PHOSPHORUS-DEOXIDISED COPPER (HIGH RESIDUAL PHOSPHORUS)

Cu-DHP

Commercially-pure copper which has been deoxidised with phosphorus to leave a relatively high residual content. It is not susceptible to hydrogen embrittlement. The conductivity of this type of copper is relatively low on account of the high phosphorus content. The raw material is normally available as cakes, slabs and billets which are hot and cold worked into wrought forms.

COMPOSITION (weight %)

Cu (+ Ag)	99.85 min.
P	0.013 - 0.050

1 SOME TYPICAL USES

Architectural and Building:

Tubes for hot and cold water services, gas and heating installations, both buried and above ground; soil and waste pipes; storage tanks, cisterns and cylinders; air conditioners.

Mechanical:

Suitable for any equipment involving heating in reducing gases either during joining processes or in service; evaporator and heat exchanger tubes; steam, air, water and oil lines; automobile radiators.

Chemical:

Stills, vats, autoclaves and general coppersmithing involving welding; tubes for relatively non-corrosive liquids and gases and for refrigeration.

Electrical:

Anodes for electroplating and electroforming from acid sulphate baths.

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	1 083 °C	1 981 °F
2.3 Coefficient of thermal expansion (linear) at:		
— 253 °C *— 423 °F* (1)	0.000 000 3 per °C	0.000 000 17 per °F
— 183 °C *— 297 °F* (1)	0.000 009 5 » »	0.000 005 28 » »
— 191 to 16 °C *— 312 to 61 °F* (2)	0.000 014 1 » »	0.000 007 83 » »
25 to 100 °C *77 to 212 °F* (2)	0.000 016 8 » »	0.000 009 33 » »
20 to 200 °C *68 to 392 °F* (3)	0.000 017 3 » »	0.000 009 61 » »
20 to 300 °C *68 to 572 °F* (4)	0.000 017 7 » »	0.000 009 83 » »
2.4 Specific heat (thermal capacity) at:		
— 253 °C *— 423 °F* (2)	0.003 1 cal/g °C	0.003 1 Btu/lb °F
— 150 °C *— 238 °F* (2)	0.067 4 »	0.067 4 »
— 50 °C *— 58 °F* (2)	0.086 2 »	0.086 2 »
20 °C *68 °F* (2)	0.092 1 »	0.092 1 »
100 °C *212 °F* (2)	0.093 9 »	0.093 9 »
200 °C *392 °F* (2)	0.096 3 »	0.096 3 »
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.70 - 0.87 cal cm/cm² s °C	169 - 211 Btu ft/ft² h °F

continued overleaf

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

Prepared by
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Cu-DHP
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2 PHYSICAL PROPERTIES (continued)

	Metric Units		English Units	
2.6 Electrical conductivity (volume) at:				
20 °C *68 °F* (annealed or cold worked)	41 - 52	m/ohm mm²	70 - 90 % IACS	
2.7 Electrical resistivity (volume) at:				
20 °C *68 °F* (annealed or cold worked)	0.025 - 0.019 2.5 - 1.9	ohm mm²/m microhm cm	15 - 12 0.97 - 0.75	ohms (circ mil/ft) microhm in
2.8 Temperature coefficient of electrical resistance at: (a)				
20 °C *68 °F* (annealed or cold worked)	0.002 75 per °C (70 % IACS) 0.003 54 » » (90 % IACS)		0.001 53 per °F (70 % IACS) 0.001 96 » » (90 % 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	117 684 12 000	N/mm² kg/mm²	17 000 000	lb/in²
cold worked	12 000 - 13 500 117684 - 132400	» N/mm²	17 000 000 - 19 000 000	»
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*:				
annealed	44 132 4 500	N/mm² kg/mm²	6 400 000	lb/in²
cold worked	4 500 - 5 000 44132 - 49035	» N/mm²	6 400 000 - 7 000 000	»

(a) — 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.

