UDC 669.35'71'1

WROUGHT MATERIALS

COPPER-ALUMINIUM ALLOYS
Aluminium Bronzes

Cu Al10 Fe3

Common name: Iron-Aluminium Bronze

A copper–aluminium–iron alloy with an alpha-plus-beta phase structure. Iron is added to inhibit grain growth and to improve strength; the alloy may also contain nickel and/or manganese. It presents a combination of high corrosion and oxidation resistance, and good hot-working properties; the material retains its strength at moderately elevated temperatures. The most commonly used wrought forms are rod, sections and forgings.

COMPOSITION (weight %)

Al	8.5–10.0
Fe	2.0– 4.0
Ni	0 – 1.0
Mn	0 – 2.0
Cu	rem.

1 SOME TYPICAL USES

Chemical
Cryogenic equipment; pickling equipment; pump components.

Marine
Fittings and fasteners.

Mechanical
Non-sparking tools for gas, oil, coal, mining, chemical and explosives industries; bushings and bearings; machine slides; gears; fasteners; wear-resistant components; hot-stamped accessories for electrical lines and machines; valve spindles; moulding dies for plastics; deep-drawing tools and dies.

2 PHYSICAL PROPERTIES

	Metric Units	English Units
2.1 Density at 20 °C *68 °F*	7.6 g/cm³	0.275 lb/in³
2.2 Melting range	1 045–1 090 °C	1 915–1 995 °F
2.3 Coefficient of thermal expansion (linear) at:		
—200 to 20 °C *—328 to 68 °F*	0.000 014 [(a)] per °C	0.000 008 [(a)] per °F
20 to 100 °C *68 to 212 °F*	0.000 016 " "	0.000 009 " "
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*	0.10 cal/g °C	0.10 Btu/lb °F
2.5 Thermal conductivity at:		
20 °C *68 °F*	0.14–0.16 cal cm/cm² s °C	34–39 Btu ft/ft² h °F
200 °C *392 °F*	0.20 [(a)] "	48 [(a)] "
2.6 Electrical conductivity (volume) at:		
20 °C *68 °F* (annealed or cold worked)	7.0–8.1 m/ohm mm²	12–14% IACS
2.7 Electrical resistivity (volume) at:		
20 °C *68 °F* (annealed or cold worked)	0.14–0.12 ohm mm²/m 14–12 microhm cm	86–74 ohms (circ mil/ft) 5.7–4.8 microhm in
2.8 Temperature coefficient of electrical resistance at:		
20 °C *68 °F* (annealed) applicable over range from 0 to 100 °C *32 to 212 °F*	0.000 8 per °C (12%–14% IACS)	0.000 4 per °F (12%–14% IACS)
2.9 Modulus of elasticity (tension) at 20 °C *68 °F*: annealed	12 000 kg/mm²	17 000 000 lb/in²
2.10 Modulus of rigidity (torsion) at 20 °C *68 °F*: annealed	4 450 kg/mm²	6 300 000 lb/in²

(a) Approximate value.

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

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3 FABRICATION PROPERTIES

Fabrication characteristics, corrosion resistance and mechanical properties of this copper–aluminium alloy are markedly influenced by composition and by heat treatment which is usually performed by the metal manufacturer.
If thermal treatment, including hot forming and joining processes, is to be undertaken by the end user, the advice of the metal supplier should be requested.

