BSI

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British Standard Specification for

Copper alloy ingots and copper alloy and high conductivity copper castings

Lingots en alliage de cuivre et pour moulages en alliages de cuivre et en cuivre à forte conductivité — Spécifications

Gußblöcke aus Kupferlegierungen und Gußstücke aus Kupferlegierungen und hochleitfähigem Kupfer

British Standards Institution

Foreword

This revision of this British Standard, which has been prepared under the direction of the Non-ferrous Metals Standards Committee, supersedes BS 1400 : 1973 which is withdrawn.

The general technical requirements of this edition differ from those of the previous edition only in minor respects. However, the range of alloys covered has been revised and the opportunity has been taken to align the chemical compositions and mechanical properties of individual alloys, where appropriate, with the corresponding alloys specified in ISO 1338-1977 'Cast copper alloys — Compositions and mechanical properties' published by the International Organization for Standardization (ISO).

Comparisons of the materials specified in the revised edition of BS 1400 with those specified in ISO 1338 are summarized in appendix H.

Four alloys have been included for the first time, reflecting current interest: two high strength cupro-nickel alloys having high resistance to sea water, one containing chromium (CN1) and the other containing niobium (CN2); a nickel-containing tin bronze (CT2); and an aluminium silicon bronze (AB3).

Alloy CMA2, included in the previous edition, has been omitted from this edition.

The practice adopted in the previous edition of grouping the alloys into three categories has been retained, with some changes, as follows.

Group A. Alloys in common use (preferred for all general purposes): PB4, LPB1, LB2, LB4, LG1[B], LG2, SCB1, SCB3, SCB6, DCB1, DCB3, PCB1.

Group B. Special purpose alloys (for applications requiring their particular properties): HCC1, CC1—TF, PB1, PB2, CT1, LG4[A], AB1, AB2, CMA1, HTB1, HTB3.

Group C. Alloys in limited production: LB1, G1, G3, G3-TF, LB5[B], SCB4, CT2, AB3, CN1, CN2.

NOTE. The superscripts (A), (B) have been used to indicate alloys that have been transferred from another group.

This general grouping has been maintained throughout this standard, and both tables quoting specification requirements and design information have been classified in this way.

This standard continues to specify inspection requirements for ingots and castings and lays down minimum requirements for the frequencies of chemical analyses and mechanical tests. In addition a series of optional inspection and test procedures for castings is incorporated as appendix A which may be selected according to the requirements of the purchaser and specified according to a set form of coding. In most cases particular conditions will also need to be specified and these are to be laid down by the purchaser in a 'purchaser's test schedule', as itemized in appendix D, provided at the enquiry stage.

Appendix G gives design information, including guidance on alloy selection. It is emphasized that this section is for information only and does not form part of the main specification.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Contents

Specification

1 Scope

This British Standard specifies requirements for the chemical compositions, mechanical properties and other characteristics for the following two types of product:

(a) copper alloy ingots intended to be remelted for the production of castings; *and*

(b) copper alloy and high conductivity copper castings.

NOTE 1. This standard is intended to apply to castings made by any metal casting process. However, in the case of mechanical properties, requirements are specified (see **6.2** and **8.1**) only for castings made by the sand, chill, continuous and centrifugal processes. The information on casting processes given in **G.3** includes shell moulding.

Methods for verifying that ingots and castings comply with the requirements of this British Standard are also specified.

NOTE 2. Optional supplementary inspection and test procedures, that enable castings to be ordered according to particular inspection and test requirements appropriate to the application of the castings, are given in appendix A.

A system of inspection coding is described (**A.1**) that enables the additional inspection and test procedures to be specified readily at the design stage, for quotation purposes and for order.

It is emphasized that over-inspection will lead to unnecessarily high costs and longer delivery times with no compensating advantages. For these reasons it is essential to select only those supplementary procedures that are necessary for the design and the product concerned.

NOTE 3. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purpose of this British Standard the following definitions apply.

2.1 cast (non-continuous melting). The product of:

(a) one furnace melt; *or*

(b) one crucible melt; *or*

(c) a number of furnace or crucible melts where such are aggregated and mixed prior to sampling.

2.2 cast (continuous melting). In continuous melting for the production of castings, when the contents of a melting/holding furnace or crucible are supplemented from time to time by the addition of metal to maintain an adequate bulk of liquid metal, a cast is 250 kg or fraction thereof of metal poured.

2.3 'TF' condition. The symbols 'TF', added to the material designations for copper chromium (CC1-TF) and nickel gunmetal (G3-TF), indicate castings supplied in the solution treated and precipitation hardened condition.

NOTE. Details of such treatments, applied in order to achieve the specified mechanical properties (see table 8), are not specified.

3 Information to be supplied by the purchaser

The following information shall be supplied by the purchaser in the enquiry and order to assist the manufacturer in supplying the correct ingots or castings:

(a) whether ingots or castings are required and, if castings are required, the casting process to be used (see note 1 to clause **1**, table 8 and table 15);

(b) the designation of the material (see tables 1 to 3 for ingot materials and tables 5 to 7 for casting materials);

(c) if centrifugal castings are required, whether the tensile test samples are to be either taken from the castings or separately cast (see item (d) of **8.1.3**).

NOTE. The purchaser should also be aware of the importance of including, in his enquiry and order, the following information as appropriate:

(1) for both ingots and castings, whether it is the purchaser's intention to inspect the material at the supplier's works (see note 3 to **7.1**);

(2) for castings only:

(i) a fully detailed and fully dimensioned drawing of the casting(s) required;

(ii) details of the actual pattern equipment if this is to be supplied by the purchaser;

(iii) full details of any of the optional supplementary inspection and test procedures required (see appendices A and F), including the inspection coding (see **A.1**) and a test schedule in accordance with the recommendation given in appendix D;

(iv) if castings in alloys AB1, AB2 and AB3 are not to be repaired (see clause **4**);

(v) if inspection and testing are to be carried out by the purchaser and the samples and test pieces are to be retained by the purchaser (see note 3 to **7.1**);

(vi) details of the tensile test samples to be taken for continuous castings and the results to be achieved (see item (c) of **8.1.3**);

(vii) if electrical conductivity tests are required for casting in high conductivity copper (HCC1) or alloy CC1-TF, the test conditions to be used (see **9.5**);

(viii) whether a certificate of compliance is required (see **7.4**);

(ix) details of retest procedures other than those permitted by **7.3** (see note to **7.3.1**);

(x) any requirements for the taking of analysis samples from the melt (see item (4) of note to **7.2.1**).

4 General requirements

Copper alloy ingots shall comply with the requirements specified in clause **5**.

Copper alloy and high conductivity copper castings shall comply with the requirements specified in clause **6**.

Inspection procedures and test methods for verifying that the ingots and castings comply with the requirements specified in clauses **5** and **6** shall be as specified in clauses **7** and **8**.

NOTE 1. For optional supplementary inspection and test procedures see appendix A.

NOTE 2. In the event of any dispute concerning compliance of the ingots or castings with the requirements of this standard, it is normal commercial practice for the supplier and the purchaser to have tests undertaken by a mutually acceptable independent testing authority and to accept the results of such tests as final.

The results obtained from analysis and mechanical property tests shall be rounded to the last place of figures specified as limits, by the application of the rounding rules in accordance with BS 1957.

NOTE 3. For further guidance see appendix B.

Castings that have been subjected to reclamation (i.e. impregnation or weld repair) shall be re-inspected to verify compliance with the requirements of this standard and any supplementary requirements specified in accordance with appendix A.

NOTE 4. In normal commercial practice, weld repair of castings in alloys AB1, AB2 and AB3 is permitted provided that the purchaser has not stipulated that the castings are to be repair free (see item (b)(5) of the note to clause **3**).

For castings in alloys other than AB1, AB2 and AB3, reclamation and repair welding are only permitted by the written approval of the purchaser and his acceptance of the proposed methods of reclamation repair.

5 Specific requirements for ingots

5.1 Chemical composition

The chemical compositions of ingots, shall be as given in tables 1 to 3.

5.2 Tensile properties

For ingots the tensile properties, determined by the method given in **9.2** on separately cast test bars taken in accordance with **7.2.2.1**, **8.1.1** and **8.1.2**, shall be as given in table 4.

NOTE. No tensile properties are specified for ingots in alloys not included in table 4.

5.3 Microstructure of alloy HTB1

For ingots cast in HTB1 the proportion of alpha phase in the microstructure, determined by the method described in **9.4** on samples taken in accordance with **7.2.3** and **8.3**, shall not be less than 15 % by area.

5.4 Freedom from defects

The ingots shall be clean and free from harmful defects.

NOTE. Ingots may be deemed not to comply with this standard because of unacceptable casting defects, even though the ingots may comply with the other requirements specified.

5.5 Identification and marking

Each cast of ingots shall be identified by a convenient method, e.g. by a cast number stamped on each ingot.

The ingots shall be colour marked to identify the alloys in which they have been cast. The colours and colour combinations used to identify the alloys shall be in accordance with those given in appendix C.

Table 1. Chemical compositions of Group A ingots (see item (b) of clause 3)

Designation	PB4		LPB1		LB2		LB4		LG1		LG2		SCB1		SCB3		SCB6		DCB1		DCB3		PCB1		Designation
Material	Phosphor-bronze (copper-tin-phosphorus)		Leaded phosphor-bronze		Leaded bronze		Leaded bronze		Leaded gunmetal		Leaded gunmetal		Brass for sand castings		Brass for sand castings		Brass for brazable castings		Brass for die castings		Brass for die castings		Brass for pressure die castings		Material
Nominal composition	Cu Sn10 Pb P		Cu Sn7 Pb P		Cu Pb10 Sn10		Cu Pb9 Sn5		Cu Sn3 Pb5 Zn8		Cu Sn5 Pb5 Zn5		Cu Zn25 Pb3 Sn2		Cu Zn33 Pb2		Cu Zn15 As		Cu Zn40		Cu Zn40 Pb		Cu Zn40 Pb		Nominal composition
Elements	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	Elements
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	
Copper	Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		70.0	77.0	63.0	66.0†	83.0	87.0	59.0	62.0	58.0	62.0†	57.0	60.0	Copper
Tin	9.7	–	6.5	8.5	9.2	11.0	4.2	6.0	2.0	3.5	4.0	6.0	1.0	3.0	–	1.5	–	–	–	–	–	1.0	–	0.5	Tin
Zinc	–	0.5	–	2.0	–	1.0	–	2.0	7.5	9.5	4.5	6.0	Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		Zinc
Lead	–	0.75	2.0	3.8	9.0	10.5	8.5	10.0	4.0	6.0	4.0	6.0	2.0	5.0	1.0	2.8	–	0.5	–	0.25*	0.5	2.5	0.5	2.5	Lead
Phosphorus	0.5	–	0.4	–	–	0.05	–	0.05	–	–	–	0.02	–	–	–	0.02	–	–	–	–	–	–	–	–	Phosphorus
Nickel	–	0.5	–	1.0	–	2.0	–	2.0	–	2.0	–	2.0	–	1.0	–	1.0	–	–	–	–	–	1.0	–	–	Nickel
Iron	–	–	–	0.2	–	0.15	–	0.15	–	–	–	0.25	–	0.5	–	0.5	–	–	–	–	–	0.5	–	0.3	Iron
Aluminium	–	–	–	0.01	–	0.01	–	0.01	–	0.01	–	0.01	–	0.01	–	0.1‡	–	–	0.25	0.5	0.2	0.8	–	0.5	Aluminium
Manganese	–	–	–	–	–	0.2	–	0.2	–	–	–	–	–	–	–	0.2	–	–	–	–	–	0.5	–	–	Manganese
Antimony	–	–	–	0.25	–	0.5	–	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Antimony
Arsenic	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.05	0.20	–	–	–	–	–	–	Arsenic
Iron + arsenic + antimony	–	–	–	–	–	–	–	–	–	0.75	–	0.50	–	–	–	–	–	–	–	–	–	–	–	–	Iron + arsenic + antimony
Silicon	–	–	–	0.01	–	0.02	–	0.02	–	0.02	–	0.02	–	–	–	0.03	–	–	–	–	–	0.05	–	–	Silicon
Bismuth	–	–	–	–	–	–	–	–	–	0.10	–	0.05	–	–	–	–	–	–	–	–	–	–	–	–	Bismuth
Sulphur	–	0.1	–	0.1	–	0.1	–	0.1	–	0.1	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	Sulphur
Total of impurities	–	0.50	–	0.50	–	0.50	–	0.50	–	1.0	–	0.80	–	1.0	–	1.0	–	1.0 incl. Pb	–	0.75	–	0.5	–	0.5	Total of impurities

NOTE. Specified impurities are shown in light type.
*DCB1. 0.1 % maximum lead if required.
†Nickel to be counted as copper.
‡For pressure tight castings aluminium shall not be greater than 0.02 %.

