

COPPER - CADMIUM

Cu CdCommon names: Cadmium Copper
Cadmium Bronze

A copper alloy with an alpha phase structure. Addition of cadmium improves mechanical properties, especially in the cold-worked condition, with a relatively small reduction in conductivity. Cadmium copper has good fatigue properties and retains its hardness and strength at temperatures higher than those at which unalloyed copper would soften. It is also resistant to wear and arcing. The alloy is, therefore, used for applications requiring a combination of high strength and conductivity, even at relatively elevated temperatures, and is mainly supplied as round or shaped hard-drawn wire.

COMPOSITION (weight %)

Cd	0.7-1.3
Cu	rem.

1 SOME TYPICAL USES

Electrical

Catenary and contact (trolley) wires for electric traction; telephone and telegraph wires; spring contacts for automotive and signal relays; tinsel for flexible cords of telephone instruments and switchboards; plugs and sockets; jointing sleeves; reinforcing strip for pressurised electric cables; overhead lines with exceptionally large span lengths.

Mechanical

Spot and seam resistance-welding electrodes and wheels; electrode holders for resistance-welding machines and arc-furnaces; flash-butt-welding dies.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C 68 °F	8.9 g/cm ³	0.320 lb/in ³
2.2 Melting range	1 010-1 080 °C	1 850-1 975 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 100 °C 68 to 212 °F	0.000 017 per °C	0.000 009 per °F
20 ,, 300 °C 68 ,, 572 °F	0.000 018 ,, ,,	0.000 010 ,, ,,
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	0.75-0.85 cal cm/cm ² s °C	180-205 Btu ft/ft ² h °F
200 °C 392 °F	0.80-0.90 ,,	195-220 ,,
2.6 Electrical conductivity (volume) at:		
20 °C 68 °F (annealed)	46-53 m/ohm mm ²	80-92 % IACS
200 °C 392 °F (annealed)	~31 ,,	~54 ,,
20 °C 68 °F (fully cold worked)	44-50 ,,	75-87 ,,
2.7 Electrical resistivity (volume) at:		
20 °C 68 °F (annealed)	0.022-0.019 ohm mm ² /m	13-11 ohms (circ mil/ft)
	2.2-1.9 microhm cm	0.85-0.74 microhm in
200 °C 392 °F (annealed)	~0.032 ohm mm ² /m	~19 ohms (circ mil/ft)
	~3.2 microhm cm	~1.3 microhm in
20 °C 68 °F (fully cold worked)	0.023-0.020 ohm mm ² /m	14-12 ohms (circ mil/ft)
	2.3-2.0 microhm cm	0.91-0.78 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C 68 °F (annealed)	0.003 1 per °C (80% IACS)	0.001 7 per °F (80% IACS)
applicable over range from 0 to 100 °C 32 to 212 °F	0.003 6 ,, ,, (92 ,, ,,)	0.002 0 ,, ,, (92 ,, ,,)
20 °C 68 °F (fully cold worked)	0.003 0 ,, ,, (75 ,, ,,)	0.001 6 ,, ,, (75 ,, ,,)
applicable over range from 0 to 100 °C 32 to 212 °F	0.003 4 ,, ,, (87 ,, ,,)	0.001 9 ,, ,, (87 ,, ,,)
2.9 Modulus of elasticity (tension) at 20 °C 68 °F:		
annealed	13 500 kg/mm ²	19 200 000 lb/in ²
cold worked	12 700 kg/mm ²	18 100 000 lb/in ²
2.10 Modulus of rigidity (torsion) at 20 °C 68 °F:		
annealed	5 000 kg/mm ²	7 100 000 lb/in ²
cold worked	4 700 kg/mm ²	6 700 000 lb/in ²

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; the melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted.

