WROUGHT MATERIALS — **COPPER-NICKEL ALLOYS Cupro-nickels**

Cu Ni5 Fe1 Mn

Common names: 95/5 Copper-Nickel-Iron
95/5 Cupro-nickel
Cupro-nickel, 95/5

A copper-nickel alloy with an alpha phase structure. Small amounts of iron and manganese are added to improve corrosion resistance in slow-moving clean seawater. The alloy is relatively insensitive to stress corrosion and has good cold- and hot-working properties. The most commonly used wrought forms are plate, sheet and tube.

COMPOSITION (weight %)

Ni	4.5–6.0
Fe	1.0–1.5
Mn	0.3–0.8
Cu	rem.

1 SOME TYPICAL USES

Marine
Tubes carrying seawater for fire mains, cooling-water circuits and sanitary services on board ship.

Mechanical
Shell bands.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.90 g/cm³	0.320 lb/in³
2.2	Melting range [a]	1 090–1 125 °C	1 995–2 055 °F
2.3	Coefficient of thermal expansion (linear) at:		
	−183 to 10 °C *−297 to 50 °F*	0.000 014 per °C	0.000 008 per °F
	20 „ 300 °C *68 „ 572 °F*	0.000 017 „ „	0.000 009 „ „
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*	0.15 cal cm/cm² s °C	36 Btu ft/ft² h °F
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	8.1 m/ohm mm²	14% IACS
	200 °C *392 °F* („ „ „ „)	6.4 „	11 „ „
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	0.12 ohm mm²/m 12 microhm cm	74 ohms (circ mil/ft) 4.8 microhm in
	200 °C *392 °F* („ „ „ „)	0.16 ohm mm²/m 16 microhm cm	94 ohms (circ mil/ft) 6.2 microhm in
2.8	Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.001 2 per °C (14% IACS)	0.000 7 per °F (14% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	13 500 kg/mm²	19 200 000 lb/in²
	cold worked [b]	12 400 kg/mm²	17 600 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20° C *68 °F*		
	annealed	5 000 kg/mm²	7 100 000 lb/in²
	cold worked [b]	4 600 kg/mm²	6 500 000 lb/in²

[a] The melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted. The values are based on: Hansen, M. and Anderko, K. Constitution of Binary Alloys. 2nd ed. (1958) McGraw-Hill, London, New York; more recent work (Feest, E.A. and Doherty, R.D. The Cu-Ni Equilibrium Phase Diagram. J. Inst. Metals, Vol. 99 (1971), pp. 102–103) indicates that the solidus temperature may be slightly higher.

[b] Approximately 50% cold work.

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 8); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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DATA SHEET No. K 1
© Cu Ni5 Fe1 Mn
1972 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	1 200–1 275 °C	2 190–2 325°F
3.2	Annealing temperature range	600– 825 °C[(a)]	1 110–1 515 °F[(a)]
	Stress relieving temperature range	275– 400 °C	525– 750 °F
3.3	Hot working temperature range	825– 950 °C	1 515–1 740 °F
3.4	Hot formability	Good	
3.5	Cold formability	Excellent	
3.6	Cold reduction between anneals	80% 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. 3.9	
	Soldering	Excellent	
	Brazing	Good [(b)]	
	Oxy-acetylene welding	Good [(b)]	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Good [(b)]	
	Coated metal-arc welding	Good [(b)]	
	Resistance welding: spot and seam	Good [(b)]	
	butt	Good [(b)]	

(a) To preserve optimum corrosion resistance, annealing temperature should be within the range 750–825°C *(1 380 – 1 515°F)*.

(b) Post-welding heat treatment above 750°C *(1 380°F)* is necessary to preserve optimum corrosion resistance at joints; accordingly, brazing operations are not always practicable.

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition [a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	—	—	—	—	—	—	—	—
Canada	CSA	HC.NF52	—	—	—	—	HC.7.3 HC.7.4	—	—
Chile	NCh (INDITECNOR)	Cu Ni5 Fe1 Mn	NCh 250. of 68	—	—	—	—	—	—
France	—	Cu Ni5 Fe1 Mn	—	—	—	—	—	—	—
Germany	DIN	CuNi5 Fe	17 664	17 670	—	—	17 671	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN [b]	Cu Ni5 Fe1 Mn	NEN 6030	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	CN101	—	1541 2870 2875	—	—	2871 [c]	—	—
United States	ASTM	No. 704	—	—	—	—	B111 B359 B395 B466	—	—
International Organization for Standardization	ISO	Cu Ni5 Fe1 Mn	R 429	—	—	—	—	—	—

(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) Included in imperial units edition (1957) but deleted from metricated revision (1972).

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

Tensile properties	see tables 5.1.1/3
Hardness	" " 5.1.1/3
Shear Strength	" " 5.1.1/3
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 5.3.2.2/3

5.4 Fatigue properties

Fatigue strength at room temperature	see table 5.4.1

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE [*]

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

This table is representative of practice in many European countries. For American practice, see table 5.1.3.

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 [a]
				%	gauge length	Brinell	Vickers		
Plate Sheet Strip	Annealed	28	9	40	$5.65\sqrt{S_o}$	60	63	21	1–20 mm thick
	Typical Cold Worked Temper	38	35	10	$5.65\sqrt{S_o}$	100	105	27	1–10 mm thick
Tube [b]	Annealed (grain size 0.025 mm)	32	13	35	$5.65\sqrt{S_o}$	65	68	24	10–30 mm O.D. 1–3 mm wall

[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 manufacturers.

[b] Tubes for condensers and heat exchangers are generally supplied in the annealed temper whose representative mechanical properties are shown.

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

Tensile properties and hardness values in SI and English units are omitted from this data sheet, since alloys within the composition range concerned are no longer in regular production by British manufacturers.

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 practice in European countries, see table 5.1.1.

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	35 000	15 000	40	2 in.	—	48	—	28 000	2 in. thick
	Annealed	38 000	12 000	41	2 in.	—	8	—	30 000	0.040 in. thick
	Cold Worked 37%	62 000	59 000	6	2 in.	—	71	—	40 000	0.040 in. thick
Tube [b]	Annealed (grain size 0.025 mm)	41 000	14 000	46	2 in.	58	—	—	31 000	1.0 in. O.D. × 0.065 in. wall
	Cold Worked Light Drawn	48 000	36 000	18	2 in.	—	67	—	34 000	1.0 in. O.D. × 0.065 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] Tubes for condensers and heat exchangers are generally supplied in the annealed or light-drawn tempers whose representative mechanical properties are shown.

[*] It will be noted that tables 5.1.1, and 5.1.3, giving typical tensile properties and hardness values in Metric, 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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress ton/in² [a]	Elongation		Reduction of Area %	Impact Strength [b]	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Plate [c] [(1)] **13–19 mm 0.5–0.75 in.**	[d]	14	57	29	**18.3**	41 000	**15.3**	**37**	1.5 in.	**70.5**	37.1	**134**
		−20	−4	29	**18.4**	41 000	**15.1**	**38**	1.5 in.	**71.0**	—	—
		−50	−58	31	**19.6**	44 000	**15.9**	**40**	1.5 in.	**70.0**	37.1	**134**
		−100	−148	32.5	**20.5**	46 000	**15.9**	**40**	1.5 in.	**69.0**	42.3	**153**
		−150	−238	35	**22.2**	49 500	**16.5**	**40**	1.5 in.	**62.0**	46.5	**168**
		−196	−321	39.5	**25.1**	56 000	**17.2**	**51**	1.5 in.	**55.0**	42.9	**155**

(a) Quoted as "yield stress" in original document, but offset strain not defined.
(b) Charpy test; V notch; cross-sectional area at the notch 0.5 cm².
(c) Results of Navy tear tests on this alloy are also included in ref. (1)
(d) Temper not stated in original document, but probably annealed.

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.

— Data not available:
Proof stress, 0.2% and 0.1% offset,
Yield strength, 0.5% extension under load.

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 [2]	Annealed	20	68	30.5	**19.5**	43 500	**17.2** [a]	**10.2**	—	**40**	2 in.
		66	150	29	**18.3**	41 000	**16.9** [a]	**9.9**	—	**41**	2 in.
		121	250	27	**17.2**	38 500	**16.4** [a]	**9.6**	—	**40**	2 in.
		177	350	26	**16.5**	37 000	**15.0** [a]	**8.7**	—	**38**	2 in.
		232	450	25	**15.8**	35 500	**15.4** [a]	**9.1**	—	**35**	2 in.
		288	550	24	**15.2**	34 000	**15.1** [a]	**9.0**	—	**34**	2 in.
		316	600	23.5	**14.9**	33 500	**14.3** [a]	**8.6**	—	**34**	2 in.
Rod [3] **29 mm diam. 1.125 in. diam.**	Annealed (grain size 0.045 mm)	20	68	29	**18.3**	41 000	**15.4** [a]	**9.2**	—	**52**	$4\sqrt{S_o}$
		200	392	25.5	**16.3**	36 500	**15.3** [a]	**9.0**	—	**46**	$4\sqrt{S_o}$
		450	842	21.5	**13.6**	30 500	**15.6** [a]	**9.2**	—	**8**	$4\sqrt{S_o}$
		500	932	19.5	**12.3**	27 500	**14.3** [a]	**8.3**	—	**6**	$4\sqrt{S_o}$
		550	1 022	16	**10.3**	23 000	**13.2** [a]	**7.9**	—	**4**	$4\sqrt{S_o}$
— [b] [c] [4]	Cold Worked 37%	200	392	40	25.5	**57 100**	—	—	—	**15.0**	2 in.
		300	572	37	23.5	**52 300**	—	—	**51 500**	**11.0**	2 in.
		400	752	32	20	**45 200**	—	—	**44 200**	**6.5**	2 in.
		500	932	27	17	**38 600**	—	—	**37 700**	**5.5**	2 in.
		600	1 112	21	13.5	**30 200**	—	—	**29 800**	**6.5**	2 in.
		700	1 292	9.5	6	**13 800**	—	—	**12 300**	**27.0**	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] Form not stated in original document.
[c] Alloy containing 1.60% Fe.

N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following papers:

- Simakovskii, A. P. Properties of Cu-Cr and Cu-Ni Alloys at Elevated Temperatures. Metalloved i Obrabotka Met. (1958), No. 6, pp. 41–47 (tests up to 350°C *(662°F)* on 20 mm sheet, hot rolled or annealed).
- Kuz'mina, N. S. Experiments in the Production of Tubes from a Copper-Nickel Alloy with Iron and Manganese (Alloy MN5). Izvest. Vyssh. Ucheb. Zaved. MVO, Razdel Tsvet. Met., (1958), No. 1, pp. 153–163 (tests on extruded material).

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

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

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate					
				0.01% per 1 000 h			0.1% per 1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod (3) **29 mm diam.** **1.125 in. diam.**	Annealed (grain size 0.045 mm)	450 500	842 932	1.6 0.32 (a)	**1.0** **0.2** (a)	2 200 450 (a)	4.3 1.7	**2.7** **1.1**	6 000 2 500

(a) Extrapolated value.

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

5.3.2.3 Stress for Rupture

Form	Temper	Testing Temperature		Stress for Rupture								
				in 10 h			in 100 h			in 10 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Tube (5)	Annealed	279 321 349	535 610 660	— — —	— — —	— — —	— — —	— — —	— — —	12.0 9.6 5.0	7.6 6.1 3.2	**17 000** **13 600** **7 100**
(a) (4)	Cold Worked 37%	300 400 500	572 752 932	28.2 16.0 9.1	17.9 10.2 5.8	**40 100** **22 800** **12 900**	24.5 11.5 5.2	15.6 7.3 3.3	**34 900** **16 300** **7 400**	— — —	— — —	— — —

(a) Form not stated in original document.

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

— Further data can be obtained from the following papers:

- Simakovskii, A.P. Properties of Cu–Cr and Cu–Ni Alloys at Elevated Temperatures. Metalloved i Obrabotka Met. (1958), No. 6, pp. 41–47.
- Kuz'mina, N.S. Experiments in the Production of Tubes from a Copper-Nickel Alloy with Iron and Manganese (Alloy MN5). Izvest. Vyssh. Ucheb. Zaved, MVO, Razdel Tsvet. Met., (1958), No. 1, pp. 153–163. (creep tests up to 1 000°C *(1 830°F)* on as-extruded tube).
- Bearham, J.H. and Parker, R.J. Elevated-Temperature Tensile, Stress-Rupture and Creep Data for Six Copper-Base Materials. Metallurgia (Manchr), Vol. 78 (1968), pp. 9–14. (stress-rupture properties of annealed rod).
- Parker, R.J. Estimation of Stress-Rupture Properties from Hot Hardness Tests, Metallurgia (Manchr.), Vol. 67 (1963), pp. 219–223 (stress-rupture tests at 450°C *(842°F)*).

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
Sheet [6] **5 mm 0.2 in.**	Annealed	2	**24.5**	**11.5** [e]	15.5	7.5 [e]	35 000	16 500 [e]
	Cold Worked	2	**28**	**13** [e]	18	8.5 [e]	40 000	18 500 [e]
Strip [7] **6 mm 0.25 in.**	Cold Worked 25%	100	—	~ 9.5 [a]	—	**~ 6** [a]	—	~13 500 [a]
Rod [8] **23 mm diam. 0.9 in. diam.**	Annealed	100	31	13.5 [b]	**19.7**	**8.5** [b]	44 000	19 000 [b]
	Cold Worked 25%	100	41	17.5 [b]	**26.0**	**11.2** [b]	58 000	25 000 [b]
	Cold Worked 50%	100	47.5	19 [b]	**30.2**	**12.1** [b]	67 500	27 000 [b]
— [c] [9]	— [d]	20	**33.6**	**17**	21.5	11	48 000	24 000

[a] Reversed-bending test.
[b] Rotating-beam test.
[c] Form not stated in original document.
[d] Temper not stated in original document.
[e] Alternating-bending test.
N.B.: Original values are printed in **bold type**; other values are converted.

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MECHANICAL PROPERTIES (Section 5)

(1) Lismer, R.E. The Properties of Some Metals and Alloys at Low Temperatures. J. Inst. Metals, Vol. 89 (1960–61), pp. 145–161.

(2) Ashbolt, D. and Bowers, J.E. The Properties of Copper and Copper Alloys at Elevated Temperatures. BNFMRA Research Report A1550 (1965).

(3) Bearham, J.H. and Parker, R.J. Elevated-Temperature Tensile, Stress-Rupture and Creep Data for Six Copper-Base Materials. Metallurgia (Manchr), Vol. 78 (1968), pp. 9–14.