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	2 085 - 2 190 °F
3.2 Annealing temperature range	250 - 650 °C	480 - 1 200 °F
Stress relieving temperature range	200 - 250 °C	390 - 480 °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. 3.1	
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	Forgings	Sections / Shapes
Australia	SAA	—	—	AS-H17	—	—	B158 B159 B160	—	—
Belgium	NBN	CuP	—	266.01	266.01	—	266.01	—	266.01
Canada	CSA	Cu-DHP 122	—	HC.4.1	HC.4.1	—	HC.7.1 HC.7.3 HC.7.5 HC.7.6 HC.7.7 HC.7.8	—	—
Chile	INDITECNOR	Cu-DHP	244 p	196 ch	—	—	395 ch	—	—
France	NF	Cu/b	A53-100	A53-601	A53-301	—	A53-501	A53-301	A53-301
Germany	DIN	SF-Cu(2.0090)	1787	17670	17672	17672	17671	17673	17674
Italy	UNI	Cu-DHP	5649	—	—	—	—	—	—
Netherlands . . .	N or NEN (b)	Cu-DHP	NEN 6023	—	—	—	NEN 2263	—	—
South Africa . .	SABS	—	—	—	—	—	460/465	—	—
Spain	UNE	CuP	37.103	—	—	—	—	—	—
Sweden	SIS	Cu-DHP	—	14 50 15	—	—	14 50 15	—	—
Switzerland . . .	VSM	Cu-DHP	10826	11852	11852	—	11852	—	—
United Kingdom .	BS	C106	1172	899 1541 1569 2027 2875 2870	2874	2873	61 (Part 1) 378 659 1306 (Part 2) 1386 1401 2017 2871	—	2874
United States . .	ASTM	DHP 122	—	B124 B133 B152	B12 B124 B133	—	B42 B68 B75 B88 B111 B280 B302 B306 B359 B395	—	B124 B133

(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	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	» » 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 below or above 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	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 up to 1 250 mm² area
		34	28	10	$5.65\sqrt{S_o}$	95	105	19	6 - 20 mm diam. or up to 300 mm² area
Tube	Annealed	24	6	45	$5.65\sqrt{S_o}$	45	50	16	—
	Typical Cold Drawn Tempers [(c)]	**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
Forgings	Hot Worked	23	6	35	$5.65\sqrt{S_o}$	50	55	16	—
Sections / Shapes	Hot Worked	24	8	35	$5.65\sqrt{S_o}$	50	55	16	—
	Typical Cold Worked Tempers [(d)]	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 suppliers.

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

(d) The mechanical properties will be largely dependent upon the complexity and cross-section 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 below or above 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	15	6	45	2 in.	65	10	over 0.25 in. thick
	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	$5.65\sqrt{S_0}$	50	10	—
	Typical Cold Worked Tempers	17 20	13 16	30 **17**	$5.65\sqrt{S_0}$ $5.65\sqrt{S_0}$	85 105	11 12	0.25 - 1 in. diam. or up to 1 in² area »
Tube	Annealed	15	5	50	2 in.	50	10	—
	Typical Cold Drawn Tempers [(b)]	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 »
Forgings	Hot Worked	15	6	35	$5.65\sqrt{S_0}$	60	10	—
Sections (extruded)	Typical Cold Drawn Tempers [(c)]	16 20	11 16	27 15	$5.65\sqrt{S_0}$ $5.65\sqrt{S_0}$	80 105	10 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 suppliers.
(b) Tubes for condensers and heat exchangers are generally supplied only to the tempers whose representative mechanical properties are printed in **bold type.**
(c) The mechanical properties will be largely dependent upon the complexity and cross-section 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 below or above 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)	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. x 0.065 in. wall
	Cold Worked [(b)]									
	Light Drawn	**40 000**	**32 000**	**25**	2 in.	**77**	**35**	**45**	**26 000**	1.0 in. O.D. x 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 [(c)]									
	Hard	40 000	32 000	30	2 in.	—	35	—	26 000	0.50 in. thick

(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 suppliers.

