Cu Ni2 Si

Common names: Copper-Nickel-Silicon
Nickel-Silicon Bronze

A copper alloy containing nickel and silicon, that can be strengthened by heat treatment. Material solution heat treated at high temperature has a soft supersaturated alpha-phase structure, and subsequent precipitation hardening at lower temperature precipitates finely dispersed nickel silicide in the matrix. In this condition, the alloy exhibits high strength and hardness, combined with good wear resistance and conductivity. Cold working before precipitation hardening can further improve strength and hardness. The alloy also has good corrosion resistance in a variety of environments. The most commonly used wrought forms are sheet, strip, rod and forgings.

COMPOSITION (weight %)

Ni	1.6–2.5
Si	0.5–0.8
Cu	rem.

1 SOME TYPICAL USES

Electrical
Contacts; switchgear and circuit-breaker parts; fuse clips; wire connectors; electrical hardware; reinforcing rings for squirrel-cage rotor end rings.

Mechanical
Cold-headed and hot-stamped bolts and fasteners; catenary supports and hardware for railway equipment; marine hardware and fittings; springs; resistance-welding electrode holders; bearings; ball and roller-bearing cages; friction pads.

2 PHYSICAL PROPERTIES

The "solution heat treated" and "precipitation hardened" conditions referred to in this section relate to material with or without cold work. When no specific condition is quoted, the value shown is applicable to material in all conditions of heat treatment and working.

	Metric Units	English Units
2.1 Density at 20 °C *68 °F* (solution heat treated or precipitation hardened)	8.9 g/cm³	0.320 lb/in³
2.2 Melting range*	1 040–1 060 °C	1 905–1 940 °F
2.3 Coefficient of thermal expansion (linear) at:		
20 to 200 °C *68 to 392 °F*	0.000 016 per °C	0.000 009 per °F
20 to 300 °C *68 to 572 °F*	0.000 018 „ „	0.000 010 „ „
2.4 Specific heat (thermal capacity) at:		
20 °C *68 °F*	0.09 cal/g °C	0.09 Btu/lb °F
2.5 Thermal conductivity at:*		
20 °C *68 °F* (solution heat treated)	~0.20 cal cm/cm² s °C	~48 Btu ft/ft² h °F
20 °C *68 °F* (precipitation hardened)	0.35–0.45 „	85–109 „
2.6 Electrical conductivity (volume) at:*		
20 °C *68 °F* (solution heat treated)	~10 m/ohm mm²	~17 % IACS
20 °C *68 °F* (precipitation hardened)	15–23 „	26–40 „ „
2.7 Electrical resistivity (volume) at:*		
20 °C *68 °F* (solution heat treated)	~0.10 ohm mm²/m ~10 microhm cm	~61 ohms (circ mil/ft) ~4.0 microhm in
20 °C *68 °F* (precipitation hardened)	0.066–0.043 ohm mm²/m 6.6–4.3 microhm cm	40–26 ohms (circ mil/ft) 2.6–1.7 microhm in
2.8 Temperature coefficient of electrical resistance at:* 20 °C *68 °F* (precipitation hardened) applicable over range from 0 to 100 °C *32 to 212 °F*	~0.002 0 per °C (26–40 % IACS)	~0.001 1 per °F (26–40 % IACS)
2.9 Modulus of elasticity (tension) of 20 °C *68 °F*		
solution heat treated	13 000 kg/mm²	18 500 000 lb/in²
precipitation hardened	14 300–15 800 „	20 300 000–22 500 000 „
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*		
solution heat treated	4 800 kg/mm²	6 800 000 lb/in²
precipitation hardened	5 300–5 900 kg/mm²	7 500 000–8 300 000 lb/in²

*Values for Cu Ni3 Si (see table 5.1.2) will show some variation from those quoted above; the higher nickel content of this alloy principally influences melting range, thermal conductivity and electrical characteristics.