(4) Pels, A.R. Elevated-Temperature Properties of Copper-Base Alloys. Wire and Wire Products, Vol. 37 (1962), pp. 1398–1404, 1502–1503.

(5) Alloy Digest. Engineering Alloys Digest, Inc., New Jersey (1967).

(6) Abramovich, V.R. The Mechanical Properties of Welded and Brazed Joints of Copper and Copper-Nickel Alloys. Svarochnoe Proizvodstvo, (1959), No. 2, pp. 31–33.

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(8) Bidmead, G.F. Wöhler Fatigue Test Data on "Kunifer 5" Rod. Imperial Metal Industries, Ltd., England. Research Dept. Rept. MD/RR/87/54 (1954).

(9) Weller, J. and Weissgerber, R. Festigkeitseigenschaften von Cu Ni Fe Mn – Werkstoffen. Institut für Leichtbau IfL – Mitteilungen, Dresden, Vol. 7 (1968), pp. 288–296.

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Cu Ni10 Fe1 Mn

Common names: 90/10 Copper-Nickel-Iron
90/10 Cupro-nickel
Cupro-nickel, 90/10

A copper-nickel alloy with an alpha phase structure. Small amounts of iron and manganese are added to improve corrosion resistance in high-velocity (from 1 to about 3.5 m/s) waters, including seawater. The alloy is relatively insensitive to stress corrosion. It has good cold- and hot- working properties and is readily weldable. The most commonly used wrought forms are plate, sheet and tube.

COMPOSITION (weight %)

Ni	9.0–11.0
Fe	1.0– 2.0
Mn	0.3– 1.0
Cu	rem.

1 SOME TYPICAL USES

Chemical
Tubes and tubeplates for light-duty condensers, feedwater heaters and evaporators, including power stations, sugar-making and desalination plant.

Marine
Tubes for condensers, evaporators and heat exchangers; tubes carrying seawater for fire mains, cooling-water circuits and sanitary services on board ship; sheathing for wooden piles; underwater fencing.

Mechanical
Multi-core cabled tubes for hydraulic and pneumatic lines.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	8.90 g/cm³	0.320 lb/in³
2.2 Melting range [a]	1 100–1 145 °C	2 010–2 095 °F
2.3 Coefficient of thermal expansion (linear) at:		
—183 to 10 °C *—297 to 50 °F*	0.000 013 per °C	0.000 007 per °F
20 to 300 °C *68 to 572 °F*	0.000 017 ,, ,,	0.000 009 ,, ,,
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*	0.12 cal cm/cm² s °C	29 Btu ft/ft² h °F
2.6 Electrical conductivity (volume) at:		
—269 °C *—452 °F* (annealed)	5.8 m/ohm mm²	10% IACS
20 °C *68 °F* (annealed or cold worked)	5 ,,	9 ,, ,,
200 °C *392 °F* (,, ,, ,, ,,)	5 ,,	8 ,, ,,
2.7 Electrical resistivity (volume) at:		
—269 °C *—452 °F* (annealed)	0.17 ohm mm²/m 17 microhm cm	104 ohms (circ mil/ft) 6.8 microhm in
20 °C *68 °F* (annealed or cold worked)	0.19 ohm mm²/m 19 microhm cm	115 ohms (circ mil/ft) 7.5 microhm in
200 °C *392 °F* (,, ,, ,, ,,)	0.22 ohm mm²/m 22 microhm cm	130 ohms (circ mil/ft) 8.5 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 7 per °C (9% IACS)	0.000 4 per °F (9% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*		
annealed	13 800 kg/mm²	19 600 000 lb/in²
cold worked [b]	13 000 kg/mm²	18 500 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
annealed	5 100 kg/mm²	7 300 000 lb/in²
cold worked [b]	4 800 kg/mm²	6 800 000 lb/in²

(a) The melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted. The values are based on: Hansen, M. and Anderko, K. Constitution of Binary Alloys. 2nd ed. (1958) McGraw-Hill, London, New York; more recent work (Feest, E.A. and Doherty, R.D. The Cu-Ni Equilibrium Phase Diagram. J. Inst. Metals, Vol. 99 (1971), pp. 102–103) indicates that the solidus temperature may be slightly higher.

(b) Approximately 50% cold work.

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 8); 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	1 225–1 300 °C	2 235–2 370 °F
3.2	Annealing temperature range	700– 825 °C	1 290–1 515 °F
	Stress relieving temperature range	275– 400 °C	525– 750 °F
3.3	Hot working temperature range	850– 950 °C	1 560–1 740 °F
3.4	Hot formability	Good	
3.5	Cold formability	Excellent	
3.6	Cold reduction between anneals	80% 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. 3.9	
	Soldering	Excellent	
	Brazing	Good	
	Oxy-acetylene welding	Not recommended	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Excellent	
	Coated metal-arc welding	Good	
	Resistance welding: spot and seam	Good	
	butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition [a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	—	—	—	—	—	—	—	—
Canada	CSA	HC.NF101	—	HC.4.6	—	—	HC.7.3 HC.7.4	—	—
Chile	NCh (INDITECNOR)	Cu Ni10 Fe1 Mn	NCh 250. of 68	—	—	—	—	—	—
France	NF	Cu Ni10 Fe1 Mn	—	—	—	—	A 51-102	—	—
Germany	DIN	Cu Ni10 Fe	17 664	17 670	17 672	17 672	1785 17 671	—	17 673
India	IS	NS 10 Cu Ni10 Fe1	—	2283	—	—	1545	—	—
Italy	UNI	Pt-Cu Ni10 Fe1 Mn	—	—	—	—	6785	—	—
Japan	JIS	CNP 1 CNTF 1 CNTF 1 S	—	H 3251	—	—	H 3635	—	—
Netherlands	N or NEN [b]	Cu Ni10 Fe1 Mn	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Ni10 Fe Mn	—	10 803	—	—	10 803 11 557	—	—
United Kingdom	BS	CN102	—	1541 2870 [c] 2875	—	—	378 2871	—	—
United States [d]	ASTM	No. 706	—	B122 B151 B171 B402	—	—	B111 B359 B395 B466 B467 B543	—	—
International Organization for Standardization	ISO	Cu Ni10 Fe1 Mn	R 429	—	—	—	—	—	—

(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 metricated revision (1968); not in imperial units edition (1962).

(d) 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 [*]

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 %	Elongation gauge length	Hardness Brinell	Hardness Vickers	Shear Strength kg/mm²	Typical Size Related to Properties Shown [a]
Plate Sheet Strip	Annealed	32	12	38	$5.65\sqrt{S_o}$	65	68	24	1–20 mm thick
	Typical Cold Worked Temper	42	38	12	$5.65\sqrt{S_o}$	120	125	29	1–10 mm thick
Tube [b]	Annealed (grain size 0.025 mm)	33	14	38	$5.65\sqrt{S_o}$	70	74	25	10–30 mm O.D. 1–3 mm wall
	Typical Cold Drawn Temper	42	35	14	$5.65\sqrt{S_o}$	120	125	29	10–30 mm O.D. 1–2 mm wall

(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 manufacturers.

(b) Tubes for condensers and heat exchangers are generally supplied in the annealed temper whose representative mechanical properties are shown.

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 hbar	Tensile strength ton/in²	Proof Stress 0.1% offset hbar	Proof Stress 0.1% offset ton/in²	Elongation %	Elongation gauge length	Vickers Hardness	Shear Strength hbar	Shear Strength ton/in²	Typical Size Related to Properties Shown [b]
Plate	Annealed	32	21	12	8	42	$5.65\sqrt{S_o}$	85	25	16	—
	Hot Rolled As Manufactured	34	22	14	9	40	$5.65\sqrt{S_o}$	95	26	17	12–50 mm (0.5–2 in.) thick
Sheet Strip	Annealed	32	21	12	8	45	50 mm (2 in.)	85	25	16	—
	Hot Rolled As Manufactured	36	23	19	12	40	50 mm (2 in.)	105	26	17	3–10 mm (0.125–0.375 in.) thick
Tube [c]	Annealed (grain size 0.025 mm)	**32**	**21**	**14**	**9**	**40**	$5.65\sqrt{S_o}$	**85**	**25**	**16**	—
	Cold Drawn or Temper Annealed										
	Temper Annealed	36	23	19	12	35	$5.65\sqrt{S_o}$	120	28	18	50–255 mm (2–10 in.) O.D. 2–5 mm (0.08–0.2 in.) wall
	Temper Annealed	**36**	**23**	**19**	**12**	**38**	$5.65\sqrt{S_o}$	**115**	**28**	**18**	6–50 mm (0.25–2 in.) O.D. 0.5–2 mm (0.02–0.08 in.) wall
	Temper Annealed	**43**	**28**	**32**	**21**	**30**	$5.65\sqrt{S_o}$	**140**	**32**	**21**	
	As-Drawn (hard)	**54**	**35**	**46**	**30**	**13**	$5.65\sqrt{S_o}$	**165**	**36**	**23**	

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

(*) 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.

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	40 000	15 000	30	2 in.	—	48	—	30 000	2.0 in. thick
	Annealed	44 000	15 000	40	2 in.	—	10	—	33 000	0.040 in. thick
		42 000	18 000	35	2 in.	—	15	—	32 000	1.0 in. thick
	Cold Worked									
	Half Hard	61 000	56 000	20	2 in.	—	65	—	43 000	0.040 in. thick
	Hard	67 000	61 000	18	2 in.	—	66	—	44 000	"
	Extra Hard	70 000	63 000	15	2 in.	—	66	—	42 000	"
	Spring	72 000	65 000	14	2 in.	—	66	—	40 000	"
	Extra Spring	75 000	67 000	12	2 in.	—	66	—	38 000	"
	Hard	58 000	45 000	20	2 in.	—	68	—	38 000	1.0 in. thick
Tube [b]	Annealed (grain size 0.025 mm)	44 000	16 000	42	2 in.	65	15	26	33 000	1.0 in. O.D. × 0.065 in. wall
	Cold Worked Light Drawn	60 000	57 000	10	2 in.	100	72	70	42 000	1.0 in. O.D. × 0.065 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) Tubes for condensers and heat exchangers are generally supplied in the annealed or light-drawn tempers whose representative mechanical properties are shown.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Yield Strength 0.5% ext. under load psi	Elongation		Reduction of Area %	Impact [a] Strength	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Flat Products[1]	Hot Rolled	20	68	34.5	22	**49 000**	**29 000**	**34**	$4.52\sqrt{S_o}$	**64**	7.2	**42**
		− 92	−134	42	27	**60 000**	**33 000**	**43**	$4.52\sqrt{S_o}$	**65**	9.7	**56**
		−126	−195	47	29.5	**66 500**	**33 600**	**50**	$4.52\sqrt{S_o}$	**62**	12	**68**
Rod [b] [c] [2] 19 mm diam. 0.75 in. diam.	Annealed	22	72	35	22	**49 600**	**21 400**	**37**	$4.52\sqrt{S_o}$	**79**	19.7	**114**
		− 78	−108	38.5	24.5	**54 700**	**24 700**	**42**	$4.52\sqrt{S_o}$	**77**	19.5	**113**
		−197	−323	50.5	32	**72 000**	**24 800**	**50**	$4.52\sqrt{S_o}$	**77**	19.9	**115**
		−253	−423	58	37	**82 500**	**30 200**	**50**	$4.52\sqrt{S_o}$	**73**	20.0	**116**
		−269	−452	56.5	36	**80 600**	**24 900**	**53**	$4.52\sqrt{S_o}$	**73**	—	—

(a) Charpy test; 10 × 10 × 55 mm specimen; 45° V notch, 2 mm deep; cross-sectional area at the notch 0.8 cm².

(b) Tensile specimen, 6.35 mm (0.25 in.) diam.

(c) Manganese content of alloy not reported 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.

— Data not available: Proof stress, 0.2% and 0.1% offset.

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	%	gauge length
Plate [3] [4]	Annealed	20	68	35	**22.2**	49 500	**16.2** [a]	**9.6**	**37**	2 in.
		66	150	33	**21.1**	47 500	**15.9** [a]	**9.5**	**37**	2 in.
		121	250	31.5	**20.1**	45 000	**16.4** [a]	**9.8**	**30**	2 in.
		177	350	30.5	**19.3**	43 000	**15.7** [a]	**9.3**	**35**	2 in.
		232	450	29	**18.5**	41 500	**15.7** [a]	**9.3**	**31**	2 in.
		288	550	28	**17.8**	40 000	**15.1** [a]	**8.9**	**30**	2 in.
		316	600	27.5	**17.4**	39 000	**14.9** [a]	**9.0**	**29**	2 in.
	Hot Worked	20	68	**31**	19.5	44 000	**12**	—	—	—
		100	212	**31**	19.5	44 000	**12**	—	—	—
		200	392	**28**	18	40 000	**11.3**	—	—	—
		250	482	**26.5**	17	37 500	**10.6**	—	—	—
		300	572	**24.5**	15.5	35 000	**10.0**	—	—	—
		350	662	**23**	14.5	32 500	**9.5**	—	—	—
Rod [5] 25 mm diam. 1 in. diam.	Hot Rolled	27	80	32	20	**45 200**	**11.2** [c]	—	**50**	2 in.
		93	200	28.5	18	**40 200**	**9.63** [c]	—	**48**	2 in.
		204	400	24.5	15.5	**34 500**	**8.79** [c]	—	**43**	2 in.
		316	600	23.5	15	**33 300**	**9.56** [c]	—	**40**	2 in.
		427	800	21	13.5	**29 900**	**8.51** [c]	—	**28**	2 in.
	Cold Worked 21%	27	80	40	25.5	**56 600**	**37.5** [c]	—	**24**	2 in.
		93	200	37.5	24	**53 300**	**35.7** [c]	—	**21**	2 in.
		204	400	34.5	22	**49 000**	**33.2** [c]	—	**18**	2 in.
		316	600	31.5	20	**44 700**	**30.4** [c]	—	**15**	2 in.
		427	800	27	17	**38 200**	**24.6** [c]	—	**11**	2 in.
	Cold Worked 36%	27	80	46.5	29.5	**66 400**	**44.9** [c]	—	**16**	2 in.
		93	200	43.5	27.5	**61 900**	**41.1** [c]	—	**17**	2 in.
		204	400	41	26	**58 400**	**38.3** [c]	—	**15**	2 in.
		316	600	37	23.5	**52 600**	**35.5** [c]	—	**13**	2 in.
		427	800	31.5	20	**44 900**	**28.5** [c]	—	**9**	2 in.
Tube [b] [6] 32 mm O.D. 2 mm wall; 1.25 in. O.D., 0.08 in. wall	Annealed	20	68	38	**24.0**	54 000	—	**10.3**	**35**	2 in.
		149	300	35	**22.3**	50 000	—	**9.8**	**31**	2 in.
		177	351	34.5	**21.8**	49 000	—	**9.6**	**29**	2 in.
		204	399	33.5	**21.3**	47 500	—	**9.5**	**28**	2 in.
		232	450	33	**21.0**	47 000	—	**9.5**	**26**	2 in.
		260	500	32.5	**20.7**	46 500	—	**9.4**	**25**	2 in.
		315	599	32	**20.2**	45 000	—	**9.2**	**23**	2 in.
		400	752	29.5	**18.6**	41 500	—	**9.0**	**18**	2 in.
	Cold Drawn 40%	20	68	51	**32.4**	72 500	—	**27.4**	**6**	2 in.
		149	300	48	**30.5**	68 500	—	**25.9**	**5**	2 in.
		177	351	46.5	**29.4**	66 000	—	**25.0**	**5**	2 in.
		204	399	45	**28.6**	64 000	—	**24.7**	**6**	2 in.
		232	450	45	**28.5**	64 000	—	**24.7**	**5**	2 in.
		260	500	44	**28.0**	62 500	—	**24.4**	**5**	2 in.
		315	599	43	**27.3**	61 000	—	**23.5**	**5**	2 in.
		400	752	35.5	**22.4**	50 000	—	**18.7**	**6**	2 in.
Condenser [7] Tube	Annealed	20	68	**34**	21.5	48 500	**12.8**	—	**36**	$11.3\sqrt{S_o}$
		100	212	**32**	20.5	45 500	**11**	—	**30**	$11.3\sqrt{S_o}$
		200	392	**28**	18	40 000	**10.5**	—	**30**	$11.3\sqrt{S_o}$
		300	572	**25**	16	35 500	**10**	—	**28**	$11.3\sqrt{S_o}$
		400	752	**24**	15	34 000	**9**	—	**22**	$11.3\sqrt{S_o}$
		500	932	**18**	11.5	25 500	**8**	—	**26**	$11.3\sqrt{S_o}$
		600	1 112	**11**	7	15 500	**7**	—	**32**	$11.3\sqrt{S_o}$

