e]
	Annealed[f]	20	68	37.5	**23.9**	53 500	—	**15.4**	—	**58.0**	2 in.	**74.0**	11.3[e]	**65.5**[e]
		-180	-292	51.5	**32.8**	73 500	—	**19.2**[g]	—	**81.0**	2 in.	**74.0**	13.6[e]	**78.5**[e]
Rod[3]	Annealed	18	64	29	18.5	**41 500**	—	—	**9 500**[g]	**82.6**	2 in.	**76.4**	14.7[c]	**85**[c]
		0	32	30	19	**42 800**	—	—	**9 800**[g]	**79.7**	2 in.	**78.7**	14.9[c]	**86**[c]
		-30	-22	30.5	19.5	**43 200**	—	—	**10 400**[g]	**75.9**	2 in.	**79.7**	15.5[c]	**89.5**[c]
		-80	-112	34	21.5	**48 600**	—	—	**12 200**[g]	**74.5**	2 in.	**80.0**	15.4[c]	**89**[c]

(a) Quoted as "¾ hard" 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. (c) Charpy specimen, V-notch; cross-sectional area at the notch 0.8 cm². (d) Tensile specimen 6.35 mm (0.25 in.) diam. (e) Izod specimen, cross-sectional area at the notch 0.8 cm². (f) Tensile specimen 12.8 mm (0.505 in.) diam. (g) Quoted as 'yield point' in original document, but offset strain not defined.

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

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

—The yield strength 0.5% extension under load values are not available.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation % 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	
Strip[4] 2 mm 0.08 in.	Annealed (grain size 0.035 mm)	20	68	34	**21.5**	48 000	—	**6.4**	—	**64**
		100	212	32	**20.4**	45 500	—	**6.1**	—	**58**
		200	392	30	**19.0**	42 500	—	**6.0**	—	**54**
		250	464	27.5	**17.5**	39 000	—	**5.8**	—	**46**
		300	572	24.5	**15.4**	34 500	—	**5.7**	—	**32**
Plate[5]	Annealed	20	68	33.5	**21.4**	48 000	**9.13**[a]	**5.6**	—	**68**
		66	150	31.5	**20.1**	45 000	**8.35**[a]	**5.2**	—	**64**
		121	250	30.5	**19.3**	43 000	**8.82**[a]	**5.5**	—	**63**
		177	350	29.5	**18.8**	42 000	**8.82**[a]	**5.3**	—	**64**
		232	450	25.5	**16.1**	36 000	**8.50**[a]	**5.2**	—	**33**
Rod[6] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.016 mm)	24	75	42	26.5	**59 500**	—	—	**22 200**	**42**
		149	300	—	—	—	—	—	**22 900**	—
		204	400	—	—	—	—	—	**22 200**	—
		260	500	—	—	—	—	—	**19 900**	—
	Annealed (grain size 0.022 mm)	24	75	36.5	23	**52 000**	—	—	**19 000**	**49.0**
		149	300	—	—	—	—	—	**19 000**	—
		204	400	—	—	—	—	—	**18 800**	—
		260	500	—	—	—	—	—	**16 900**	—
	Annealed (grain size 0.085 mm)	24	75	34	21.5	**48 500**	—	—	**11 300**	**57.0**
		149	300	—	—	—	—	—	**12 700**	—
		204	400	—	—	—	—	—	**11 500**	—
		260	500	—	—	—	—	—	**11 000**	—
Rod[7] 12.8 mm diam. 0.505 in. diam.	Cold Worked 20%	25	77	44.5	28.5	**63 300**	—	—	—	**25**
		200	392	41.5	26.5	**58 800**	—	—	—	**16**
		310	590	34	21.5	**48 200**	—	—	—	**4**
		460	860	9.5	6	**13 500**	—	—	—	**25**
		615	1 139	3	2	**4 500**	—	—	—	**26**
		735	1 355	1.5	1	**2 300**	—	—	—	**53**
		835	1 535	0.8	0.5	**1 200**	—	—	—	**91**
		865	1 625	0.4	0.3	**600**	—	—	—	**43**
Rod[8] 16 mm diam. 0.625 in. diam.	Cold Worked 30%	24	75	49	31.5	**70 000**	—	—	—	**24.3**
		204	400	46	29.5	**65 550**	—	—	—	**12.0**
		316	600	36	23	**51 500**	—	—	—	**4.5**
		427	800	15	9.5	**21 000**	—	—	—	**26.0**
		538	1 000	6.5	4	**9 400**	—	—	—	**24.5**