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

(c) The mechanical properties will be largely dependent upon the complexity and cross-section 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
Sheet [5] 3.2 mm 0.125 in.	Annealed (grain size 0.045 mm)	+ 24	+ 75	21.5	13.5	**30 250**	6.31 [a]	**9 750**	**51.2**	2 in	**89.8**	—	—
		— 40	— 40	25	16	**35 580**	7.20 [a]	**11 350**	**56.5**	2 in	**74.3**	—	—
		— 68	— 90	26.5	17	**37 580**	8.02 [a]	**11 830**	**55.8**	2 in	**77.8**	—	—
		— 196	— 321	35.5	23	**50 800**	7.40 [a]	**11 400**	**55.8**	2 in	**64.1**	—	—
	Cold Worked 5 - 7 %	+ 24	+ 75	23	14.5	**32 600**	17.1 [a]	**24 700**	**39.0**	2 in	**91.8**	—	—
		— 40	— 40	26	16.5	**37 250**	18.5 [a]	**26 450**	**41.0**	2 in	**78.8**	—	—
		— 68	— 90	28	17.5	**39 600**	18.6 [a]	**27 100**	**38.8**	2 in	**68.7**	—	—
		— 196	— 321	37.5	23.5	**53 100**	20.2 [a]	**28 980**	**49.0**	2 in	**62.0**	—	—
Sheet [5] 6.4 mm 6.35 mm	Annealed (grain size 0.043 mm)	+ 24	+ 75	21.5	13.5	**30 750**	5.94 [a]	**9 140**	**57.1**	2 in	**63.3**	—	—
		— 40	— 40	24.5	15.5	**34 600**	6.00 [a]	**9 490**	**55.3**	2 in	**61.6**	—	—
		— 68	— 90	26.5	17	**37 900**	5.86 [a]	**9 450**	**55.8**	2 in	**58.3**	—	—
		— 196	— 321	35	22.5	**49 900**	5.69 [a]	**9 240**	**58.8**	2 in	**54.8**	—	—
	Cold Worked 5 - 7 %	+ 24	+ 75	23.5	15	**33 160**	17.8 [a]	**25 450**	**52.0**	2 in	**84.6**	—	—
		— 40	— 40	26.5	17	**37 900**	18.1 [a]	**26 030**	**51.0**	2 in	**78.1**	—	—
		— 68	— 90	27.5	17.5	**39 050**	18.4 [a]	**26 400**	**50.5**	2 in	**77.6**	—	—
		— 196	— 321	37	23.5	**52 300**	18.6 [a]	**26 700**	**61.8**	2 in	**70.1**	—	—
Rod [6] 19 mm diam. 0.75 in. diam.	Annealed	+ 20	+ 68	23	14.5	**32 600**	—	**8 290**	**57.5**	2 in	—	12.9 [b]	**46.8** [b]
		+ 3	+ 37	—	—	—	—	—	—	—	—	12.9 [b]	**46.6** [b]
		— 18	— 0.4	—	—	—	—	—	—	—	—	12.1 [b]	**43.9** [b]
		— 30	— 22	—	—	—	—	—	—	—	—	12.4 [b]	**44.7** [b]
		— 50	— 58	—	—	—	—	—	—	—	—	12.1 [b]	**43.7** [b]
		— 80	— 112	—	—	—	—	—	—	—	—	12.8 [b]	**46.3** [b]
		— 115	— 175	—	—	—	—	—	—	—	—	13.3 [b]	**48.2** [b]

[a] This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.
[b] Charpy, keyhole notch, standard specimen; cross-sectional area 0.5 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.
— Further data can be obtained from the following paper:
■ Reed, R.P. and Mikesell, R.P. Low-temperature (295 to 4 K) Mechanical Properties of Selected Copper Alloys. J. of Materials, Vol. 2, No. 2, June (1967), pp. 370-392.
— 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 % on 2 in
		°C	°F	kg/mm²	ton/in²	psi	0.2 % offset kg/mm²	Yield Strength 0.5 % ext. under load psi	
Sheet [5] **3.2 - 6.35 mm 0.125 - 0.25 in.**	Annealed (grain size 0.044 mm)	24	75	21.5	13.5	**30 430**	6.01 [a]	**9 370**	**53.4**
		100	212	18.5	12	**26 600**	6.30 [a]	**9 550**	**52.5**
		204	400	16	10	**22 520**	5.46 [a]	**8 320**	**52.1**
Sheet [5] **6.35 mm 0.25 in.**	Cold Worked 5 - 7 %	24	75	23.5	15	**33 160**	17.8 [a]	**25 450**	**52.0**
		60	140	22	14	**31 530**	16.5 [a]	**23 570**	**50.9**
		100	212	20.5	13	**29 480**	17.4 [a]	**24 850**	**45.4**
		149	300	19.5	12.5	**27 430**	15.4 [a]	**22 000**	**46.8**
		204	400	17.5	12	**25 180**	15.5 [a]	**22 120**	**46.5**
		288	550	14	9.5	**21 650**	11.9 [a]	**17 340**	**49.6**
		371	700	11.5	8	**17 550**	9.93 [a]	**14 330**	**57.8**
		454	850	9.5	6.5	**13 180**	7.26 [a]	**10 480**	**68.0**
		496	925	8	5	**11 090**	—	—	**88.0**
		538	1 000	6	3.5	**8 180**	—	—	**94.8**
		593	1 100	4.5	3	**6 260**	—	—	**98.0**
		648	1 200	3.5	2	**4 800**	—	—	**98.0**
Rod [5] **3.2 mm diam. 0.125 in. diam.**	Annealed (grain size 0.032 mm)	24	75	23.5	15	**33 300**	3.48 [a]	**5 850**	**49.0**
		149	300	—	—	—	3.13 [a]	**5 250**	—
		204	400	—	—	—	2.99 [a]	**5 050**	—
		260	500	—	—	—	2.67 [a]	**4 500**	—
	Cold Worked 21 %	24	75	30	19	**42 700**	27.3 [a]	**40 100**	**14.0**
		149	300	—	—	—	24.3 [a]	**35 100**	—
		204	400	—	—	—	20.5 [a]	**30 300**	—
		260	500	—	—	—	17.3 [a]	**26 000**	—
	Cold Worked 84 %	24	75	39.5	25	**56 400**	35.6 [a]	**52 000**	**10.0**
		149	300	—	—	—	30.9 [a]	**44 300**	—
		204	400	—	—	—	27.0 [a]	**39 200**	—
		260	500	—	—	—	8.86 [a]	**14 300**	—

(a) 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.