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

(b) The tensile and elongation values include 30 mins. creep.

(c) 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.

— Data not available: Yield strength, 0.5% extension under load.

— Further data can be obtained from the following papers:

- Simakovskii, A.P. Properties of Cu-Cr and Cu-Ni Alloys at Elevated Temperatures. Metalloved i Obrabotka Met. (1958), No. 6, pp. 41–47. (tests up to 350°C *(662°F)* on 20 mm sheet, hot rolled or annealed).
- Mechanical Properties of 90/10 Copper-Nickel Alloys. U.S. Naval EES Rept. 4E (B-1) 101717 (1956). (tests on plate and rod, with Fe contents up to 1.8%).

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 %	Minimum Creep Rate % per 1 000 h
Rod (d) (5) 3 mm diam. 0.125 in. diam.	Annealed (grain size 0.025 mm)	149	300	10.5	6.7	**15 000**	**6 000**	**0.870 5**	**0.128**	**< 0.000 1**
				14.1	8.9	**20 000**	**6 000**	**2.131**	**0.242**	**0.000 16**
				17.6	11.2	**25 000**	**6 000**	**4.705**	**0.163 7**	**0.000 22**
		204	400	6.5	4.1	**9 200**	**6 000**	**0.058 5**	**0.003**	**0.000 1**
				10.0	6.3	**14 200**	**6 000**	**0.603 9**	**0.079 5**	**0.000 73**
				13.5	8.6	**19 200**	**6 000**	**2.178**	**0.202**	**0.002 0**
				15.6	9.9	**22 200**	**6 000**	**2.650**	**0.465**	**0.002 8**
		260	500	6.5	4.1	**9 200**	**6 000**	**0.090**	**0.014 3**	**0.000 61**
				9.8	5.9	**13 150**	**6 000**	**0.516**	**0.253 8**	**0.001 7**
				12.8	8.1	**18 150**	**6 000**	**1.803**	**0.175 6**	**0.003 8**
	Cold Worked 21 %	149	300	14.1	8.9	**20 050**	**6 000**	**0.139 1**	**0.018 8**	**< 0.000 1**
				21.1	13.4	**30 000**	**6 000**	**0.199**	**0.014 8**	**0.000 2**
				28.2	17.9	**40 050**	**6 000**	**0.277**	**0.027 6**	**0.001 4**
				31.6	20.1	**45 000**	**6 000**	**0.410**	**0.061 0**	**0.002 4**
				35.2	22.3	**50 000**	**6 000**	**0.635**	**0.164**	**0.003 5**
		204	400	10.7	6.8	**15 150**	**6 000**	**0.110 4**	**0.019 2**	**0.000 2**
				17.7	11.2	**25 150**	**6 000**	**0.184**	**0.028**	**0.001 0**
				24.7	15.7	**35 100**	**6 000**	**0.308 2**	**0.062 8**	**0.002 9**
				28.1	17.8	**40 000**	**6 000**	**0.411 5**	**0.111 5**	**0.006 3**
				31.7	20.1	**45 100**	**6 000**	**0.709**	**0.143**	**0.036 6**
		260	500	14.3	9.1	**20 300**	**6 000**	**0.198 8**	**0.057 6**	**0.002 2**
				21.2	13.5	**30 150**	**6 000**	**0.442 5**	**0.169**	**0.013 6**
				25.0	15.9	**35 500**	**4 320**	**0.607**	**0.189**	**0.044**
				25.0	15.9	**35 500**	**6 000**	**0.700**	**0.102**	**0.061 7** (b)
Rod (c) (5)	Annealed (grain size 0.030 mm)	316	600	2.8	1.8	**4 000**	**1 175**	**0.039**	**0.028**	**0.009**
				4.2	2.7	**6 000**	**1 525**	**0.056**	**0.046**	**0.000 66**
				5.6	3.6	**8 000**	**1 525**	**0.08**	**0.07**	**0.006 6**
				8.4	5.4	**12 000**	**965**	**0.136**	**0.10**	**0.037**
				12.0	7.6	**17 000**	**1 125**	**0.254**	**0.185**	**0.061**

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

(b) Accelerating creep rate from third stage of creep.

(c) Alloy containing: 0.89% Fe; 0.21% Mn.

(d) Mn content: 0.12%.

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

— Further data can be obtained from the following papers:

- Simakovskii, A.P. Properties of Cu–Cr and Cu–Ni Alloys at Elevated Temperatures. Metalloved i Obrabotka Met. (1958), No. 6, pp. 41–47.
- Blucher, J.T. and Grant, N.J. Recrystallization, Tensile and Stress-Rupture Properties of Nickel-Copper Alloys. Proc. ASTM, Vol. 62 (1962), pp. 593–601.

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature °C	Testing Temperature °F	Stress for Designated Creep Rate: 0.001% per 1 000 h kg/mm²	0.001% per 1 000 h ton/in²	0.001% per 1 000 h psi	0.01% per 1 000 h kg/mm²	0.01% per 1 000 h ton/in²	0.01% per 1 000 h psi	0.1% per 1 000 h kg/mm²	0.1% per 1 000 h ton/in²	0.1% per 1 000 h psi
Rod [b] [5] **3 mm diam. 0.125 in. diam.**	Annealed (grain size 0.025 mm)	149	300	>21.1	>13.4	**>30 000**	—	—	—	—	—	—
		204	400	11.2	7.1	**16 000**	21.1*	13.4*	**30 000***	—	—	—
		260	500	7.7	4.9	**11 000**	17.2*	10.9*	**24 500***	—	—	—
	Cold Worked 21%	149	300	26.6	16.9	**37 800**	>35.2	>22.3	**>50 000**	—	—	—
		204	400	18.0	11.4	**25 600**	29.9	19.0	**42 500**	32.3*	20.5*	**46 000***
		260	500	11.7	7.5	**16 700**	20.0	12.7	**28 500**	25.3	16.1	**36 000**
Rod [a] [5]	Annealed (grain size 0.030 mm)	316	600	—	—	—	4.2	2.7	**6 000**	13.4	8.5	**19 000**

(a) Alloy containing 0.89% Fe; 0.21% Mn.
(b) Manganese content: 0.12%.
(*) Extrapolated value.
N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following paper:
■ Weaver, V.P. and Imperati, J. Copper and Copper Alloys for Pressure Vessels. Welding Research Council, New York. Bull. No. 73 (1961) November.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles × 10^6	Metric Units kg/mm²: Tensile Strength	Metric Units kg/mm²: Fatigue Strength	English Units ton/in²: Tensile Strength	English Units ton/in²: Fatigue Strength	American Units psi: Tensile Strength	American Units psi: Fatigue Strength
Strip [8] **6 mm 0.25 in.**	Cold Worked 25%	100	—	~ 9.5 [a]	—	**~ 6** [a]	—	~13 500 [a]
— [b] [9]	— [c]	20	**41.4**	**17**	26.5	11	59 000	24 000
— [b] [10]	Cold Worked [e]	100	38	15 [d]	24	9.5 [d]	**53 800**	**21 000** [d]

(a) Reversed-bending test.
(b) Form not stated in original document.
(c) Temper not stated in original document.
(d) Rotating-cantilever test.
(e) Quoted as "hard" in original document, but amount of cold work not defined.
N.B.: Original values are printed in **bold type**; other values are converted.

REFERENCES

MECHANICAL PROPERTIES (Section 5)

(1) Alloy Digest. Engineering Alloys Digest, Inc., New Jersey (1967).
(2) Reed, R.P. and Mikesell, R.P. Low-Temperature (295 to 4 K) Mechanical Properties of Selected Copper Alloys. J. Materials, Vol. 2, (1967), No. 2, pp. 370–392.
(3) Ashbolt, D. and Bowers, J.E. The Properties of Copper and Copper Alloys at Elevated Temperatures. BNFMRA Research Report A1550 (1965).
(4) Private communication from Vereinigte Deutsche Metallwerke AG, Germany.
(5) Upthegrove, C. and Burghoff, H.L. Elevated – Temperature Properties of Coppers and Copper-Base Alloys. American Society for Testing and Materials, Philadelphia, Pa. (1956) (ASTM Spec. Tech. Pub. No. 181).
(6) Benson, N.D. 0.1% Proof Stress Values at Elevated Temperatures of 90/10 Cupro-Nickel and an 87½/10/1½/½ Copper-Nickel-Iron-Manganese Alloy. Imperial Metal Industries, Ltd., England. Research Dept. Rept. MD/RR/32/50 (1950).
(7) Nothing, F.W. Kupfer-Nickel-Legierungen mit weniger als 50% Nickel. Nickel-Informationsbüro GmbH, Dusseldorf. Publication No. 7 (1964). 76 pp.
(8) Bale, E.S. Fatigue Tests at Room Temperature on Copper-Nickel-Iron Alloys. BNFMRA Tech. Memo TM94 (1952).
(9) Weller, J. and Weissgerber, R. Festigkeitseigenschaften von Cu Ni Fe Mn – Werkstoffen. Institut für Leichtbau IfL – Mitteilungen, Dresden, Vol. 7 (1968), pp. 288–296.
(10) Gross, M. R. and Schwab, R.C. Fatigue Properties of Non-Ferrous Alloys for Heat Exchangers, Pumps and Piping. US Navy Marine Engineering Laboratory, Annapolis, Md. R and D Rept. No. 232/66 (1966). (AD 633771).

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Cu Ni20

Common names: 80/20 Copper-Nickel
80/20 Cupro-nickel
Cupro-nickel, 80/20

A copper-nickel alloy with an alpha phase structure. The material has good corrosion resistance in slow-moving water and is relatively insensitive to stress corrosion. It has excellent cold-and good hot-working properties and is readily weldable. The most commonly used wrought forms are sheet and strip.

COMPOSITION (weight %)

Ni	19.0–21.0
Mn	0 – 0.5
Cu	rem.

1 SOME TYPICAL USES

Electrical
Resistors; transistor cans; radar waveguides.

Mechanical
Bullet envelopes (clad on steel); corrosion-resistant deep-drawn and spun components.

Plumbing
Domestic water heaters.

Coinage
Coins, medals, and medallions.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.95 g/cm³	0.325 lb/in³
2.2	Melting range [(a)]	1 130–1 190 °C	2 065–2 175 °F
2.3	Coefficient of thermal expansion (linear) at:		
	−183 to 10 °C *−297 to 50 °F*	0.000 013 per °C	0.000 007 per °F
	20 to 300 °C *68 to 572 °F*	0.000 016 ,, ,,	0.000 009 ,, ,,
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*	0.09 cal cm/cm² s °C	22 Btu ft/ft² h °F
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	3.5 m/ohm mm²	6% IACS
	200 °C *392 °F* (,, ,, ,, ,,)	3.5 ,,	6 ,, ,,
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	0.29 ohm mm²/m 29 microhm cm	173 ohms (circ mil/ft) 11 microhm in
	200 °C *392 °F* (,, ,, ,, ,,)	0.29 ohm mm²/m 29 microhm cm	173 ohms (circ mil/ft) 11 microhm in
2.8	Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 4 per °C (6% IACS)	0.000 2 per °F (6% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	14 900 kg/mm²	21 200 000 lb/in²
	cold worked [(b)]	13 600 kg/mm²	19 300 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*		
	annealed	5 500 kg/mm²	7 800 000 lb/in²
	cold worked [(b)]	5 050 kg/mm²	7 200 000 lb/in²

(a) The melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted. The values are based on: Hansen, M. and Anderko, K. Constitution of Binary Alloys. 2nd ed. (1958) McGraw-Hill, London, New York; more recent work (Feest, E.A. and Doherty, R.D. The Cu-Ni Equilibrium Phase Diagram. J. Inst.Metals, Vol. 99 (1971), pp. 102–103) indicates that the solidus temperature may be slightly higher.

(b) Approximately 50% cold worked.