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	1 140–1 200 °C	2 085–2 190 °F
3.2 Annealing temperature range	650– 800 °C	1 200–1 470 °F
Stress relieving temperature range	300– 400 °C	570– 750 °F
3.3 Hot working temperature range	800– 950 °C	1 470–1 740 °F
3.4 Hot formability	Good	
3.5 Cold formability	Limited	
3.6 Cold reduction between anneals	15% max.	
3.7 Machinability:	See General Data Sheet No. 2	
Machinability rating (free cutting brass = 100)	30	
3.8 Joining methods:	See General Data Sheet No. 3.8	
Soldering	Not recommended	
Brazing (with special fluxes)	Fair	
Oxy-acetylene welding	Not recommended	
Carbon-arc welding	Fair	
Gas-shielded arc welding	Good	
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.AS72 637	—	—	HC.5.7	—	—	HC.5.7	—
Chile	NCh (INDITECNOR)	Cu Al9 Fe4 Cu Al10 Fe3	—	—	—	—	—	—	NCh 249 of. 68
France	NF	—	—	—	—	—	—	—	—
Germany	DIN	Cu Al10 Fe	17 665	—	17 672	—	17 671	—	17 673
India	IS	—	—	—	—	—	—	—	—
Italy	UNI	—	—	—	—	—	—	—	—
Japan	JIS	ABP 1 ABB 1	—	H3208	H3441	—	—	—	—
Netherlands	N or NEN[b]	Cu Al10 Fe3	NEN 6030	—	—	—	—	—	—
South Africa	SABS	—	—	—	—	—	—	—	—
Spain	UNE	—	—	—	—	—	—	—	—
Sweden	SIS	—	—	—	—	—	—	—	—
Switzerland	VSM	Cu Al10 Fe	—	10 802	10 802	—	—	—	—
United Kingdom	BS	CA 103	—	—	2032 2872 2874	—	—	2032 2874	2872
United States[c]	SAE	No. 623	—	J461b	J461b	—	—	J461b	J461b
International Organisation for Standardization	ISO	Cu Al10 Fe3	R 428	—	—	—	—	—	—

[a] Applicable when the chemical composition is not given in the specifications for wrought forms.

[b] Older specifications bear prefix N; for new specifications the NEN prefix is used.

[c] In the United States, bar is covered under the Plate-Sheet-Strip column.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

Tensile properties	see tables 5.1.1/2/3
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
Impact properties	see table 5.3.1
Creep properties	see tables 5.3.2.1/2

5.4 Fatigue properties

Fatigue strength at room temperature	see table 5.4.1

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE *

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

This table is representative of practice in many European countries. For British and American practices, see tables 5.1.2 and 5.1.3, respectively.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.
For a given temper, individual elongation values may show some variation above or below the typical values indicated.

Form	Temper	Tensile Strength kg/mm²	Proof Stress 0.2% offset kg/mm²	Elongation		Hardness		Shear Strength kg/mm²	Typical Size Related to Properties Shown[(a)]
				%	gauge length	Brinell	Vickers		
Rod[(b)]	Hot Worked	62	32	18	$5.65\sqrt{S_o}$	160	170	47	20–80 mm diam. or equivalent area
	Typical Cold Worked Temper	70	45	10	$5.65\sqrt{S_o}$	180	190	46	10–40 mm diam. or equivalent area
Sections[(b)] / Shapes	Hot Worked	62	30	15	$5.65\sqrt{S_o}$	160	170	47	—
Forgings[(b)]	Hot Worked	65	35	15	$5.65\sqrt{S_o}$	170	180	49	—

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

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

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[(d)]		Vickers Hardness	Shear Strength		Typical Size Related to Properties Shown[(b)]
		hbar	ton/in²	hbar	ton/in²	%	gauge length		hbar	ton/in²	
Rod[(c)]	Hot or Hot + ColdWorked	57	37	26	17	30	$5.65\sqrt{S_o}$	150	40	26	50–100 mm (2–4 in.) diam. or equivalent area
	As Manufactured	59	38	28	18	28	$5.65\sqrt{S_o}$	160	42	27	10–50 mm (0.375–2 in.) diam. or equivalent area
		65	42	34	22	22	$5.65\sqrt{S_o}$	190	45	29	" "
Sections[(c)] (extruded)	Hot Worked As Manufactured	59	38	23	15	25	$5.65\sqrt{S_o}$	160	42	27	—
Forgings[(c)]	Hot Worked As Manufactured	57	37	23	15	25	$5.65\sqrt{S_o}$	150	40	26	—

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

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

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

(d) Elongation values for this alloy can be increased, above the typical values quoted, by appropriate heat treatment.