(a) This value was originally reported in ton/in²; 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 h	Total Extension %[a]	Intercept %	Min. Creep Rate % per 1 000 h
Rod[6] 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.016 mm)	149	300	3.2	2.0	**4 500**	**5 210**	**0.045**	**0.016**	**0.002 2**
				10.6	6.7	**15 050**	**4 680**	**0.204**	**0.081**	**0.014**
				14.1	9.0	**20 100**	**4 800**	**0.570**	**0.240**	**0.053**
		204	400	0.72	0.46	**1 020**	**5 100**	**0.047**	**0.024**	**0.002 9**
				1.4	0.88	**1 980**	**3 240**	**0.044**	**0.011**	**0.005 7**
				2.1	1.4	**3 040**	**5 400**	**0.104**	**0.023**	**0.011**
				4.2	2.7	**5 980**	**5 400**	**0.339**	**0.069**	**0.042**
		260	500	0.37	0.23	**520**	**5 000**	**0.111**	**0.059**	**0.009 3**
				0.70	0.44	**990**	**5 000**	**0.190**	**0.038**	**0.028 2**
				1.0	0.66	**1 480**	**4 650**	**0.335**	**0.033**	**0.061 0**
				2.1	1.4	**3 050**	**2 950**	**1.495**	**0.255**	**0.413**
	Annealed (grain size 0.022 mm)	204	400	2.0	1.2	**2 790**	**3 300**	**0.052**	**0.016**	**0.008 1**
				4.0	2.5	**5 690**	**1 600**	**0.104**	**0.025**	**0.036**
				6.0	3.8	**8 580**	**3 300**	**0.430**	**0.035**	**0.11**
		260	500	0.79	0.50	**1 125**	**4 080**	**0.115**	**0.014**	**0.021**
				1.4	0.86	**1 930**	**3 720**	**0.357**	**0.061**	**0.074**
				1.9	1.2	**2 730**	**4 080**	**0.908**	**0.090**	**0.195**
				2.6	1.6	**3 680**	**3 720**	**1.557**	**0.147**	**0.37**
	Annealed (grain size 0.085 mm)	149	300	3.2	2.0	**4 500**	**4 680**	**0.029**	**0.006**	**0.000 4**
				7.1	4.5	**10 100**	**5 210**	**0.110**	**0.026**	**0.001 2**
				10.6	6.7	**15 100**	**4 770**	**1.932**	**0.210**	**0.006 0**
		204	400	1.0	0.66	**1 470**	**4 050**	**0.013**	**0.002**	**<0.000 5**
				2.1	1.4	**3 050**	**5 400**	**0.034**	**0.013**	**0.001 1**
				2.8	1.8	**4 000**	**5 060**	**0.048**	**0.020**	**0.001 5**
				5.7	3.6	**8 050**	**5 060**	**0.147**	**0.031**	**0.014**
		260	500	1.0	0.65	**1 460**	**4 650**	**0.035**	**0.007**	**0.003 3**
				2.1	1.3	**3 020**	**8 150**	**0.319**	**−0.076**	**0.045**
				4.3	2.7	**6 150**	**5 000**	**2.559**	**0.340**	**0.44**
	Cold Worked 37% (fine grained)	149	300	3.5	2.2	**5 030**	**5 100**	**0.037**	**0.017**	**0.000 6**
				10.5	6.7	**14 950**	**4 800**	**0.160**	**0.059**	**0.004 4**
				14.0	8.9	**19 900**	**5 230**	**0.230**	**0.090**	**0.006 4**
				21.0	13.3	**29 800**	**4 800**	**0.470**	**0.190**	**0.017 6**
				34.8	22.1	**49 550**	**4 680**	**1.900**	**0.470**	**0.223**
		204	400	0.70	0.45	**1 000**	**5 400**	**0.030**	**−0.012**	**0.007[b]**
				2.5	1.4	**3 500**	**6 500**	**0.160**	**−0.043**	**0.027[b]**
				3.5	2.3	**5 040**	**12 200**	**0.427**	**−0.124**	**0.042[b]**
		260	500	0.44	0.28	**620**	**5 000**	**0.186**	**0.070**	**0.021 4**
				0.70	0.45	**1 000**	**4 650**	**0.460**	**0.080**	**0.079 6**
				1.5	0.93	**2 080**	**4 800**	**1.912**	**0.160**	**0.366**
	Cold Worked 84% (fine grained)	149	300	7.0	4.5	**10 000**	**5 200**	**0.156**	**0.058**	**0.002 5**
				13.9	8.8	**19 700**	**5 230**	**0.326**	**0.129**	**0.005 4**
				28.1	17.8	**39 950**	**6 850**	**0.780**	**0.260**	**0.026**
				35.6	22.6	**50 600**	**4 750**	**1.430**	**0.540**	**0.10**
		204	400	0.72	0.46	**1 020**	**5 100**	**0.128**	**0.084**	**0.006 7**
				2.2	1.4	**3 060**	**5 060**	**0.530**	**0.180**	**0.063 6**
				3.5	2.2	**5 030**	**4 700**	**1.494**	**0.213**	**0.265**
		260	500	0.35	0.22	**500**	**5 000**	**0.311**	**0.121**	**0.037**
				0.56	0.36	**800**	**5 000**	**0.970**	**0.175**	**0.159**
				1.0	0.66	**1 480**	**2 620**	**3.015**	**0.212**	**1.07**