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 8); 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	1 250–1 325 °C	2 280–2 415 °F
3.2	Annealing temperature range	625– 825 °C	1 155–1 515 °F
	Stress relieving temperature range	300– 400 °C	570– 750 °F
3.3	Hot working temperature range	875– 975 °C	1 605–1 785 °F
3.4	Hot formability	Good	
3.5	Cold formability	Good	
3.6	Cold reduction between anneals	75% 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. 3.9	
	Soldering	Excellent	
	Brazing	Excellent	
	Oxy-acetylene welding	Fair	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Excellent	
	Coated metal-arc welding	Good	
	Resistance welding: spot and seam	Good	
	butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition [a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	Cu Ni20	—	266.31	—	266.31	266.31	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Ni20	NCh 250. of 68	—	—	—	—	—	—
France	—	Cu Ni20	—	—	—	—	—	—	—
Germany	DIN	—	—	—	—	—	—	—	—
India	IS	NS20	—	2283	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN [b]	Cu Ni20	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	Cu Ni20	—	37 103	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	CN104	—	374 1541 2870 2875 [c]	—	—	—	—	—
United States	ASTM	—	—	—	—	—	—	—	—
International Organization for Standardization	ISO	Cu Ni20	R 429	—	—	—	—	—	—

(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) Included in imperial units edition (1963), but deleted from metricated revision (1969).

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 [*]

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 [a]
				%	gauge length	Brinell	Vickers		
Plate Sheet Strip	Annealed	34	15	40	$5.65\sqrt{S_o}$	80	84	25	1–10 mm thick
	Typical Cold Worked Tempers	40	34	25	$5.65\sqrt{S_o}$	115	120	28	1–10 mm thick
		46	42	12	$5.65\sqrt{S_o}$	135	140	32	1– 5 mm thick

[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 manufacturers.

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	Tensile Strength		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [a]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Sheet Strip	Annealed	34	22	12	8	40	50 mm (2 in.)	85	25	16	—
	Typical Cold Worked Tempers	40	26	31	20	25	50 mm (2 in.)	120	28	18	0.2–3 mm (0.008–0.125 in.) thick
		45	29	39	25	15	50 mm (2 in.)	140	29	19	"
		56	36	49	32	4	50 mm (2 in.)	165	31	20	"
Rod [b]	Typical Cold Worked Temper [c]	45	29	37	24	12	$5.65\sqrt{S_o}$	130	29	19	6–25 mm (0.25–1 in.) diam. or equivalent area
Wire	Annealed [c]	32	21	—	—	35	100 mm (4 in.)	—	25	16	2.5–5 mm (0.1–0.2 in.) diam.
		36	23	—	—	30	100 mm (4 in.)	—	26	17	0.5–2 mm (0.02–0.08 in.) diam.
		39	25	—	—	25	100 mm (4 in.)	—	29	19	0.2–0.4 mm (0.008–0.016 in.) diam.

[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 manufacturers.

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

[c] The principal application for rod and wire of this composition is as a material of controlled electrical resistance; rod is usually supplied in an appropriate cold-worked temper and wire in the annealed condition.

[*] 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.

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	48 000 40 000	36 000 18 000	35 35	2 in. 2 in.	— —	48 48	— —	36 000 30 000	0.75 in. thick 2 in. thick
	Annealed	41 000	14 000	45	2 in.	—	—	—	31 000	0.040 in. thick
	Cold Worked Hard	63 000	52 000	17	2 in.	102	78	69	40 000	1.0 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 manufacturers.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.1% offset ton/in²	Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Rod [1] 25 mm diam. 1 in. diam.	Annealed [a]	20	68	36	**23.0**	51 500	**12.36**	**25.5**	2 in.	**77.5**	13.3 [b]	**77.0** [b]
		− 10	− 14	39.5	**25.1**	56 000	**12.79**	**28.2**	2 in.	**77.0**	—	—
		− 40	− 40	42	**26.6**	59 500	**12.96**	**28.9**	2 in.	**77.0**	14.0 [b]	**81.0** [b]
		− 80	−112	43.5	**27.5**	61 500	**12.91**	**28.7**	2 in.	**76.0**	13.6 [b]	**79.0** [b]
		−114	−173	46.5	**29.5**	66 000	**13.04**	**28.2**	2 in.	**75.0**	—	—
		−120	−184	—	—	—	—	—	—	—	14.5 [b]	**84.0** [b]
		−180	−292	52	**32.9**	73 500	**14.49**	**35.6**	2 in.	**72.0**	14.7 [b]	**85.0** [b]
	Annealed [c]	20	68	38.5	**24.3**	54 500	**14.7**	**34.0**	2 in.	**76.0**	13.3 [b]	**77.0** [b]
		−180	−292	57	**36.35**	81 500	**21.65** [d]	**44.0**	2 in.	**71.0**	14.7 [b]	**85.0** [b]
Plate [2] [f] 13–19 mm 0.5–0.75 in.	[g]	16	61	—	—	—	—	—	—	—	12 [e]	**44** [e]
		22	72	31	**19.7**	44 000	—	**56**	1.5 in.	**70.0**	—	—
		− 20	− 4	33.5	**21.3**	47 500	—	**57**	1.5 in.	**68.5**	—	—
		− 50	− 58	34.5	**21.9**	49 000	—	**57**	1.5 in.	**66.0**	9.7 [e]	**35** [e]
		−100	−148	37.5	**23.9**	53 500	—	**55**	1.5 in.	**63.0**	9.4 [e]	**34** [e]
		−150	−238	40	**25.5**	57 000	—	**56**	1.5 in.	**57.0**	9.7 [e]	**35** [e]
		−196	−321	48.5	**30.9**	69 000	—	**62**	1.5 in.	**57.0**	8.3 [e]	**30** [e]

(a) Tensile specimen 6.35 mm (0.25 in.) diam.

(b) Izod specimen; cross-sectional area at the notch 0.8 cm².

(c) Tensile specimen 12.8 mm (0.505 in.) diam.

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

(e) Charpy test; V notch; cross-sectional area at the notch 0.5 cm².

(f) Results of Navy tear tests on this alloy are also included in ref. (2).

(g) Temper not stated in original document, but probably annealed.

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.

— Data not available: Proof stress, 0.2% offset,
Yield strength, 0.5% extension under load.

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	%	gauge length
Plate [3]	Hot Rolled	20	68	30.5	**19.5**	43 500	**10.6** [a]	**6.3**	**53**	2 in.
		66	150	29	**18.3**	41 000	**10.1** [a]	**6.0**	**53**	2 in.
		121	250	27	**17.2**	38 500	**10.3** [a]	**5.8**	**50**	2 in.
		177	350	25.5	**16.2**	36 500	**9.76** [a]	**5.6**	**49**	2 in.
		232	450	24.5	**15.5**	34 500	**9.45** [a]	**5.5**	**49**	2 in.
		288	550	23.5	**14.9**	33 500	**9.61** [a]	**5.5**	**46**	2 in.
		343	650	22.5	**14.3**	32 000	**8.66** [a]	**5.1**	**45**	2 in.
		371	700	22.5	**14.2**	32 000	**8.19** [a]	**4.8**	**42**	2 in.
Strip [4] 2 mm 0.08 in.	Annealed	20	68	31	**19.7**	44 000	—	**5.3**	**45**	2 in.
		100	212	28	**17.9**	40 000	—	**4.8**	**41**	2 in.
		200	392	25.5	**16.3**	36 500	—	**4.3**	**37**	2 in.
		300	572	22.5	**14.4**	32 500	—	**4.0**	**34**	2 in.
		400	752	21	**13.2**	29 500	—	**3.7**	**29**	2 in.
		500	932	16.5	**10.4**	23 500	—	**3.4**	**20**	2 in.
Rod [5] 22 mm diam. 0.875 in. diam.	Annealed	20	68	31.5	**20.1**	45 000	—	**3.1** [b]	**48.5**	$4\sqrt{S_o}$
		250	482	24.5	**15.5**	34 500	—	**2.0** [b]	**34.5**	$4\sqrt{S_o}$
		500	932	16	**10.2**	23 000	—	—	**11.5**	$4\sqrt{S_o}$
		750	1 382	5	**3.3**	7 500	—	—	**6.5**	$4\sqrt{S_o}$

(a) This value was originally reported in ton/in²; in this table it is given in kg/mm² to 3 significant figures.
(b) Quoted as "proportional limit" in original document but offset strain not defined.
N.B.: — Original values are printed in **bold type**; other values are converted.
— The 0.5% yield strength values are not available.
— Further data can be obtained from the following paper:

■ Volkogon, G.M. Velocity of the Deformation Occurring in Testing Affecting the Measured Mechanical Properties of Cupronickel MN19 and Monel NMZHMTS28-2.5-1.5. Tsvetnye Metally (1961) May, pp. 62–64. (tensile data up to 1 000°C (*1 832°F*) for alloy containing 19.2% Ni; 0.24% Fe; 0.46% Mn).

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension % [a]	Intercept %	Minimum Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod [6] [b] 3 mm diam. 0.125 in. diam.	Annealed (grain size 0.025 mm)	149	300	7.0	4.5	**10 000**	**6 260**	**0.085**	**0.004 5**	**0.000 1**
				10.5	6.7	**15 000**	**6 260**	**0.155 5**	**0.010**	**0.000 1**
				14.1	8.9	**20 000**	**6 260**	**1.226**	**0.104**	**0.000 4**
				17.5	11.1	**24 900**	**6 260**	**3.483**	**1.100**	**0.000 4**
		260	500	7.0	4.5	**10 000**	**6 260**	**0.117**	**0.013**	**0.000 6**
				10.5	6.7	**15 000**	**6 200**	**0.481**	**0.008**	**0.000 4**
				14.1	8.9	**20 000**	**6 260**	**1.685**	**0.086**	**0.006**
				15.5	9.9	**22 100**	**6 200**	**2.174**	**0.369**	**0.001 2**
				17.6	11.2	**25 000**	**6 260**	**3.130**	**0.012 5**	**0.001 1**

(a) Total Extension = Initial Extension + Total Creep = Initial Extension + Intercept + (Minimum creep rate × Duration).
(b) Alloy containing: 0.60% Mn; 0.19% Fe; 0.76% Zn; 19.95% Ni.
N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following paper:

■ Marin, J. Interpretation of Creep and Long-Time Test Data. Proc. Soc. Exptl. Stress Anal., Vol. 11 (1954), pp. 207–212.

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		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
Rod (6) (b) **3 mm diam.** **0.125 in. diam.**	Annealed (grain size 0.025 mm)	149 260	300 500	>17.6 (a) 12.0	>11.2 (a) 7.6	**>25 000** (a) **17 000**	— >21.1	— >13.4	— **>30 000**

(a) Extrapolated value.
(b) Alloy containing 0.60% Mn; 0.19% Fe; 0.76% Zn; 19.95% Ni.
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 (7) **1 mm** **0.04 in.**	Annealed	(f)	36	12	23	7.5	**51 000**	**17 000**
	Cold Worked	(f)	55.5	19	35.5	12	**79 000**	**27 000**
Rod (8) (g) **25 mm diam.** **1 in. diam.**	Cold Rolled	80	35	12.5 (a)	22.5	8 (a)	**49 900**	**18 000** (a)
Rod (9) (e)	— (c)	20	35.5	13 (d)	**22.5**	**8.1** (d)	50 500	18 000 (d)
Wire (10) **2 mm diam.** **0.072 in. diam.**	Cold Worked 88%	100	59.5	24 (b)	37.5	15 (b)	**84 300**	**34 000** (b)

(a) Rotating-cantilever test.
(b) Rotating-wire-arc test.
(c) Temper not stated in original document.
(d) Direct-stress test.
(e) Alloy containing 0.19% Fe.
(f) Number of cycles not stated in original document.
(g) Alloy containing 0.27% Fe.

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

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(1) Colbeck, E.W. and MacGillivray, W.E. The Mechanical Properties of Metals at Low Temperatures. Part 2: Non-Ferrous Materials. Trans. Instn. Chem. Engrs, Vol. 11 (1933), pp. 107–123.

(2) Lismer, R.E. The Properties of Some Metals and Alloys at Low Temperatures. J. Inst. Metals, Vol. 89 (1960–61), pp. 145–161.

(3) Ashbolt, D. and Bowers, J.E. The Properties of Copper and Copper Alloys at Elevated Temperatures. BNFMRA Research Report A1550 (1965).

(4) Parker, R. J. and Pittam, S.E. 0.1% Proof Stress Values at Elevated Temperatures of 80/20 and 70/30 Cupro-Nickel Strip to B.S.S. 374. Imperial Metal Industries, Ltd., England. Research Dept. Rept. MD/RR/51/48, (1948).

(5) Voce, E. and Read, H.C.S. The Influence of Aluminium Upon 80/20 Cupro-Nickel with Special Reference to Mechanical Properties and Oxidation at High Temperatures. BNFMRA Research Rept. A264 (1931).

(6) Upthegrove, C. and Burghoff, H.L. Elevated – Temperature Properties of Coppers and Copper-Base Alloys. American Society for Testing and Materials, Philadelphia, Pa. (1956) (ASTM Spec. Tech. Pub. No. 181).

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(9) Gough, H.G. and Sopwith, D.J. Atmospheric Action as a Factor in Fatigue of Metals. J. Inst. Metals, Vol. 49 (1932), pp. 93–122.

(10) Burghoff, H.L. and Blank, A.I. Fatigue Tests on Some Copper Alloys in Wire Form. Proc. ASTM, Vol. 43 (1943), pp. 774–784.

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Cu Ni20 Mn1 Fe

Common names: 80/20 Copper-Nickel-Iron
80/20 Cupro-nickel
Cupro-nickel, 80/20

A copper-nickel alloy with an alpha phase structure. Small amounts of iron and manganese are added to improve corrosion resistance in high-velocity (from 1 to about 4 m/s) waters, including seawater. The alloy is relatively insensitive to stress corrosion. It has good cold-and hot-working properties and is readily weldable. The most commonly used wrought forms are plate, sheet and tube.

COMPOSITION (weight %)

Ni	19.0–22.0
Mn	0.5– 1.5
Fe	0.4– 1.0
Cu	rem.

1 SOME TYPICAL USES

Chemical & Marine

Tubes and tubeplates for medium-duty condensers, feedwater heaters and evaporators.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.95 g/cm³	0.325 lb/in³
2.2	Melting range [a]	1 130–1 190 °C	2 065–2 175 °F
2.3	Coefficient of thermal expansion (linear) at:		
	−183 to 10 °C *−297 to 50 °F*	0.000 013 per °C	0.000 007 per °F
	20 to 300 °C *68 to 572 °F*	0.000 016 „ „	0.000 009 „ „
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*	0.09 cal cm/cm² s °C	22 Btu ft/ft² h °F
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	3.5 m/ohm mm²	6% IACS
	200 °C *392 °F* („ „ „ „)	3.5 „	6 „ „
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	0.29 ohm mm²/m 29 microhm cm	173 ohms (circ mil/ft) 11 microhm in
	200 °C *392 °F* („ „ „ „)	0.29 ohm mm²/m 29 microhm cm	173 ohms (circ mil/ft) 11 microhm in
2.8	Temperature coefficient of electrical resistance at:		
	20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 4 per °C (6% IACS)	0.000 2 per °F (6% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	14 800 kg/mm²	21 100 000 lb/in²
	cold worked [b]	13 600 kg/mm²	19 300 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*		
	annealed	5 500 kg/mm²	7 800 000 lb/in²
	cold worked [b]	5 050 kg/mm²	7 200 000 lb/in²

(a) The melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted. The values are based on: Hansen, M. and Anderko, K. Constitution of Binary Alloys. 2nd ed. (1958) McGraw-Hill, London, New York; more recent work (Feest, E.A. and Doherty, R.D. The Cu-Ni Equilibrium Phase Diagram. J. Inst.Metals, Vol. 99 (1971), pp. 102–103) indicates that the solidus temperature may be slightly higher.