* 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		
Rod [b]	Hot Worked	75 000	35 000	35	2 in.	—	80	—	56 500	3.0 in. diam.
	Cold Worked Hard	98 000 95 000	52 000 50 000	22 25	2 in. 2 in.	— —	89 88	— —	63 500 64 000	0.5 in. diam. 1.0 in. diam.
Sections [b] / Shapes	Hot Worked	85 000	35 000	25	2 in.	—	80	—	64 000	3.0 in. diam.
Forgings [b]	Hot Worked	85 000	35 000	25	2 in.	—	80	—	64 000	3.0 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

Form	Temper	Testing Temperature		Tensile Strength			Yield Strength 0.5% ext. under load psi	Elongation		Reduction of Area %	Impact Strength [a]	
		°C	°F	kg/mm²	ton/in²	psi		%	gauge length		kg m/cm²	ft lb
Rod [1] [2] 49 mm diam. 1.9 in. diam.	Annealed	20	68	63.5	40	**90 000**	**42 600**	**32**	2 in.	**39**	2.8	**16**
		— 29	— 20	66	42	**93 800**	**46 900**	**31**	2 in.	**38**	2.4	**14**
		— 59	— 75	67.5	43	**96 300**	**47 900**	**33**	2 in.	**39**	2.2	**13**
		—182	—295	77.5	49.5	**110 500**	**54 700**	**35**	2 in.	**38**	1.7	**10**
	Cold Worked 0.4%	20	68	66.5	42	**94 500**	**46 400**	**34**	2 in.	**44**	6.0	**35**
		— 29	— 20	67.5	43	**96 200**	**47 300**	**34**	2 in.	**44**	5.9	**34**
		— 59	— 75	69.5	44	**98 900**	**49 300**	**34**	2 in.	**41**	5.9	**34**
		—182	—295	79.5	50.5	**112 800**	**56 500**	**37**	2 in.	**41**	4.7	**27**
[3] [b]	Forged	20	68	62.5	39.5	**88 900**	**47 900** [c]	**45.2**	2 in.	**46.9**	—	—
		—192	—314	79	50	**112 500**	**84 900** [c]	**38.4**	2 in.	**42.1**	—	—

(a) Charpy test, V notch, cross-sectional area at the notch 0.8 cm².

(b) Form not stated in original document.

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

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

—All converted values for impact strength are to be taken as indicative only; the impact energy has been converted from ft lb into kg m/cm² taking into account the actual cross-sectional area of the specimen at the notch.

—The 0.1% and 0.2% offset proof stress values are not available.