[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		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[6] **3.2 mm diam 0.125 in. diam.**	Annealed (grain size 0.016 mm)	149	300	—	—	—	9.1	5.8	**13 000**	—	—	—
		204	400	—	—	—	2.0	1.3	**2 900**	—	—	—
		260	500	—	—	—	0.46[a]	0.29[a]	**650**[a]	1.2	0.78	**1 750**
	Annealed (grain size 0.022 mm)	204	400	—	—	—	2.1	1.3	**3 000**	6.0	3.8	**8 500**
		260	500	—	—	—	0.56[a]	0.36[a]	**800**[a]	1.5	0.98	**2 200**
	Annealed (grain size 0.085 mm)	149	300	6.7	4.2	**9 500**	11.2[a]	7.1[a]	**16 000**[a]	—	—	—
		204	400	—	—	—	5.4	3.4	**7 700**	—	—	—
		260	500	0.70	0.45	**1 000**	1.4	0.89	**2 000**	2.8	1.8	**4 000**
	Cold Worked 37% (fine grained)	149	300	—	—	—	16.9	10.7	**24 000**	30.9	19.6	**44 000**
		260	500	—	—	—	0.32[a]	0.20[a]	**450**[a]	0.81	0.51	**1 150**
	Cold Worked 84% (fine grained)	149	300	—	—	—	15.5	9.8	**22 000**	35.2	22.2	**50 000**
		204	400	—	—	—	0.98[a]	0.63[a]	**1 400**[a]	2.5	1.6	**3 500**
		260	500	—	—	—	0.18[a]	0.11[a]	**250**[a]	0.49[a]	0.31[a]	**700**[a]