N.B.: The values shown in Section 2, which have been appropriately rounded in view of the composition range involved, are based on selected literature references; the melting range covers the highest liquidus and lowest solidus temperatures over the composition range quoted.

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

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3 FABRICATION PROPERTIES

The information given in this table is for general guidance only, since many factors influence fabrication techniques. The values shown are approximate only, since those used in practice are dependent upon form and size of metal, equipment available, techniques adopted and properties required in the material.
For further information on heat treatment and the related properties of this alloy, see General Data Sheet No. 4.

		Metric Units	English Units
3.1	Casting temperature range	1 130–1 200 °C	2 065–2 190 °F
3.2	Heat treatment conditions		
3.2.1	Solution heat treatment		
3.2.1.1	Temperature range [b]	750– 850 °C	1 380–1 560 °F
3.2.1.2	Time at temperature	60–15 min.	
3.2.1.3	Type of furnace	Muffle	
3.2.1.4	Cooling	Water quench	
3.2.2	Interstage annealing temperature range	650– 725 °C	1 200–1 335 °F
3.2.3	Precipitation hardening		
3.2.3.1	Temperature range [b]	425– 490 °C	795– 915 °F
3.2.3.2	Time at temperature	3 – 1 h	
3.2.3.3	Type of furnace	Muffle or salt bath	
3.2.3.4	Cooling	Air	
3.3	Hot working temperature range	800– 900 °C	1 470–1 650 °F
3.4	Hot formability	Excellent	
3.5	Cold formability		
	Solution heat treated	Good	
	Precipitation hardened	Fair	
3.6	Cold reduction		
	Solution heat treated	75% max.	
	Precipitation hardened	20% max.	
3.7	Machinability:	See General Data Sheet No. 2	
	Machinability rating (free-cutting brass = 100)		
	Solution heat treated and cold worked	20%	
	Precipitation hardened	30%	
3.8	Joining methods: [a]	See General Data Sheet No. 3.3	
	Soldering	Good	
	Brazing	Good	
	Oxy-acetylene welding	Good	
	Carbon-arc welding	Not recommended	
	Gas-shielded arc welding	Good	
	Coated metal-arc welding	Fair	
	Resistance welding: spot and seam	Good	
	butt	Good	

(a) These processes, involving the application of heat, are generally restricted to solution-heat-treated material, but soldering must be carried out after precipitation hardening to avoid melting of the joint.

(b) Typical solution-heat-treatment and precipitation-hardening temperature ranges for Cu Ni3 Si (see table 5.1.2.) are 850–900°C (*1560–1650 °F*) and 520–540°C (*970–1005 °F*) respectively.

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	—	—	—	—	—	—	—	—
Chile	NCh (INDITECNOR)	Cu Ni2 Si	252 of. 68	—	—	—	259 of. 70	—	—
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	Cu Ni2 Si	17 666	17 670	17 672	17 677	17 671	—	17 673 17 678
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	—	—	—	—	—	—	—	—
Netherlands	N or NEN (b)	—	—	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	—	—	—	—	—	—	—	—
United Kingdom (d)	BS or DTD	A3/2	—	—	BS 4577 DTD 498 DTD 504	—	—	—	BS 4577 DTD 498
United States (c)	ASTM	No. 647	—	B 441 B 422	B 411	B 412	—	—	—
International Organisation for Standardization	ISO	Cu Ni2 Si	R 1187	—	—	—	—	—	—

(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 and flat wire are covered under the Plate-Sheet-Strip column.
(d) The specifications quoted relate to Cu Ni3 Si (2.0-3.5% Ni, 0.4-0.8% Si, Cu rem.); see table 5.1.2.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

Tensile properties	see tables 5.1.1/2/3.1/3.2
Hardness	,, ,, 5.1.1/2/3.1/3.2
Shear strength	,, ,, 5.1.1/2/3.1/3.2
Modulus of elasticity (tension)	see 2.9
Modulus of rigidity (torsion)	,, 2.10

5.2 Mechanical properties at low temperature

Tensile properties	see tables 5.2.1.1/2
Impact properties	,, ,, 5.2.1.1/2

5.3 Mechanical properties at elevated temperature

Short-time tensile properties	see tables 5.3.1.1/2
Creep properties	,, ,, 5.3.2.1/2.1/2.2

5.4 Fatigue properties

Fatigue strength at room temperature	see tables 5.4.1.1/2

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE [a]

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

This tabel 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.