Table 2. Chemical compositions of Group B ingots (see item (b) of clause 3)

Designation	PB1		PB2		CT1		LG4		AB1		AB2		CMA1		HTB1†		HTB3		Designation
Material	Phosphor-bronze (copper-tin-phosphorus)		Phosphor-bronze (copper-tin-phosphorus)		Copper-tin		Leaded gunmetal		Aluminium bronze (copper-aluminium)		Aluminium bronze (copper-aluminium)		Copper-manganese-aluminium		High tensile brass		High tensile beta brass		Material
Nominal composition	Cu Sn10 P		Cu Sn11 P		Cu Sn10		Cu Sn7 Pb3 Zn3		Cu Al10 Fe3		Cu Al10 Fe5 Ni5		Cu Mn13 Al8 Fe3 Ni3		Cu Zn35 Al Fe Mn		Cu Zn28 Al5 Fe Mn		Nominal composition
Elements	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	Elements
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	
Copper	Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		57.0	–	55.0	–	Copper
Tin	10.2	11.5	11.2	13.0	9.2	11.0	6.0	8.0*	–	0.1	–	0.1	–	0.50	–	1.0	–	0.20	Tin
Zinc	–	0.05	–	0.30	–	0.05	1.7	3.2	–	0.50	–	0.50	–	1.0	Remainder		Remainder		Zinc
Lead	–	0.25	–	0.50	–	0.25	2.7	3.5	–	0.03	–	0.03	–	0.05	–	0.50	–	0.20	Lead
Phosphorus	0.60	1.0	0.25	0.6	–	0.05	–	0.02	–	–	–	–	–	0.05	–	–	–	–	Phosphorus
Nickel	–	0.10	–	0.50	–	0.25	–	2.0*	–	1.0	4.0	5.5	1.5	4.5	–	1.0	–	1.0	Nickel
Iron	–	0.10	–	0.10	–	0.15	–	0.2	1.5	3.5	4.0	5.5	2.0	4.0	0.7	2.0	1.5	3.25	Iron
Aluminium	–	0.01	–	0.01	–	0.01	–	0.01	8.7	10.5	8.8	10.0	7.0	8.5	0.5	2.5	3.0	6.0	Aluminium
Manganese	–	0.05	–	–	–	0.2	–	–	–	1.0	–	3.0	11.0	15.0	0.1	3.0	1.5	4.0	Manganese
Antimony	–	0.05	–	–	–	0.2	–	0.25	–	–	–	–	–	–	–	–	–	–	Antimony
Arsenic	–	–	–	–	–	–	–	0.15	–	–	–	–	–	–	–	–	–	–	Arsenic
Iron + arsenic + antimony	–	–	–	–	–	–	–	0.40	–	–	–	–	–	–	–	–	–	–	Iron + arsenic + antimony
Silicon	–	0.02	–	0.02	–	0.02	–	0.01	–	0.2	–	0.1	–	0.15	–	0.10	–	0.10	Silicon
Bismuth	–	–	–	–	–	–	–	0.05	–	–	–	–	–	–	–	–	–	–	Bismuth
Magnesium	–	–	–	–	–	–	–	–	–	0.05	–	0.05	–	–	–	–	–	–	Magnesium
Sulphur	–	0.05	–	0.1	–	0.05	–	0.1	–	–	–	–	–	–	–	–	–	–	Sulphur
Total of impurities	–	0.60	–	0.20	–	0.80	–	0.70	–	0.30	–	0.20	–	0.30	–	0.20	–	0.20	Total of impurities

NOTE. Specified impurities are shown in light type.
*Tin + ½ nickel content shall be within the range 7.0 % to 8.0 %.
†HTB1. Subject to microstructure requirements (see 5.3). If required lead may be specified as not more than 0.10 %.

Table 3. Chemical compositions of Group C ingots (see item (b) of clause 3)

Designation	LB1		LB5		G1		G3		SCB4		CT2		AB3		CN1		CN2		Designation
Material	**Leaded bronze**		**Leaded bronze**		**Gunmetal**		**Nickel gunmetal**		**Naval brass for sand casting**		**Copper tin**		**Aluminium silicon bronze**		**Copper nickel chromium**		**Copper nickel niobium**		**Material**
Nominal composition	Cu Pb15 Sn9		Cu Pb20 Sn5		Cu Sn10 Zn2		Cu Sn7 Ni5 Zn3		Cu Zn36 Sn		Cu Sn12 Ni		Cu Al6 Si2 Fe		Cu Ni30 Cr		Cu Ni30 Nb		**Nominal composition**
Elements	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	**Elements**
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	
Copper	**Remainder**		**Remainder**		**Remainder**		**Remainder**		**60.0**	**63.0**	**85.0**	**87.3†**	**Remainder**		**Remainder**		**Remainder**		Copper
Tin	**8.0**	**10.0**	**4.0**	**6.0**	**9.7**	**10.5**	**6.5**	**7.5**	**1.0**	**1.5**	**11.2**	**13.0**	—	0.10	—	—	—	—	Tin
Zinc	—	**1.0**	—	**1.0**	**1.75**	**2.75**	**1.75**	**3.0**	**Remainder**		—	0.4	—	0.40	—	—	—	—	Zinc
Lead	**13.5**	**16.5**	**19.0**	**23.0**	—	**1.5**	**0.10**	**0.50**	—	**0.5***	—	0.2*	—	0.03	—	0.005	—	0.005	Lead
Phosphorus	—	0.1	—	0.10	—	**0.02**	—	**0.02**	—	—	—	0.05‡	—	—	—	0.005	—	0.005	Phosphorus
Nickel	—	**2.0**	—	**2.0**	—	**1.0**	**5.25**	**5.75**	—	—	**1.5**	**2.0**	—	0.10	**29.0**	**33.0**	**28.0**	**32.0**	Nickel
Iron	—	—	—	0.15	—	0.15§	—	§	—	—	—	0.15	**0.5**	**0.7**	**0.4**	**1.0**	**1.0**	**1.4**	Iron
Aluminium	—	—	—	0.01	—	0.01	—	0.01	—	0.01	—	0.01	**6.0**	**6.4**	—	—	—	—	Aluminium
Manganese	—	—	—	0.2	—	—	—	0.02	—	—	—	0.2	—	0.50	**0.5**	**1.0**	**1.1**	**1.4**	Manganese
Antimony	—	**0.5**	—	**0.50**	—	§	—	§	—	—	—	0.1	—	—	—	—	—	—	Antimony
Arsenic	—	—	—	—	—	§	—	§	—	—	—	—	—	—	—	—	—	—	Arsenic
Silicon	—	—	—	0.01	—	0.02	—	0.01	—	—	—	0.01	**2.0**	**2.4**	**0.20**	**0.30**	**0.20**	**0.30**	Silicon
Bismuth	—	—	—	—	—	0.03	—	0.02	—	—	—	—	—	—	—	0.002	—	0.002	Bismuth
Sulphur	—	0.1	—	0.1	—	0.1	—	0.1	—	—	—	0.05	—	—	—	0.01	—	0.01	Sulphur
Magnesium	—	—	—	—	—	—	—	—	—	—	—	—	—	0.05	—	—	—	—	Magnesium
Niobium + tantalum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**1.20**	**1.40**	Niobium + tantalum
Carbon	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.02	—	0.02	Carbon
Chromium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**1.6**	**2.0**	—	—	Chromium
Zirconium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**0.1**	**0.15**	—	—	Zirconium
Cobalt	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.05	—	0.05	Cobalt
Total of impurities	—	0.30	—	0.30	—	0.50	—	0.50	—	0.75	—	0.80*	—	0.80	—	0.20	—	0.30	Total of impurities

NOTE. Specified impurities are shown in light type.
*0.1 % lead maximum may be specified.
†Copper content includes nickel.
‡Phosphorus content may be increased by agreement.
§Iron + antimony + arsenic 0.20 % max.

Table 4. Mechanical properties of separately cast test bars for ingots

Designation	Material	Tensile strength		0.2 % proof stress		Elongation on $5.65\sqrt{S_o}$	
		Sand cast min.	Chill cast min.	Sand cast min.	Chill cast min.	Sand cast min.	Chill cast min.
		N/mm^2	N/mm^2	N/mm^2	N/mm^2	%	%
AB1	Aluminium bronze	500	540	170*	200*	18	18
AB2	Aluminium bronze	640	650	250	250	13	13
AB3	Aluminium silicon bronze	460	—	180	—	20	—
CMA1	Copper-manganese-aluminium	650	670	280	310	18	27
HTB1	High tensile brass	470	500	170	210	18	18
HTB3	High tensile beta brass	740	—	400	—	11	—
CN1	High strength chromium cupro-nickel	480	—	300	—	18	—
CN2	High strength niobium cupro-nickel	480	—	300	—	18	—

*For information only.

6 Specific requirements for castings

6.1 Chemical composition

The chemical compositions of castings shall be as given in tables 5 to 7.

6.2 Mechanical properties

For castings the mechanical properties, determined by the methods given in **9.2** on samples taken in accordance with **7.2.2.2**, **8.1.1**, **8.1.3** and **8.2**, shall be given as in table 8.

NOTE. No mechanical properties are specified for castings in high conductivity copper (HCC1) or in alloys or casting processes other than those included in table 8.

6.3 Microstructure of HTB1

For castings in alloy HTB1 the proportion of alpha phase in the microstructure, determined by the method given in **9.4**, on samples taken in accordance with **7.2.3** and **8.3** shall not be less than 15 % by area.

6.4 Freedom from defects

The castings shall be clean and free from harmful defects.

NOTE 1. Castings may be deemed not to comply with this standard because of unacceptable casting defects, even though the castings may comply with the other requirements specified.

NOTE 2. Supplementary requirements for the detection of flaws and defects in castings by proof machining, pressure testing, penetrant flaw detection and radiographic examination may be specified at the purchaser's option (see item (2)(iii) of the note to clause 3 and appendix A).

6.5 Electrical resistivities of HCC1 and CC1-TF

The electrical resistivities of castings in high conductivity copper HCC1 and alloy CC1-TF, determined in accordance with **9.5**, shall not exceed the following values:

(a) HCC1: 0.019 Ω·m (approximately equivalent to an electrical conductivity of 90 % IACS*);

(b) CC1-TF: 0.022 Ω·m (approximately equivalent to an electrical conductivity of 80 % IACS*).

NOTE 1. Copper that has an electrical resistivity of 0.017 241 Ω·m is said to have an electrical conductivity of 100 % IACS*.

NOTE 2. For sampling, see **7.2.4**.

6.6 Identification and marking

Castings inspected to supplementary procedures specified by the purchaser in accordance with appendix A shall be individually marked, or batched and tallied, by a suitable means as soon as possible after casting. The identification shall be maintained in such a manner as to enable the castings to be correlated with their relevant inspection records at the time of their despatch from the foundry.

NOTE. In normal commercial practice the inspection records are kept in such a manner as to enable them to be made available to the purchaser, or his representative, on request.

*International Annealed Copper Standard (see IEC 28 (1925) 'International standard of resistance for copper', obtainable from the International Electrotechnical Commission (IEC), 3, Rue de Varembé, Geneva, Switzerland).

Table 5. Chemical compositions of Group A castings (see item (b) of clause 3)

Designation	PB4		LPB1		LB2		LB4		LG1		LG2		SCB1		SCB3		SCB6		DCB1		DCB3		PCB1		Designation
Material	Phosphor-bronze (copper-tin-phosphorus)		Leaded phosphor-bronze		Leaded bronze		Leaded bronze		Leaded gunmetal		Leaded gunmetal		Brass for sand castings		Brass for sand castings		Brass for brazable castings		Brass for die castings		Brass for die castings		Brass for pressure die castings		Material
Nominal composition	Cu Sn10 Pb P		Cu Sn7 Pb P		Cu Sn10 Pb10		Cu Sn5 Pb9		Cu Sn3 Pb5 Zn8		Cu Sn5 Pb5 Zn5		Cu Zn25 Pb3 Sn2		Cu Zn33 Pb2		Cu Zn15 As		Cu Zn40		Cu Zn40 Pb		Cu Zn40 Pb		Nominal composition
Elements	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	Elements
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	
Copper	Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		70.0	80.0	63.0	67.0	83.0	88.0	59.0	63.0	58.0	63.0	57.0	60.0	Copper
Tin	9.5	11.0	6.5	8.5	9.0	11.0	4.0	6.0	2.0	3.5	4.0	6.0	1.0	3.0	—	1.5	—	—	—	—	—	1.0	—	0.5	Tin
Zinc	—	0.5	—	2.0	—	1.0	—	2.0	7.0	9.5	4.0	6.0	Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		Zinc
Lead	—	0.75	2.0	5.0	8.5	11.0	8.0	10.0	4.0	6.0	4.0	6.0	2.0	5.0	1.0	3.0	—	0.5	—	0.25‡	0.5	2.5	0.5	2.5	Lead
Phosphorus	0.4	1.0	0.3	—	—	0.10*	—	0.10*	—	—	—	—	—	—	—	0.05	—	—	—	—	—	—	—	—	Phosphorus
Nickel	—	0.5	—	1.0	—	2.0	—	2.0	—	2.0	—	2.0	—	1.0	—	1.0	—	—	—	—	—	1.0§	—	—	Nickel
Iron	—	—	—	—	—	0.15	—	0.25	—	—	—	—	—	0.75	—	0.75	—	—	—	—	—	0.8	—	0.3	Iron
Aluminium	—	—	—	—	—	0.01	—	0.01	—	0.01	—	0.01	—	0.01	—	0.1†	—	—	—	0.5	0.2	0.8	—	0.5	Aluminium
Manganese	—	—	—	—	—	0.2	—	0.2	—	—	—	—	—	—	—	0.2	—	—	—	—	—	0.5	—	—	Manganese
Antimony	—	—	—	0.25	—	0.5	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Antimony
Arsenic	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.05	0.20	—	—	—	—	—	—	Arsenic
Iron + arsenic + antimony	—	—	—	—	—	—	—	—	—	0.75	—	0.50	—	—	—	—	—	—	—	—	—	—	—	—	Iron + arsenic + antimony
Silicon	—	—	—	—	—	0.02	—	0.02	—	0.02	—	0.02	—	—	—	0.05	—	—	—	—	—	0.05	—	—	Silicon
Bismuth	—	—	—	—	—	—	—	—	—	0.10	—	0.05	—	—	—	—	—	—	—	—	—	—	—	—	Bismuth
Sulphur	—	0.1	—	0.1	—	0.1	—	0.1	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Sulphur
Total of impurities	—	0.50	—	0.50	—	0.50	—	0.50	—	1.0	—	0.80	—	1.0	—	1.0	—	1.0 incl. Pb	—	0.75	—	0.5	—	0.5	Total of impurities

NOTE. Specified impurities are shown in light type.
*For continuous castings, phosphorus content may be increased to a maximum of 1.5 % and alloy coded with suffix /L.
†For pressure-tight castings in SCB3, the aluminium should not be greater than 0.02 %.
‡DCB1. 0.1 % lead if required.
§ DCB3. Nickel to be counted as copper.