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

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3 FABRICATION PROPERTIES

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

	Metric Units	English Units
3.1 Casting temperature range ^(a)	1 130–1 220 °C	2 065–2 230 °F
3.2 Annealing temperature range	500– 700 °C	930–1 290 °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		Good
3.5 Cold formability		Excellent
3.6 Cold reduction between anneals		90% max.
3.7 Machinability:		See General Data Sheet No. 2
Machinability rating (free cutting brass = 100)		25%
3.8 Joining methods: ^(a)		See General Data Sheet No. 3.3
Soldering		Excellent
Brazing		Good
Oxy-acetylene welding		Fair
Carbon-arc welding		Not recommended
Gas-shielded arc welding		Fair
Coated metal-arc welding		Not recommended
Resistance welding: spot and seam		Fair
butt		Fair

^(a) Adequate fume extraction must be ensured during melting, casting and welding to avoid risk of toxicity from cadmium oxide.

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	—	—	—	266.02	266.02	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Cd	245 of. 68	—	—	—	259 of. 70	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	CuCd1	17 666	—	17 672	17 677	—	17 674	17 673 17 678
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	CU CD1	—	—	—	2528	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN ^(b)	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	50 55	—	—	—	—	—	MNC 50 E 14 50 55	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	C108 A1/3	—	2875	4577	23 125 174 177 2755 2873	—	—	4577
United States	ASTM	No. 162	—	—	—	B 105	—	—	—
International Organisation for Standardization	ISO	Cu Cd1	R 1336	—	—	—	—	—	—

^(a) Applicable when the chemical composition is not given in the specifications for wrought forms.

^(b) Older specifications bear prefix N; for new specifications the NEN prefix is used.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

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

5.2 Mechanical properties at low temperature

Tensile properties	no data
Impact properties

5.3 Mechanical properties at elevated temperature

Short-time tensile properties	see table 5.3.1
Creep properties	see tables 5.3.2.1/2

5.4 Fatigue properties

Fatigue strength at room temperature	see table 5.4.1
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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/mm ²	Proof Stress 0.2% offset kg/mm ²	Elongation		Hardness		Shear Strength kg/mm ²	Typical Size Related to Properties Shown ^(b)
				%	gauge length	Brinell	Vickers		
Plate Sheet Strip	Annealed	25	8	45	5.65√S ₀	55	58	18	—
	Hot Rolled ^(c)	27	9	40	5.65√S ₀	65	68	20	—
	Typical Cold Worked Tempers	34 42	27 38	20 7	5.65√S ₀ 50 mm	100 120	105 125	23 27	0.2–5 mm thick 0.2–1 mm thick
Rod ^(c)	Annealed	24	7	45	5.65√S ₀	50	53	18	—
	Hot Worked	27	9	40	5.65√S ₀	60	63	20	—
	Typical Cold Worked Tempers	40 48	35 45	10 5	5.65√S ₀ 5.65√S ₀	110 130	115 135	26 31	5–30 mm diam. or equivalent area 5–10 mm diam. or equivalent area
Wire	Annealed	26	8	35	200 mm	—	—	19	—
	Typical Cold Drawn Tempers	52	48	3	200 mm	—	—	28	2–5 mm diam. 0.8–2 mm diam. up to 0.8 mm diam.
		62	59	—	—	—	—	31	
70		69	—	—	—	—	35		
Sections ^{(c) (d)} Shapes	Hot Worked	27	9	35	5.65√S ₀	60	63	20	—
	Typical Cold Worked Tempers	35	27	15	5.65√S ₀	100	105	23	—
		42	38	5	5.65√S ₀	120	125	27	—
47		44	3	200 mm	130	135	30	—	
Forgings ^(c)	Hot Worked	28	10	35	5.65√S ₀	70	74	21	—

(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 metal working 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.

(d) Contact (trolley) wire is generally supplied only to the temper whose representative mechanical properties are printed in **bold type**.

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.