The mechanical properties of this alloy are largely dependent upon heat treatment conditions. For further information, see General Data Sheet No. 4.

Form	Temper	Tensile Strength kg/mm²	Proof Stress 0.2% offset kg/mm²	Elongation		Hardness		Typical Size Related to Properties Shown [b]
				%	gauge length	Brinell	Vickers	
Sheet Strip	Solution Heat Treated	30	12	35	$5.65\sqrt{S_o}$	70	73	1–5 mm thick
	Solution Heat Treated and Cold Worked to Typical Temper	44	40	12	$5.65\sqrt{S_o}$	120	125	1–5 mm thick
	Precipitation Hardened	58	52	14	$5.65\sqrt{S_o}$	170	180	1–5 mm thick
	Precipitation Hardened after Cold Working to Typical Temper	70	65	10	$5.65\sqrt{S_o}$	190	200	1–5 mm thick
Rod [c]	Solution Heat Treated	30	12	35	$5.65\sqrt{S_o}$	70	73	5–50 mm diam. or equivalent area
	Solution Heat Treated and Cold Worked to Typical Tempers	45	40	10	$5.65\sqrt{S_o}$	125	130	5–25 mm diam. or equivalent area
		55	52	3	$5.65\sqrt{S_o}$	150	160	2–10 mm diam. or equivalent area
	Precipitation Hardened	60	54	12	$5.65\sqrt{S_o}$	160	170	5–50 mm diam. or equivalent area
	Precipitation Hardened after Cold Working to Typical Tempers	65	57	12	$5.65\sqrt{S_o}$	170	180	5–25 mm diam. or equivalent area
		75	65	10	$5.65\sqrt{S_o}$	200	210	2–10 mm diam. or equivalent area
Wire	Solution Heat Treated	30	12	30	100 mm	—	—	1–5 mm diam.
	Solution Heat Treated and Cold Drawn to Typical Temper	55	52	—	—	—	—	1–5 mm diam.
	Precipitation Hardened after Cold Drawing to Typical Temper	75	67	7	100 mm	—	—	1–5 mm diam.
Tube	Solution Heat Treated	30	12	35	$5.65\sqrt{S_o}$	70	73	10–80 mm O.D., 2–10 mm wall
	Solution Heat Treated and Cold Drawn to Typical Temper	45	38	10	$5.65\sqrt{S_o}$	125	130	10–30 mm O.D., 1–3 mm wall
	Precipitation Hardened	55	45	15	$5.65\sqrt{S_o}$	170	180	10–80 mm O.D., 2–10 mm wall
	Precipitation Hardened after Cold Drawing to Typical Temper	72	63	10	$5.65\sqrt{S_o}$	200	210	10–30 mm O.D., 1–3 mm wall
Forgings [c]	Precipitation Hardened	58	50	12	$5.65\sqrt{S_o}$	160	170	—

(a) It will be noted that tables 5.1.1, 5.1.2 (Cu Ni3 Si) and 5.1.3, giving typical tensile properties and hardness values in Metric, SI and English, and American units, 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) 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.

The mechanical properties of this alloy are largely dependent upon heat treatment conditions. For further information, see General Data Sheet No. 4.

The copper-nickel-silicon alloy generally manufactured in UK production is Cu Ni3 Si (2.0–3.5% Ni, 0.4–0.8% Si, Cu rem.) for which the properties quoted in this table are typical.