Table 6. Chemical compositions of Group B castings (see item (b) of clause 3)

Designation	HCC1*	CC1-TF		PB1		PB2		CT1		LG4‡		AB1		AB2		CMA1		HTB1§		HTB3		Designation
Material	High conductivity copper	Copper chromium		Phosphor-bronze (copper-tin-phosphorus)		Phosphor-bronze (copper-tin-phosphorus)		Copper-tin		87/7/3/3 leaded gunmetal		Aluminium bronze (copper-aluminium)		Aluminium bronze (copper-aluminium)		Copper-manganese aluminium		High tensile brass		High tensile beta brass		Material
Nominal composition		Cu Cr1		Cu Sn10 P		Cu Sn11 P		Cu Sn10		Cu Sn7 Pb3 Zn3		Cu Al10 Fe3		Cu Al10 Fe5 Ni5		Cu Mn13 Al8 Fe3 Ni3		Cu Zn35 Al Fe Mn		Cu Zn28 Al5 Fe Mn		Nominal composition
Elements	min. max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	Elements
	% %	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	
Copper		Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		Remainder		57.0	–	55.0	–	Copper
Tin		–	–	10.0	11.5	11.0	13.0	9.0	11.0	6.0	8.0‡	–	0.1	–	0.1	–	0.50	–	1.0	–	0.20	Tin
Zinc		–	–	–	0.05	–	0.30	–	0.03	1.5	3.0	–	0.50	–	0.50	–	1.0	Remainder		Remainder		Zinc
Lead		–	–	–	0.25	–	0.50	–	0.25	2.5	3.5	–	0.03	–	0.03	–	0.05	–	0.50	–	0.20	Lead
Phosphorus		–	–	0.50	1.0	0.15	0.6	–	0.15†	–	–	–	–	–	–	–	0.05	–	–	–	–	Phosphorus
Nickel		–	–	–	0.10	–	0.50	–	0.25	–	2.0‡	–	1.0	4.0	5.5	1.5	4.5	–	1.0	–	1.0	Nickel
Iron		–	–	–	0.10	–	0.10	–	0.20	–	0.20	1.5	3.5	4.0	5.5	2.0	4.0	0.7	2.0	1.5	3.25	Iron
Aluminium		–	–	–	0.01	–	0.01	–	0.01	–	0.01	8.5	10.5	8.8	10.0	7.0	8.5	0.5	2.5	3.0	6.0	Aluminium
Manganese		–	–	–	0.05	–	–	–	0.2	–	–	–	1.0	–	3.0	11.0	15.0	0.1	3.0	–	4.0	Manganese
Antimony		–	–	–	0.05	–	–	–	0.2	–	0.25	–	–	–	–	–	–	–	–	–	–	Antimony
Arsenic		–	–	–	–	–	–	–	–	–	0.15	–	–	–	–	–	–	–	–	–	–	Arsenic
Iron + arsenic + antimony		–	–	–	–	–	–	–	–	–	0.40	–	–	–	–	–	–	–	–	–	–	Iron + arsenic + antimony
Silicon		–	–	–	0.02	–	0.02	–	0.01	–	0.01	–	0.2	–	0.1	–	0.15	–	0.10	–	0.10	Silicon
Bismuth		–	–	–	–	–	–	–	–	–	0.05	–	–	–	–	–	–	–	–	–	–	Bismuth
Magnesium		–	–	–	–	–	–	–	–	–	–	–	0.05	–	0.05	–	–	–	–	–	–	Magnesium
Sulphur		–	–	–	0.05	–	0.1	–	0.05	–	–	–	–	–	–	–	–	–	–	–	–	Sulphur
Chromium		0.50	1.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Chromium
Total of impurities	–	–	–	–	0.60	–	0.20	–	0.80	–	0.70	–	0.30	–	0.30	–	0.30	–	0.2	–	0.2	Total of impurities

NOTE. Specified impurities are shown in light type.
*HCC1. Castings shall be made from the copper grades Cu–CATH–2, CU–ETP–2, or Cu–FRHC, as specified in BS 6017.
†For continuous casting phosphorous content may be increased to a maximum of 1.5 % and alloy coded with suffix /L.
‡Tin + ½ Nickel content shall be within the range 7.0 % to 8.0 %.
§ HTB1. Subject also to microstructure requirements (see 6.3).

Table 7. Chemical compositions of Group C castings (see item (b) of clause 3)

Designation	LB1		LB5		G1		G3		G3-TF		SCB4		CT2		AB3		CN1		CN2		Designation
Material	Leaded bronze		Leaded bronze		Gunmetal		Nickel gunmetal		Nickel gunmetal fully heat treated		Naval brass for sand casting		Copper tin		Aluminium silicon bronze		Copper nickel chromium		Copper nickel niobium		Material
Nominal composition	Cu Pb15 Sn9		Cu Pb20 Sn5		Cu Sn10 Zn2		Cu Sn7 Ni5 Zn3		Cu Sn7 Ni5 Zn3		Cu Zn36 Sn		Cu Sn12 Ni		Cu Al6 Si2 Fe		Cu Ni30 Cr		Cu Ni30 Nb		Nominal composition
Elements	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	Elements
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	
Copper	Remainder		Remainder		Remainder		Remainder		Remainder		60.0	63.0	85.0	87.5	Remainder		Remainder		Remainder		Copper
Tin	8.0	10.0	4.0	6.0	9.5	10.5	6.5	7.5	6.5	7.5	1.0	1.5	11.0	13.0	–	0.10	–	–	–	–	Tin
Zinc	–	1.0	–	1.0	1.75	2.75	1.5	3.0	1.5	3.0	Remainder		–	0.4	–	0.40	–	–	–	–	Zinc
Lead	13.0	17.0	18.0	23.0	–	1.5	0.10	0.50	0.10	0.50	–	0.5	–	0.3	–	0.03	–	0.005	–	0.005	Lead
Phosphorus	–	0.1	–	0.10	–	–	–	0.02	–	0.02	–	–	0.05	0.40*	–	–	–	0.005	–	0.005	Phosphorus
Nickel	–	2.0	–	2.0	–	1.0	5.25	5.75	5.25	5.75	–	–	1.5	2.5	–	0.10	29.0	33.0	28.0	32.0	Nickel
Iron	–	–	–	–	–	0.15†	–	†	–	†	–	–	–	0.20	0.5	0.7	0.4	1.0	1.0	1.4	Iron
Aluminium	–	–	–	–	–	0.01	–	0.01	–	0.01	–	0.01	–	0.01	6.0	6.4	–	–	–	–	Aluminium
Manganese	–	–	–	–	–	–	–	0.20	–	0.20	–	–	–	0.2	–	0.50	0.4	1.0	1.0	1.4	Manganese
Antimony	–	0.5	–	0.5	–	†	–	†	–	†	–	–	–	–	–	–	–	–	–	–	Antimony
Arsenic	–	–	–	–	–	†	–	†	–	†	–	–	–	–	–	–	–	–	–	–	Arsenic
Silicon	–	0.02	–	0.01	–	0.02	–	0.02	–	0.02	–	–	–	0.01	2.0	2.4	0.20	0.40	0.20	0.40	Silicon
Bismuth	–	–	–	–	–	0.03	–	0.02	–	0.02	–	–	–	–	–	–	–	0.002	–	0.002	Bismuth
Sulphur	–	0.1	–	–	–	0.1	–	0.1	–	0.1	–	–	–	0.05	–	–	–	0.01	–	0.01	Sulphur
Magnesium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.05	–	–	–	–	Magnesium
Niobium + tantalum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.20	1.40	Niobium + tantalum
Carbon	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.02	–	0.02	Carbon
Chromium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.5	2.0	–	–	Chromium
Zirconium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.05	0.15	–	–	Zirconium
Cobalt	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.05	–	0.05	Cobalt
Total of impurities	–	0.30	–	0.30	–	0.50	–	0.50	–	0.50	–	0.75	–	0.80	–	0.80	–	0.20	–	0.30	Total of impurities

NOTE. Specified impurities are shown in light type.
*For continuous casting phsophorus content may be increased to a maximum of 1.5 % and alloy coded with suffix /L.
†Iron + antimony + arsenic 0.20 % max.

Table 8. Mechanical properties for castings

Designation	Tensile strength				0.2 % proof stress				Elongation $5.65\sqrt{S_o}$			
	Sand	Chill	Continuous	Centrifugal	Sand	Chill	Continuous	Centrifugal	Sand	Chill	Continuous	Centrifugal
	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	%	%	%	%
Group A alloys												
PB4	190	270	330	280	100*	140*	160*	140*	3	2	7	4
LPB1	190	220	270	230	80*	130*	130*	130*	3	2	5	4
LB2	190	220	280	230	80*	40*	160*	140*	5	3	6	5
LB4	160	200	230	220	60*	80*	130*	80*	7	5	9	6
LG1	180	180	—	—	80*	80*	—	—	11	2	—	—
LG2	200	200	270	220	100*	110*	100*	110*	13	6	13	8
Group B alloys												
HCC1	(Resistivity values only to be specified, see 6.5)											
CC1-TF†	—	—	—	—	—	—	—	—	—	—	—	—
PB1	220	310	360	330	130*	170*	170*	170*	3	2	6	4
PB2	220	270	310	280	130*	170*	170*	170*	5	3	5	3
CT1	240	—	—	—	130*	—	—	—	—	—	—	—
LG4	250	250	300	250	130*	130*	130*	130*	16	5	13	6
AB1	500	540	—	560	170*	200*	—	200*	18	18	—	20
AB2	640	650	640	670	250	250	250	250	13	13	13	13
CMA1	650	670	—	—	280	310	—	—	18	27	—	—
HTB1	470	500	—	500	170	210	—	210	18	18	—	20
HTB3	740	—	—	740	400	—	—	400	11	—	—	13
Group C alloys												
LB1	170	200	230	220	80*	130*	130*	130*	4	3	9	4
LB5	160	170	190	190	60*	80*	100*	80*	5	5	8	7
G1	270	230	300	250	130*	130*	140*	130*	13	3	9	5
G3	280	—	340	—	140*	—	170*	—	16	—	18	—
G3-TF‡	430	—	430	—	280*	—	280*	—	3	—	3	—
CT2	280	—	300	300	160*	—	180*	180*	12	—	8	10
AB3	460	—	—	—	180	—	—	—	20	—	—	—
CN1	480	—	—	—	300	—	—	—	18	—	—	—
CN2	480	—	—	—	300	—	—	—	18	—	—	—

NOTE. Because the mechanical properties for a given material are generally dependent on the casting process, it is important that the casting process be stated at the time of enquiry and order (see item (a) of clause 3).
*For information only.
†The minimum hardness of CC1-TF shall be 100 HB.
‡The minimum hardness of G3-TF shall be 160 HB.

7 Inspection procedures

7.1 General

Minimum requirements for the frequencies at which initial analyses and tests are to be carried out shall be as specified in **7.2**. Retests shall be permitted as specified in **7.3**.

NOTE 1. A regular frequency of analysis and testing is essential if an adequate level of technical control is to be achieved in a foundry providing castings in accordance with this standard. The frequencies specified in **7.2** are adequate for good quality general work and no additional requirements are necessary for the majority of castings.

NOTE 2. The purchaser has the option, subject to agreement with the supplier, to specify inspection and test procedures for castings that are supplementary to those specified in **7.2** (see item (2)(iii) of the note to clause **3**). Appendix A gives details of the options available. The purchaser's drawings and/or order should identify the options required by means of the codes given in **A.1**. The purchaser should also submit to the supplier, at the enquiry stage, a test schedule giving full details of any special test conditions that may apply. Recommendations on the information to be included in the test schedule are given in appendix D.

NOTE 3. In normal commercial practice all inspection and testing to verify compliance with the requirements of this standard are carried out by the supplier, the samples and test pieces being retained by the supplier, unless otherwise agreed between the supplier and the purchaser at the time of enquiry and order (see item (2)(v) of the note to clause **3**).

Where the inspection and testing are to be carried out by the supplier, it is normal commercial practice for the supplier to afford the purchaser all reasonable facilities to satisfy himself that the ingots or castings comply with the requirements of this standard. For this purpose the purchaser or his representative may, by prior arrangement, visit the supplier's works to inspect the castings, to select and identify the test samples and to witness the tests. However, it is essential that the purchaser notifies the supplier, when placing the order, if it is his intention to visit the supplier's works for the purposes described (see item (1) of the note to clause **3**).

7.2 Minimum inspection requirements

7.2.1 *Analysis.* For ingots, when analysis samples are taken from the melt and analysed to represent each cast the number of samples taken shall be as follows:

(a) for ingot casts of less than 2 tonnes: one sample;

(b) for ingot casts of 2 tonnes or more: two samples, one taken at the beginning of the cast and the other taken at the end of the cast.

NOTE. In the case of castings, the frequencies of sampling from the melt and of analysis are normally left to the discretion of the supplier when the furnace charge wholly consists of a combination of:

(1) ingots complying with the requirements of clause **5** of this standard and for which an analysis is already available; *and*

(2) properly segregated and identified foundry returns.

For other furnace charge compositions, samples are taken from the melt and analysed at either of the following frequencies:

(3) one analysis sample taken from the melt to represent each cast and analyses made on at least one cast in five for each individual alloy supplied; *or*

(4) as agreed between the supplier and the purchaser at the time of enquiry and order (see item (2)(x) of the note to clause **3**).

