

COPPER-CADMIUM-TIN

Cu Cd SnCommon names: **Conductivity Bronze**
Cadmium Bronze

A copper alloy containing cadmium and tin, and with an alpha phase structure. The tin addition gives this material higher strength, especially in the cold-worked condition, and lower conductivity than copper-cadmium; wear resistance, tensile and fatigue properties are significantly greater than those of unalloyed copper. The material is generally supplied as hard-drawn wire.

COMPOSITION (weight %)

| | | |
|----|-----------|---------|
| Cd | | 0.5-1.0 |
| Sn | | 0.2-0.6 |
| Cu | | rem. |

1 SOME TYPICAL USES

Electrical

Catenary wires for electric traction; telephone and telegraph wires; contact shoes.

Mechanical

Spot-resistance-welding electrodes; electrode holders for resistance-welding machines and arc furnaces.

2 PHYSICAL PROPERTIES

| | Metric Units | English Units |
|--|---------------------------------------|-------------------------------------|
| 2.1 Density at 20 °C 68 °F | 8.9 g/cm ³ | 0.320 lb/in ³ |
| 2.2 Melting range | 980-1 070 °C | 1 795-1 960 °F |
| 2.3 Coefficient of thermal expansion (linear) at: | | |
| 20 to 100 °C 68 to 212 °F | 0.000 017 per °C | 0.000 009 per °F |
| 20 ,, 300 °C 68 ,, 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 | 0.50-0.60 cal cm/cm ² s °C | 120-145 Btu ft/ft ² h °F |
| 2.6 Electrical conductivity (volume) at: | | |
| 20 °C 68 °F (annealed) | 35-44 m/ohm mm ² | 60-75 % IACS |
| 20 °C 68 °F (fully cold worked) | 32-41 " " | 55-70 " " |
| 2.7 Electrical resistivity (volume) at: | | |
| 20 °C 68 °F (annealed) | 0.029-0.023 ohm mm ² /m | 17-14 ohms (circ mil/ft) |
| | 2.9-2.3 microhm cm | 1.1-0.91 microhm in |
| 20 °C 68 °F (fully cold worked) | 0.031-0.025 ohm mm ² /m | 19-15 ohms (circ mil/ft) |
| | 3.1-2.5 microhm cm | 1.2-0.97 microhm in |
| 2.8 Temperature coefficient of electrical resistance at: | | |
| 20 °C 68 °F (annealed) | 0.002 4 per °C (60% IACS) | 0.001 3 per °F (60% IACS) |
| | 0.003 0 " " (75 " ") | 0.001 6 " " (75% " ") |
| applicable over range from 0 to 100 °C 32 to 212 °F | | |
| 20 °C 68 °F (fully cold worked) | 0.002 2 " " (55 " ") | 0.001 2 " " (55% " ") |
| | 0.002 8 " " (70 " ") | 0.001 5 " " (70% " ") |
| applicable over range from 0 to 100 °C 32 to 212 °F | | |
| 2.9 Modulus of elasticity (tension) at 20 °C 68 °F: | | |
| annealed | 13 500 kg/mm ² | 19 200 000 lb/in ² |
| cold worked | 12 700 kg/mm ² | 18 100 000 lb/in ² |
| 2.10 Modulus of rigidity (torsion) at 20 °C 68 °F: | | |
| annealed | 5 000 kg/mm ² | 7 100 000 lb/in ² |
| cold worked | 4 700 kg/mm ² | 6 700 000 lb/in ² |

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

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3 FABRICATION PROPERTIES

The information given in this table is for general guidance only, since many factors influence fabrication techniques. The values shown are approximate only, since those used in practice are dependent upon form and size of metal, equipment available, techniques adopted and properties required in the material.

| | Metric Units | English Units |
|---|----------------|--------------------------------|
| 3.1 Casting temperature range ^(a) | 1 130–1 220 °C | 2 065–2 230 °F |
| 3.2 Annealing temperature range | 500– 700 °C | 930–1 290 °F |
| Stress relieving temperature range | 250– 350 °C | 480– 660 °F |
| 3.3 Hot working temperature range | 700– 850 °C | 1 290–1 560 °F |
| 3.4 Hot formability | | Fair |
| 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: ^(a) | | See General Data Sheet No. 3.3 |
| Soldering | | Excellent |
| Brazing | | Good |
| Oxy-acetylene welding | | Fair |
| Carbon-arc welding | | Not recommended |
| Gas-shielded arc welding | | Fair |
| Coated metal-arc welding | | Not recommended |
| Resistance welding: spot and seam | | Fair |
| butt | | Fair |

^(a) Adequate fume extraction must be ensured during melting, casting and welding to avoid risk of toxicity from cadmium oxide.