Form	Temper	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	
Strip	Precipitation Hardened after Cold Working to Typical Temper [a]	65	42	54	35	10	50 mm (2 in.)	220	—	—	0.15–2 mm (0.006–0.08 in.) thick
Rod [c]	Precipitation Hardened after Solution Heat Treatment	62	40	46	30	18	$5.65\sqrt{S_o}$	190	—	—	—
	Precipitation Hardened after Cold Drawing to Typical Tempers [a]	65	42	57	37	22	$5.65\sqrt{S_o}$	200	—	—	22–32 mm (0.875–1.25 in.) diam. or equivalent area
		73	47	65	42	18	$5.65\sqrt{S_o}$	210	—	—	12–22 mm (0.5–0.875 in.) diam. or equivalent area
		80	52	73	47	13	$5.65\sqrt{S_o}$	220	—	—	3–12 mm (0.125–0.5 in.) diam. or equivalent area
Forgings [c]	Precipitation Hardened after Solution Heat Treatment	62	40	46	30	15	$5.65\sqrt{S_o}$	195	—	—	—
	Precipitation Hardened after Cold Working [a]	70	45	60	39	12	$5.65\sqrt{S_o}$	210	—	—	—

[a] Solution heat treated, cold worked and finally precipitation hardened.

[b] It is possible to obtain sizes outside the ranges given in this column, but information on their mechanical properties should be obtained from the metal manufacturers.

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

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.

The mechanical properties of this alloy are largely dependent upon heat treatment conditions. For further information, see General Data Sheet No. 4.

5.1.3.1 Solution-Heat-Treated Material

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, Bar and Flat Wire)	Solution Heat Treated	41 000	14 000	40	2 in.	82	35	50	28 000	0.040 in. thick
	Solution Heat Treated and Cold Worked									
	Half Hard	48 000	46 000	15	2 in.	93	59	60	33 000	0.040 in. thick
	Hard	58 000	57 000	3	2 in.	98	69	65	39 000	"
Rod [b]	Solution Heat Treated	46 000	13 000	35	2 in.	46	—	—	31 000	0.187 in. diam.
	Solution Heat Treated and Cold Worked									
	Extra Hard	68 000	62 000	10	2 in.	99	71	66	46 000	0.187 in. diam.
	Extra Spring	73 000	68 000	11	2 in.	100	72	67	49 000	"
Wire	Solution Heat Treated	46 000	15 000	25	10 in.	—	—	—	31 000	0.200 in. diam.
	Solution Heat Treated and Cold Worked									
	Hard Drawn	65 000	60 000	15	10 in.	—	—	—	44 000	0.500 in. diam.

5.1.3.2 Precipitation-Hardened Material

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	B	G	30 T		
Flat Products (Strip, Bar and Flat Wire)	Precipitation Hardened	85 000	65 000	15	2 in.	88	62	75	50 000	0.040 in. thick
	Precipitation Hardened after Cold Working to Typical Tempers									
	Half Hard	91 000	81 000	13	2 in.	93	69	77	56 000	0.040 in. thick
	Hard	98 000	85 000	9	2 in.	95	74	79	57 000	"
	Hard	90 000	75 000	10	2 in.	92	69	77	56 000	1 in. thick
Rod [b]	Precipitation Hardened	88 000	55 000	20	2 in.	71	34	64	51 000	0.187 in. diam.
	Precipitation Hardened after Cold Working to Typical Tempers									
	Extra Hard	103 000	90 000	14	2 in.	91	67	77	60 000	0.187 in. diam.
	Extra Spring	101 000	89 000	15	2 in.	90	66	76	59 000	"
	Hard	100 000	88 000	22	2 in.	90	66	76	59 000	1 in. diam.
	Precipitation Hardened and Cold Worked to Typical Tempers									
	Extra Hard	106 000	77 000	8	2 in.	95	74	79	61 000	0.187 in. diam.
	Extra Spring	111 000	80 000	7	2 in.	98	79	81	63 000	"
Wire	Precipitation Hardened	88 000	57 000	15	10 in.	—	—	—	51 000	
	Precipitation Hardened and Cold Worked to Typical Temper									
	Extra Spring	115 000	97 000	8	10 in.	—	—	—	65 000	0.200 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.