(b) Approximately 50% cold work.

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 6); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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© Cu Ni20 Mn1 Fe
1972 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	1 250–1 325 °C	2 280–2 415 °F
3.2	Annealing temperature range	650– 825 °C	1 200–1 515 °F
	Stress relieving temperature range	300– 400 °C	570– 750 °F
3.3	Hot working temperature range	875– 975 °C	1 605–1 785 °F
3.4	Hot formability	Good	
3.5	Cold formability	Good	
3.6	Cold reduction between anneals	60% 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. 3.9	
	Soldering	Excellent	
	Brazing	Excellent	
	Oxy-acetylene welding	Fair	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Excellent	
	Coated metal-arc welding	Good	
	Resistance welding: spot and seam	Good	
	butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	—	—	—	—	—	—	—	—
Canada	CSA	HC.NF 201	—	—	—	—	HC.7.3 HC.7.4	—	—
Chile	NCh (INDITECNOR)	Cu Ni20 Mn1 Fe	NCh 250. of 68	—	—	—	—	—	—
France	NF	Cu Ni20 Mn1 Fe	—	—	—	—	A 51-102	—	—
Germany	DIN	Cu Ni20 Fe	17 664	17 670	—	—	—	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	Pt-Cu Ni20 Mn1 Fe	—	—	—	—	6785	—	—
Japan	JIS	CNTF 2 CNTF 2 S	—	—	—	—	H 3635	—	—
Netherlands	N or NEN[b]	Cu Ni20 Mn1 Fe	NEN 6030	NEN 6033	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States[c]	ASTM	No.710	—	B122	—	—	B111 B359 B395 B466 B467		
International Organization for Standardization	ISO	Cu Ni20 Mn1 Fe	R 429	—	—	—	—	—	—

[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 5.1.1/3
Hardness	„ „ 5.1.1/3
Shear Strength	„ „ 5.1.1/3
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	no data

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 American practice, see table 5.1.3.

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	34	15	38	$5.65\sqrt{S_o}$	80	84	25	1–20 mm thick
Tube [c]	Annealed (grain size 0.025 mm)	37	16	40	$5.65\sqrt{S_o}$	85	89	28	10–30 mm O.D. 1–3 mm wall
	Typical Cold Drawn Temper	47	42	14	$5.65\sqrt{S_o}$	130	135	33	10–30 mm O.D. 1–2 mm wall

(a) It will be noted that tables 5.1.1 and 5.1.3, giving typical tensile properties and hardness values in Metric 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 condensers and heat exchangers are generally supplied in the annealed temper whose representative mechanical properties are shown.

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

Tensile properties and hardness values in SI and English units are omitted from this data sheet, since alloys within the composition range concerned are not normally produced by British manufacturers.

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 practice in European countries, see table 5.1.1.

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)	Annealed	47 000	19 000	27	2 in.	—	32	—	35 000	0.040 in. thick
	Cold Worked 37%	76 000	73 000	6	2 in.	—	83	—	43 000	0.040 in. thick
Tube [b]	Annealed (grain size 0.025 mm)	49 000	18 000	40	2 in.	72	—	—	37 000	1.0 in. O.D. × 0.065 in. wall
	Cold Worked									
	Light Drawn	68 000	62 000	14	2 in.	—	76	—	44 000	1.0 in. O.D. × 0.065 in. wall
	Hard Drawn	80 000	75 000	—	—	—	81	—	48 000	0.75 in. O.D. × 0.049 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) Tubes for condensers and heat exchangers are generally supplied in the annealed temper whose representative mechanical properties are shown.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation		Reduction of Area %	Impact [a] Strength	
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length		kg m/cm²	ft lb
Plate [1] [b] **13–19 mm 0.5–0.75 in.**	(c)	18	64	42.5	**27.0**	60 500	**33**	1.5 in.	**70.8**	19.6	**71**
		−20	−4	45	**28.5**	64 000	**33**	1.5 in.	**70.0**	—	—
		−50	−58	47	**29.7**	66 500	**34**	1.5 in.	**68.5**	20.5	**74**
		−100	−148	49	**31.2**	70 000	**38**	1.5 in.	**61.5**	21.6	**78**
		−150	−238	51.5	**32.8**	73 500	**36**	1.5 in.	**65.0**	20.7	**75**
		−196	−321	58.5	**37.3**	83 500	**46**	1.5 in.	**61.5**	20.5	**74**

(a) Charpy test, V notch, cross-sectional area at the notch 0.5 cm².

(b) Results of Navy tear tests on this alloy are also included in ref. (1).

(c) Temper not stated in original document, but probably annealed.

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.

— Data not available: Proof stress 0.2%, and 0.1% offset,
Yield strength, 0.5% extension under load.

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	%	gauge length
Strip [2] 2 mm 0.08 in.	Annealed	20	68	35.5	**22.4**	50 000	—	**6.1**	**44**	2 in.
		100	212	32.5	**20.7**	46 500	—	**5.7**	**39**	2 in.
		200	392	30	**19.0**	42 500	—	**5.3**	**35**	2 in.
		300	572	27.5	**17.5**	39 000	—	**4.8**	**30**	2 in.
		400	752	26.5	**16.7**	37 500	—	**4.6**	**27**	2 in.
		500	932	22	**14.0**	31 500	—	**4.3**	**23**	2 in.
Condenser [3] Tube	Annealed	20	68	**36**	23	51 000	**13.5**	—	**38**	$11.3\sqrt{S_o}$
		100	212	**33**	21	47 000	**12.5**	—	**35**	$11.3\sqrt{S_o}$
		200	392	**31**	19.5	44 000	**11.0**	—	**33**	$11.3\sqrt{S_o}$
		300	572	**30**	19	42 500	**10**	—	**30**	$11.3\sqrt{S_o}$
		400	752	**28**	18	40 000	**9.5**	—	**25**	$11.3\sqrt{S_o}$
		500	932	**20**	12.5	28 500	**9**	—	**27**	$11.3\sqrt{S_o}$
		600	1 112	**13**	8.5	18 500	**7**	—	**35**	$11.3\sqrt{S_o}$

N.B.: — Original values are printed in **bold type**; other values are converted.
— Data not available: Yield strength, 0.5% extension under load.

5.3.2 Creep Properties

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

Data on an alloy with similar composition to Cu Ni20 Mu1 Fe, but with 1.0 zinc content, are available in the following paper:

■ Weaver, V.P. and Imperati, J. Copper and Copper Alloys for Pressure Vessels. Welding Research Council, New York. Bull. No. 73 (1961), Nov.

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
[4] [5] [a] Rod 25 mm diam. 1 in. diam.	Annealed	100	33.5	12.5 [c]	21	8 [c]	**47 300**	**17 800** [c]
	Cold Worked and Stress Relieved [b]	100	44	18 [c]	28	11.5 [c]	**62 400**	**25 500** [c]
Rod [6] 25 mm diam. 1 in. diam.	Annealed	100	36.5	15.5 [d]	**23.2**	**9.7** [d]	52 000	21 500 [d]
	Cold Worked 25%	100	51	19 [d]	**32.3**	**12.2** [d]	72 500	27 500 [d]
	Cold Worked 50%	100	57	23.5 [d]	**36.2**	**14.9** [d]	81 000	33 500 [d]
Tube [7]	Soft	100	**34**	**12**	21.5	7.5	48 500	17 000
	Cold Worked and Stress Relieved	100	**43**	**15** [e]	27.5	9.5 [e]	61 000	21 500 [e]

(a) Alloy containing 0.51% Fe; 0.29% Mn.
(b) Stress relieved for 3h at 204°C *(400°F)*.
(c) Rotating-cantilever test.
(d) Rotating-beam test.
(e) Bending-fatigue test.
N.B.: Original values are printed in **bold type**; other values are converted.

REFERENCES

MECHANICAL PROPERTIES (Section 5)

(1) Lismer, R.E. The Properties of Some Metals and Alloys at Low Temperatures. J. Inst. Metals. Vol. 89 (1960–61), pp. 145–161.
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(3) Nothing, F.W. Kupfer-Nickel-Legierungen mit weniger als 50% Nickel. Nickel-Informationsbüro GmbH, Dusseldorf. Publication No. 7 (1964). 76 pp.
(4) McAdam, Jr., D.J. Fatigue and Corrosion – Fatigue of Spring Material. Trans. ASME, Appl. Mechanics, Vol. 51 (1929), pp. 45–58.
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(6) Bidmead, G. F. Wöhler Fatigue Test Data on "Everdur A" and "Kunifer 20". Imperial Metal Industries, Ltd., England. Research Dept. Rept. MD/RR/35/53 (1953).
(7) Private communication from Kabelmetall, Osnäbruck, Germany.

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Cu Ni25

Common names: 75/25 Copper-Nickel
75/25 Cupro-nickel
Cupro-nickel, 75/25

A copper-nickel alloy with an alpha phase structure. The alloy has good corrosion, wear and tarnish resistance, together with excellent cold forming and coining characteristics. The most commonly used wrought forms are sheet and strip.

COMPOSITION (weight %)

Ni	24.0–26.0
Mn	0– 0.5
Cu	rem.

1 SOME TYPICAL USES

Coinage
Coins, medals and medallions.

Electrical
Resistance wires.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.95 g/cm³	0.325 lb/in³
2.2	Melting range [a]	1 150–1 220 °C	2 100–2 230 °F
2.3	Coefficient of thermal expansion (linear) at:		
	−183 to 10 °C *−297 to 50 °F*	0.000 013 per °C	0.000 007 per °F
	20 „ 300 °C *68 „ 572 °F*	0.000 016 „ „	0.000 009 „ „
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*	0.08 cal cm/cm² s °C	19 Btu ft/ft² h °F
2.6	Electrical conductivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	3 m/ohm mm²	5% IACS
	200 °C *392 °F* („ „ „ „)	3 „	5 „ „
2.7	Electrical resistivity (volume) at:		
	20 °C *68 °F* (annealed or cold worked)	0.34 ohm mm²/m 34 microhm cm	207 ohms (circ mil/ft) 14 microhm in
	200 °C *392 °F* („ „ „ „)	0.34 ohm mm²/m 34 microhm cm	207 ohms (circ mil/ft) 14 microhm in
2.8	Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 2 per °C (5% IACS)	0.000 1 per °F (5% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	14 900 kg/mm²	21 200 000 lb/in²
	cold worked [b]	14 100 kg/mm²	20 100 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*		
	annealed	5 500 kg/mm²	7 800 000 lb/in²
	cold worked [b]	5 200 kg/mm²	7 400 000 lb/in²

[a] The melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted. The values are based on: Hansen, M. and Anderko, K. Constitution of Binary Alloys. 2nd ed. (1958) McGraw-Hill, London, New York; more recent work (Feest, E.A. and Doherty, R.D. The Cu-Ni Equilibrium Phase Diagram. J. Inst. Metals, Vol. 99 (1971), pp. 102–103) indicates that the solidus temperature may be slightly higher.

[b] Approximately 50% cold work.

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 6); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

Prepared by
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Orchard House, Mutton Lane, Potters Bar, Herts.

DATA SHEET No. K 5
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1972 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	1 300–1 375 °C	2 370–2 505 °F
3.2	Annealing temperature range	650– 825 °C	1 200–1 515 °F
	Stress relieving temperature range	300– 400 °C	570– 750 °F
3.3	Hot working temperature range	900–1 000 °C	1 650–1 830 °F
3.4	Hot formability	Good	
3.5	Cold formability	Good	
3.6	Cold reduction between anneals	70% 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. 3.9	
	Soldering	Excellent	
	Brazing	Excellent	
	Oxy-acetylene welding	Fair	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Excellent	
	Coated metal-arc welding	Good	
	Resistance welding: spot and seam	Good	
	butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[(a)]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	Cu Ni25	—	266.31	—	266.31	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Ni25	NCh 250. of 68	—	—	—	—	—	—
France	—	Cu Ni25	—	—	—	—	—	—	—
Germany	DIN	Cu Ni25	17 664	17 670	—	—	—	—	—
India	IS	Cu Ni31 Mn1 Fe	—	—	—	—	1545	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN[(b)]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Ni25	—	10 803	—	—	—	—	—
United Kingdom	BS	CN105	—	374 2870	—	—	—	—	—
United States	ASTM	—	—	—	—	—	—	—	—
International Organization for Standardization	ISO	Cu Ni25	R 429	—	—	—	—	—	—

(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	no data
Creep properties	" "

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		
Sheet Strip	Annealed	37	16	42	$5.65\sqrt{S_o}$	85	89	28	0.5–5 mm thick

(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 range given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.

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	Tensile Strength		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [a]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Sheet Strip	Annealed	36	23	14	9	40	50 mm (2 in.)	90	26	17	—
	Typical Cold Worked Tempers	45	29	39	25	15	50 mm (2 in.)	145	29	19	0.2–3 mm (0.008–0.125 in.) thick
		59	38	53	34	3	50 mm (2 in.)	170	32	21	,,
Wire	Annealed [b]	34	22	—	—	35	100 mm (4 in.)	—	25	16	2.5–5 mm (0.1–0.2 in.) diam.
		37	24	—	—	30	100 mm (4 in.)	—	28	18	0.5–2 mm (0.02–0.08 in.) diam.
		40	26	—	—	25	100 mm (4 in.)	—	31	20	0.2–0.4 mm (0.008–0.016 in.) diam.

(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 manufacturers.

(b) The principal application for wire of this composition is as a material of controlled electrical resistance; it is usually supplied in the annealed condition.

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)	Annealed	46 000	18 000	35	2 in.	—	35	—	35 000	0.040 in. thick
	Cold Worked Hard	65 000	55 000	10	2 in.	—	75	—	42 000	0.040 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 manufacturers.