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 Cd Sn | 245 of. 68 | — | — | — | 259 of. 70 | — | — |
| France | NF | — | — | — | — | — | — | — | — |
| Germany | DIN | Cu Cd Sn | 17 666 | — | 17 672 | 17 677 48 200 48 300 | — | — | — |
| India | IS | — | — | — | — | — | — | — | — |
| Italy | UNI | BS CD 0.6/2 CU CD1 SN0.4 | — | — | — | 2527 2528 | — | — | — |
| Japan | JIS | — | — | — | — | — | — | — | — |
| Netherlands . . | N or NEN ^(b) | — | — | — | — | — | — | — | — |
| South Africa . . | SABS | — | — | — | — | — | — | — | — |
| Spain | UNE | — | — | — | — | — | — | — | — |
| Sweden | SIS | 50 53 | — | — | — | 14 50 53 | — | — | — |
| Switzerland . . | VSM | — | — | — | — | — | — | — | — |
| United Kingdom | BS | — | — | — | — | — | — | — | — |
| United States . | ASTM | No. 164 | — | — | — | B 105 | — | — | — |
| International Organisation for Standardization | ISO | — | — | — | — | — | — | — | — |

^(a) Applicable when the chemical composition is not given in the specifications for wrought forms.

^(b) Older specifications bear prefix N; for new specifications the NEN prefix is used.

5 MECHANICAL PROPERTIES

5.1 Mechanical properties at room temperature

| | |
|---------------------------------|--------------------|
| Tensile properties | see tables 5.1.1/3 |
| Hardness | „ „ 5.1.1/3 |
| Shear strength | „ „ 5.1.1/3 |
| Modulus of elasticity (tension) | see 2.9 |
| Modulus of rigidity (torsion) | „ 2.10 |

5.2 Mechanical properties at low temperature

| | |
|--------------------|---------|
| Tensile properties | no data |
| Impact properties | „ „ |

5.3 Mechanical properties at elevated temperature

| | |
|-------------------------------|----------------------|
| Short-time tensile properties | see table 5.3.1 |
| Creep properties | see tables 5.3.2.1/2 |

5.4 Fatigue properties

| | |
|--------------------------------------|-----------------|
| Fatigue strength at room temperature | see table 5.4.1 |
|--------------------------------------|-----------------|

5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE ^(*)

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

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

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.

For a given temper, individual elongation values may show some variation above or below the typical values indicated.

| Form | Temper | Tensile Strength kg/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 | | |
| Rod ^(b) | Annealed | 26 | 9 | 45 | 5.65√S ₀ | 55 | 58 | 19 | — |
| | Typical Cold Worked Tempers | 45 | 40 | 7 | 5.65√S ₀ | 120 | 125 | 31 | 5–20 mm diam. or equivalent area |
| | | 52 | 49 | 3 | 5.65√S ₀ | 140 | 145 | 34 | 5–10 mm diam. or equivalent area |
| Wire | Annealed | 28 | 10 | 35 | 200 mm | — | — | 21 | — |
| | Typical Cold Drawn Tempers | 58 | 55 | 2 | 200 mm | — | — | 32 | 2–5 mm diam. |
| | | 68 | 66 | — | — | — | — | 34 | 0.8–2 mm diam. |
| | | 75 | 74 | — | — | — | — | 39 | up to 0.8 mm diam. |

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

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

^(*) It will be noted that tables 5.1.1. and 5.1.3, giving typical tensile properties and hardness values in Metric, and American units respectively are not directly comparable. This is because the properties quoted reflect to some extent the metalworking techniques, specification practices, and testing procedures in the countries concerned, and in view of the different sizes of products referred to in these tables. Individual manufacturers of semi-fabricated products, can, however, normally meet the requirements of any national standard

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

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

5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American Standards. For practice in European countries, see table 5.1.1.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted.