Form	Temper ^(a)	Tensile Strength		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown ^(b)
		hbar	ton/in ²	hbar	ton/in ²	%	gauge length		hbar	ton/in ²	
Plate	Cold Rolled	29	19	22	14	30	5.65√S ₀	95	20	13	16–25 mm (0.625–1 in.) thick 10–16 mm (0.375–0.625 in.) thick
	Hard	32	21	25	16	22	5.65√S ₀	105	23	15	
Strip	Annealed	25	16	6	4	50	50 mm (2 in.)	60	17	11	—
	Typical Cold Worked Tempers	32	21	25	16	25	50 mm (2 in.)	105	23	15	0.2–3 mm (0.008–0.125 in.) thick
		39	25	34	22	12	50 mm (2 in.)	120	26	17	„
Rod ^(c)	Hot Worked	26	17	8	5	40	5.65√S ₀	65	19	12	12–50 mm (0.5–2 in.) diam. or equivalent area
	Typical Cold Worked Temper	43	28	37	24	8	5.65√S ₀	130	29	19	6–25 mm (0.25–1 in.) diam. or equivalent area
Wire	Cold Drawn Hard	62	40	—	—	3	200 mm (8 in.)	—	34	22	3–4 mm (0.12–0.16 in.) diam.
		70	45	—	—	—	—	—	36	23	1–2.5 mm (0.04–0.10 in.) diam.
Sections ^(c) (Extruded)	Hot Worked	26	17	8	5	35	5.65√S ₀	65	19	12	—
	Typical Cold Drawn Temper	34	22	25	16	15	5.65√S ₀	110	23	15	—
Sections ^(d) (Contact Wire)	Typical Cold Drawn Tempers	40	26	34	22	5	200 mm (8 in.)	120	26	17	~195 mm ² (~0.30 in. ²) cross-sectional area
		43	28	37	24	4	200 mm (8 in.)	130	28	18	~160 mm ² (~0.25 in. ²) cross-sectional area
		46	30	40	26	3	200 mm (8 in.)	135	29	19	~105 mm ² (~0.16 in. ²) cross-sectional area
Forgings ^(c)	Hot Worked	28	18	9	6	35	5.65√S ₀	75	19	12	—
	Hot/Cold Worked	~37	~24	~31	~20	~12	5.65√S ₀	~120	~25	~16	—

(a) The recognised temper designations used in the relevant British Standards are also given.

(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.

(d) Trolley and contact wire sections for electric traction; cold drawn from hot-rolled rod.

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)	As Hot Rolled	39 000	13 000	40	2 in.	47	—	—	25 000	—	
	Annealed	37 000	12 000	50	2 in.	47	—	—	24 000	0.040 in. thick	
	Cold Worked	Half Hard	48 000	46 000	15	2 in.	93	62	58	27 000	0.040 in. thick
		Hard	55 000	53 000	6	2 in.	95	66	60	28 000	"
		Extra Hard	60 000	59 000	6	2 in.	96	68	62	30 000	"
		Spring	63 000	60 000	5	2 in.	97	70	63	31 000	"
Extra Spring	66 000	63 000	4	2 in.	98	72	65	33 000	"		
Rod ^(b)	As Hot Rolled	39 000	13 000	40	2 in.	47	—	—	25 000	—	
	Annealed—Soft	35 000	12 000	45	2 in.	42	—	—	24 000	—	
	Cold Worked	Extra Hard	94 000	85 000	1	2 in.	103	82	72	61 000	0.25 in. diam.
		Half Hard	50 000	36 000	7	2 in.	87	46	55	33 000	0.50 in. diam.
		Hard	71 000	65 000	1	2 in.	97	70	63	47 000	"
		Hard	53 000	50 000	8	2 in.	97	70	63	34 000	1 in. diam.
Wire	Cold Worked										
	Hard	95 000	91 000	1	10 in.	—	—	—	63 000	0.035 in. diam.	
	Hard	91 000	87 000	1.5	10 in.	—	—	—	60 000	0.050 in. diam.	
	Hard	88 000	84 000	2	10 in.	—	—	—	57 000	0.070 in. diam.	
	Hard	85 000	81 000	2	10 in.	—	—	—	55 000	0.090 in. diam.	
Hard	83 000	78 000	3	10 in.	—	—	—	54 000	0.100 in. diam.		
Shapes ^(b)	As Hot Rolled	38 000	12 000	45	2 in.	47	—	—	24 000	—	
	Annealed	37 000	12 000	50	2 in.	45	—	—	24 000	—	
	Cold Worked Hard	60 000	54 000	5	2 in.	98	73	65	38 000	—	
Forgings ^(b)	Cold Worked Hard	60 000	54 000	5	2 in.	98	73	65	38 000	—	