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

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

5.3.2 Creep Properties

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Wire [1] 2 mm diam. 0.072 in. diam.	Cold Worked 88%	100	65.5	27.5 [a]	41.5	17.5 [a]	**93 000**	**39 000** [a]

[a] Rotating-wire-arc test

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

— Further data can be obtained from the following paper:

■ Bierlein, J.C. and Dodd, R.A. Fatigue Properties of Some FCC Copper-Based Solid Solutions. Trans. Met. Soc. AIME, Vol. 242 (1968), pp. 1431–1436.

Printed in England by the Martin Cadbury Printing Group

REFERENCE

MECHANICAL PROPERTIES (Section 5)

(1) Burghoff, H. L. and Blank, A. I. Fatigue Tests on Some Copper Alloys in Wire Form. Proc. ASTM, Vol. 43 (1943), pp. 774–784.

Cu Ni30 Mn1 Fe

Common names: 70/30 Copper-Nickel-Iron
70/30 Cupro-nickel
Cupro-nickel, 70/30

A copper-nickel alloy with an alpha phase structure. Small amounts of iron and manganese are added to improve corrosion resistance in high-velocity (from 1.5 to about 4.5 m/s) waters, including polluted seawater. The alloy is almost insensitive to stress corrosion. It retains its strength well at moderately elevated temperatures, has good cold- and hot-working properties and is readily weldable. The most commonly used wrought forms are plate, sheet, rod and tube.

COMPOSITION (weight %)

Ni	29.0–32.0
Mn	0.5– 1.5
Fe	0.4– 1.0
Cu	rem.

1 SOME TYPICAL USES

Chemical & Marine*
Tubes and tubeplates for heavy-duty condensers, feedwater heaters and evaporators, including desalination plant.

Mechanical
Fasteners.

*Several varieties of this alloy, with higher iron and manganese contents, are used in tube form under severe conditions of impingement and erosion.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.95 g/cm³	0.325 lb/in³
2.2	Melting range [(a)]	1 170–1 240 °C	2 140–2 265 °F
2.3	Coefficient of thermal expansion (linear) at:		
	−183 to 10 °C *−297 to 50 °F*	0.000 012 per °C	0.000 007 per °F
	20 to 300 °C *68 to 572 °F*	0.000 016 „ „	0.000 009 „ „
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*	0.07 cal cm/cm² s °C	17 Btu ft/ft² h °F
2.6	Electrical conductivity (volume) at:		
	−269 °C *−452 °F* (annealed)	3 m/ohm mm²	5% IACS
	20 °C *68 °F* (annealed or cold worked)	3 „	5 „ „
	200 °C *392 °F* („ „ „ „)	3 „	5 „ „
2.7	Electrical resistivity (volume) at:		
	−269 °C *−452 °F* (annealed)	0.34 ohm mm²/m 34 microhm cm	207 ohms (circ mil/ft) 14 microhm in
	20 °C *68 °F* (annealed or cold worked)	0.34 ohm mm²/m 34 microhm cm	207 ohms (circ mil/ft) 14 microhm in
	200 °C *392 °F* („ „ „ „)	0.34 ohm mm²/m 34 microhm cm	207 ohms (circ mil/ft) 14 microhm in
2.8	Temperature coefficient of electrical resistance at:		
	20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 05 per °C (5% IACS)	0.000 03 per °F (5% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	15 500 kg/mm²	22 000 000 lb/in²
	cold worked [(b)]	14 600 kg/mm²	20 800 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20 °C *68 °F*		
	annealed	5 750 kg/mm²	8 200 000 lb/in²
	cold worked [(b)]	5 400 kg/mm²	7 700 000 lb/in²

(a) The melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted. The values are based on: Hansen, M. and Anderko, K. Constitution of Binary Alloys. 2nd ed. (1958) McGraw-Hill, London, New York; more recent work (Feest, E.A. and Doherty, R.D. The Cu-Ni Equilibrium Phase Diagram. J. Inst. Metals, Vol. 99 (1971), pp. 102–103) indicates that the solidus temperature may be slightly higher.

(b) Approximately 50% cold work.

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 10); INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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DATA SHEET No. K 6

1972 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	1 325–1 400 °C	2 415–2 550 °F
3.2	Annealing temperature range	650– 850 °C	1 200–1 560 °F
	Stress relieving temperature range	300– 400 °C	570– 750 °F
3.3	Hot working temperature range	925–1 025 °C	1 695–1 875 °F
3.4	Hot formability	Good	
3.5	Cold formability	Good	
3.6	Cold reduction between anneals	50% 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. 3.9	
	Soldering	Excellent	
	Brazing	Excellent	
	Oxy-acetylene welding	Good	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Excellent	
	Coated metal-arc welding	Good	
	Resistance welding: spot and seam	Good	
	butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	—	—	—	—	—	—	—	—
Canada	CSA	HC.NF301	—	HC.4.6	—	—	HC.7.3 HC.7.4	—	—
Chile	NCh (INDITECNOR)	Cu Ni30 Mn1 Fe	NCh 250. of 68	—	—	—	—	—	—
France	NF	Cu Ni30 Mn1 Fe	—	—	—	—	A51-102	—	—
Germany	DIN	Cu Ni30 Fe	17 664	17 670	17 672	17 672	1785 17 671	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	Pt-Cu Ni30 Mn 1Fe	—	—	—	—	6785	—	—
Japan	JIS	CNP 3 CNTF 3 CNTF 3 S	—	H 3251	—	—	H 3635	—	—
Netherlands	N or NEN[b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Ni30 Fe Mn	—	10 803	—	—	10 803 11 557	—	—
United Kingdom	BS	CN107	—	1541 2870[d] 2875	—	—	378 1464 2579 (Part1) 2871	—	—
United States[c]	ASTM	No. 715	—	B 122 B 151 B 171 B 402	B 151	—	B 111 B 359 B 395 B 466 B 467 B 543	—	—
International Organization for Standardization	ISO	Cu Ni30 Mn1 Fe	R 429	—	—	—	—	—	—

(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.

(d) In metricated revision (1968); not in imperial units edition (1962).

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 5.3.2.1/2/3

5.4 Fatigue properties

Fatigue strength at room temperature	see table 5.4.1

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE (*)

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 (a)
				%	gauge length	Brinell	Vickers		
Plate Sheet Strip	Annealed	36	15	42	$5.65\sqrt{S_o}$	85	89	27	1–20 mm thick
	Hot Rolled	38	16	38	$5.65\sqrt{S_o}$	90	95	28	10–50 mm thick
	Typical Cold Worked Temper	50	43	16	$5.65\sqrt{S_o}$	140	145	35	1–5 mm thick
Rod(c)	Annealed	40	17	40	$5.65\sqrt{S_o}$	95	100	30	6–40 mm diam. or equivalent area
	Typical Cold Worked Temper	50	42	18	$5.65\sqrt{S_o}$	130	135	35	6–25 mm diam. or equivalent area
Tube (b)	Annealed (grain size 0.025 mm)	42	17	42	$5.65\sqrt{S_o}$	90	95	31	10–30 mm O.D. 1–3 mm wall
	Typical Cold Drawn Temper	52	45	18	$5.65\sqrt{S_o}$	145	150	36	10–30 mm O.D. 1–2 mm wall

(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 manufacturers.
(b) Tubes for condensers and heat exchangers are generally supplied in the annealed temper whose representative mechanical properties are shown.
(c) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.

5.1.2 Typical Tensile Properties and Hardness Values—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/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Plate	Annealed	39	25	15	10	42	$5.65\sqrt{S_o}$	95	29	19	—
	Hot Rolled As-Manufactured	40	26	17	11	40	$5.65\sqrt{S_o}$	105	31	20	12–50 mm (0.5–2 in.) thick
Sheet Strip	Annealed	39	25	15	10	45	50 mm (2 in.)	95	29	19	—
	Hot Rolled As-Manufactured	43	28	20	13	40	50 mm (2 in.)	120	32	21	3–10 mm (0.125–0.375 in.) thick
Tube (c)	Annealed (grain size 0.025 mm)	**42**	**27**	**17**	**11**	**42**	$5.65\sqrt{S_o}$	**105**	**31**	**20**	—
	Cold Drawn or Temper Annealed As-Drawn (hard)	51	33	37	24	25	$5.65\sqrt{S_o}$	150	32	21	50–255 mm (2–10 in.) O.D. 2–5 mm (0.08–0.2 in.) wall
	Temper Annealed	**43**	**28**	**20**	**13**	**40**	$5.65\sqrt{S_o}$	**120**	**32**	**21**	
	Temper Annealed	**49**	**32**	**34**	**22**	**30**	$5.65\sqrt{S_o}$	**140**	**37**	**24**	6–50 mm (0.25–2 in.) O.D.
	As-Drawn	**56**	**36**	**46**	**30**	**15**	$5.65\sqrt{S_o}$	**170**	**39**	**25**	0.5–2 mm (0.02–0.08 in.) wall
	As-Drawn (hard)	**66**	**43**	**57**	**37**	**7**	$5.65\sqrt{S_o}$	**190**	**37**	**24**	

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

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 %	Elongation gauge length	Rockwell Hardness F	Rockwell Hardness B	Rockwell Hardness 30 T	Shear Strength psi	Typical Size Related to Properties Shown [a]
Flat Products (Plate, Sheet, Strip)	As Hot Rolled	55 000	20 000	45	2 in.	—	35	—	41 000	1.0 in. thick
		50 000	20 000	35	2 in.	—	—	—	37 000	2.0 in. thick
	Annealed	55 000	18 000	36	2 in.	—	40	—	41 000	0.040 in. thick
		54 000	22 000	40	2 in.	—	35	—	40 000	1.0 in. thick
	Cold Worked									
	Half Hard	73 000	67 000	4	2 in.	—	80	—	51 000	0.040 in. thick
	Hard	81 500	76 000	3	2 in.	—	85	—	52 000	"
	Extra Hard	86 000	79 000	3	2 in.	—	87	—	52 000	"
	Spring	89 000	80 000	3	2 in.	—	88	—	48 000	"
Rod [b]	Annealed	55 000	20 000	45	2 in.	—	37	—	41 000	1.0 in. diam.
	Cold Worked									
	Half Hard	75 000	70 000	15	2 in.	—	80	—	52 000	1.0 in. diam.
	Hard	85 000	78 000	15	2 in.	—	81	—	55 000	"
Tube [c]	Annealed									
	(grain size 0.025 mm)	60 000	25 000	45	2 in.	80	45	—	45 000	1.0 in. O.D. × 0.065 in. wall
	(grain size 0.025 mm)	54 000	—	45	2 in.	77	36	—	40 000	4.5 in. O.D. × 0.109 in. wall
	Cold Worked									
	Light Drawn	75 000	68 000	15	2 in.	—	80	—	52 000	1.0 in. O.D. × 0.065 in. wall
	Hard Drawn	84 000	—	4	2 in.	—	—	—	55 000	0.75 in. O.D. × 0.049 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 or complexity of the product.
(c) Tubes for condensers and heat exchangers are generally supplied in annealed or drawn and stress-relieved tempers.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature °C	Testing Temperature °F	Tensile Strength kg/mm²	Tensile Strength ton/in²	Tensile Strength psi	Proof Stress 0.2% offset kg/mm²	Proof Stress Yield Strength 0.5% ext. under load psi	Elongation %	Elongation gauge length	Reduction of Area %	Impact Strength kg m/cm²	Impact Strength ft lb
Rod [1] **12 mm diam. 0.47 in. diam.**	Cold Worked	20	68	65	41.5	92 500	—	56 900 [a]	12	16 mm	—	—	—
		0	32	65	41.5	92 500	—	61 200 [a]	13	16 mm	—	—	—
		−100	−148	70	44.5	99 500	—	76 800 [a]	17	16 mm	—	—	—
		−196	−321	80	51	114 000	—	99 600 [a]	24	16 mm	—	—	—
		−224	−371	83	52.5	118 000	—	107 000 [a]	22	16 mm	—	—	—
		−247	−413	90	57	128 000	—	114 000 [a]	20	16 mm	—	—	—
		−269	−452	95	60.5	135 000	—	121 000 [a]	18	16 mm	—	—	—
Rod [d] [2] **19 mm diam. 0.75 in. diam.**	Annealed	22	72	40.5	26	57 800	—	18 700	47	$4.52\sqrt{S_o}$	68	19.9 [b]	115 [b]
		−78	−108	48	30.5	68 000	—	22 200	48	$4.52\sqrt{S_o}$	70	19.7 [b]	114 [b]
		−197	−323	63	40	89 800	—	31 600	52	$4.52\sqrt{S_o}$	70	19.7 [b]	114 [b]
		−253	−423	72.5	46	103 100	—	38 100	51	$4.52\sqrt{S_o}$	66	19.7 [b]	114 [b]
		−269	−452	73.5	46.5	104 600	—	40 100	48	$4.52\sqrt{S_o}$	65	—	—
Rod [3] [4] **22 mm diam. 0.875 in. diam.**	Annealed	24	75	38	24.5	54 400	15.1 [c]	—	52	2 in.	80.5	—	—
		−30	−22	41	26	58 600	15.5 [c]	—	49.5	2 in.	79	—	—
		−78	−108	45	28.5	64 300	16.9 [c]	—	56	2 in.	77.5	—	—
		−140	−220	50.5	32	71 900	19.3 [c]	—	57.5	2 in.	77.5	—	—
		−196	−320	59	37.5	83 700	21.7 [c]	—	61.5	2 in.	77.5	—	—

(a) This value was originally reported in kg/mm²; in this table it is given in psi to 3 significant figures.
(b) Charpy test; 10 × 10 × 55 mm specimen; 45° V notch 2 mm deep; cross-sectional area at the notch 0.8 cm².
(c) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.
(d) Tensile specimen 6.35 mm (0.25 in.) diam.
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.
— Data not available: Proof stress, 0.1% offset.