Samples of each alloy that have been taken but not analysed are normally kept until the next analysis for that alloy has been carried out and found to be satisfactory.

7.2.2 *Mechanical properties*

7.2.2.1 *Ingots.* For determination of the tensile properties, at least one separately cast bar shall be tested to represent each cast.

7.2.2.2 *Castings.* For determination of the tensile properties, tensile tests shall be carried out in accordance with either item (a) or item (b), whichever yields the less frequent rate of testing:

(a) one test per cast; *or*

(b) one test per alloy for the maximum mass of fettled castings given in table 9.

For determination of hardness (alloys in alloys CC1-TF and G3-TF only) at least one test shall be made to represent each cast or each heat treatment batch, whichever is the smaller.

7.2.3 *Alpha phase content (ingots and castings in alloy HTB1 only).* At least one determination shall be made to represent each cast of ingots or castings.

7.2.4 *Electrical conductivity (castings in HCC1 and alloy CC1-TF only).* No minimum test frequency is specified.

NOTE. Unless electrical conductivity measurements are specifically requested by the purchaser from the options given in appendix A, the tests necessary to verify that a particular batch or consignment of castings in HCC1 or alloy CC1-TF comply with the requirements of **6.5** are left to the discretion of the supplier.

7.3 Retests

7.3.1 *General.* Retests for analysis and tensile test results shall be permitted as specified in **7.3.2** and **7.3.3**.

NOTE. No requirements for retests are specified in respect of microstructure (alloy HTB1 only), freedom from defects, Brinell hardness (of castings) and electrical resistivity (of castings). Actions to be taken in the event that the initial samples fail to meet these requirements should be agreed between the supplier and the purchaser (see item (2)(ix) of note to clause **3**).

7.3.2 *Analysis.* If analysis shows results outside the specification limits (tables 1 to 3, 5 to 7, as appropriate), a further portion of the same sample shall be permitted to be taken for check analysis. If this check analysis shows results that comply with the specification limits, the ingots or castings represented thereby shall be deemed to comply with this standard. If the check analysis shows results that confirm the original analysis, the ingots or castings represented thereby shall be deemed not to comply with this standard.

7.3.3 *Tensile test.* If a test piece fails to meet the requirements for tensile or mechanical properties specified in **5.2** or **6.2** respectively, two further pieces taken at the same time and from the same cast shall be permitted to be tested in the same manner. If one of the further test pieces meets the requirements specified, the ingots or castings represented thereby shall be deemed to comply with this standard. If both of the test pieces fail to meet the requirements specified, the ingots or castings represented thereby shall be deemed not to comply with this standard.

Table 9. Frequency of mechanical property tests relating to castings

Material	Alloy designation	Maximum mass of fettled castings per test for each alloy
		kg
Sand cast aluminium bronze	AB1 AB2 AB3	1000
Sand cast manganese aluminium bronze	CMA1	
Sand cast high tensile brass	HTB1 HTB3	
Cupro-nickel	CN1 CN2	
Gunmetal	LG1 LG2 LG4 G1 G3	5000
Phosphor bronze	PB1 PB2 PB4 LPB1	
Copper-tin alloy	CT1 CT2	
Leaded bronze	LB1 LB2 LB4 LB5	
Chill cast aluminium bronze	AB1 AB2 AB3	
Chill cast manganese aluminium bronze	CMA1	
Brass	SCB1 SCB3 SCB4 SCB6 DCB1 DCB3 PCB1	No tensile tests required
High conductivity copper	HCC1	
Copper-chromium	CC1-TF	

7.4 Certificates or other information to be provided by the supplier

In the case of ingots the analysis of each cast and, where applicable, the tensile test results for each cast shall be provided by the supplier with each consignment of ingots.

NOTE. In the case of castings a certificate of compliance with all the requirements of this standard, including any supplementary requirements specified by the purchaser in accordance with appendix A, should be provided by the supplier with each cast when requested by the purchaser (see item (2)(viii) of the note to clause 3).

8 Test samples

8.1 Samples for tensile tests

8.1.1 *General.* The test samples shall be of suitable size for machining to the dimensions of standard proportional tensile test pieces in accordance with BS 18 : Part 1.

8.1.2 *Ingots.* The test samples shall be re-melted ingots separately cast into sand moulds, except in the case of ingots intended for subsequent die casting for which the test samples should be cast into chill moulds. The forms of the test samples for the different alloys shall be in accordance with appendix E.

8.1.3 *Castings.* The test samples shall be taken as follows.

(a) *Sand castings.* The test samples shall be separately cast into sand moulds from the same cast as the castings they represent. If the castings are to be subsequently heat treated, test samples shall be heat treated with the castings they represent.

The forms of the test samples for the different alloys shall be in accordance with appendix E.

(b) *Chill and die castings.* The test samples shall be separately cast into chill moulds from the same cast as the castings they represent.

NOTE. A recommended form of test sample is given in appendix E.

(c) *Continuous castings.* The test samples shall be taken from the actual castings.

NOTE. If the use of standard proportional tensile test pieces (see **8.1.1**) is precluded by the shape of the casting, e.g. thin walled castings, the form of the test samples and the test results to be achieved should be agreed between the supplier and the purchaser at the time of enquiry and order (see item (2)(vi) of note to clause **3**).

(d) *Centrifugal castings.* The test samples shall be: *either*

(1) taken from the castings; *or*

(2) separately cast from the same cast as the castings they represent (see item (c) of clause **3**).

For castings in sand moulds, separately cast test samples shall be cast into sand moulds. The forms of the test samples for the different alloys shall be in accordance with appendix E.

For castings in chill moulds, separately cast test samples shall be cast into chill moulds.

NOTE. Recommended forms of test samples are given in appendix E.

8.2 Samples for hardness tests (castings in alloys CC1-TF and G3-TF only)

Whenever possible, hardness tests for castings alloys CC1-TF and G3-TF shall be performed on the actual castings. When this is not possible the tests shall be performed on separately cast samples, e.g. the grip ends of tensile test samples.

8.3 Samples for determination of alpha content (alloy HTB1 only)

The alpha content shall be determined on separately cast samples, e.g. the grip ends of separately cast tensile test samples.

9 Test methods

9.1 General

The test samples and test pieces shall not be worked or heat treated before testing, except in the case of test samples that are heat treated with the casting they represent.

9.2 Tensile test

From the test samples taken in accordance with **8.1**, tensile test bars shall be machined to the dimensions of proportional test pieces in accordance with BS 18 : Part 1.

The testing machine shall be calibrated in accordance with BS 1610 and shall comply with the requirements for grade A.

The tests shall be carried out in accordance with BS 18 : Part 1.

9.3 Brinell hardness test

The tests shall be carried out in accordance with BS 240.

NOTE. Wherever possible the tests should be carried out using a ball of 10 mm diameter and a test force of 9.807 kN (1000 kgf). Where this combination is not suitable, an alternative preserving an F/D^2 ratio of 10 should be used.

The test shall consist of three hardness determinations and the average of the three hardness numbers shall be taken as the hardness for the material.

9.4 Determination of alpha content (alloy HTB1 only)

A suitable section of the test sample shall be polished and etched to reveal the microstructure under microscopic examination. The proportion of the alpha phase in the microstructure shall be measured by any suitable counting method. The test shall consist of at least five counts and the average of the five counts shall be taken as the alpha content for the material.

9.5 Electrical conductivity (high conductivity copper, HCC1, and alloy CC1-TF only)

When the electrical conductivity of castings is determined, the test shall be by means of a calibrated eddy current testing instrument.

NOTE. The test conditions should be agreed between the supplier and the purchaser at the time of enquiry and order (see item (2)(vii) of note to clause **3**).

Appendices

Appendix A. Optional supplementary inspection and test procedures for castings

A.1 Introduction

The following optional supplementary inspection and test procedures for castings are available (see item (2)(iii) of the note to clause 3):

(a) analysis: code A1 or A2 (see **A.2.1**);

(b) mechanical property testing: code T1 or T2 (see **A.2.2**);

(c) proof machining or finish machining: code M (see **A.2.3**);

(d) pressure testing: code P (see **A.2.4**);

(e) penetrant flaw detection: code F (see **A.2.5**);

(f) radiographic examination: code R1 or R2 (see **A.2.6**);

(g) electrical conductivity testing: code L (see **A.2.7**).

Examples of optional supplementary inspection and test procedures, with appropriate codings, for typical applications are as follows:

(1) castings requiring machining followed by pressure testing: code MP;

(2) pressure-tight gunmetal castings where corrosion resistance is critical, some analysis, proof machining and pressure testing: code A2MP;

(3) castings in aluminium bronze subject to severely corrosive conditions, some analysis, some test bars, proof machining and flaw detection: code A2T2MF;

(4) copper-chromium castings requiring high strength and high conductivity, some analysis, 100 % hardness test and electrical conductivity: code A2T1L;

(5) castings in gunmetal subject to stress and a significantly corrosive environment, 100 % analysis, some test bars, proof machining, flaw detection, some radiography: code A1T2MFR2;

(6) highly stressed aluminium bronze castings for a corrosive application, 100 % analysis, 100 % test bars, proof machining, flaw detection and full radiography: code A1T1MFR1.

NOTE. Appendix F gives guidance of a general nature on the codes for additional inspection which may be recommended for various classes of work. If more than one requirement applies, the codes are additive.

A.2 Optional procedures

A.2.1 *Codes A1 and A2 (analysis)*

(a) When code A1 is ordered, analyse at least one sample to represent each cast.

(b) When code A2 is ordered, take at least one analysis sample to represent each cast. Analyse the sample(s) from at least one cast in five. Keep samples taken but not analysed until the next analysis has been made and found to be satisfactory.

A.2.2 *Codes T1 and T2 (mechanical property tests)*

(a) When code T1 is ordered, carry out at least one tensile test and/or, where appropriate, one hardness test to represent each cast.

(b) When code T2 is ordered, carry out at least one tensile test and/or, where appropriate, one hardness test to represent each 250 kg of fettled castings.

A.2.3 *Code M (machining).* It is frequently the case that the quality of castings subject to machining cannot be assessed adequately in the as-cast state. Provision is made in this category for machining by the supplier, either partially or fully, before inspection. Visual inspection of the proof machined surface is normally sufficient to identify gross defects, but proof machining is also particularly valuable in conjunction with either pressure testing (code MP) or penetrant flaw detection (code MF).

It is important that the region or regions to be machined before inspection are agreed between the purchaser and the supplier, detailed on the drawing and noted in the purchaser's test schedule. Where the proportion of the ordered castings that are to be proof machined is not stated on the purchaser's test schedule, proof machine all the castings.

A.2.4 *Code P (pressure testing).* Where castings form part of a product (e.g. valve) that is the subject of a British Standard, use the test method and the test pressure that is specified in the relevant British Standard.

Where the castings do not form part of such a product, carry out the pressure test in accordance with the test method, the test conditions and the instructions concerning the production stage at which the test is to be performed, as stated in the purchaser's test schedule. Use either the hydraulic test in accordance with item (a), or an initial hydraulic test followed by the pneumatic test in accordance with item (b).

NOTE. It is recommended that a pneumatic test should not be carried out unless preceded by a hydraulic test to at least twice the proposed air pressure.

(a) *Hydraulic test.* Blank off the castings by a suitable method and subject them to the hydrostatic pressure stated on the purchaser's test schedule. Hold the test pressure for a sufficient length of time to permit adequate inspection and for not less than 5 min.

Any casting from which leakage occurs is deemed to have failed the test.

NOTE. Water is the preferred test medium, but others may be specified on the purchaser's test schedule subject to the agreement of the supplier.

(b) *Pneumatic test.* Blank off the castings by a suitable method, submerge them to a depth of not more than 150 mm in clean water and subject them to the pneumatic pressure stated on the purchaser's test schedule. Hold the test pressure for a sufficient length of time to permit adequate inspection and for not less than 5 min.

Any casting from which leakage occurs is deemed to have failed the test.

NOTE. Air is the preferred test medium but other suitable gases may be specified on the purchaser's test schedule subject to the agreement of the supplier.

Wherever conditions permit carry out the test after machining or, where this is not practicable, after proof machining.

When the proportion of the ordered castings that are to be pressure tested is not stated on the purchaser's test schedule, pressure test all the castings.

A.2.5 *Code F (penetrant flaw detection).* For the detection of surface defects with the aid of penetrants, use the conditions of test stated in the purchaser's test schedule. Where the number of tests is not stated, test all the castings.

Before testing, thoroughly clean the castings by shot blasting or other comparable methods in order to remove all visible residues (e.g. sand, dressings or other deposits) from the mould.

A.2.6 *Codes R1 and R2 (radiographic examination).* Radiographically examine the test regions marked on the purchaser's drawing and all repaired areas, in accordance with the radiographic techniques and standards of acceptance agreed between the supplier and the purchaser and stated on the purchaser's test schedule (see appendix D).

The following classes of examination are available:

(a) code R1: radiography of the test regions on all castings supplied;

(b) code R2: radiography of the test regions of the first castings to be produced to any particular order, followed by check radiographs on a proportion of the remainder, in accordance with the purchaser's test schedule.

NOTE 1. The purchaser's test schedule should state whether he requires to approve the radiographic procedure and also the system of inspection and approval of radiographs required.

NOTE 2. The system of inspection and approval may include the following:

(1) acceptance of the decision of the supplier subject to periodic assessment by a representative of the purchaser;

(2) viewing of each batch of radiographs at the supplier's works by a representative of the purchaser before delivery;

(3) delivery of radiographs with each batch of castings. In this case it is essential that the radiographs are accompanied by sketches and/or other descriptive matter to identify each radiograph with its related casting.