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

5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

5.2.1 Tensile Properties—Impact Properties

5.2.1.1 Solution-Heat-Treated Material

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm^2	Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm^2	ton/in^2	psi		%	gauge length		$kg\ m/cm^2$	ft lb
Rod [1] 5–20 mm diam. 0.2–0.8 in. diam.	Solution heat treated and cold worked ~35%	20	68	**70**	44.5	99 500	**60**	**15**	$4.52\sqrt{S_o}$	**62**	>**13** [b]	>75 [b]
		—60	—76	**72**	45.5	102 500	—	**18**	$4.52\sqrt{S_o}$	**70**	>**15** [b]	>87 [b]

5.2.1.2 Precipitation-Hardened Material

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress 0.2% offset kg/mm^2	Elongation		Reduction of Area %	Impact Strength	
		°C	°F	kg/mm^2	ton/in^2	psi		%	gauge length		$kg\ m/cm^2$	ft lb
Rod [2] 19 mm diam. 0.75 in. diam.	Precipitation Hardened	22	72	79	50	**112 400**	**73.8** [a]	**15**	$4.52\sqrt{S_o}$	**60**	19.0 [b]	**110** [b]
		—78	—108	84	53.5	**119 400**	**77.9** [a]	**18**	$4.52\sqrt{S_o}$	**66**	18.3 [b]	**106** [b]
		—197	—323	87	55	**123 600**	**80.2** [a]	**24**	$4.52\sqrt{S_o}$	**70**	18.8 [b]	**109** [b]
		—253	—423	94	59.5	**133 700**	**83.2** [a]	**33**	$4.52\sqrt{S_o}$	**68**	20.0 [b]	**116** [b]
		—269	—452	95.5	60.5	**135 800**	**84.2** [a]	**31**	$4.52\sqrt{S_o}$	**65**	—	—
Rod [3]	Precipitation Hardened after Cold Working ~75%	20	68	**80**	51	114 000	**68**	**9**	$5.65\sqrt{S_o}$	**50**	**13** [b]	75 [b]
		—20	—4	**80**	51	114 000	**68**	**10**	$5.65\sqrt{S_o}$	**54**	**14.5** [b]	84 [b]
		—70	—94	**82**	52	116 500	**69**	**11.5**	$5.65\sqrt{S_o}$	**61**	**15** [b]	87 [b]
		—170	—274	**86**	54.5	122 500	**72**	**18.5**	$5.65\sqrt{S_o}$	**63**	**15** [b]	87 [b]
	Precipitation Hardened after Cold Working > 75%	20	68	**82**	52	116 500	**70**	**2**	$5.65\sqrt{S_o}$	**5**	**2** [b]	11 [b]
		—20	—4	**85**	54	121 000	**72**	**5**	$5.65\sqrt{S_o}$	**12**	**2** [b]	11 [b]
		—70	—94	**86**	54.5	122 500	**73**	**4**	$5.65\sqrt{S_o}$	**12**	**2** [b]	11 [b]
		—170	—274	**92**	58.5	131 000	**79**	**14**	$5.65\sqrt{S_o}$	**23**	**3.5** [b]	20 [b]

(a) This value was originally reported in psi; in this table it is given in kg/mm^2, to 3 significant figures.

(b) Charpy V-notch specimen; cross-sectional area at the notch 0.8 cm^2.

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 $kg\ m/cm^2$ (and vice versa) taking into account the actual cross-sectional area of the specimen at the notch.

