UDC 669.35'5'6

Cu Zn38 Sn1

Common name: Naval Brass

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

COMPOSITION (weight %)*

Cu	59.5–63.5
Sn	0.5– 1.5
Zn	rem.

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

1 SOME TYPICAL USES

Marine and Mechanical

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

2 PHYSICAL PROPERTIES

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

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

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

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DATA SHEET No. F 3
Cu Zn38 Sn1

1970 Edition

3 FABRICATION PROPERTIES

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

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

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

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	—	—	—	H3 H4	—	—	H3 H4	H3 H4
Belgium . .	NBN	Lt60 Sn1	—	266.13	266.13	—	—	—	—
Canada . .	CSA	HC.ZT391 464 HC.ZT381P 482 HC.ZP372T 485	—	HC.4.6 HC.4.9	HC.5.9 HC.5.10	—	—	HC.5.9 HC.5.10	HC.8.1
Chile . . .	INDITECNOR	Cu Zn38 Sn1	247 of. 68	257 c. 65	256 c. 65	258 c. 65	259 c. 65	256 c. 65	—
France. . .	NF	—	—	—	—	—	—	—	—
Germany . .	DIN	Cu Zn39 Sn (2.0530)	17 660	17 670	—	—	—	—	—
India . . .	IS	—	—	—	320	—	—	320	—
Italy . . .	UNI	P-Cu Zn39 Sn1	—	6399	6399	—	6399	6399	6399
Japan . . .	JIS	NBsP1 NBsB1 NBsP2 NBsB2 BsTP	—	H3203	H3424	—	H3633	—	—
Netherlands	N or NEN[b]	Cu-Zn38 Sn1	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain . .	UNE	Cu Zn Sn 62-1	—	37 103	37 103	—	37 103	—	—
Sweden . .	SIS	—	—	—	—	—	—	—	—
Switzerland .	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	CZ112	—	409 1541 2870 2875	251 2872 2874	—	—	251 2874	251 2872
United States[c]	ASTM	Nos. 462, 464, 465, 466, 467, 482 and 485	—	B21 B124 B171	B21 B124	—	—	B21 B124	B283
International Organization for Standardization	ISO	Cu Zn38 Sn1	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

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.

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

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

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

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

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

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

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

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

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

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

Form	Temper[a]	Tensile Strength		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown[b]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Plate	Annealed	37	24	14	9	40	$5.65\sqrt{S_o}$	95	28	18	—
	Hot Rolled	40	26	17	11	35	$5.65\sqrt{S_o}$	110	30	20	12-50 mm (0.5-2 in.) thick
	Cold Rolled Hard	45	29	23	15	30	$5.65\sqrt{S_o}$	125	33	21	16-25 mm (0.625-1 in.) thick
	"	46	30	26	17	25	$5.65\sqrt{S_o}$	135	34	22	10-16 mm (0.375-0.625 in.) thick
Sheet Strip	Annealed	37	24	14	9	45	50 mm (2 in.)	95	28	18	—
	Hot Rolled	43	28	25	16	35	50 mm (2 in.)	125	32	21	3-10 mm (0.125-0.375 in.) thick
	Cold Worked Hard	49	32	31	20	25	50 mm (2 in.)	150	34	22	3-10 mm (0.125-0.375 in.) thick
	"	53	34	34	22	20	50 mm (2 in.)	160	37	24	0.5- 3 mm (0.02-0.125 in.) thick
	Hot Worked[c]	39	25	15	10	35	$5.65\sqrt{S_o}$	110	29	19	12-50 mm (0.5-2 in.) diam. or equivalent area
Rod	Cold Worked[c]	40	26	20	13	35	$5.65\sqrt{S_o}$	120	30	20	25-50 mm (1-2 in.) diam. or equivalent area
	As-Manufactured	43	28	25	16	30	$5.65\sqrt{S_o}$	135	32	21	10-25 mm (0.375-1 in.) diam. or equivalent area
		46	30	28	18	20	$5.65\sqrt{S_o}$	150	35	23	3-10 mm (0.125-0.375 in.) diam. or equivalent area
Sections (extruded)	Hot Worked[c]	39	25	15	10	35	$5.65\sqrt{S_o}$	110	29	19	—
	Cold Drawn As-Manufactured[c]	42	27	22	14	30	$5.65\sqrt{S_o}$	130	32	20	—
Forgings	Hot Worked[c]	39	25	15	10	35	$5.65\sqrt{S_o}$	110	29	19	—

(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.

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

Form	Temper	Tensile Strength 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	55 000	25 000	50	2 in.	—	55	55	40 000	1 in. thick
	Annealed									
	Light	62 000	30 000	40	2 in.	—	60	57	41 000	0.040 in. thick
	Soft	58 000	25 000	49	2 in.	—	56	55	40 000	0.250 in. thick
	Light	60 000	28 000	45	2 in.	—	58	56	41 000	"
	Cold Worked									
	Quarter Hard	70 000	58 000	17	2 in.	—	75	68	43 000	0.040 in. thick
Rod	Annealed[b]									
	Soft	58 000	27 000	45	2 in.	—	56	—	40 000	0.250 in. diam.
	Light	63 000	30 000	40	2 in.	—	60	—	42 000	"
	Soft	57 000	25 000	47	2 in.	—	55	—	40 000	1 in. diam.
	Light	63 000	30 000	40	2 in.	—	60	—	42 000	"
	Soft	56 000	25 000	47	2 in.	—	55	—	40 000	2 in. diam.
	Light	62 000	28 000	43	2 in.	—	60	—	42 000	"
	Cold Worked[b]									
	Quarter Hard	70 000	48 000	25	2 in.	—	80	—	43 000	0.250 in. diam.
	Half Hard	80 000	57 000	20	2 in.	—	85	—	45 000	"
	Quarter Hard	69 000	46 000	27	2 in.	—	78	—	43 000	1 in. diam.
	Half Hard	75 000	53 000	20	2 in.	—	82	—	44 000	"
	Quarter Hard	67 000	40 000	35	2 in.	—	75	—	43 000	2 in. diam.
Tube	Cold Worked Hard Drawn (35%)	88 000	66 000	18	2 in.	—	95	—	48 000	0.375 in. O.D. × 0.097 in. wall

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

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

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

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

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

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

(d) Form not stated in original document.

(e) Amount of cold working not defined in original document.

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

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

continued on opposite page

5.3.1 Short-Time Tensile Properties (continued)

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

(a) This value was originally reported in ton/in²; in this table it is given in kg/mm² to 3 significant figures.
(b) Proportional limit.
(c) Yield Point.
N.B.: — Original values are printed in **bold type**; other values are converted.
— Values for impact strength up to 205 °C are given in reference (2).

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

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

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

5.3.2.2 Stress for Designated Creep Rate

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

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

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

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

continued overleaf

5.4.1. Fatigue Strength at Room Temperature (continued)

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

(a) Rotating-beam test.

(b) Fine grained.

(c) Coarse grained.

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

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

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