A.2.7 *Code L (electrical conductivity testing).* Carry out at least one resistivity test per cast or heat treatment batch, whichever is the smaller.

Appendix B. The rounding of numbers rule

Table 10 illustrates the application of the rounding rules described in BS 1957.

Table 10. Rounding of numbers

Specification limits		Extreme values which round to specification limits	
min.	max.	min.	max.
–	0.050	–	0.0505
0.2	0.6	0.15	0.65
6	9	5.5	9.4
6.0	9.0	5.95	9.05
7	10	6.6	10.5
7.5	10.5	7.46	10.54

Appendix C. Colour codes for ingots

The following colour codes should be used.

Group A

PB4	Black/red
LPB1	Black
LB2	White
LB4	White/green
LG1	Blue/red
LG2	Blue
SCB1	Green/blue
SCB3	Green
SCB6	Green/brown
DCB1	Yellow/blue
DCB3	Yellow/brown
PCB1	White/blue

Group B

PB1	Yellow
PB2	Yellow/red
CT1	Black/aluminium
LG4	Blue/brown
AB1	Aluminium
AB2	Aluminium/green
CMA1	Aluminium/red
HTB1	Brown
HTB3	Brown/red

Group C

LB1	White/black
LB5	White/brown
SCB4	Green/yellow
CT2	Black/yellow
AB3	Aluminium/blue
CN1	Red/white
CN2	Red/green
G1	Red
G3	Blue/black

The colours used for identifying ingots should be those specified in BS 381C as follows.

	No.
Yellow	309
Red	537
Black	–
White	–
Blue	166
Green	218
Brown	414
Aluminium	–

Appendix D. Information to be included in the purchaser's test schedule

It is recommended that provision should be made for the following minimum information to be included.

General

Component description.
Drawing numbers.
Alloy specification.
Inspection coding.
Pattern numbers.

Analysis

Whether code A1 or A2 (analysis) is applicable.

Mechanical testing

Whether code T1 or T2 (mechanical property tests) is applicable.

Machining

Whether code M (machining) is applicable.
Whether full machining or proof machining is required.
Reference to the drawings to call attention to all necessary machining information.
Proportion of castings to be machined if less than 100 %.

Pressure testing

Whether code P (pressure testing) is applicable.
Type of test.
Test pressure and working pressure.
Special test requirements.
Proportion of castings to be tested if less than 100 %.

Penetrant flaw detection

Whether code F (penetrant flaw detection) is applicable.
Type of test.
Areas to be subject to testing with reference to the casting.
Whether testing is to be carried out before or after machining or proof machining.
Proportion of castings to be tested if less than 100 %.

Radiography

Whether code R1 or R2 (radiography) is applicable.
Proportion of castings to be radiographed when R2 is specified.
Areas to be subject to testing with reference to the drawing.
The system of agreement on technique.
The system of radiograph approval.

Electrical conductivity

Whether code L (electrical conductivity) is applicable.
Methods of test acceptable.

Certificates

Whether the following certificates are required:

(a) certificate of analysis;

(b) certificate of mechanical property test results;

(c) certificate of compliance:

(1) with the standard;

(2) with the test schedule.

Arrangements for inspection

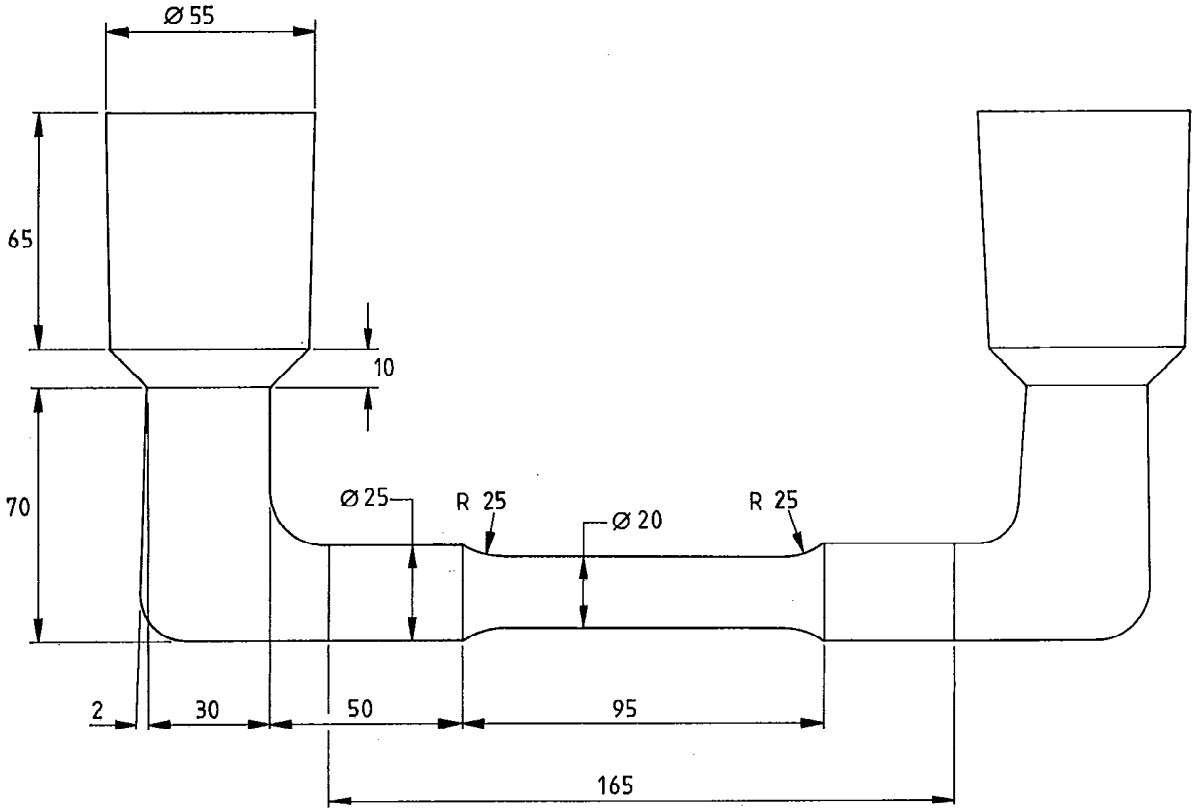
Details of any outside inspection required by the purchaser before delivery of the castings.

Representatives of the purchaser

Details of the names of the representative of the design department and purchasing department with whom contact should be made.

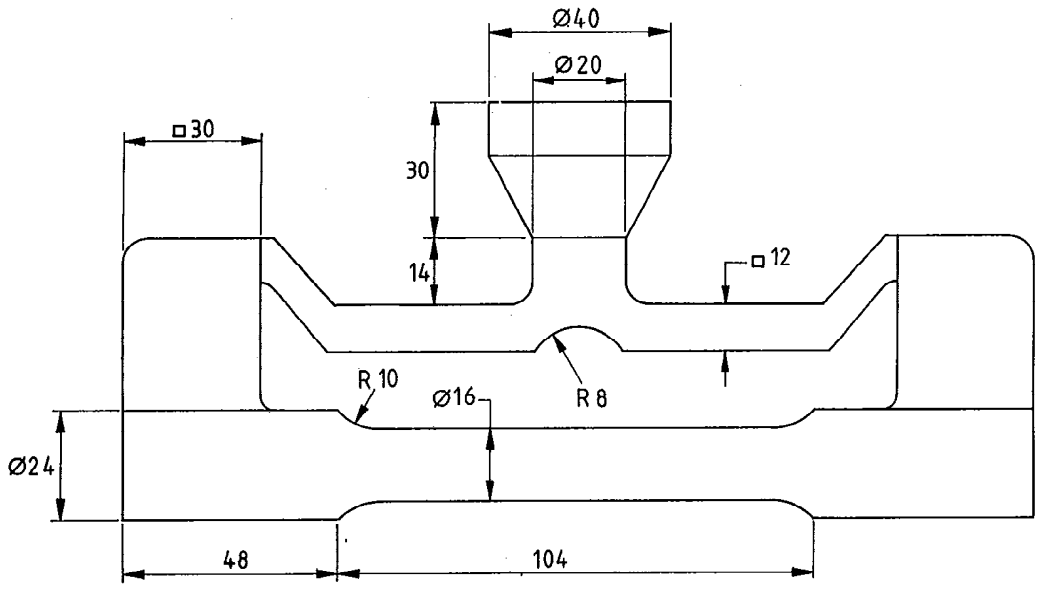
Appendix E. Shapes of standard test bars

The shape of sand cast test bars specified for long and short freezing range copper alloys are shown in figures 1 and 2 respectively. The shape of a recommended chill cast test bar is shown in figure 3.



(a) BNF 'Cast to shape' test bar pattern dimensions

All dimensions in millimetres (not to scale).

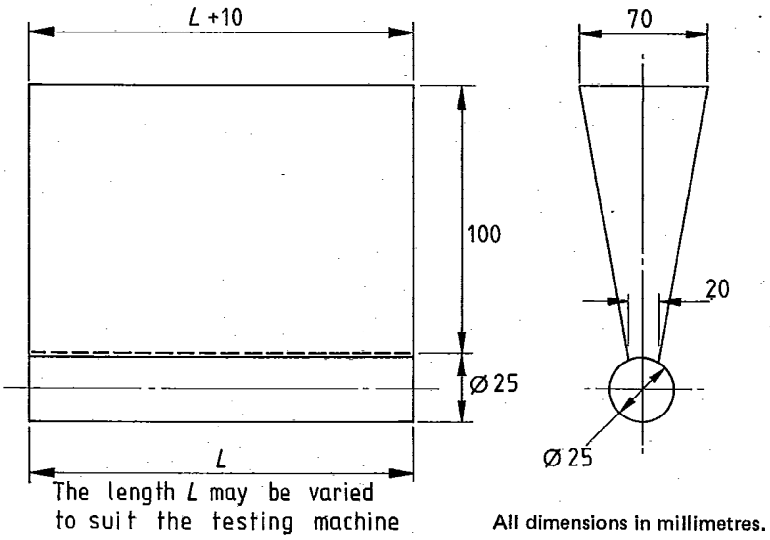


(b) Alternative test bar pattern dimensions

All dimensions in millimetres (not to scale).

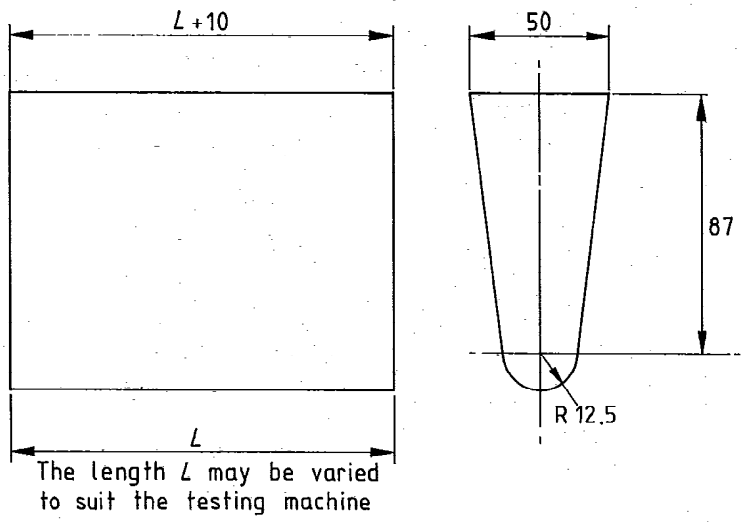
NOTE. Test bars (a) or (b) are used for the following alloys:
LG1, LG2, LG4 and G1.
The test bars may also be used, when required for the following alloys:
PB4, LPB1, LB1, LB2, LB4, LB5, PB1, PB2, CT1, CT2, G3 and G3-TF.

Figure 1. Sand cast test bars for long freezing range alloys



NOTE. This test bar is used for the following alloys:
AB1, AB2, AB3, CMA1, HTB1, HTB3, CN1 and CN2.

Figure 2. Sand cast test bar for short freezing range alloys



All dimensions in millimetres.

Figure 3. Recommended chill cast test bar

Appendix F. Guide to inspection grading

Guidance of a general nature on the codes for additional inspection which may be recommended for various classes of work is given in table 11. Should more than one requirement apply the codes are additive.

NOTE. See also item (2)(iii) of the note to clause **3.**

Table 11. Guide to inspection grading

How critical	Consequence of failure	Corrosion resistance	Pressure tightness	Strength level	Wear resistance	Conductivity	
						HCC1	CC1-TF
Slight	Slight	–	–	–	–	–	–
Slight	Severe	A2	MP	T2MF	A2	L	L
Moderate	Slight	–	MP	–	–	L	L
Moderate	Severe	A2MF	MP	T2MFR2	A2MF	L	A2T2L
Severe	Slight	A1	MP	A1T2MF	A1	L	A1T2L
Severe	Severe	A1MF	MPFR2	A1T1MFR1	A1MF	L	A2T1L

NOTE. For castings in aluminium bronzes, AB1, AB2, AB3, in CMA1, in high tensile brasses HTB1 and HTB3 and in cupro-nickels CN1 and CN2, it is recommended that analysis and mechanical property tests always be called for, i.e. grades A1 or A2 and T1 or T2 depending on the applications.

Appendix G. A guide to alloy selection

G.1 Introduction

This appendix has been prepared to provide guidance to the design engineer in selecting the most appropriate alloy and to give data upon which design can be based. The data is for information only and should not be used as the basis of agreement between the supplier and the purchaser.

The information given is quoted in the following form.

