

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/cm ³	0.320 lb/in ³	
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/cm ² s °C	29 Btu ft/ft ² h °F	
2.6	Electrical conductivity (volume) at: -269 °C -452 °F (annealed)	5.8 m/ohm mm ²	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 mm ² /m	104 ohms (circ mil/ft)	
		17 microhm cm	6.8 microhm in	
		20 °C 68 °F (annealed or cold worked)	0.19 ohm mm ² /m	115 ohms (circ mil/ft)
		19 microhm cm	7.5 microhm in	
200 °C 392 °F (" " " ")	0.22 ohm mm ² /m	130 ohms (circ mil/ft)		
	22 microhm cm	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	13 800 kg/mm ²	19 600 000 lb/in ²	
		annealed		
	cold worked (b)	13 000 kg/mm ²	18 500 000 lb/in ²	
2.10	Modulus of rigidity (torsion) at 20 °C 68 °F	5 100 kg/mm ²	7 300 000 lb/in ²	
		annealed		
		cold worked (b)	4 800 kg/mm ²	6 800 000 lb/in ²

(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 (Feist, 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
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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/mm ²	Proof Stress 0.2% offset kg/mm ²	Elongation		Hardness		Shear Strength kg/mm ²	Typical Size Related to Properties Shown ^(a)
				%	gauge length	Brinell	Vickers		
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		Proof Stress 0.1% offset		Elongation		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown ^(b)
		hbar	ton/in ²	hbar	ton/in ²	%	gauge length		hbar	ton/in ²	
Plate	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	
	Temper Annealed	43	28	32	21	30	$5.65\sqrt{S_o}$	140	32	21	6–50 mm (0.25–2 in.) O.D.
	As-Drawn (hard)	54	35	46	30	13	$5.65\sqrt{S_o}$	165	36	23	0.5–2 mm (0.02–0.08 in.) wall

(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/mm ²	ton/in ²	psi		%	gauge length		kg m/cm ²	ft lb
Flat Products ⁽¹⁾	Hot Rolled	20	68	34.5	22	49 000	29 000	34	4.52√S ₀	64	7.2	42
		−92	−134	42	27	60 000	33 000	43	4.52√S ₀	65	9.7	56
		−126	−195	47	29.5	66 500	33 600	50	4.52√S ₀	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√S ₀	79	19.7	114
		−78	−108	38.5	24.5	54 700	24 700	42	4.52√S ₀	77	19.5	113
		−197	−323	50.5	32	72 000	24 800	50	4.52√S ₀	77	19.9	115
		−253	−423	58	37	82 500	30 200	50	4.52√S ₀	73	20.0	116
		−269	−452	56.5	36	80 600	24 900	53	4.52√S ₀	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/mm ²	ton/in ²	psi	0.2% offset kg/mm ²	0.1% offset ton/in ²	%	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
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.
Condenser ⁽⁷⁾ Tube	Annealed	20	68	34	21.5	48 500	12.8	—	36	11.3√S ₀
		100	212	32	20.5	45 500	11	—	30	11.3√S ₀
		200	392	28	18	40 000	10.5	—	30	11.3√S ₀
		300	572	25	16	35 500	10	—	28	11.3√S ₀
		400	752	24	15	34 000	9	—	22	11.3√S ₀
		500	932	18	11.5	25 500	8	—	26	11.3√S ₀
		600	1 112	11	7	15 500	7	—	32	11.3√S ₀

(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		Stress			Duration h	Total Extension % ^(a)	Intercept %	Minimum Creep Rate % per 1 000 h
		°C	°F	kg/mm ²	ton/in ²	psi				
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
	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	
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		Stress for Designated Creep Rate								
		°C	°F	0.001% per 1 000 h			0.01% per 1 000 h			0.1% per 1 000 h		
				kg/mm ²	ton/in ²	psi	kg/mm ²	ton/in ²	psi	kg/mm ²	ton/in ²	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/mm ²		English Units ton/in ²		American Units psi	
			Tensile Strength	Fatigue Strength	Tensile Strength	Fatigue Strength	Tensile Strength	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.

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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. BNFMR Research Report A1550 (1965).
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- (6) Benson, N.D. 0.1% Proof Stress Values at Elevated Temperatures of 90/10 Cupro-Nickel and an 87½/10/1½/¾ 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. BNFMR Tech. Memo TM94 (1952).
- (9) Weller, J. and Weissgerber, R. Festigkeitseigenschaften von Cu Ni Fe Mn – Werkstoffen. Institut für Leichtbau IIL – 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).