(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

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress			Elongation	
		°C	°F	kg/mm ²	ton/in ²	psi	0.2% offset kg/mm ²	0.1% offset ton/in ²	Yield Strength 0.5% ext. under load psi	%	gauge length
Rod ⁽¹⁾ 14 mm diam. 0.56 in. diam.	Annealed	20	68	27	17.0	38 000	—	4.7 ^(a)	—	63	4√ S_o
		400	752	17	10.7	24 000	—	3.3 ^(a)	—	112	4√ S_o
Rod ⁽²⁾ 15 mm diam. 0.59 in. diam.	Cold Worked 44%	20	68	39.4	25	56 000	39.0	22.7 ^(b)	—	16.9	5.65√ S_o
		200	392	36.7	23.5	52 000	35.1	21.8 ^(b)	—	14.8	5.65√ S_o
		300	572	31.0	19.5	44 000	27.5	16.4 ^(b)	—	17.5	5.65√ S_o
Rod ⁽³⁾	Cold Worked 37%	200	392	39	24.5	55 200	—	—	55 100	14.0	2 in.
		300	572	36.5	23	51 800	—	—	51 200	11.5	2 in.
		400	752	23	14.5	32 400	—	—	20 200	37.5	2 in.
		500	932	12	7.5	17 100	—	—	6 400	111.2	2 in.
		600	1 112	7	4.5	10 000	—	—	4 200	107.5	2 in.
		700	1 292	4.5	3	6 400	—	—	3 900	139.5	2 in.
Rod ⁽⁴⁾	Cold Worked ~45%	20	68	40	25.5	57 000	38	—	—	15	5.65√ S_o
		100	212	40	25.5	57 000	36	—	—	10	5.65√ S_o
		200	392	38	24	54 000	35	—	—	12	5.65√ S_o
		300	572	33	21	47 000	28	—	—	17	5.65√ S_o
		350	662	32	20.5	45 500	23	—	—	28	5.65√ S_o
Rod ⁽⁵⁾	Cold Worked ~60%	20	68	65	41.5	92 500	62	—	—	1	(c)
		100	212	60	38	85 500	58	—	—	2	(c)
		200	392	47	30	67 000	44	—	—	5	(c)
		300	572	37	23.5	52 500	30	—	—	10	(c)
		350	662	33	21	47 000	29	—	—	15	(c)

(a) Quoted as "yield point" in original document, but offset strain not defined.

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

(c) Gauge length not stated.

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

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension % ^(a)	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm ²	ton/in ²	psi				
Strip ⁽⁶⁾ 2.5 mm 0.1 in.	Cold Worked 20%	130	266	14.1	8.9	20 000	2 400	0.155	0.142	0.006
		225	437	5.6	3.6	8 000	2 400	0.128	0.102	0.011
				11.2	7.1	16 000	2 400	0.325	0.246	0.065
				14.1	8.9	20 000	2 000	0.485	0.332	0.127
Rod ⁽²⁾ 15 mm diam. 0.59 in. diam.	Cold Worked 44%	200	392	14.0	8.9	19 900	3 018	0.19 ^(b)	—	—
				16.0	10.2	22 800	2 512	0.22 ^(b)	—	—
				18.0	11.4	25 600	3 018	0.29 ^(b)	—	—
				20.0	12.7	28 400	2 655	0.35 ^(b)	—	—
		250	482	12.2	7.7	17 400	4 276	0.29 ^(b)	—	—
				13.8	8.8	19 600	4 276	0.41 ^(b)	—	—
				14.0	8.9	19 900	5 010	0.51 ^(b)	—	—
				16.0	10.2	22 800	1 747	0.56 ^(b)	—	—
				20.0	12.7	28 400	1 747	1.42 ^(b)	—	—

(a) Total extension = Initial extension + Total Creep = Initial extension + Intercept + (Minimum creep rate x Duration).

