

BS 2B 100:2009



BSI British Standards

AEROSPACE SERIES

Procedure for inspection, testing and acceptance of wrought copper alloys

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Summary of pages

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Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 December 2009. It was prepared by Panel ACE/61/-/16, *Copper and miscellaneous alloys*, under the authority of Technical Committee ACE/61, *Metallic materials for aerospace purposes*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS B 100:1992, which is withdrawn.

Information about this document

This is a full revision of BS B 100 and introduces the following principal changes:

Section 1:

- a) Tensile testing to BS 4A 4:1966, Part 1, Section 1 has been replaced by BS EN 2002-1.
- b) Hardness testing to BS 4A 4:1966, Part 5 has been replaced by BS EN ISO 6506-1, BS EN ISO 6507-1 and BS EN ISO 6508-1.
- c) Reference to Appendix A has been deleted and "application of values for numerical and other units" details have been added.
- d) Temperature control method has been amended.

Section 2: Inspection and testing requirements summary table has been deleted.

Section 3: Inspection and testing requirements summary table has been deleted.

Section 4:

- a) Reference to Appendix B has been deleted and reference to BS EN ISO 196, *Wrought copper and copper alloys – Detection of residual stress – Mercury(I) nitrate test* has been added.
- b) Inspection and testing requirements summary table has been deleted.

Section 5:

- a) For the eddy current test drilled hole sizes have been added. These hole sizes, formerly in BS B 27, were originally taken from ASTM B111 and were conversions from imperial sizes. They have been amended to align with BS EN 12451 (*Copper and copper alloys – Seamless, round tubes for heat exchangers*).
- b) Inspection and testing requirements summary table has been deleted.

Section 6: Inspection and testing requirements summary table has been deleted.

Section 7: Inspection and testing requirements summary table has been deleted.

Appendix A has been deleted.

Appendix B has been deleted.

Hazard warnings

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed either as a set of instructions or in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1: General

1 Scope

This British Standard specifies procedures for the inspection, testing and acceptance of wrought copper alloys for aerospace purposes.

The standard is applicable to material specifications in the British Standard Aerospace B series and also to other British Standard material specifications for wrought copper alloys which are suitable for aerospace use.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 1971, *Copper and copper alloys – Eddy current test for tubes*

BS EN 2002-1, *Metallic materials – Test methods – Part 1: Tensile testing at ambient temperature*

BS EN 4179, *Qualification and approval of personnel for non-destructive testing*

BS EN ISO 196, *Wrought copper and copper alloys – Detection of residual stress – Mercury(I) nitrate test*

BS EN ISO 6506-1, *Metallic materials – Brinell hardness test – Part 1: Test method*

BS EN ISO 6507-1, *Metallic materials – Vickers hardness test – Part 1: Test method*

BS EN ISO 6508-1, *Metallic materials – Rockwell hardness test – Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

BS EN ISO 7438, *Metallic materials – Bend test*

BS EN ISO 8492, *Metallic materials – Tube – Flattening test*

BS EN ISO 8493, *Metallic materials – Tube – Drift-expanding test*

AMS 2750, *Pyrometry*¹⁾

3 Terms and definitions

For the purposes of this British Standard the following terms and definitions apply.

3.1 batch

quantity of a product of the same nominal dimensions and treated as a set for quality control purposes

NOTE Where applicable, batch sizes for specific products are specified in the relevant sections of this standard.

¹⁾ Available from www.sae.org.

- 3.2 cast**
metal taken from the same melt in a furnace or crucible or from several melts mixed in the same furnace or crucible; or, when a continuous process is used, metal taken from the furnace before the next charge
- 3.3 design authority**
organization responsible for the detailed design of material and which has the responsibility for certifying designs and/or for sealing drawings and specifications
- 3.4 foil**
wrought material of uniform thickness of 0.15 mm or less, of any width over 10 times the thickness supplied flat, folded or in coil
[BS 6931]
- 3.5 forging**
shape produced by hammering or pressing between open or closed dies, including hammering between flat surfaces, normally when hot
NOTE The term "forging" includes the processes of forging, drop forging, hot stamping and hot pressing; the term "forgings" includes the products resulting from any of these processes of manufacture.
[BS 6931]
- 3.6 forging stock**
extruded, rolled, drawn or cast material intended for the production of forgings, usually in the form of rod, bar or sections
[BS 6931]
- 3.7 harmful defect**
defect prejudicial to the suitable and proper use of the material
- 3.8 hollow rod**
hollow wrought product of uniform cross-section with only one enclosed void along its whole length
- 3.9 manufacturer**
organization that produces the material in the form and condition in which it is supplied to the purchaser
- 3.10 pre-production forgings**
forgings produced to a particular design to qualify the method of manufacture and equipment configuration and to demonstrate that the requirements of the purchaser can be met
- 3.11 purchaser**
organization which orders and purchases the product
- 3.12 quality assurance authority**
body responsible for authorizing the manufacturer or supplier to issue certification, when to certify means to attest as meeting a standard
- 3.13 rod**
solid wrought product of uniform cross-section along its whole length, usually supplied in straight lengths
NOTE The term "bar" is often used to denote a rod of comparatively large cross-section, and, especially a heavy rectangular cross-section.
[BS 6931]