For a given temper, individual elongation values may show some variation above or below the typical values indicated.

| Form | Temper | Tensile Strength psi | Yield Strength 0.5% extension under load psi | Elongation | | Rockwell Hardness | | | Shear Strength psi | Typical Size Related to Properties Shown ^(a) |
|---|--|-------------------------|--|------------|------------------|----------------------|----------|----------|--------------------------|--|
| | | | | % | gauge length | F | B | 30 T | | |
| Flat Products (Plate, Sheet, Strip) | As Hot Rolled | 41 000 | 15 000 | 50 | 2 in. | 50 | — | — | 25 000 | — |
| | Annealed | 40 000 | 15 000 | 53 | 2 in. | 40 | — | — | 25 000 | — |
| | Cold Worked Half Hard Hard | 51 000 59 000 | 47 000 57 000 | 15 5 | 2 in. 2 in. | 95 97 | 67 70 | 61 63 | 28 000 30 000 | 0.040 in. thick „ |
| Rod ^(b) | As Hot Rolled | 41 000 | 15 000 | 50 | 2 in. | 50 | — | — | 25 000 | — |
| | Annealed—Soft | 40 000 | 15 000 | 53 | 2 in. | 40 | — | — | 25 000 | — |
| | Cold Worked Hard Hard | 78 000 55 000 | 70 000 52 000 | 2 8 | 2 in. 2 in. | 102 97 | 78 70 | 68 63 | 52 000 36 000 | 0.25 in. diam. 1 in. diam. |
| Wire | Annealed | 43 000 | 18 000 | 40 | 10 in. | — | — | — | 27 000 | — |
| | | 45 000 | 19 000 | 25 | 10 in. | — | — | — | 28 000 | — |
| | Cold Worked Half Hard Hard Extra Hard Spring | 70 000 | 63 000 | 5 | 10 in. | — | — | — | 45 000 | 0.080 in. diam. |
| | | 80 000 | 73 000 | 3 | 10 in. | — | — | — | 51 000 | „ |
| | | 88 000 104 000 | 84 000 102 000 | 2 1 | 10 in. 10 in. | — — | — — | — — | 57 000 67 000 | „ „ |
| Shapes ^(b) | As Hot Rolled | 41 000 | 15 000 | 50 | 2 in. | 50 | — | — | 25 000 | — |
| | Annealed—Soft | 40 000 | 15 000 | 53 | 2 in. | 40 | — | — | 25 000 | — |
| | Cold Worked Hard | 63 000 | 57 000 | 5 | 2 in. | 98 | 73 | 65 | 40 000 | — |
| Forgings ^(b) | Cold Worked Hard | 63 000 | 57 000 | 5 | 2 in. | 98 | 73 | 65 | 40 000 | — |

^(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

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

5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

5.3.1 Short-Time Tensile Properties

| Form | Temper | Testing Temperature | | Tensile Strength | | | Proof Stress | | Elongation % on $5.65\sqrt{S_0}$ |
|--|-------------|---------------------|-----|--------------------|---------------------|--------|-----------------------------------|------------------------------------|--|
| | | °C | °F | kg/mm ² | ton/in ² | psi | 0.2% offset kg/mm ² | 0.1% offset ton/in ² | |
| Rod ⁽¹⁾ ^(a) 17 mm diam. 0.67 in. diam. | Cold Worked | 20 | 68 | 44.0 | 28 | 62 500 | 43.3 | 25.8 ^(b) | 16.0 |
| | | 200 | 392 | 40.2 | 25.5 | 57 000 | 39.4 | 24.4 ^(b) | 12.4 |
| | | 300 | 572 | 38.4 | 24.5 | 54 500 | 37.6 | 23.6 ^(b) | 12.2 |

^(a) Values obtained using Cu-0.91% Sn test specimens and presented for guidance only, since no other data has been traced; it is assumed that Cu Cd Sn is likely to exhibit similar tensile properties at elevated temperatures.