(b) 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 Extension

Form	Temper	Testing Temperature		Stress for Designated Extension											
		°C	°F	0.1% in 1 000 h			0.2% in 1 000 h			0.1% in 2 000 h			0.2% in 2 000 h		
				kg/mm ²	ton/in ²	psi	kg/mm ²	ton/in ²	psi	kg/mm ²	ton/in ²	psi	kg/mm ²	ton/in ²	psi
Rod ⁽²⁾ 15 mm diam. 0.59 in. diam.	Cold Worked 44%	200	392	12.2	7.7	17 400	16.5	10.5	23 500	11.0	7.0	15 600	15.5	9.8	22 000
		250	482	10.1	6.4	14 400	12.5	7.9	17 800	9.4	6.0	13 400	11.4	7.2	16 200

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/mm ²		English Units ton/in ²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Strip ⁽⁷⁾ 1 mm 0.040 in.	Cold Worked 21%	100	33.5	20.5 ^(a)	21.5	13 ^(a)	48 000	29 000 ^(a)
Rod ⁽⁸⁾ 13 mm diam. 0.5 in. diam.	Annealed (grain size 0.050 mm)	300	24.5	10 ^(b)	15.5	6.5 ^(b)	35 200	14 500 ^(b)
	Cold Worked 29.1%	300	51.5	21 ^(b)	32.5	13.5 ^(b)	73 100	30 000 ^(b)
Rod ⁽⁴⁾ 20 mm diam. 0.8 in. diam.	Forged 50%	30	52	16 ^(c)	33	10 ^(c)	74 000	23 000 ^(c)
Wire ⁽⁹⁾ 2.5 mm diam. 0.1 in. diam.	Cold Drawn ^(g)	10	—	~14 ^(d)	—	~9 ^(d)	—	~20 000 ^(d)
Wire ⁽¹⁰⁾ 10 mm diam. 0.4 in. diam.	Cold Drawn	10	45	13.5 ^(e) 20.5 ^(f)	28.7	8.5 ^(e) 13.0 ^(f)	64 500	19 000 ^(e) 29 000 ^(f)
		10	46	14 ^(e) 19 ^(f)	29.1	9.0 ^(e) 12.0 ^(f)	65 000	20 000 ^(e) 27 000 ^(f)
		10	55	12 ^(e) 25 ^(f)	35.0	7.5 ^(e) 16.0 ^(f)	78 500	17 000 ^(e) 36 000 ^(f)
		10	55.5	10 ^(e) 25 ^(f)	35.2	6.5 ^(e) 16.0 ^(f)	79 000	14 500 ^(e) 36 000 ^(f)
Wire ⁽¹¹⁾ 10 mm diam. 0.4 in. diam.	Cold Drawn	10	45	11.5 ^(e)	28.7	7.2 ^(e)	64 500	16 000 ^(e)
		10	46	12 ^(e)	29.2	7.5 ^(e)	65 500	17 000 ^(e)
		10	46	12 ^(e) 18.5 ^(f)	29.1	7.6 ^(e) 11.9 ^(f)	65 000	17 000 ^(e) 26 500 ^(f)
		10	46.5	10 ^(e) 21.5 ^(f)	29.5	6.2 ^(e) 13.6 ^(f)	66 000	14 000 ^(e) 30 500 ^(f)
		10	48	12 ^(e) 21.5 ^(f)	30.4	7.7 ^(e) 13.6 ^(f)	68 000	17 000 ^(e) 30 500 ^(f)
		10	50.5	11.5 ^(e) 22.5 ^(f)	32.1	7.3 ^(e) 14.2 ^(f)	72 000	16 500 ^(e) 32 000 ^(f)
		10	51	11.5 ^(e) 20 ^(f)	32.3	7.2 ^(e) 12.8 ^(f)	72 500	16 000 ^(e) 28 500 ^(f)
		10	53	13 ^(e) 23 ^(f)	33.7	8.4 ^(e) 14.5 ^(f)	75 500	19 000 ^(e) 32 500 ^(f)

^(a) Reversed-bending test.

^(b) Rotating-beam test.

^(c) Rotating-cantilever test.

^(d) Rotating-bending test.

^(e) Rotating-bending test on "full-diameter" as-drawn wire.

^(f) Rotating-bending test on specimen machined from as-drawn wire.

^(g) Quoted as "hard drawn" in original document, but amount of cold work not defined.

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

—Further data can be obtained from the following paper:

■ Fatigue of Cadmium Copper Trolley Wires. Third Report-Grooved Wires. Electrical Research Association, Leatherhead, England. Tech. Rept. No. O/TI (1947). 13 pp.

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