G.2 General considerations

G.2.1 Corrosion resistance

G.2.2 Wear resistance: bearings and gears

G.2.3 Elevated temperature service

G.2.4 Pressure tightness

Table 12. Suitability for casting pressure-tight sand castings

Table 13. Machining properties

Table 14. Joining properties

G.3 Casting processes and suitability for casting processes

Table 15. Suitability for casting processes

G.4 Typical mechanical and physical properties

Table 16. Typical tensile properties and hardness values

Table 17. Dividing factors for variations in strength of castings

Table 18. Typical fatigue properties

Table 19. Typical impact properties at room temperature

Table 20. Typical impact properties at various temperatures

Table 21. Typical creep properties at elevated temperatures

Table 22. Typical electrical and thermal properties

Table 23. Density and coefficient of thermal expansion

Table 24. Typical values for magnetic permeability

G.2 General considerations

G.2.1 *Corrosion resistance*

G.2.1.1 *Introduction.* These notes are intended to give general guidance on the selection of an alloy. It is emphasized most strongly that it is impossible to do more than give general guidance as local conditions can materially alter the behaviour of an alloy. It is essential that full details of the service conditions be taken into account. The user is strongly recommended to consult his supplier unless he has previous experience of the behaviour of copper alloys in the particular circumstances concerned.

G.2.1.2 *Atmospheric corrosion.* All the cast copper alloys have good resistance to atmospheric corrosion, although most undergo superficial tarnishing generally resulting in the development of the well-known greenish patina. Corrosion rates of copper base alloys are higher in sulphur-bearing atmospheres and such alloys are, therefore, less suitable for use in atmospheres where the concentration of sulphur dioxide reaches a high level, with the exception of alloy G3 which is suitable for this application. Alloy AB2 can be used at moderate levels of contamination.

G.2.1.3 *Natural waters.* Corrosion rates in natural waters are generally negligible and the cast brasses are traditionally used for plumbing and similar fittings. Pipe fittings made from duplex brasses such as DCB1, DCB3, PCB1, SCB3 and HTB1 may suffer dezincification in supply waters in some areas. Terminal fittings such as taps, radiator valves and fittings in closed circuit central heating systems are not affected. Some mine waters may be appreciably acid in character and these are more aggressive, especially where they contain iron salts, in particular ferric chloride. The phosphor bronzes, aluminium bronze AB2 or alloy CMA1 are the most suitable alloys for such applications.

G.2.1.4 *Sea water.* The phosphor bronzes and gunmetals have notably good resistance to corrosion by sea-water and are used for such purposes as pipe fittings, cocks and pump bodies. The high zinc brasses DCB1, DCB3, PCB1, SCB1 and SCB3, tend to undergo slow dezincification.

High tensile brasses of suitable composition are widely used for marine propellers. Aluminium bronze AB2, aluminium silicon bronze AB3, and alloy CMA1 have outstanding resistance to sea-water under most conditions of service and are used extensively for such items as pump impellers, marine propellers, valves and under-water fittings. Whilst AB1 also exhibits good general corrosion resistance, it suffers dealuminification under some circumstances, notably in crevices and under stagnant, non-aerated conditions.

The cupro-nickels CN1 and CN2 have high resistance to sea water. CN1 has outstanding resistance to impingement erosion.

G.2.1.5 *Boiler feed waters.* The phosphor bronzes, copper-tin CT1, gunmetals, aluminium bronzes AB1 and AB2 and alloy CMA1 are all used for handling boiler feed waters. The brasses tend to suffer dezincification and are not generally suitable. Dealuminification of aluminium bronze AB1 may sometimes occur under adverse conditions.

G.2.1.6 *Mineral acids.* Copper alloys are not completely resistant to attack by acids, but rates of attack in many acids where conditions are non-oxidizing are very low, ranging from about 0.05 mm to 2.0 mm per year according to the concentration and degree of aeration. The best resistance to attack is afforded by aluminium bronze AB2. The phosphor bronzes and CT1 are also very suitable for handling dilute acids. Leaded bronzes are sometimes recommended for dilute sulphuric acid. Brasses are not generally satisfactory. Corrosion rates are higher in hydrochloric acid than in sulphuric acid, but the phosphor bronzes, CT1, aluminium bronzes AB1 and AB2, and alloy CMA1 are frequently used. The aluminium bronzes AB1 and AB2, and CMA1 find considerable application in both hydrochloric and sulphuric acid steel pickling and metal treatment processes. The aluminium bronzes also show useful resistance to hydrofluoric acid.

Strong aeration or the presence of oxidizing salts often increase the rate of attack on copper alloys with the exception of the aluminium bronzes whose corrosion can be significantly reduced under many oxidizing conditions, notably in pickling acid solutions containing 'ferric' iron salts.

G.2.1.7 *Organic acids.* The copper alloys have good resistance to organic acids and salts and the gunmetals, phosphor bronzes, CT1, aluminium bronzes and some special alloy compositions are used in many food processing applications involving dilute acids such as acetic acid, formic acid, etc. The aluminium bronzes, notably AB2, also find some application in the processing of acetic acid.

G.2.1.8 *Alkalis.* The resistance of the copper alloys to alkaline solutions, although not so high as to acids, enables them to be used for handling many alkalis and salt solutions. All the alloys suffer considerable attack in solutions of ammonia or ammonium salts and they are unsatisfactory for these applications.

G.2.1.9 *Food products.* Copper alloys are widely used for handling food products, although in many cases they are given a heavy coating of tin. This is not so much to protect the alloys against attack, but rather to avoid the risk of traces of copper affecting the food. Very small amounts of copper can cause discoloration or an alteration in the flavour of certain foods. Leaded alloys should not be used.

G.2.1.10 *Stress corrosion.* There is a danger of stress corrosion with stressed components cast in beta brass HTB3. Failure takes the form of cracks spreading rapidly with little or no general corrosion. Two conditions are necessary, firstly, the presence of tensile stresses and, secondly, exposure to a corrosive medium which may include industrial or marine atmospheres.

G.2.1.11 *High velocities.* For handling high velocity natural water or sea-water, the maximum resistance to impingement attack is offered by aluminium bronze AB2, alloy CMA1, gunmetal G1, or copper-tin CT1.

G.2.2 *Wear resistance: Bearings and gears*

G.2.2.1 *Introduction.* Foundries specializing in this class of work will, in many cases, be able to give valuable assistance in the selection of a suitable alloy. The information normally required before a decision can be taken is as follows:

(a) working load;

(b) hardness and material of shaft or mating gear;

(c) surface speed at the bearing face;

(d) lubrication (method of lubrication, lubricant, and possibility of interruption of supply);

(e) working temperature with consideration of peak temperature;

(f) impact loading;

(g) abrasive conditions;

(h) backing for bearings.

G.2.2.2 *Working load.* The working load for bearings and bushes should take into account the ability of the assembly to provide support, the size of the bearing, and the projected area taking the load. The material should be well within its compressive load limits and the fatigue strength, hardness and bearing properties should be sufficient to resist surface cracking.

Whilst the working load is dependent on the design of the structure supporting the bearing, the compressive strength and resistance to cracking are to some extent related to each other. The 0.2 % proof stress both in tension and compression are approximately the same and the performance may therefore be estimated from table 16.

Similar considerations prevail in gear and wormwheel design. The wheel should be designed so that the tooth web and other sections are capable of withstanding the axial and tangential loads put upon them. BS 721 provides recommendations in wormwheel design. As the aluminium bronzes and high tensile brasses do not possess ideal bearing qualities, the harder phospher-bronzes of the PB2 type are commonly preferred for these conditions.

G.2.2.3 *Hardness and material of shaft or mating gear.* Hardened steel or case hardened steel shafts require a hard bearing material, provided there is adequate lubrication to resist wear and to ensure freedom from pick-up of the bearing material by the shaft. The converse applies for soft shafts, however, which are liable to scoring by the harder materials and also pick-up of the shaft material by hard bearing bronzes. For the softer shafts, the leaded alloys are more accommodating, whilst the harder phosphor-bronzes are generally used for the harder shafts.

G.2.2.4 *Surface speed at the rubbing face.* Surface speeds, by themselves, are not the operative factor in alloy selection because their effect depends on lubrication and working load, surface finish and running clearance to determine the degree of continuity of the oil film and the surface temperature of the mating parts. However, extremes and rapid and large changes of speed accentuate the effects of the other factors.

G.2.2.5 *Lubrication.* Unless operating under negligible load conditions, bearing materials will not withstand a complete absence of lubrication. However, bearing design should necessarily allow for temporary absence of lubrication in very many applications, particularly under starting conditions. The leaded alloys, particularly the leaded bronzes, are very useful under such conditions as the lower dry coefficient of friction reduces the chance of pick-up or seizure in the event of a temporary breakdown of lubrication. It should be emphasized, however, that for any lengthy period of running, the leaded alloys require as much lubrication as the harder bearing materials in order to resist wear. Where the bearing surface area is adequate in relation to the load, phosphor-bronze bearing surfaces may be grooved and filled with a suitable graphite wax compound to provide a dry lubricant.

G.2.2.6 *Working temperature with consideration of peak temperature.* Table 21 gives thermal conductivity values for copper alloy castings. In many cases, lubricating oil temperatures are erroneously quoted as the operating temperatures of bearings or gears. Surface temperatures are usually considerably in excess of the oil temperature and it is the surface temperature which is the operative factor.

G.2.2.7 *Impact loading.* Although true impact loading is not a condition normally associated with bearings or correctly designed gears, bearings and more often gears are occasionally subjected to shock loading. More generally, impact loading is associated with resistance to pounding.

G.2.2.8 *Abrasive material.* The presence of abrasive material is, of course, to be avoided wherever possible. Where working conditions make it necessary, the presence of abrasive material should be taken into consideration in the operation of bearings. The leaded alloys LB2, LB4 and LB5 are used in certain field conditions because of their ability to absorb abrasive particles which become embedded in the surface of the bearing.

G.2.2.9 *Backing for bearings.* Most bearings are secured into a rigid housing of either cast iron, steel or aluminium alloy. Phosphor-bronzes, gunmetals, the leaded gunmetals and the low-lead leaded bronzes generally have sufficient strength to render the type of backing for the bearing relatively unimportant so long as the structure is rigid enough to carry the load. The high-lead leaded bronzes of the LB1 and LB5 types, however, because of their greater plasticity and lower operative strength, require greater attention to be paid to their method of support.

Gunmetals and phosphor bronzes are themselves often used as backing materials for white metal bearings.

G.2.2.10 *General recommendations.* It is recommended that, where appropriate, continuous, chill or centrifugal casting be selected for wear resisting applications. These casting methods generally provide high levels of soundness and a more suitable structure to give consistent performance. In the specific recommendations given in items (a) and (b) below, the alloys are given in order of preference.

(a) *Bearings.* For hard shafts with any combination of high working load, high speed, impact loading or pounding; when there is adequate lubrication and good alignment: PB1, PB4, PB2.

For hard or moderately hard shafts with loads and speeds moderate or low with rather less adequate lubrication and alignment: LB2, LB4, LPB1.

For soft (mild steel) shafts with low working temperatures, low impact loading or pounding, in conjunction with doubtful lubrication for short periods or misalignment and where adequate backing for the bearing should be provided: LB5, LB1, LB4.

For non-critical applications with low loads and adequate lubrication: LG2, LG4, LB4.

(b) *Gears.* Heavy duty gears and wormwheels with high working loads or high speeds and with adequate lubrication and good alignment. Some shock loading and presence of abrasive material can be tolerated: PB2, PB1.

Very heavy loads and slow speeds with good lubrication and alignment: PB2, AB2.

Medium duty gears with adequate lubrication and alignment: PB4.

Very light duty gears when loading is negligible: LG2, DCB3, AB1.

G.2.3 *Service at elevated temperatures (including superheated steam)*

G.2.3.1 *Introduction.* When considering service at elevated temperatures the important factors are resistance to oxidation, load carrying capacity and structural stability.

G.2.3.2 *Resistance to oxidation.* Some of the copper base alloys contain additions of aluminium and these have exceptional resistance to oxidation. The aluminium bronzes, alloy CMA1 and certain of the high tensile brasses remain practically unaffected by oxidation almost up to the melting point. The casting alloys containing no aluminium are less resistant to oxidation but suffer no more than superficial tarnishing at temperatures up to 320 °C. Copper and copper chromium oxidize more readily than the other alloys specified in this standard.

G.2.3.3 *Load carrying capacity.* Despite the relatively good room temperature mechanical properties of some of the alloys, none of the cast copper base alloys are suitable for sustaining high loads at high temperatures. Their high temperature applications are mainly in cases where resistance to corrosion and oxidation are important and steel is unsuitable.

In connection with load carrying capacity at elevated temperatures, it should be emphasized that the mechanical properties of an alloy at room temperature are not a reliable guide to its performance at elevated temperatures and that it is not safe to base design stresses on the results of short time tensile tests carried out at the operating temperature. Safe working stresses can only be determined with confidence from the results of creep tests of several thousand hours' duration in which the deformation of the specimen under load is recorded as time proceeds. Under sustained stress at high temperatures metals undergo slow permanent deformation (plastic strain) and the information most useful to the designer is the load which will cause not more than a certain amount of plastic strain in a given time. For long term applications the load to produce 0.1 % plastic strain (an extension or compression of 0.001 mm/mm) in 10 000 h is often determined. Unfortunately only a limited number of alloys have been evaluated in this way.

Although they have good room temperature properties, all the brasses begin to fall in strength at temperatures above 150 °C and they are not suitable for load carrying applications at higher temperatures. There are, however, many applications where the loads involved are very low and the resistance of the brasses to oxidation and corrosion makes them a good choice.