^(b) This value was originally reported in kg/mm²; in this table it is given in ton/in² 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.

5.3.2 Creep Properties
5.3.2.1 Original Creep Data

| Form | Temper | Testing Temperature | | Stress | | | Duration h | Total Creep % ^(a) |
|---|-------------|---------------------|-----|--------------------|---------------------|--------|---------------|---------------------------------|
| | | °C | °F | kg/mm ² | ton/in ² | psi | | |
| Rod ⁽¹⁾ (b) 17 mm diam. 0.67 in. diam. | Annealed | 200 | 392 | 4.0 | 2.5 | 5 700 | 2 764 | 0.19 |
| | | | | 6.0 | 3.8 | 8 500 | 2 764 | 0.78 |
| | | | | 8.0 | 5.1 | 11 400 | 2 764 | 1.75 |
| | Cold Worked | 200 | 392 | 14.0 | 8.9 | 19 900 | 3 018 | 0.15 |
| | | | | 16.0 | 10.2 | 22 800 | 3 018 | 0.19 |
| | | | | 18.0 | 11.4 | 25 600 | 3 018 | 0.22 |

(a) Total creep = Total extension — Initial extension.

(b) Values obtained using Cu-0.91% Sn test specimens and presented for guidance only, since no other data has been traced; it is assumed that Cu Cd Sn is likely to exhibit similar creep properties at elevated temperatures.

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

—Data not available:

Initial extension,
Intercept,
Minimum creep rate.

5.3.2.2 Stress for Designated Extension

| Form | Temper | Testing Temperature | | Stress for Designated Extension | | | | | | | | | | | |
|---|----------------------------|---------------------|-----|---------------------------------|---------------------|--------|--------------------|---------------------|--------|--------------------|---------------------|--------|--------------------|---------------------|--------|
| | | | | 0.1% in 1 000 h | | | 0.2% in 1 000 h | | | 0.1% in 2 000 h | | | 0.2% in 2 000 h | | |
| | | °C | °F | kg/mm ² | ton/in ² | psi | kg/mm ² | ton/in ² | psi | kg/mm ² | ton/in ² | psi | kg/mm ² | ton/in ² | psi |
| Rod ⁽¹⁾ (b) 17 mm diam. 0.67 in. diam. | Annealed | 200 | 392 | 3.6 | 2.3 | 5 100 | 4.3 | 2.7 | 6 100 | 3.3 | 2.1 | 4 700 | 4.1 | 2.6 | 5 800 |
| | Cold Worked ^(a) | 200 | 392 | 13.1 | 8.3 | 18 600 | 19.7 | 12.5 | 28 000 | 11.8 | 7.5 | 16 800 | 18.3 | 11.6 | 26 000 |

(a) Quoted as 'hard' in original document (RT tensile strength 44.0 kg/mm²), but amount of cold work not defined.

(b) Values obtained using Cu-0.91% Sn test specimens and presented for guidance only, since no data has been traced; it is assumed that Cu Cd Sn is likely to exhibit similar creep properties.

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

5.4 FATIGUE PROPERTIES

5.4.1 Fatigue Strength at Room Temperature

| Form | Temper | Number of Cycles × 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 |
| Rod ⁽²⁾ 13 mm diam. 0.5 in. diam. | Annealed (grain size 0.020 mm) | 300 | 28 | 14 ^(a) | 18 | 9 ^(a) | 39 800 | 20 000 ^(a) |
| | Cold Worked 67.4% | 300 | 54 | 22 ^(a) | 34 | 14 ^(a) | 76 700 | 31 000 ^(a) |

(a) Rotating-beam test.

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

REFERENCES

MECHANICAL PROPERTIES (SECTION 5)

- (1) Dies, K. and Jung-König, W. Zeitstandverhalten einiger technischer Kupferlegierungen in der Wärme. Metall, Vol. 16, (1962), pp. 1097-1102.
(2) Anderson, A. R., Swan, E. F. and Palmer, E. W., Fatigue Tests on Some Additional Copper Alloys. Proc. ASTM, Vol. 46 (1946), pp. 678-692.