— Further data can be obtained from the following papers:

- Ashbolt, D. and Bowers, J.E. The Properties of Copper and Copper Alloys at Elevated Temperatures. B.N.F.M.R.A. Report A1550, July 1965.
- Reference (5) in the bibliography on page 10.

— The 0.1 % proof stress values are not available.

5.3.2 Creep Properties

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 in % per 1 000 h
Rod (5) 3.2 mm diam. 0.125 in. diam.	Annealed (grain size 0.015 mm)	204	400	0.7	0.5	1 000	7.08	0.030	0.013	0.001 4
				1.5	1	2 050	6.00	0.068	0.023	0.005 3
				2	1.5	3 050	6.00	0.147	0.054	0.011
				3.5	2	5 000	7.08	0.875	0.325	0.067
				5.5	3.5	8 000	6.00	3.090	1.640	0.148
	Annealed (grain size 0.032 mm)	204	400	0.7	0.5	1 050	7.08	0.019 5	0.005 5	0.001 0
				1.5	1	2 050	6.00	0.078	0.037	0.003 9
				2	1.5	3 050	7.08	0.355	0.164	0.018 5
				3.5	2.5	5 080	7.08	1.378	0.660	0.051
				5.5	3.5	8 050	6.00	3.340	1.120	0.120
	Annealed (grain size 0.070 mm)	204	400	1.5	1	2 050	6.00	0.069	0.029	0.001 2
				2	1.5	3 050	6.00	0.415	0.194	0.006 0
				3	2	4 500	7.08	1.098	0.359	0.013
				4	2.5	6 000	6.00	1.862	0.647	0.029
				5.5	3.5	8 000	7.08	3.460	1.040	0.084
	Cold Worked 21 %	204	400	3.5	2.5	4 050	7.08	0.065	0.027 5	0.001 3
				4	2.5	6 000	7.08	0.099	0.039	0.002 4
				6.5	4	9 100	7.08	0.156	0.051	0.006
				10.5	6.5	15 000	6.00	0.400	0.148	0.023
				17.5	11	25 000	0.90	4.412	— 0.485	5.18 (b)
	Cold Worked 37 %	204	400	3.5	2.5	4 050	7.08	0.063	0.024	0.001 6
				4	2.5	6 000	7.08	0.100	0.034	0.003 5
				6.5	4	9 100	7.08	0.191	0.074	0.007 8
				10.5	6.5	15 000	6.00	0.408	0.147	0.026
				17.5	11	25 150	1.45	1.586	0.324	0.735
				17.5	11	25 150	6.00	7.276	— 5.760	2.14 (b)
				21	13.5	30 000	0.24	2.89	—	— (b)
	Cold Worked 84 %	204	400	2.5	1.5	3 550	7.70	0.126	— 0.015 1	0.015 2
				3.5	2	5 050	7.08	0.119	— 0.085	0.038 (b)
				6.4	4	9 050	7.08	0.534	— 1.110	0.224 (b)
				10.5	6.5	15 000	0.58	0.169	0.034	0.055
				10.5	6.5	15 000	4.20	2.813	— 8.630	2.70 (b)
				21	13.5	30 000	0.74	3.920	—	— (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.
— Further data can be obtained from reference (5) in the bibliography on page 10.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles x 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 [7] 0.8 mm 0.032 in.	Cold Worked 21 %	100	30	10 [a]	19	6 [a]	**42 800**	**14 000** [a]
	Cold Worked 37 %	100	36	13.5 [a]	23	8.5 [a]	**51 600**	**19 000** [a]
	Cold Worked 60 %	100	41.5	13 [a]	26.5	8.5 [a]	**59 300**	**18 500** [a]
Tube [8]	Annealed (grain size 0.050 mm)	20	22.5	7.5 [b]	14	5 [b]	**32 000**	**11 000** [b]
	Cold Worked 15 %	20	28	10 [b]	18	6 [b]	**40 000**	**14 000** [b]
	Cold Worked 40 %	20	38.5	13.5 [b]	24.5	8.5 [b]	**55 000**	**19 000** [b]

(a) Reversed-bending test.
(b) Rotating-beam test on rod.
N.B.: — Original values are printed in **bold type;** other values are converted.

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