G.2.3.4 *Superheated steam.* Many years of service experience have proved the suitability of gunmetal components for handling superheated steam at temperatures up to 260 °C. Aluminium bronzes have also been used for similar applications, but under service conditions where the steam contains chemically active impurities, selective attack on these alloys has been experienced. The aluminium bronzes are not recommended for handling steam at high temperatures if the steam is contaminated with small amounts of sulphur dioxide or chloride; alloy CMA1 is not affected by such contaminants and is suitable for this application.

G.2.4 *Pressure tightness.* Hydraulic or gas pressure is a particularly searching test of the quality of a casting, revealing defects which might have quite insignificant effects on the strength of the casting. Any discontinuities through the metal forming the wall of the casting, however small, are potential sources of leakage.

Given a reasonable design, it is possible to make pressure-tight castings from any of the materials covered by this British Standard.

The best alloys for the production of pressure-tight castings are those containing substantial amounts of lead and the majority of pressure-tight castings are made from leaded gunmetals. These leaded alloys are also very much more easily machined than other copper base alloys, an important consideration with such castings as valves and pump bodies. In designing castings for these applications, sudden changes in thickness in adjacent sections should be avoided as far as possible. Where this cannot be done the angles should be rounded or filleted. The greatest number of failures in pressure tightness occur round areas where there are sudden changes of wall thickness. Machining allowances should be kept to a minimum.

The aluminium bronzes, high tensile brasses and alloy CMA1 require careful foundry techniques but it is possible to make excellent pressure-tight castings from these alloys and, because of the greatly increased mechanical properties, it is possible to make weight reductions in the castings which should more than compensate for the extra costs involved in producing them.

A test of pressure tightness frequently applied to small valve bodies and similar castings is that in which air at a pressure of 700 kPa is applied to the casting submerged in water. This test is applied to castings such as valve bodies with masses approximately between 0.1 kg and 10 kg. For larger castings it is more usual to test under hydraulic pressure.

Suitability of alloys for casting pressure-tight sand castings is given in table 12.

Table 12. Suitability for casting pressure-tight sand castings

Alloy designation	Thin sections	Thick sections
Group A		
PB4	3	3
LPB1	2	2
LB2	2	2
LB4	2	2
LG1	1	2
LG2	1	2
SCB1	1	1
SCB3	1*	1*
SCB6	1	1
Group B		
HCC1	1	2
CC1-TF	2	2
PB1	3	3
PB2	3	3
CT1	2	3
LG4	2	1
AB1	1	1
AB2	1	1
CMA1	1	1
HTB1	1	1
HTB3	1	1
Group C		
LB1	2	3
LB5	2	3
G1	2	2
G3	1	1
G3-TF	1	1
SCB4	1	1
CT2	2	3
AB3	1	1
CN1	1	1
CN2	1	1

1 = Suitable
2 = Less suitable
3 = Unsuitable

*For pressure-tight castings, aluminium to be not greater than 0.02 %.

Table 13. Machining properties

Alloy designation	Rating
Group A	
PB4	2
LPB1	1
LB2	1
LB4	1
LG1	1
LG2	1
SCB1	1
SCB3	1
SCB6	3
DCB1	2
DCB3	1
PCB1	2
Group B	
HCC1	3
CC1-TF	3
PB1	2
PB2	2
CT1	2
LG4	1
AB1	3
AB2	3
CMA1	3
HTB1	3
HTB3	3
Group C	
LB1	1
LB5	1
G1	2
G3	2
G3-TF	2
SCB4	2
CT2	2
AB3	2
CN1	3
CN2	3

The following ratings are based on comparisons between the copper alloys rather than with other metals.

1 = Excellent
2 = Good
3 = Satisfactory with special techniques

Table 14. Joining properties

Alloy designation	Arc welding (metal and inert gas)	Oxy-acetylene welding (light sections)	Oxy-acetylene bronze welding and brazing	Silver brazing	Soft soldering
Group A					
PB4	3	3	3	1	1
LPB1	4	4	3	1	1
LB2	4	4	4	3	1
LB4	4	4	4	3	1
LG1	3	4	3	2	1
LG2	3	4	3	2	1
SCB1	3	3	3	2	1
SCB3	3	3	3	1	1
SCB6	2	1	1	1	1
DCB1	3	3	3	1	2
DCB3	4	4	4	1	2
PCB1	3	3	3	1	2
Group B					
HCC1	3	3	2	1	1
CC1-TF	3	3	3	3	1
PB1	3	4	2	1	1
PB2	3	4	2	1	1
CT1	3	4	2	1	1
LG4	3	4	3	2	1
AB1	1	4	3	3	3
AB2	1	4	3	3	3
CMA1	1	4	3	3	3
HTB1	1	3	4	1	2
HTB3	2	2	4	3	3
Group C					
LB1	4	4	4	3	2
LB5	4	4	4	3	2
G1	3	4	1	1	1
G3	3	4	1	1	1
G3-TF	3	4	1	1	1
SCB4	3	3	3	1	1
CT2	2	4	2	1	1
AB3	1	4	3	3	3
CN1	3	4	3	3	3
CN2	3	4	3	3	3

1 = Excellent
2 = Satisfactory
3 = Possible with special techniques
4 = Unsatisfactory

G.3 Casting processes and suitability for casting processes

G.3.1 *Casting processes*

G.3.1.1 *Sand casting.* Sand casting may be chosen for shaped castings of any complexity. Sand casting is suitable for castings from 0.1 kg to several tonnes, particularly for small quantities. The general surface finish obtainable is moderate and the quality level is more vulnerable to occasional variations than with other casting methods.

G.3.1.2 *Shell moulding.* Shell moulding is a special method of sand casting which enables moderate or large quantities of castings to be produced with a general level of dimensional tolerances and surface finish superior to other sand castings. This is a mechanical system which is applicable only to small and medium size work.

G.3.1.3 *Die casting.* Die castings may be produced as pressure die castings in brass, or gravity die castings in brass, high tensile brass or aluminium bronze. Die casting is suitable for large quantity production (greater than 1000 off) for gravity die castings of mass to about 10 kg and is suitable for large quantity production (greater than 10 000 off) for pressure die castings of mass to about 2 kg. The surface finish is good, and tolerances may be kept consistently closer than is normal for sand castings.

G.3.1.4 *Continuous casting.* Continuous casting is limited to lengths of solid or hollow sectioned rods, although special shapes are also available. Continuous castings are obtainable mainly in phosphor-bronzes, leaded bronzes and gunmetals. Surface finish and general quality levels are consistently good.

G.3.1.5 *Centrifugal casting.* Centrifugal casting is confined to shapes broadly based on a cylinder or ring, although shapes with lugs, bosses, etc., on the outside face can be produced. Cylinders from 100 mm to 2 m in diameter may be obtained. The general quality level closely approaches that of continuous castings. Most alloys can be cast by this process.

G.3.1.6 *Chill casting.* Chill casting is a form of die casting for the production of short bars and shaped castings in metal dies. Chill castings may be cored. Chill casting is mainly applicable to phosphor-bronzes, leaded bronzes and gunmetals.

G.3.2 *Suitability for casting processes.* Guidance on the suitability of the various alloy types for the casting processes is given in table 15.

G.4 Typical mechanical and physical properties

Typical properties are given in tables 16 to 24.

Table 15. Suitability for casting processes (see also item (a) of clause 3)

Alloy designation	Sand casting	Gravity die casting	Continuous casting	Centrifugal casting	Chill casting
Group A					
PB4	2	3	1	1	1
LPB1	2	3	1	2	1
LB2	2	4	1	2	1
LB4	2	4	1	2	1
LG1	1	3	2	2	2
LG2	1	3	1	1	2
SCB1	1	–	2	3	–
SCB3	1	–	2	3	–
SCB6	1	–	2	3	–
DCB1	–	1	–	2	–
DCB3	–	1	3	2	–
PCB1	–	1	–	2	–
Group B					
HCC1	2	3	3	2	–
CC1-TF	2	3	3	2	–
PB1	2	3	1	1	1
PB2	2	3	1	1	1
CT1	2	–	–	–	–
LG4	1	3	1	1	2
AB1	2	1	3	2	–
AB2	2	2	3	2	2
CMA1	2	2	3	2	2
HTB1	2	2	–	2	–
HTB3	2	4	–	2	–
Group C					
LB1	3	4	1	2	2
LB5	3	4	3	3	2
G1	2	3	1	2	3
G3	2	3	2	2	3
G3-TF	2	3	2	2	3
SCB4	1	–	–	3	–
CT2	2	3	1	1	1
AB3	2	–	–	2	–
CN1	2	–	–	–	–
CN2	2	–	–	–	–

1 = Excellent
2 = Satisfactory
3 = Possible with special techniques
4 = Unsuitable
A dash denotes that the process is not applicable to this alloy.

Table 16. Typical tensile properties and hardness values*

Designation	Freezing range category	Tensile strength				0.2 % proof stress				Elongation on $5.65\sqrt{S_o}$				Hardness				Designation
		Sand†	Chill	Continuous	Centrifugal‡	Sand†	Chill	Continuous	Centrifugal‡	Sand	Chill	Continuous	Centrifugal‡	Sand	Chill	Continuous	Centrifugal‡	
		N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	%	%	%	%	HB	HB	HB	HB	
Group A																		*Group A*
PB4	L	190-270	270-370	330-450	280-400	100-160	140-230	160-270	140-230	3-12	2-10	7-30	4-20	70-95	95-140	95-140	95-140	PB4
LPB1	L	190-250	220-270	270-360	230-310	80-130	130-160	130-200	130-160	3-12	2-12	5-18	4-22	60-90	85-110	85-110	85-110	LPB1
LB2	L	190-270	220-280	280-390	230-310	80-130	140-200	160-220	140-190	5-15	3-7	6-15	5-10	65-85	80-90	80-90	80-90	LB2
LB4	L	160-190	200-270	230-310	220-300	60-100	80-110	130-170	80-110	7-12	5-10	9-20	6-13	55-75	60-80	60-80	60-80	LB4
LG1	L	180-220	180-270	–	–	80-130	80-130	–	–	11-15	2-8	–	–	55-65	65-80	–	–	LG1
LG2	L	200-270	200-280	270-340	220-310	100-130	110-140	100-140	110-140	13-25	6-15	13-35	8-30	65-75	80-95	75-90	80-95	LG2
SCB1	S	170-200	–	–	–	80-110	–	–	–	18-40	–	–	–	45-60	–	–	–	SCB1
SCB3	S	190-220	–	–	–	70-110	–	–	–	11-30	–	–	–	45-65	–	–	–	SCB3
SCB6	S	170-190	–	–	–	80-110	–	–	–	18-40	–	–	–	45-60	–	–	–	SCB6
DCB1	S	–	280-370	–	–	–	90-120	–	–	–	23-50	–	–	–	60-70	–	–	DCB1
DCB3	S	–	300-340	–	–	–	90-120	–	–	–	13-40	–	–	–	60-70	–	–	DCB3
PCB1	S	–	280-370	–	–	–	90-120	–	–	–	25-40	–	–	–	60-70	–	–	PCB1
Group B																		*Group B*
HCC1	S	160-190	–	–	–	–	–	–	–	23-40	–	–	–	40-45	–	–	–	HCC1
CC1-TF	S	270-340	–	–	–	170-250	–	–	–	18-30	–	–	–	100-120	–	–	–	CC1-TF
PB1	L	220-280	310-390	360-500	330-420	130-160	170-230	170-280	170-230	3-8	2-8	6-25	4-22	70-100	95-150	100-150	95-150	PB1
PB2	L	220-310	270-340	310-430	280-370	130-170	170-200	170-250	170-200	5-15	3-7	5-15	3-14	75-110	100-150	100-150	100-150	PB2
CT1	L	230-310	270-340	310-390	280-370	130-160	140-190	160-220	180-190	6-20	5-15	9-25	6-25	70-90	90-130	90-130	90-130	CT1
LG4	L	250-320	250-340	300-370	280-370	130-140	130-160	130-160	130-160	16-25	5-15	13-30	6-30	70-85	80-95	80-95	80-95	LG4
AB1	S	500-590	540-620	–	560-650	170-200	200-270	–	200-270	18-40	18-40	–	20-30	90-140	130-160	–	120-160	AB1
AB2	S	640-700	650-740	–	670-730	250-300	250-310	–	250-310	13-20	13-20	–	13-20	140-180	160-190	–	140-180	AB2
CMA1	S	650-730	670-740	–	–	280-340	310-370	–	–	18-35	27-40	–	–	160-210	–	–	–	CMA1
HTB1	S	470-570	500-570	–	500-600	170-280	210-280	–	210-280	18-35	18-35	–	20-38	100-150	–	–	100-150	HTB1
HTB3	S	740-810	–	–	740-930	400-470	–	–	400-500	11-18	–	–	13-21	150-230	–	–	150-230	HTB3

See notes 1 and 2 and footnotes at end of table.