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 [5]	Hot Rolled	20	68	37.5	**23.9**	53 500	**12.4** [a]	**7.4**	—	**50**	2 in.
		66	150	35.5	**22.7**	51 000	**12.4** [a]	**7.5**	—	**49**	2 in.
		121	250	33.5	**21.4**	48 000	**11.5** [a]	**6.7**	—	**48**	2 in.
		177	350	32.5	**20.5**	46 000	**10.4** [a]	**6.3**	—	**48**	2 in.
		232	450	31	**19.7**	44 000	**10.6** [a]	**6.2**	—	**46**	2 in.
		288	550	30	**19.0**	42 500	**10.2** [a]	**6.0**	—	**55**	2 in.
		343	650	29	**18.5**	41 500	**9.29** [a]	**5.2**	—	**54**	2 in.
		371	700	29	**18.3**	41 000	**9.45** [a]	**5.6**	—	**63**	2 in.
Plate [6]	Hot Worked	20	68	**38**	24	54 000	**13.5**	—	—	—	—
		100	212	**38**	24	54 000	**13.5**	—	—	—	—
		200	392	**35.5**	22.5	50 500	**12**	—	—	—	—
		300	572	**33**	21	47 000	**11.5**	—	—	—	—
		400	752	**30**	19	42 500	**10**	—	—	—	—
Strip [7] 2 mm 0.08 in.	Annealed	20	68	40.5	**25.8**	58 000	—	**7.9**	—	**44**	2 in.
		100	212	37.5	**23.8**	53 500	—	**7.5**	—	**40**	2 in.
		200	392	34.5	**21.9**	49 000	—	**6.6**	—	**37**	2 in.
		300	572	32.5	**20.5**	46 000	—	**6.1**	—	**34**	2 in.
		400	752	30.5	**19.4**	43 500	—	**5.8**	—	**31**	2 in.
		500	932	26	**16.4**	36 500	—	**5.4**	—	**20**	2 in.
Rod [8] 14 mm diam. 0.55 in. diam.	Annealed	20	68	**44**	28	62 500	**16**	—	—	**38**	$11.3\sqrt{S_o}$
		100	212	**41**	26	58 500	**11**	—	—	**36**	$11.3\sqrt{S_o}$
		200	392	**38**	24	54 000	**11**	—	—	**33**	$11.3\sqrt{S_o}$
		300	572	**35**	22	50 000	**11**	—	—	**32**	$11.3\sqrt{S_o}$
		390	734	**33.5**	21.5	47 500	**11**	—	—	**29**	$11.3\sqrt{S_o}$
		500	932	**28**	18	40 000	**11**	—	—	**22**	$11.3\sqrt{S_o}$
		600	1 112	**19**	12	27 000	**9**	—	—	**16**	$11.3\sqrt{S_o}$
		700	1 292	**11**	7	15 500	**8**	—	—	**6**	$11.3\sqrt{S_o}$
		790	1 454	**6.5**	4	9 000	**5.5**	—	—	**3**	$11.3\sqrt{S_o}$
Rod [3] 22 mm diam. 0.875 in. diam.	Cold Worked 25%	24	75	52.5	33.5	**74 500**	**50.9** [b]	—	—	**19**	2 in.
		149	300	48	30.5	**68 600**	**45.7** [b]	—	—	**17**	2 in.
		371	700	40.5	25.5	**57 600**	**39.0** [b]	—	—	**13**	2 in.
		482	900	30.5	19.5	**43 600**	**27.1** [b]	—	—	**11.5**	2 in.
		649	1 200	12	7.5	**16 900**	**6.82** [b]	—	—	**26**	2 in.
		816	1 500	5	3	**7 200**	**2.88** [b]	—	—	**16**	2 in.
		927	1 700	3	2	**4 110**	**1.16** [b]	—	—	**22**	2 in.
	Cold Worked 70%	24	75	67	42.5	**95 200**	**65.0** [b]	—	—	**16**	2 in.
		149	300	61.5	39	**87 500**	**56.8** [b]	—	—	**16**	2 in.
		371	700	51.5	33	**73 600**	**50.0** [b]	—	—	**11**	2 in.
		482	900	40	25.5	**56 900**	**37.0** [b]	—	—	**14**	2 in.
		649	1 200	12	7.5	**16 900**	**6.89** [b]	—	—	**29**	2 in.
		816	1 500	5	3	**6 990**	**2.60** [b]	—	—	**19**	2 in.
		927	1 700	2.5	1.5	**3 680**	**1.12** [b]	—	—	**22.5**	2 in.
Rod [9] [c] 25 mm diam. 1.0 in. diam.	Annealed	28	82	45	28.5	**64 100**	—	—	**32 000**	**34.5**	2 in.
		260	500	37.5	24	**53 300**	—	—	**26 300**	**31.5**	2 in.
		343	650	34.5	22	**49 200**	—	—	**25 000**	**27.0**	2 in.
		427	800	33	21	**46 700**	—	—	**22 500**	**25.6**	2 in.
		510	950	26	16.5	**37 250**	—	—	**21 500**	**16.2**	2 in.
		593	1 100	18.5	12	**26 550**	—	—	**20 000**	**12.3**	2 in.
Rod [10] 27 mm diam. 1.1 in. diam.	Annealed (grain size 0.025–0.035 mm)	20	68	41.5	**26.5**	59 500	**13.7** [a]	**8.6**	—	**56**	$4\sqrt{S_o}$
		250	482	35	**22.2**	49 500	**10.9** [a]	**6.8**	—	**45**	$4\sqrt{S_o}$
		350	662	34	**21.6**	48 500	**10.4** [a]	**6.5**	—	**39**	$4\sqrt{S_o}$
		450	842	31.5	**20.0**	45 000	**10.7** [a]	**6.6**	—	**42**	$4\sqrt{S_o}$
		550	1 022	26.5	**16.7**	37 500	**11.8** [a]	**6.8**	—	**33**	$4\sqrt{S_o}$
Condenser [11] Tube	Annealed	20	68	**43**	27.5	61 000	**16**	—	—	**38**	$11.3\sqrt{S_o}$
		100	212	**39**	25	55 500	**14.5**	—	—	**35**	$11.3\sqrt{S_o}$
		200	392	**36**	23	51 000	**13.5**	—	—	**36**	$11.3\sqrt{S_o}$
		300	572	**34.5**	22	49 000	**12.0**	—	—	**28**	$11.3\sqrt{S_o}$
		400	752	**33**	21	47 000	**11.0**	—	—	**30**	$11.3\sqrt{S_o}$
		500	932	**24**	15	34 000	**10**	—	—	**25**	$11.3\sqrt{S_o}$
		600	1 112	**17**	11	24 000	**8**	—	—	**25**	$11.3\sqrt{S_o}$

(a) This value was originally reported in ton/in²; in this table it is given in kg/mm² to 3 significant figures.
(b) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.
(c) Alloy containing 0.40% Mn.

N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following papers:

- Simmons, W.F., Sirois, B.J.; Williams, D.N. & Jaffee, R.I. Properties of 70–30 Copper-Nickel Alloy at Temperatures Ranging up to 1 050°F. Proc. ASTM. Vol. 59 (1959), pp. 1035–1051. (data for cold drawn and stress relieved rod; alloy containing 0.35% Mn).
- Reference [3].

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 %	Minimum Creep Rate % per 1 000 h
Rod [(12) (b)] 3 mm diam. 0.125 in. diam.	Annealed (grain size 0.020 mm)	149	300	3.2	2.0	4 550	2 600	0.033	0.010	<0.000 1
				10.6	6.7	15 100	2 600	0.109	0.022	<0.000 1
				14.0	8.9	19 900	4 400	0.884	0.022	0.000 4
				20.0	12.7	28 450	5 200	3.230	0.025	0.001 0
				23.0	14.6	32 700	3 700	4.532	0.030	0.000 6
		204	400	3.5	2.2	4 980	2 880	0.026	0.004	<0.000 1
				11.2	7.1	15 950	4 100	0.167	0.006	<0.000 2
		260	500	3.5	2.2	4 980	2 780	0.031	0.001	<0.000 1
				7.2	4.6	10 250	5 000	0.075	0.012	<0.000 5
				11.0	7.0	15 650	5 000	0.310	0.015	0.000 9
				14.9	9.4	21 150	5 000	1.498	0.030	0.003 7
				18.6	11.8	26 500	5 100	2.775	0.028	0.005 3
				21.5	13.7	30 650	5 100	4.671	0.048	0.008 4
	Cold Worked 84%	149	300	14.0	8.9	19 900	3 600	0.108	0.018	<0.000 1
				24.5	15.6	34 900	3 700	0.174	0.016	<0.000 1
				34.9	22.1	49 600	5 150	0.259	0.024	0.000 5
				42.1	26.8	59 950	4 650	0.345	0.036	0.000 9
		260	500	3.5	2.2	4 960	2 760	0.036	0.012	0.000 7
				7.1	4.5	10 100	4 980	0.074	0.024	0.001 1
				14.6	9.3	20 800	4 800	0.124	0.023	0.001 6
				28.7	18.2	40 800	4 800	0.243	0.049	0.002 4
				34.6	21.9	49 150	5 100	0.322	0.066	0.003 0
				42.1	26.7	59 850	5 750	0.648	0.267	0.012
Rod [(13)] 19 mm diam. 0.75 in. diam.	Cold Worked and Stress relieved	316	600	28.1	17.8	40 000	500	0.255 [(c)]	—	0.015 [(d)]
				35.1	22.3	50 000	500	0.426	—	0.02 [(d)]
				38.6	24.5	55 000	500	0.940	—	0.08 [(d)]
		399	750	12.6	8.0	18 000	2 500	0.219	—	0.015
				17.6	11.1	25 000	2 500	0.319 [(c)]	—	0.032
				21.1	13.4	30 000	1 500	0.359 [(c)]	—	0.055
				24.6	15.6	35 000	1 000	0.490 [(c)]	—	0.17
				28.1	17.8	40 000	1 000	0.818	—	0.40
				31.6	20.1	45 000	1 500	3.25	—	1.0
		454	850	4.9	3.1	7 000	2 500	0.142	—	0.019
				9.8	6.2	14 000	1 500	0.339	—	0.072
				17.6	11.1	25 000	1 000	0.993	—	0.61
				21.1	13.4	30 000	1 500	9.80	—	2.2
		510	950	1.4	0.89	2 000	1 500	0.096	—	0.032
				4.2	2.7	6 000	1 000	0.292	—	0.18
				12.6	8.0	18 000	1 500	11.2	—	3.4
		566	1 050	1.0	0.67	1 500	500	0.185	—	0.3
				7.3	4.4	10 000	500	7.20	—	7
Rod [(14) (e)]	Annealed	149	300	30	19	42 670	2 370	13.16	13.16	0 [(f)]
				32.3	20.5	46 000	2 182	19.84	19.84	0 [(f)]
				33	21	47 000	2 340	20.42	20.42	0 [(f)]
		482	900	13	8.3	18 670	2 752	49.0	2.3	9.5 [(f)]
Rod [(15) (e)]	Cold Worked 40%	371	700	30	19	42 670	8 490	3	0.27	0.33 [(f)]
		482	900	11.2	7.1	16 000	14 044	46	0.32	0.39 [(f)]
				15	9.5	21 330	4 190	23	0.45	1.5 [(f)]
		649	1 200	1	0.64	1 450	5 002	28.5	0.40	2.65 [(f)]

(a) Total Extension = Initial Extension + Total creep = Initial extension + Intercept + (Minimum Creep Rate × Duration).
(b) Fe content 0.03%.
(c) Extrapolated value.
(d) Lowest creep rate within duration of test.
(e) Creep specimen 0.505 in. diam.
(f) Average second-stage creep rate.

N.B.: — Original values are printed in **bold type;** other values are converted.
— Further data can be obtained from refs. [(14)] and [(15)].

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate											
				0.000 4% per 1 000 h			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	kg/mm²	ton/in²	psi
Rod [b] [12] 3 mm diam. 0.125 in. diam.	Annealed (grain size 0.020 mm)	149	300	—	—	—	16.9	10.7	**24 000**	24.6 [a]	15.6 [a]	**35 000** [a]	—	—	—
		260	500	—	—	—	11.2	7.1	**16 000**	21.1 [a]	13.4 [a]	**30 000** [a]	—	—	—
	Cold Worked 84%	260	500	—	—	—	5.6	3.6	**8 000**	—	—	—	—	—	—
Rod [13] 19 mm diam. 0.75 in. diam.	Cold Worked and Stress relieved	316	600	—	—	—	—	—	—	33.7	21.4	**48 000**	—	—	—
		371	700	—	—	—	—	—	—	18.6	11.8	**26 500**	—	—	—
		399	750	—	—	—	—	—	—	10.5	6.7	**15 000**	—	—	—
		454	850	—	—	—	—	—	—	3.5	2.2	**5 000**	—	—	—
		510	950	—	—	—	—	—	—	0.56	0.36	**800**	—	—	—
Rod [10] 27 mm diam. 1.1 in. diam.	Annealed (grain size 0.025–0.035 mm)	350	662	—	—	—	—	—	—	25.2	**16.0**	35 800	14.2	**9.0**	20 200
		450	842	—	—	—	—	—	—	10.2	**6.5**	14 600	5.7	**3.6**	8 100
		550	1 022	—	—	—	—	—	—	1.6	**1.0**	2 200	0.47 [a]	**0.3** [a]	670 [a]
Rod [16]	Annealed	399	750	6.3	4.0	**9 000**	—	—	—	—	—	—	—	—	—
	Cold Worked [c]	399	750	—	—	—	—	—	—	6.4	4.1	**9 100**	—	—	—

[a] Extrapolated value.
[b] Fe content 0.03%.
[c] Tensile strength of material at 85°F *(29°C)* quoted as 64 700 psi in original document but amount of cold work not defined.

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

5.3.2.3 Stress for Rupture

Form	Temper	Testing Temperature		Stress for Rupture			Time for Rupture h
		°C	°F	kg/mm²	ton/in²	psi	
Rod [13] 19 mm diam. 0.75 in. diam.	Cold Worked and Stress relieved	399	750	31.6	20.1	**45 000**	**2 124.4**
				35.2	22.3	**50 000**	**467.9**
				38.7	24.6	**55 000**	**22.9**
		454	850	21.1	13.4	**30 000**	**1 539.7**
				24.6	15.6	**35 000**	**469.4**
				28.1	17.9	**40 000**	**96.7**
				31.6	20.1	**45 000**	**29.2**
		510	950	12.7	8.0	**18 000**	**1 839.6**
				19.0	12.1	**27 000**	**117.9**
				24.6	15.6	**35 000**	**11.8**
		566	1 050	7.0	4.5	**10 000**	**968.6**
				13.4	8.5	**19 000**	**82.6**
				16.9	10.7	**24 000**	**25.5**
Rod [9] 25 mm diam. 1 in. diam.	Annealed	260	500	36.9	23.4	**52 500**	**>3 000** [a]
				35.2	22.3	**50 000**	**14 322**
		343	650	33.4	21.2	**47 500**	**121.0**
				31.6	20.1	**45 000**	**106.1**
				28.1	17.9	**40 000**	**4 016**
		427	800	24.6	15.6	**35 000**	**7.6**
				22.8	14.5	**32 500**	**12.8**
				21.1	13.4	**30 000**	**48.5**
				17.6	11.2	**25 000**	**167.2**
				15.8	10.0	**22 500**	**3 767**
		510	950	15.8	10.0	**22 500**	**3.3**
				14.8	9.4	**21 000**	**10.1**
				14.1	8.9	**20 000**	**35.8**
				12.7	8.0	**18 000**	**38.3**
				10.5	6.7	**15 000**	**1 048.0**

[a] Test stopped after 3 000 h.