3.14 section

wrought product of uniform cross-section along its whole length with a cross-sectional shape other than that of a rod, bar, hollow rod, wire, tube, sheet or strip, usually supplied in straight lengths

[BS 6931]

3.15 sheet

flat wrought product of exact length and of rectangular cross-section with uniform thickness over 0.15 mm up to and including 10.0 mm, supplied in straight lengths (i.e. flat) and usually with sheared or sawn edges

NOTE The thickness does not exceed one-tenth of the width.

[BS 6931]

3.16 strip

product of rectangular cross-section with a uniform thickness over 0.15 mm, usually supplied in coils but may be flat or folded

NOTE The edges are usually slit to size but the length is not exact. The thickness does not exceed one-tenth of the width.

[BS 6931]

3.17 supplier

organization which has not necessarily made the product, but which supplies it to the purchaser

3.18 test piece

test sample, or a portion of a test sample, as finally prepared for testing

3.19 test sample

portion of the material selected for testing

3.20 tube

hollow wrought product of uniform cross-section with only one enclosed void along its whole length, and with a uniform wall thickness, supplied in straight lengths or in coiled form

[BS 6931]

3.21 wire

solid wrought product of uniform cross-section along its whole length supplied in coil form or on spools, reels or drums

[BS 6931]

4 General

This standard details the basic requirements for the inspection and testing of British Standard Aerospace B series *wrought copper alloys*.

In addition to the definitive requirements, this standard also requires the items detailed in Clause 5 to be documented. For compliance with this standard, both the definitive requirements and the documented items have to be satisfied.

If the purchaser wishes to specify an inspection, testing or acceptance procedure for any property of any product, which differs from that specified in this standard, this shall be agreed between the purchaser and the manufacturer and shall be fully documented on the order,

drawing or inspection schedule, provided that the purchaser is also the quality assurance authority. If the purchaser is not also the quality assurance authority, deviations from the requirements of this standard shall only be agreed and documented after written approval has been obtained from the quality assurance authority.

5 Information and requirements to be agreed and to be documented

5.1 Information to be supplied by the purchaser

The following information to be supplied by the purchaser, which is specified in the clauses referred to, shall be fully documented on the order, drawing or inspection schedule, on which the number of this British Standard shall also be given.

Both the definitive requirements specified throughout the standard and the following documented items shall be satisfied before a claim of compliance with the standard²⁾ can be made and verified:

a) General:

- 1) the number of the material specification with which this standard is to be used;
- 2) the required delivery condition of the material, if other than that specified in the material specification (see 6.2);
- 3) the maximum limits for elements not named in the material specification, if no limits for these elements are specified in the material specification (see 8.6);
- 4) if ultrasonic testing is required, in cases where this is not a requirement of the material specification (see 14.3, 18.3 and 23.5.1);
- 5) the dimensional tolerances required, if no tolerances are specified in the material specification or if tolerances other than those specified in the material specification are required for a particular use (see 14.4, 18.4, 26.4, 29.2 and 32.3);
- 6) the tensile properties required if other than those specified in the material specification (see 18.5.5 and 23.7.6);
- 7) the hardness required if other than that specified in the material specification (see 18.6.3).

b) Forgings only:

- 1) any particular procedure required for visual examination (see 23.4.1);
- 2) if ultrasonic testing is required, the stage of manufacture at which this is to be carried out (see 23.5.2);

²⁾ Marking a British Standard identifier (e.g. BS 2B 23:2009) on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