(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 ×10⁶	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Strip[9] **0.81 mm 0.032 in.**	Annealed (grain size 0.025 mm)	100	34.5	11[a]	22	7[a]	49 000	15 500[a]
	Annealed (grain size 0.035 mm)	100	35	9[a]	22	5.5[a]	49 500	12 500[a]
	Annealed (grain size 0.100 mm)	100	31.5	7.5[a]	20	4.5[a]	45 000	10 500[a]
	Annealed (grain size 0.120 mm)	100	31.5	8[a]	20	5[a]	45 000	11 500[a]
	Cold Worked 21%[b]	100	44.5	13[a]	28.5	8.5[a]	63 400	18 500[a]
	Cold Worked 21%[c]	100	43.5	12.5[a]	27.5	8[a]	62 000	18 000[a]
	Cold Worked 37%[d]	100	54	15.5[a]	34	10[a]	76 500	22 000[a]
	Cold Worked 37%[e]	100	50.5	15[a]	32	9.5[a]	71 500	21 000[a]
	Cold Worked 60%[b]	100	65	15.5[a]	41.5	10[a]	92 500	22 000[a]
	Cold Worked 60%[e]	100	64.5	17[a]	41	10.5[a]	92 000	24 000[a]
Strip[10] **1 mm 0.04 in.**	Cold Worked 60% and Stress Relieved[f]	10	67	19[a]	42.5	12[a]	95 000	27 000[a]
Sheet[11] **1 mm thick 0.04 in. thick**	Quarter Hard[g]	100	38.5	12[a]	24.5	7.5[a]	54 900	17 000[a]
	Half Hard[h]	100	43.5	15[a]	27.5	9.5[a]	61 700	21 000[a]
	Three Quarter Hard[i]	100	61.5	16[a]	39	10[a]	87 800	22 600[a]
	Hard[h]	100	54	17[a]	34	10.5[a]	76 600	23 900[a]
	Extra Hard[i]	100	66	18[a]	42	11.5[a]	93 900	25 500[a]
	Spring[i]	100	66.5	18[a]	42	11.5[a]	94 300	25 500[a]
	Extra Spring[i]	100	70.5	19[a]	44.5	12[a]	100 200	27 200[a]
	Super Spring[i]	100	77.5	20[a]	49	13[a]	110 000	28 700[a]
Rod[12] **16 mm diam. 0.625 in. diam.**	Cold Worked 21%	100	40	10.5[j]	25.5	6.5[j]	57 000	15 000[j]

continued overleaf

5.4.1. Fatigue Strength at Room Temperature (continued)

Form	Temper	Number of Cycles ×10^6	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod[13] 19 mm diam. 0.75 in. diam.	Annealed	50	33	16[j]	21	10[j]	**47 200**	**22 500**[j]
	Cold Worked 27%	50	52	15.5[j]	33	10[j]	**74 100**	**22 000**[j]
	Cold Worked 27% and Stress Relieved[k]	50	51.5	19.5[j]	33	12.5[j]	**73 500**	**28 000**[j]
Rod[14] 25.4 mm diam. 1 in. diam.	Annealed	100	31.5	10.5[j]	20	6.5[j]	**45 000**	**15 000**[j]
	Cold Worked	100	51.5	12.5[j]	32.5	8[j]	**73 200**	**17 500**[j]
	Cold Worked and Stress Relieved[l]	80	51.5	14[j]	32.5	9[j]	**73 000**	**20 000**[j]
	Cold Worked and Stress Relieved[m]	80	52	14[j]	33	9[j]	**73 800**	**20 000**[j]
	Cold Worked and Stress Relieved[n]	70	51.5	15[j]	33	9.5[j]	**73 400**	**21 500**[j]
Rod[15]	Annealed (grain size 0.016 mm)	50	38	14[j]	**24.2**	**9**[j]	54 000	20 000[j]
	Annealed (grain size 0.04 mm)	50	33	10[j]	**21.0**	**6.5**[j]	47 000	14 500[j]
Wire[16] 1.8 mm diam. 0.072 in. diam.	Cold Worked 60%	100	69.5	13.5[j]	44	8.5[j]	**98 500**	**19 500**[j]
	Cold Worked 84%	100	84.5	15.5[j]	53.5	10[j]	**120 000**	**22 000**[j]

[a] Reversed-bending test. [b] Ready-to-finish grain size 0.025 mm. [c] Ready-to-finish grain size 0.080 mm. [d] Ready-to-finish grain size 0.035 mm. [e] Ready-to-finish grain size 0.075mm. [f] Stress relieved for 1 h at 204 °C *(400 °F)*. [g] Ready-to-finish grain size 0.025 mm. [h] Ready-to-finish grain size 0.015 mm. [i] Ready-to-finish grain size 0.010 mm. [j] Rotating-beam test. [k] Stress relieved at 275 °C *(527 °F)*. [l] Stress relieved for 1.5 h at 204 °C *(400 °F)*. [m] Stress relieved for 1.5 h at 232 °C *(450 °F)*. [n] Stress relieved for 1.5 h at 260 °C *(500 °F)*.

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

— Further data can be obtained from the following:

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