N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following papers:

- Bearham, J.H. and Parker, R.J. Elevated-Temperature Tensile, Stress-Rupture and Creep Data for Six Copper-Base Materials. Metallurgia (Manchr) Vol. 78, (1968), pp. 9–14.
- Blucher, J. T. and Grant, N. J. Recristallization, Tensile and Stress-Rupture Properties of Nickel- Copper Alloys. Proc. ASTM, Vol. 62 (1962), pp. 593–601.
- Parker, R. J. Estimation of Stress-Rupture Properties from Hot Hardness Tests. Metallurgia (Manchr), Vol. 67 (1963), pp. 219–223.

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
Plate [17]	Annealed	100	~41	~14 [a]	~26	~ 9 [a]	**~58 000**	**~20 000** [a]
Rod [18] **14 mm diam. 0.56 in. diam.**	Cold Drawn 33%	100	57.5	24.5 [b]	36.5	15.5 [b]	**81 700**	**34 500** [b]
Rod [19] **20 mm diam. 0.8 in. diam.**	Cold Worked	50	**55**	**20** [a]	35	12.5 [a]	78 500	28 500 [a]
Rod [20] **25 mm diam. 1 in. diam.**	Annealed	[e]	38.5	15.5	24.5	10	**55 000**	**22 000**
	Cold Drawn 50%	[e]	60	22.5	38	14.5	**85 000**	**32 000**
Tube [21] **280 mm I.D., 10 mm wall 11 in. I.D., 0.375 in. wall**	Annealed	100	41	14.5 [c]	**26.1**	**9.2** [c]	58 500	20 500 [c]
Tube [22]	Soft	100	**35**	**15**	22	9.5	50 000	21 500
	Cold Worked and Stress Relieved	100	**45**	**18** [d]	28.5	11.5 [d]	64 000	25 500 [d]

(a) Rotating-cantilever test.
(b) Rotating-beam test.
(c) Direct-stress test.
(d) Bending fatigue test.
(e) Number of cycles not stated in original document.

N.B.: — Original values are printed in **bold type**; other values are converted.
— Further data can be obtained from the following papers:

- Tewes, W.A. and Gross, M.R. Investigation of the Low-Cycle Fatigue Behavior of Non-Ferrous Metals for Heat Exchangers and Salt-Water Piping. U.S. Naval EES Rept. 910 196A (1962).
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Cu Ni44 Mn1

Common names: 55/45 Copper-Nickel "Constantan"

A copper-nickel alloy with an alpha phase structure. The alloy usually contains small amounts of iron and manganese. It is characterised by fairly high electrical resistivity and a very low temperature coefficient of electrical resistance. The material is easily fabricated and readily weldable. The most commonly used wrought forms are strip and wire.

COMPOSITION (weight %)

Ni	43.0–45.0
Mn	0.5– 2.0
Fe	0 – 0.5
Cu	rem.

1 SOME TYPICAL USES

Electrical
Precision instrument and control resistors operating at moderately elevated temperatures; thermocouple wires and compensating leads; components for thermionic valves; heating elements; bimetal thermostats and switches.

2 PHYSICAL PROPERTIES

		Metric Units	English Units
2.1	Density at 20 °C *68 °F*	8.90 g/cm³	0.320 lb/in³
2.2	Melting range [(a)]	1 225–1 300 °C	2 235–2 370 °F
2.3	Coefficient of thermal expansion (linear) at:		
	−183 to 20 °C *−297 to 68 °F*	0.000 012 per °C	0.000 007 per °F
	20 to 300 °C *68 to 572 °F*	0.000 015 „ „	0.000 008 „ „
	20 to 500 °C *68 to 932 °F*	0.000 016 „ „	0.000 009 „ „
	20 to 1 000 °C *68 to 1 832 °F*	0.000 019 „ „	0.000 010 „ „
2.4	Specific heat (thermal capacity) at:		
	20 °C *68 °F*	0.10 cal/g °C	0.10 Btu/lb °F
2.5	Thermal conductivity at:		
	20 °C *68 °F*	0.05 cal cm/cm² s °C	12 Btu ft/ft² h °F
2.6	Electrical conductivity (volume) at:		
	−269 °C *−452 °F* (annealed)	2.0 m/ohm mm²	3.5% IACS
	20 °C *68 °F* (annealed or cold worked)	2.0 „	3.5 „ „
	200 °C *392 °F* („ „ „ „)	2.0 „	3.5 „ „
2.7	Electrical resistivity (volume) at:		
	−269 °C *−452 °F* (annealed)	0.49 ohm mm²/m 49 microhm cm	296 ohms (circ mil/ft) 19 microhm in
	20 °C *68 °F* (annealed or cold worked)	0.49 ohm mm²/m 49 microhm cm	296 ohms (circ mil/ft) 19 microhm in
	200 °C *392 °F* („ „ „ „)	0.49 ohm mm²/m 49 microhm cm	296 ohms (circ mil/ft) 19 microhm in
2.8	Temperature coefficient of electrical resistance at: 20 °C *68 °F* (annealed or cold worked) applicable over range from 0 to 100 °C *32 to 212 °F*	± 0.000 04 per °C (3.5% IACS)	± 0.000 02 per °F (3.5% IACS)
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	16 800 kg/mm²	23 900 000 lb/in²
	cold worked[(b)]	16 000 kg/mm²	22 800 000 lb/in²
2.10	Modulus of rigidity (torsion) at 20°C *68 °F*		
	annealed	6 200 kg/mm²	8 800 000 lb/in²
	cold worked [(b)]	5 900 kg/mm²	8 400 000 lb/in²

(a) The melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted. The values are based on: Hansen, M. and Anderko, K. Constitution of Binary Alloys. 2nd ed. (1958) McGraw-Hill, London, New York; more recent work (Feest, E.A. and Doherty, R.D. The Cu-Ni Equilibrium Phase Diagram. J. Inst.Metals, Vol. 99 (1971), pp. 102–103) indicates that the solidus temperature may be slightly higher.

(b) Approximately 50% cold work.

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 6); 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	1 350–1 425 °C	2 460–2 595 °F
3.2 Annealing temperature range	700– 875 °C	1 290–1 605 °F
Stress relieving temperature range	300– 400 °C	570– 750 °F
3.3 Hot working temperature range	950–1 050 °C	1 740–1 920 °F
3.4 Hot formability	Good	
3.5 Cold formability	Good	
3.6 Cold reduction between anneals	50% 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. 3.9	
Soldering	Excellent	
Brazing	Excellent	
Oxy-acetylene welding	—	
Carbon-arc welding	Not recommended	
Gas-shielded arc welding	Excellent	
Coated metal-arc welding	—	
Resistance welding: spot and seam	Good	
butt	Good	

4 NATIONAL SPECIFICATIONS FOR MANUFACTURED FORMS

and ISO Recommendation

Country	Designation of Standards	Designation of Material in Standards	Specification for Chemical Composition[a]	Plate Sheet Strip	Rod	Wire	Tube	Sections / Shapes	Forgings
Australia	SAA	—	—	—	—	—	—	—	—
Belgium	NBN	Cu Ni44 Fe Mn	—	266.31	—	266.31	—	—	—
Canada	CSA	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Ni44 Fe Mn	NCh 250. of 68	—	—	—	—	—	—
France	—	Cu Ni44 Fe Mn	—	—	—	—	—	—	—
Germany	DIN	Cu Ni44	17 664	17 670	—	17 471 17 672 46 460	—	—	—
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN[b]	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Ni44 Mn	—	10 803	—	10 803	—	—	—
United Kingdom	BS	—	—	—	—	—	—	—	—
United States	ASTM	—	—	—	—	—	—	—	—
International Organization for Standardization	ISO	Cu Ni44 Mn1	R 429	—	—	—	—	—	—

(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 temperatures

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 5.3.2.2

5.4 Fatigue properties

Fatigue strength at room temperature	see table 5.4.1

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE *

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 [a]
				%	gauge length	Brinell	Vickers		
Strip	Annealed	48	20	45	50 mm	95	100	36	0.5–3 mm thick
	Typical Cold Worked Temper	68	55	5	50 mm	165	175	44	0.5–2 mm thick
Wire	Annealed	48	—	32	100 mm	—	—	36	0.5–3 mm diam.
	Typical Cold Drawn Temper	70	—	6	100 mm	—	—	45	0.5–2 mm diam.

(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 manufacturers.

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	Tensile Strength		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown [a]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Strip	Annealed [b]	46	30	19	12	45	50 mm (2 in.)	120	36	23	—
	Typical Cold Worked Temper	65	42	53	34	5	50 mm (2 in.)	180	42	27	0.2–3 mm (0.008–0.125 in.) thick
Wire	Annealed [b]	45	29	—	—	40	100 mm (4 in.)	—	34	22	2.5–5 mm (0.1–0.2 in.) diam.
		48	31	—	—	35	100 mm (4 in.)	—	37	24	0.5–2 mm (0.02–0.08 in.) diam.
		51	33	—	—	30	100 mm (4 in.)	—	39	25	0.2–0.4 mm (0.008–0.016 in.) diam.

(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 manufacturers.

(b) This alloy is usually supplied in the annealed condition, for applications involving its important electrical resistance characteristics.

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 (Strip)	Annealed	65 000	28 000	40	2 in.	—	78	—	49 000	0.040 in. thick
	Cold Worked 37%	95 000	82 000	4	2 in.	—	90	—	62 000	0.040 in. thick
Wire	Annealed	65 000	—	25	20 in.	—	—	—	—	up to 0.039 in. diam.
		65 000	—	35	4 in.	—	—	—	—	over 0.039 in. diam.
	Cold Worked	78 000	—	6	8 in.	—	—	—	—	0.040–0.118 in. diam.
		93 000	—	4	8 in.	—	—	—	—	0.021–0.039 in. diam.
		115 000	—	3	8 in.	—	—	—	—	0.004–0.02 in. diam.

(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.

(*) 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.

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.1% offset ton/in²	Elongation		Reduction of Area %	Impact [b] Strength	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Rod [1] 25 mm diam. 1 in. diam.	Annealed [a]	20	68	42	**26.8**	60 000	**8.74**	**40.2**	2 in.	**77.0**	13.9	**80.5**
		− 10	14	46.5	**29.5**	66 000	**8.21**	**46.9**	2 in.	**78.0**	—	—
		− 40	− 40	47.5	**30.2**	67 500	**9.38**	**42.6**	2 in.	**77.5**	14.7	**85.0**
		− 80	−112	51	**32.25**	72 000	**9.86**	**48.4**	2 in.	**75.0**	14.0	**81.0**
		−120	−184	54	**34.4**	77 000	**10.74**	**48.0**	2 in.	**74.0**	14.3	**83.0**
		−180	−292	63	**40.0**	89 500	**11.73**	**57.4**	2 in.	**76.0**	14.9	**86.0**
	Annealed [c]	20	68	43	**27.2**	61 000	**9.35**	**49.0**	2 in.	**77.0**	13.9	**80.5**
		−180	−292	62	**39.4**	88 500	**24.0** [d]	**60.0**	2 in.	**74.0**	14.9	**86.0**

(a) Tensile specimen 6.35 mm (0.25 in.) diam.

(b) Izod specimen; cross-sectional area at the notch 0.8 cm².

(c) Tensile specimen 12.8 mm (0.505 in.) diam.

(d) 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.

— Data not available: Proof stress, 0.2% offset,
Yield strength, 0.5% extension under load.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

Form	Temper	Testing Temperature		Tensile Strength			Elongation	
		°C	°F	kg/mm²	ton/in²	psi	%	gauge length
Wire [2] 1 mm diam. 0.04 in. diam.	Annealed	20	68	**50**	31.5	71 000	**30**	100 mm
		400	752	**41**	26	58 500	**19**	100 mm
Wire [3] 1 mm diam. 0.04 in. diam.	Cold Drawn [a]	20	68	**74**	47	105 500	**1**	100 mm
		100	212	**70**	44.5	99 500	**1**	100 mm
		200	392	**65**	41.5	92 500	**1**	100 mm
		300	572	**59**	37.5	84 000	**1**	100 mm
		400	752	**53**	33.5	75 500	**1**	100 mm
		500	932	**43**	27.5	61 000	**1**	100 mm
		600	1 112	**33**	21	47 000	**3**	100 mm
		700	1 292	**12.5**	8	18 000	**6**	100 mm
		800	1 472	**8.5**	5.5	12 000	**8**	100 mm

(a) 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.

— Data not available: Proof stress, 0.1% and 0.2% offset,
Yield strength, 0.5% extension under load.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

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

5.3.2.2 Stress for Rupture

Form	Temper	Testing Temperature		Stress			Time for Rupture h
		°C	°F	kg/mm²	ton/in²	psi	
— [4]	Annealed	452	845	24.6	15.6	**35 000**	**498**
				28.1	17.9	**40 000**	**67.6**
				31.6	20.1	**45 000**	**9.3**
				35.2	22.3	**50 000**	**1.06**

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles $\times 10^6$	Metric Units kg/mm²		English Units ton/in²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength
Rod [5] 25 mm diam. 1 in. diam.	Hot Rolled	80	49.5	24.5 [a]	31.5	15.5 [a]	**70 500**	**34 500** [a]
Rod [6]	Annealed	80	49	19.5 [a]	31	12.5 [a]	**69 500**	**28 000** [a]
	Cold Worked and Stress Relieved [b]	100	68	29 [a]	43	18.5 [a]	**96 500**	**41 000** [a]
	Cold Worked	40	73	30 [a]	46	19 [a]	**103 500**	**43 000** [a]
Wire [2] 3 mm diam. 0.12 in. diam.	Annealed	10	**50**	**21** [c]	31.5	13.5 [c]	71 000	30 000 [c]
— [d] [7]	Annealed	[g]	**44**	**17.5** [c]	28	11 [c]	62 500	25 000 [c]
	Cold Worked [f]	[g]	**54**	**22** [c]	34.5	14 [c]	77 000	31 500 [c]
— [d] [8]	— [e]	20	**41.4**	**17**	26.5	11	59 000	24 000

(a) Rotating cantilever test.

(b) Stress relieved for 3h at 399°C *(750°F)*.

(c) Bending-fatigue test.

(d) Form not stated in original document.

(e) Temper not stated in original document, but probably annealed.

(f) Quoted as "half hard" in original document, but amount of cold work not defined.

(g) Number of cycles not stated in original document.

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

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