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

—Further data can be obtained from the following book:

■Dies, K. Kupfer und Kupferlegierungen in der Technik. Springer-Verlag, Berlin (1967).

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

5.3.1.1 Solution-Heat-Treated Material

Form	Temper	Testing Temperature		Tensile Strength			Yield Strength 0.5% ext. under load	Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi	psi	
— (4) (a)	Solution Heat Treated	20	68	26.5	16.5	**37 400**	—	—
		200	392	25	16	**35 400**	—	—
		300	572	24.5	15.5	**34 700**	—	—
		450	842	19	12	**27 300**	—	—
		600	1 112	18.5	12	**26 400**	—	—

5.3.1.2 Precipitation-Hardened Material

Form	Temper	Testing Temperature		Tensile Strength			Yield Strength 0.5% ext. under load	Elongation % on 2 in.
		°C	°F	kg/mm²	ton/in²	psi	psi	
— (4) (5) (a)	Precipitation Hardened	20	68	60.5	38.5	**86 000**	—	—
		200	392	56.5	36	**80 200**	—	—
		300	572	50	31.5	**71 000**	—	—
		450	842	35.5	22.5	**50 200**	—	—
		600	1 112	24	15	**33 800**	—	—
	Precipitation Hardened after Cold Working 75%	20	68	74	47	**105 000**	—	—
		200	392	69	44	**98 100**	**92 100**	**11.0**
		300	572	64.5	41	**91 800**	—	**7.5**
		400	752	57	36	**81 000**	**80 500**	**4.5**
		500	932	44	28	**62 400**	**59 800**	**1.5**
		600	1 112	23.5	15	**33 300**	**32 900**	**4.5**
		700	1 292	6.5	4.5	**9 600**	**9 600**	**32.0**

(a) Form and size not stated in original document.

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

—Data not available:

Proof Stress, 0.1% and 0.2% offset.

—Further data can be obtained from the following references:

- Dies, K. Kupfer und Kupferlegierungen in der Technik. Springer- Verlag, Berlin (1967).
- Ref. (6).
- Properties of Chase Silnic Bronze: A New High-Strength Nickel Silicon Bronze Alloy of Superior Properties. Chase Brass and Copper Co., Connecticut. Metallurgical Rept. 10 pp.
- Jenkins, C. H. M., Bucknall, E. H. and Jenkinson, E. A. The Inter-Relation of Age-Hardening and Creep Performance. Part 2 – The Behaviour in Creep of an Alloy containing 3 per cent Nickel and Silicon in Copper. J. Inst. Metals, Vol. 70, (1944), pp. 57-79.

5.3.2 Creep Properties

5.3.2.1 Original Creep Data

Form	Temper	Testing Temperature		Stress			Duration h	Total Extension % (a)	Intercept %	Min. Creep Rate % per 1 000 h
		°C	°F	kg/mm²	ton/in²	psi				
Rod (6) 4.75 mm diam. 0.187 in. diam.	Precipitation Hardened after Cold Working 88%	204	400	7.0	4.5	**10 000**	**6 000**	**0.16**	**0.018**	**0.002 8**
				14.1	8.9	**20 000**	**5 830**	**0.192**	**0.030**	**0.002 9**
				21.1	13.4	**30 000**	**5 400**	**0.255**	**0.037**	**0.003 3**
				28.1	17.9	**40 000**	**5 760**	**0.385**	**0.045**	**0.005 2**
				35.2	22.3	**50 000**	**5 760**	**0.50**	**0.072**	**0.004 9**
				42.2	26.8	**60 000**	**6 000**	**0.78**	**0.18**	**0.027**

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

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

—Further data can be obtained from the following paper:

- Jenkins, C. H. M., Bucknall, E. H. and Jenkinson, E. A. The Inter-Relation of Age-Hardening and Creep Performance. Part 2 – The Behaviour in Creep of an Alloy containing 3 per cent Nickel and Silicon in Copper. J. Inst. Metals, Vol. 70, (1944), pp. 57-79 (includes data for solution heat treated and precipitation hardened materials respectively).