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties—Impact Properties

Form	Temper	Testing Temperature		Tensile Strength			Proof Stress		Elongation		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
Flat Products [4] 12 mm 0.5 in.	Hot Rolled	20	68	**55**	35	78 000	**26**	—	**20**	$5.65\sqrt{S_o}$	—	—
		200	392	**53.5**	34	76 000	—	—	**17**	$5.65\sqrt{S_o}$	—	—
		400	752	**43**	27.5	61 000	—	—	**28**	$5.65\sqrt{S_o}$	—	—
		600	1 112	**18**	11.5	25 500	—	—	**32**	$5.65\sqrt{S_o}$	—	—
		800	1 472	**2**	1.5	3 000	—	—	**45**	$5.65\sqrt{S_o}$	—	—
Rod [1] [2] 49 mm diam. 1.9 in. diam.	Annealed	20	68	63.5	40	**90 000**	—	**42 600**	**32**	2 in.	2.8 [b]	**16** [b]
		204	400	54.5	34.5	**77 500**	—	**43 800**	**20**	2 in.	3.3 [b]	**19** [b]
		316	600	45.5	29	**65 000**	—	**41 800**	**10**	2 in.	3.3 [b]	**19** [b]
		427	800	21.5	13.5	**30 500**	—	**22 200**	**46**	2 in.	1.2 [b]	**7** [b]
		538	1 000	9.5	6	**13 600**	—	**12 200**	**27**	2 in.	1.4 [b]	**8** [b]
	Cold Worked 0.4%	20	68	66.5	42	**94 500**	—	**46 400**	**34**	2 in.	6.0 [b]	**35** [b]
		204	400	56	35.5	**79 800**	—	**43 000**	**22**	2 in.	6.0 [b]	**35** [b]
		316	600	47.5	30	**67 500**	—	**43 000**	**10**	2 in.	5.7 [b]	**33** [b]
		427	800	20	12.5	**28 500**	—	**20 000**	**32**	2 in.	1.2 [b]	**7** [b]
		538	1 000	10.5	6.5	**15 000**	—	**13 300**	**18**	2 in.	1.4 [b]	**8** [b]
Rod [6] 51 mm diam. 2 in. diam.	[d]	27	80	67	42.5	**95 000**	—	—	**34.0**	2 in.	—	—
		149	300	60.5	38.5	**86 000**	—	—	**28.0**	2 in.	—	—
		260	500	53.5	34	**76 000**	—	—	**14.0**	2 in.	—	—
		371	700	36	23	**51 000**	—	—	**21.0**	2 in.	—	—
Rod [7]	Annealed [e]	20	68	67.5	**42.7**	95 500	—	—	**26**	$4\sqrt{S_o}$	4.6 [c]	**27** [c]
		200	392	—	—	—	—	—	—	—	4.8 [c]	**28** [c]
		250	482	—	—	—	—	—	—	—	5.9 [c]	**34** [c]
		300	572	—	—	—	—	—	—	—	6.2 [c]	**36** [c]
		350	662	—	—	—	—	—	—	—	4.8 [c]	**28** [c]
		400	752	26.5	**16.8**	37 500	—	—	**77**	$4\sqrt{S_o}$	2.6 [c]	**15** [c]
		450	842	—	—	—	—	—	—	—	1.4 [c]	**8** [c]
		500	932	—	—	—	—	—	—	—	1.7 [c]	**10** [c]
		550	1 022	—	—	—	—	—	—	—	3.6 [c]	**21** [c]
		600	1 112	—	—	—	—	—	—	—	7.9 [c]	**46** [c]
	Hot Forged [f]	20	68	62.5	**39.7**	89 000	—	—	**32**	$4\sqrt{S_o}$	2.2 [c]	**13** [c]
		200	392	—	—	—	—	—	—	—	2.6 [c]	**15** [c]
		250	482	—	—	—	—	—	—	—	2.9 [c]	**17** [c]
		300	572	—	—	—	—	—	—	—	3.5 [c]	**20** [c]
		350	662	—	—	—	—	—	—	—	3.3 [c]	**19** [c]
		400	752	25.5	**16.1**	36 000	—	—	**73**	$4\sqrt{S_o}$	2.4 [c]	**14** [c]
		450	842	—	—	—	—	—	—	—	2.1 [c]	**12** [c]
		500	932	—	—	—	—	—	—	—	2.4 [c]	**14** [c]
		550	1 022	—	—	—	—	—	—	—	3.1 [c]	**18** [c]
		600	1 112	—	—	—	—	—	—	—	6.6 [c]	**38** [c]
	Extruded [e]	20	68	74	**46.9**	105 000	—	—	**17**	$4\sqrt{S_o}$	—	—
		400	752	30.5	**19.4**	43 500	—	—	**51**	$4\sqrt{S_o}$	—	—

(b) Charpy test; V notch; cross-sectional area at the notch 0.8 cm².

(c) Charpy-type test on Izod machine; Izod notch, cross-sectional area at the notch 0.8 cm².

(d) Temper not stated in original document.

(e) Alloy containing 10.13% Al, 2.80% Fe, Cu rem.

(f) Alloy containing 9.95% Al, 4.1% Fe, Cu rem.

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.

—The 0.1% offset proof stress values are not available.

