Copper-Nickel 90/10 and 70/30 Alloys
Technical Data

CDA Publication TN31, 1982

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Copper Development Association

Copper Development Association is a non-trading organisation sponsored by the copper producers and fabricators to encourage the use of copper and copper alloys and to promote their correct and efficient application. Its services, which include the provision of technical advice and information, are available to those interested in the utilisation of copper in all its aspects. The Association also provides a link between research and user industries and maintains close contact with other copper development associations throughout the world.

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Contents

Introduction

This file was first published in 1982 and consists of two data sheets for 90-10 Copper-Nickel and 70-30 Copper-Nickel respectively. The original data sheets were published in 1972, prepared by the then International Copper Development Council from data collected 1968-1972. They contain a unique summary of data relating to the physical and mechanical properties of the materials and low, ambient and elevated temperatures which is not available elsewhere. Tensile, hardness, impact, creep and fatigue data have been abstracted from the relevant original literature. For the sake of accuracy, it is presented in bold type in the units in which it was originally published with the lighter type equivalents in corresponding units.

To convert to SI units the following factors will be useful:

To convert to N/mm^2 from	**multiply by**
hbar	10
mega pascals (MPa)	1
MN/m^2	1
kgf/mm^2	9.806 65
Ibf/in^2	6.894 757 3 x 10^{-3}
ksi	6.894 757 3
UK tonf/in^2	15.444 256
Sh tonf/in^2	13.789 515

To identify current standards and designations for 90-10 and 70-30 copper- nickels, link to the Copper Key (http://www.copper-key.org/index.php?lang=english) or refer to international and national standards organisations.

CuNi10Fe1Mn

Common names:

90/10 Copper-Nickel-lron
90/10 Cu pro-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)	0.000 7 per °C (9% IACS)	0.000 4 per °F (9% IACS)
	applicable over range from 0 to 100 °C *32 to 212 °F*		
2.9	Modulus of elasticity (tension) at 20 °C *68 °F*		
	annealed	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 REFERENCE; INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE

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.

To identify current standards and designations for 90-10 and 70-30 copper- nickels, link to the Copper Key (http://www.copper-key.org/index.php?lang=english) or refer to international and national standards organisations.

5. Mechanical Properties

5.1 Mechanical Properties at Room Temperature

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.

5.1.1 Typical Tensile Properties and Hardness Values - Metric Units

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	32	12	38	$5.65\sqrt{S_0}$	65	68	24	1–20 mm thick
	Typical Cold Worked Temper	42	38	12	$5.65\sqrt{S_0}$	120	125	29	1–10 mm thick
Tube [b]	Annealed (grain size 0.025 mm)	33	14	38	$5.65\sqrt{S_0}$	70	74	25	10–30 mm O.D. 1–3 mm wall
	Typical Cold Drawn Temper	42	35	14	$5.65\sqrt{S_0}$	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

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	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

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.

*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 standards.

5.2 Mechanical Properties at Low Temperatures

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
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. 593–60

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)	149 204 260	300 400 500	>21.1 11.2 7.7	>13.4 7.1 4.9	**>30 000** **16 000** **11 000**	— 21.1* 17.2*	— 13.4* 10.9*	— **30 000*** **24 500***	— — —	— — —	— — —
	Cold Worked 21%	149 204 260	300 400 500	26.6 18.0 11.7	16.9 11.4 7.5	**37 800** **25 600** **16 700**	>35.2 29.9 20.0	>22.3 19.0 12.7	**>50 000** **42 500** **28 500**	— 32.3* 25.3	— 20.5* 16.1	— **46 000*** **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

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)

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

Reed, R P and Mikesell R P. Low Temperature (295 to 4K) Mechanical Properties of Selected Alloys. J. Materials, Vol 2 (1967), No 2, pp 370-392.

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

Private communication from Vereinigte Deutsche Metallwerke AG, Germany.

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).

Benson, N D. 0.1% Proof Stress Values at Elevated Temperatures of 90/10 Cupro-Nickel and an 87 ½/10/1 ¾ / ¾ Copper-Nickel-Iron-Manganese Alloy. Imperial Metal Industries Ltd, England. Research Dept. Rept MD/RR/32/50 (1950).

Nothing, F W. Kupfer-Nickel-Legierungen mit weniger als 50% Nickel. Nickel-Informationsburo GmbH, Dusseldorf, Publication No 7 (1964). 76pp.

Bale, E S. Fatigue Tests at Room Temperature on Copper-Nickel-Iron Alloys. BNFMRA Tech Memo TM94 (1952)

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

Gross M R and Schwab, R C. Fatigue Properties of Non-Ferrous Alloys for Heat Exchanger, Pumps and Piping. US Navy Marine Engineering Laboratory, Annapolis, Md. R and D Rept No 232/66 (1966) (A D 633771).

Cu Ni30 Mn1 Fe

Common names:

70/10 Copper-Nickel-lron

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
Fe	0.5 - 1.5
Mn	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.

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).

To identify current standards and designations for 90-10 and 70-30 copper- nickels, link to the Copper Key (http://www.copper-key.org/index.php?lang=english) or refer to international and national standards organisations.

5. Mechanical Properties

5.1 Mechanical Properties at Room Temperature

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.

5.1.1 Typical Tensile Properties and Hardness Values - Metric Units

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	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

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.) thicl
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

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	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.

*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 standards.

5.2 Mechanical Properties at Low Temperatures

5.2.1 Tensile Properties – Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress		Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm²	ton/in²	psi	0.2% offset kg/mm²	Yield Strength 0.5% ext. under load psi	%	gauge length		kg m/cm²	ft lb
Rod [(1)] 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.

5.4. 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).
- Czyryca, E.J. and Gross, M.R. Low-Cycle Fatigue of Non-Ferrous Alloys for Heat Exchangers and Salt-Water Piping. U.S. Navy MEL Rept. 26/66 (1966).
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