5.3.2.2. Stress for Rupture

5.3.2.2.1. Solution-Heat-Treated Material

Form	Temper	Testing Temperature		Stress for Rupture in Time Indicated								
				10 h			100 h			1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
—(4) (a)	Solution Heat Treated	300	572	—	—	—	14.6	9.3	**20 800**	10.7	6.8	**15 200**
		450	842	—	—	—	6.7	4.3	**9 600**	3.7	2.3	**5 200**

5.3.2.2.2 Precipitation-Hardened Material

Form	Temper	Testing Temperature		Stress for Rupture in Time Indicated								
				10 h			100 h			1 000 h		
		°C	°F	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi	kg/mm²	ton/in²	psi
—(4) (a)	Precipitation Hardened	200	392	—	—	—	40.1	25.4	**57 000**	34.7	22.0	**49 300**
		300	572	—	—	—	13.4	8.5	**19 000**	10.4	6.6	**14 800**
		450	842	—	—	—	5.8	3.7	**8 200**	2.9	1.9	**4 150**
Wire (6) (7) 3 mm diam. 0.125 in. diam.	Precipitation Hardened after Cold Working 88%	204	400	58.4	37.1	**83 000**	56.9	36.2	**81 000**	54.8	34.8	**78 000**
		260	500	55.5	35.3	**79 000**	47.8	30.4	**68 000**	38.7	24.6	**55 000**
—(4) (5) (a)	Precipitation Hardened after Cold Working 75%	300	572	43.0	27.3	**61 100**	40.2	25.5	**57 200**	30.9 (b)	19.6 (b)	**44 000**(b)
		400	752	30.2	19.2	**43 000**	21.1	13.4	**30 000**	11.2 (b)	7.1 (b)	**16 000**(b)
		500	932	13.4	8.5	**19 000**	—	—	—	—	—	—

(a) Form not stated in original document.

(b) Extrapolated value.

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

—Further data can be obtained from the following paper:

■Jenkins, C. H. M., Bucknall, E. H. and Jenkinson, E. A. The Inter-Relation of Age-Hardening and Creep Performance. Part 2 – The Behaviour in Creep of an Alloy containing 3 per cent Nickel and Silicon in Copper. J. Inst. Metals. Vol. 70 (1944), pp. 57-79.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

5.4.1.1 Solution-Heat-Treated Material

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
Rod [8] **5–20 mm diam. 0.2–0.8 in. diam.**	Solution Heat Treated and Cold Worked 35%	>10	**70** **70** **70**	**35** [a] **17** [b] **45** [c]	44.5 44.5 44.5	22 [a] 11 [b] 28.5 [c]	99 500 99 500 99 500	50 000 [a] 24 000 [b] 64 000 [c]

5.4.1.2 Precipitation-Hardened Material

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
Strip [9] **1 mm 0.040 in.**	Precipitation Hardened after Cold Working 37%	20	69	24.5	43.5	15.5	**98 000**	**35 000**
— [10] [11] [a]	Precipitation Hardened after Cold Working 37%	20 [e]	—	25 [d]	—	16 [d]	—	35 500 [d]

[a] Reversed alternating tension test.

[b] Torsional test.

[c] Pulsating test.

[d] Reversed bending test.

[e] Alloy containing Ni, 1.7–2.6%, Si 0.5–0.8%.

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

—Further data can be obtained from the following papers:

■Moredock, A. E. Copper-Base Alloy Spring Materials. Electro-Technology, Vol. 68 (1961), pp. 76-81.

■Heubner, U., Jung-Konig, W. and Wincierz, P. Beitrag zur Biegewechselfestigkeit und Kerbempfindlichkeit von Kupferlegierungen. Teil. 1, Metall, Vol. 2 (1967), pp. 1147-1154.

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(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.

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