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 (5) (b) 19 mm diam. 0.75 in. diam.	Extruded	316	600	7.0	4.5	**10 000**	**5 760**	**0.46**	**0.217**	**0.041**
		371	700	7.0 21.1	4.5 13.4	**10 000** **30 000**	**1 368** **3.2** (c)	**0.539** **20.8** (d)	**0.195** **0.390**	**0.25** **1 960**
		427	800	2.1	1.3	**3 000**	**2 640**	**0.531**	**0.160**	**0.121**
		482	900	2.1	1.3	**3 000**	**1 152**	**0.971**	**0.290**	**0.38**
Rod (7) (h)	Extruded and Normalised (i)	250	482	1.6 7.9 13.4 31.5	**1** **5** (e) **8.5** **20** (f)	2 200 11 200 19 000 44 800	**816** **960** **1 344** **1 920**	**0.022** (g) **0.121** (g) **0.352** (g) **11.7** (g)	— — — —	<**0.004 2** (k) **0.020** (k) **0.087 5** (k) —

(a) Total extension = Initial extension + Total creep = Initial extension + Intercept + (Minimum creep rate × Duration).
(b) Alloy containing 0.27% Si.
(c) Rupture test.
(d) Total elongation.
(e) Following 1 ton/in².
(f) Following 8.5 ton/in².
(g) After 960 hours (0.022% by extrapolation).
(h) Alloy containing 10.13% Al, 2.80% Fe.
(i) Normalising treatment: 1 h at 825°C (1517°F), cooled in air.
(k) After 960 hours, or minimum if earlier (< 0.004 2% by extrapolation).
N.B.:—Original values are printed in **bold type**; other values are converted.

5.3.2.2 Stress for Designated Creep Rate

Form	Temper	Testing Temperature		Stress for Designated Creep Rate		
		°C	°F	0.01% per 1 000 h		
				kg/mm²	ton/in²	psi
(5) (a)	Hot Worked	316 371 427 482	600 700 800 900	5.1 3.2 1.1 0.98	3.2 2.1 0.71 0.63	**7 200** **4 600** **1 600** **1 400**

(a) Form not stated in original document; alloy containing 0.27% Si.
N.B.:—Original values are printed in **bold type**; other values are converted.
—The stresses for 0.001% per 1 000 h and 0.1% per 1 000 h creep rate values are not available.
—Further data can be obtained from the following paper:
■Reference (7), Table VII.

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

Form	Temper	Number of Cycles x10⁶	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] [d] **14 mm diam. 0.565 in. diam.**	Drawn 10%	100	65.5	20 [b]	41.5	12.5 [b]	**93 000**	**28 500** [b]
Rod [9] [c] **25 mm diam. 1 in. diam.**	Rolled	100	69.5	24.5 [a]	44	15.5 [a]	**99 000**	**35 000** [a]

(a) Rotating cantilever test.

(b) Rotating-beam test.

(c) Alloy containing 10.40% Al, 2.92% Fe.

(d) Alloy containing 9.65% Al, 1.95% Fe, 0.52% Te.

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

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

(1) Jaffee R.I., and Ramsey, R.H. Properties of Aluminium Bronzes at Subzero and High Temperatures. Metal Progress, Vol. 54, (1948), pp. 57-63.

(2) Ramsey, R.H., Jaffee, R.I. and Nekervis, R.J. Report on the Mechanical and Physical Properties of Certain Aluminium-Bronze Alloys over a Temperature Range of —295°F to 1000°F. Battelle Memorial Institute, (20 May, 1946). 46 pp.

(3) Strauss, J. Metals and Alloys for Industrial Applications Requiring Extreme Stability. Trans. ASST, Vol. 16 (1929), pp. 191-226.

(4) Luzhnikov, L.P. Werkstoffe in Maschinenbau—Vol. 1: NE—Metalle und Legierungen. Izdatelstvo Mashinostroenie, Moskva (1967). 304 pp.

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

(6) Properties of Chase Silnic Bronze: A New High Strength Nickel Silicon Bronze Alloy of Superior Properties. Chase Brass and Copper Co., Inc., Connecticut. Metallurgical Report (undated). 10 pp.

(7) Voce, E. The Mechanical Properties, Including Creep, of Aluminium Bronzes at Elevated Temperatures. Metallurgia, Manchr, Vol. 35 (1946), pp. 3-9.

(8) Burghoff, H.L. and Blank, A.I. Fatigue Characteristics of Some Copper Alloys. Proc. ASTM, Vol. 47 (1947), pp. 695-712.

(9) McAdam, D.J.Jr. Endurance Properties of Alloys of Nickel and of Copper. Part I. Trans. ASST, Vol. 7 (1925), pp. 54-81.