Table 16 *(concluded)*

Designation	Freezing range category	Tensile strength				0.2 % proof stress				Elongation on 5.65 $\sqrt{S_o}$				Hardness				Designation
		Sand†	Chill	Continuous	Centrifugal‡	Sand†	Chill	Continuous	Centrifugal‡	Sand	Chill	Continuous	Centrifugal‡	Sand	Chill	Continuous	Centrifugal‡	
		N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	N/mm² (= MPa)	%	%	%	%	HB	HB	HB	HB	
Group C																		*Group C*
LB1	L	170-230	200-270	230-310	220-300	80-110	130-160	130-190	130-160	4-10	3-7	9-10	4-10	50-70	70-90	70-90	70-90	LB1
LB5	L	160-190	170-230	190-270	190-270	60-100	80-110	100-160	80-110	5-10	5-12	8-16	7-15	45-65	50-70	50-70	50-70	LB5
G1	L	270-340	230-310	300-370	250-340	130-160	130-170	140-190	130-170	13-25	3-8	9-25	5-16	70-95	85-130	90-130	70-95	G1
G3	L	280-340	—	340-370	—	140-160	—	170-190	—	16-25	—	18-25	—	70-95	—	90-130	—	G3
G3-TF	L	430-480	—	430-500	—	280-310	—	280-310	—	3-5	—	3-7	—	160-180	—	160-180	—	G3-TF
SCB4	S	250-310	—	—	—	70-110	—	—	—	18-40	—	—	—	50-75	—	—	—	SCB4
CT2	L	280-330	—	300-350	300-350	160-180	—	180-210	180-210	12-20	—	8-15	10-15	75-110	—	100-150	100-150	CT2
AB3	S	460-500	—	—	—	180-190	—	—	—	20-30	—	—	—	—	—	—	—	AB3
CN1	S	480-540	—	—	—	300-320	—	—	—	18-25	—	—	—	170-200	—	—	—	CN1
CN2	S	480-540	—	—	—	300-320	—	—	—	18-25	—	—	—	170-200	—	—	—	CN2

NOTE 1. These typical mechanical properties are included to supplement the minimum requirements specified in this standard in order to provide the user with guidance on design. The values give a direct indication of the properties of continuous, centrifugal or chill castings as the test pieces are taken from the castings themselves. The values quoted for sand castings are the results of tests on separately cast test bars and therefore do not necessarily give a direct indication of properties in castings. The wide range of properties quoted for these continuous, chill and centrifugal castings is largely due to the effect of thickness*. As a general principle, material of heavier section tends towards the lower end of the range for tensile strength, proof stress and hardness, while the elongation lies at the upper end of the range. The column headed 'Freezing range category' in the table is included for design purposes.

NOTE 2. Current practice uses the 0.2 % proof stress as the basis of stress calculations in design. Table 17 indicates factors by which this value may be divided to make allowance for variations in strength of castings resulting from the casting process and the effect of freezing range of the alloy.

*Values in the table based on 15 mm to 40 mm thickness.
†On separately cast test bars.
‡Values apply to samples cut from centrifugal castings made in metallic moulds. Minimum properties of centrifugal castings made in sand moulds are the same as for other sand castings.

Table 17. Dividing factors for variations in strength of castings

Casting process	Short freezing range alloys (marked S)	Long freezing range alloys (marked L)
Continuous casting	–	1.1
Centrifugal casting	1.2	1.2
Chill casting	–	1.4
Die casting	1.3	–
Sand casting	1.4	1.6

NOTE. Following this calculated reduction of the 0.2 % proof stress, factors of safety pre-determined for the particular design may then be applied to this value according to normal engineering practice.

Table 18. Typical fatigue properties

Alloy designation	Process	Fatigue limit ± (10^8 cycles)
		N/mm² (= MPa)
Group A		
LB2	sand/chill	80
	continuous	150*
LG2	sand/chill	70
	continuous	110
LB4	continuous	90*
DCB3	chill	110
Group B		
PB1	sand/chill	110
	continuous	150*
LG4	sand/chill	80
	sand/chill	80*
AB1	sand/chill	200
AB2	sand	220
CMA1	sand	230
HTB1	sand	140
HTB3	sand	170
Group C		
G1	sand/chill	90
	continuous	150

NOTE. The values given in this table are mean values resulting from tests obtained on specially cast test pieces tested in air on a Wohler-type machine.

*Estimated from progressive loading fatigue tests.

Table 19. Typical impact properties at room temperature

Alloy designation	Impact value
	J
Group A	
LB2	11
LB4	11
LG2	26
Group B	
HCC1	61
LG4	26
AB1	41
AB2	24
CMA1	41
HTB1	26
HTB3	20
Group C	
AB3	38
CN1	45
CN2	45

NOTE. Properties are mean values.

Table 20. Typical impact properties at various temperatures

Alloy designation	Temperature	Impact value
	°C	J
Group A		
LG2	−188	15
	−74	18
	20	26
	200	20
	300	18
Group B		
LG4	−196	18
	−78	19
	20	26
	100	19
	200	18
	300	16
AB1	−196	34
	20	41
	100	45
AB2	−188	16
	−130	22
	−60	24
	20	24
	200	38
	300	35
CMA1	−180	14
	−100	22
	−50	31
	20	41
	100	49
HTB1	−188	16
	−74	26
	20	26
	100	24

NOTE. Properties are mean values.

Table 21. Typical creep properties at elevated temperatures

Alloy designation	Temperature	Stress to cause 0.1 % plastic strain in 10 000 h
	°C	N/mm²
Group A		
LB2	176	70
	232	31
	288	11
LG1	232	46
	288	27
LG2	232	70
	288	31
SCB1	176	77
	232	55
	288	11
Group B		
LG4	232	54
	288	23
AB1 (die)	204	132
	315	38
AB2 (sand)	204	190
	315	65
AB2 (die)	204	200
	315	38
HTB1	176	38
	204	23
	232	15
HTB3	176	124
	204	62
	232	4
Group C		
G1	232	54
	288	19

NOTE. Sources of information on creep data are as follows:

Alloys LG1, LG2, LG4, G1
STOLARCZYK, J. E. The structure and properties of sand cast gunmetals. *Proc. Inst. Brit. Foundrymen,* **53**, 1960, 545-548.

Alloys SCB1, HTB1, HTB3
MOON, P. D. and SIMMONS, W. F. Creep and rupture properties of five copper-base casting alloys. *Proc. ASTM,* **61**, 1961, 938-955.

Alloys LG2, LB2
SIMMONS, W. F. and KURA, J. G. Creep properties of three low-shrinkage copper-base casting alloys. *Proc. ASTM,* **58**, 1958, 791-804.

Alloys AB1, AB2
LUSHEY, R. D. S. and BOWERS, J. E. The creep of cast aluminium bronzes. *Metallurgia,* **78**, 1968, 59-67.

Table 22. Typical electrical and thermal properties*

Alloy designation	Electrical conductivity		Electrical resistivity		Thermal conductivity		
	15 °C	200 °C	15 °C	200 °C	% of copper	15 °C	200 °C
	% IACS	% IACS	μΩ·m	μΩ·m	%	W/(m·K)	W/(m·K)
Group A							
PB4	10	9	0.17	0.19	12	47	59
LPB1	11	10	0.16	0.17	12	47	59
LB2	10	9	0.17	0.19	12	47	59
LB4	17	15	0.11	0.13	18	71	90
LG1	16	14	0.11	0.12	21	81	100
LG2	15	13	0.11	0.13	18	71	90
SCB1	18	15	0.09	0.11	21	81	100
SCB3	20	16	0.08	0.11	23	90	109
SCB6	25	22	0.07	0.08	29	111	128
DCB1	18	15	0.09	0.11	21	81	100
DCB3	18	15	0.09	0.11	21	81	100
PCB1	18	15	0.09	0.11	21	81	100
Group B							
HCC1	90	54	0.019	0.032	97	372	372
CC1-TF	80	51	0.022	0.034	82	312	317
PB1	9	8	0.17	0.19	12	47	59
PB2	9	8	0.19	0.25	10	45	55
CT1	11	10	0.16	0.17	13	50	62
LB5	14	12	0.11	0.13	18	71	90
LG4	13	11	0.13	0.16	16	61	78
AB1	13	11	0.13	0.16	16	61	78
AB2	8	7	0.22	0.25	10	42	55
CMA1	3	2	0.58	0.65	4	14	21
HTB1	22	16	0.08	0.10	22	87	107
HTB3	8	7	0.22	0.25	10	42	55
Group C							
LB1	11	10	0.16	0.17	12	47	59
G1	11	10	0.16	0.17	12	47	59
G3	12	11	0.15	0.16	12	47	59
G3-TF	12	11	0.15	0.16	12	47	59
SCB4	18	15	0.09	0.11	21	81	100
CT2	9	8	0.19	0.25	10	45	55
AB3	8	7	0.22	0.25	11	45	58
CN1	5	4	0.35	0.39	6	23	33
CN2	5	4	0.35	0.39	6	23	33

*Where experimental data are not available, figures have been estimated. The values are approximate.

Table 23. Density and coefficient of thermal expansion

Alloy designation	Density	Linear coefficient of thermal expansion × 10^{-6} 0 °C to 250 °C
	g/cm³	K^{-1}
Group A		
PB4	8.8	18
LPB1	8.8	18
LB2	9.0	19
LB4	9.0	18
LG1	8.8	18
LG2	8.8	18
SCB1	8.5	19
SCB3	8.4	20
SCB6	8.6	19
DCB1	8.3	21
DCB3	8.3	21
PCB1	8.3	21
Group B		
HCC1	8.9	17
CC1-TF	8.9	17
PB1	8.8	18
PB2	8.8	19
CT1	8.8	18
LB5	9.2	19
LG4	8.8	18
AB1	7.6	17
AB2	7.6	17
CMA1	7.5	19
HTB1	8.3	21
HTB3	7.9	21
Group C		
LB1	9.1	19
G1	8.8	18
G3	8.8	18
G3-TF	8.8	18
SCB4	8.3	21
CT2	8.8	19
AB3	7.7	18
CN1	8.8	18
CN2	8.8	18

Table 24. Typical values for magnetic permeability

Alloy designation	Relative magnetic permeability
Group A	
LG2	1.01
SCB1	1.02
SCB3	1.02
Group B	
CC1-TF	1.001
PB1	1.001
LG4	1.01
AB1	1.2
AB2	1.6
HTB1	1.27
Group C	
SCB4	1.004
AB3	1.035
CN1	1.01
CN2	1.01

Appendix H. Comparisons of the materials specified in BS 1400 with those specified in ISO 1338-1977

Comparisons of the materials specified in BS 1400 with those specified in ISO 1338-1977 are given in table 25.

NOTE. In the ISO designation system (see ISO 1190/1) the prefix G may be used before a metal designation to indicate that it is cast. Other characters indicate the method of casting, i.e.:

GS sand casting
GM permanent mould casting
GZ centrifugal casting
GC continuous casting
GP pressure die casting

These prefixes are also used in some national standards of other countries.

Table 25. Comparisons with alloys in ISO 1338

BS 1400	ISO 1338		
	Equivalent	Similar	Others
Group A			
PB4	–	–	
LPB1	–	Cu Sn8 Pb2	
LB2	Cu Pb10 Sn10	–	
LB4	Cu Pb9 Sn5	–	
LG1	–	–	
LG2	Cu Pb5 Sn5 Zn5	–	
SCB1	–	–	
SCB3	Cu Zn33 Pb2	–	
SCB6	–	–	
DCB1	–	–	
DCB3	Cu Zn40 Pb	–	
PCB1	–	Cu Zn40 Pb	
Group B			
HCC1	–	–	
CC1	–	–	
PB1	Cu Sn10 P	–	
PB2	Cu Sn11 P	–	
CT1	Cu Sn10	–	
LG4	–	Cu Sn8 Pb2	
AB1	Cu Al10 Fe3	–	
AB2	Cu Al10 Fe5 Ni5	–	
CMA1	–	–	
HTB1	Cu Zn35 Al Fe Mn	–	
HTB3	–	Cu Zn26 Al4 Fe3 Mn3 Cu Zn24 Al6 Fe3 Mn3	
Group C			
G1	Cu Sn10 Zn2	–	
G3	–	–	
LB1	Cu Pb15 Sn8	–	
LB5	Cu Pb20 Sn5	–	
CT2	Cu Sn12 Ni2	–	
SCB4	–	–	
AB3	–	–	
CN1	–	–	
CN2	–	–	
–			Cu Al9
–			Cu Sn12
–			Cu Sn12 Pb2
–			Cu Sn7 Pb7 Zn3

Publications referred to

BS 18	Methods for tensile testing of metals Part 1 Non-ferrous metals
BS 240	Method for Brinell hardness test
BS 381C	Specification for colours for identification, coding and special purposes
BS 721	Specification for worm gearing
BS 1610	Methods for the load verification of testing machines
BS 1957	Presentation of numerical values (fineness of expression; rounding of numbers)
BS 5714	Method of measurement of resistivity of metallic materials
BS 6017	Specification for copper refinery shapes
ISO 1190/1	Copper and copper alloys — Code of designation — Part 1 : Designation of materials
ISO 1338	Cast copper alloys — Compositions and mechanical properties

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Coopted members

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Association of Bronze and Brass Founders
Association of Supervisory and Executive Engineers
BEAMA Transmission & Distribution Association
BNF Metals Technology Centre
British Bronze & Brass Ingot Manufacturers
British Malleable Tube Fittings Association
British Valve Manufacturers' Association Ltd.
Copper Smelters' and Refiners' Association
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International Tin Research Institute
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Specification for copper alloy ingots and copper alloy and high conductivity copper castings

Revised text

AMD 6634
September 1990

Table 1

Delete the existing table and substitute the new table 1.

AMD 6634
September 1990

Table 5

Delete the existing table and substitute the new table 5.

AMD 6634
September 1990

Table 6

Delete the existing table and substitute the new table 6.

AMD 6634
September 1990

Table 7

Delete the existing table and substitute the new table 7.

AMD 6634
September 1990

Table 9

Under the column headed 'Material', delete the entry 'High tensile brass' and substitute 'Sand cast high tensile brass'.

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September 1990

Table 12

In group A of the table delete entirely the entry for alloy PCB1.

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September 1990

Table 16

Under the column headed 'Tensile strength', in column 6 headed 'Centrifugal', for alloy LG4, delete '230' and substitute '280'.

Under the column headed 'Hardness', in column 18 headed 'Centrifugal', for alloy PB1, delete '25' and substitute '95'.

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September 1990

Table 24

In column 2, delete the heading 'Magnetic permeability, μ' and substitute 'Relative magnetic permeability'. Delete the unit 'H/m' at the top of this column.