- 3) any dimensions which require checking on each forging (see 23.6.2);
 - 4) the procedure required for producing batch release tensile test samples (see 23.7.1);
 - 5) the required sampling frequency for tensile tests if other than specified in 23.7.2;
 - 6) the required location of the test pieces for tensile tests, if other than specified in 23.7.3;
 - 7) if grain flow examination is required, the type and frequency (see 23.9.1) and the required characteristics (see 23.9.2);
 - 8) any markings required in addition to those specified in 24.1;
 - 9) the required position of the markings (see 24.2).
- c) Sheet, strip and foil only:
- 1) if more than one sample is required from a coil (see 29.3.5).

5.2 Items to be agreed between the contracting parties

The following items to be agreed between the contracting parties, which are specified in the clauses referred to, shall be fully documented.

Both the definitive requirements specified throughout the standard and the following documented items shall be satisfied before a claim of compliance with the standard³⁾ can be made and verified:

- a) General:
 - 1) the method of temperature control if other than AMS 2750 (see 7.2);
 - 2) the ultrasonic testing technique to be used and the acceptance level, where these are not specified in the material specification (see 14.3, 18.3, and 23.5.1).
- b) Forgings only:
 - 1) the dimensional tolerances of the forgings (see 23.6.1);
 - 2) the sampling requirements for the residual stress test (see 23.10.2).
- c) Sheet, strip and foil only:
 - 1) the method for taking one or more additional samples from a coil, where applicable (see 29.3.5).

6 Manufacture and freedom from defects

6.1 The method of manufacture shall conform to the material specification. If alternative methods are specified in the material specification, or if no method is specified, the selection of the method shall be at the discretion of the manufacturer.

³⁾ Marking a British Standard identifier (e.g. BS 2B 23:2009) on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

6.2 The material shall be delivered in the condition specified in the material specification or on the order [see 5.1a2)].

6.3 The material shall be free from harmful defects.

6.4 Notwithstanding prior acceptance of a material as conforming to this standard, any defect in the material which is found at a later stage and which is likely to be detrimental to subsequent use, shall be a cause for rejection.

7 Heat treatment

7.1 Heat treatment shall be carried out in accordance with the material specification.

7.2 Unless otherwise agreed between the manufacturer and the purchaser [see 5.2a1)], temperature control during heat treatment shall be in accordance with AMS 2750.

7.3 If a specific temperature (value and tolerance) is specified in the material specification, that temperature shall be used. If a temperature range is specified in the material specification, a temperature within that range, reduced by the furnace tolerance, shall be selected that will give the properties specified in the material specification.

7.4 The total volume of the charge shall be maintained at the selected temperature (θ), subject to the following furnace tolerances, for the period specified in the material specification:

- a) $\theta < 750\text{ }^{\circ}\text{C}$: $\pm 5\text{ }^{\circ}\text{C}$
- b) $750\text{ }^{\circ}\text{C} \leq \theta \leq 1250\text{ }^{\circ}\text{C}$: $\pm 10\text{ }^{\circ}\text{C}$

7.5 If no period or temperature is specified in the material specification these shall be at the discretion of the manufacturer.

8 Chemical composition

8.1 The chemical composition shall conform to the material specification.

NOTE The manufacturer should carry out chemical analysis of samples at the casting stage so that any necessary corrective action can be taken at that stage to ensure subsequent compliance with the material specification.

8.2 The chemical composition of each batch of material shall be determined.

8.3 The samples taken for analytical purposes shall be representative of the product. The sampling frequency shall be as specified in the relevant section of this standard. The method of analysis shall be at the discretion of the manufacturer. In case of dispute, the method of chemical analysis to be used shall be agreed between the purchaser and the manufacturer.

8.4 Elements not listed in the material specification shall not be added for any purpose other than fluxing, degassing or grain refining.

8.5 Overall control of the chemical composition, the use of scrap and the method of analytical control shall be such that the chemical composition of the final product conforms to the material specification (see note to 8.1).

8.6 If in the course of testing the presence of elements other than those named in the material specification is detected, the amounts of these other elements and/or their total shall not exceed the limits specified in the material specification. If no limits for such elements are specified in the material specification the limits shall be as specified on the order [see 5.1a3)].

8.7 Values for chemical composition given in the material specification shall be applied in accordance with Annex A.

9 Testing

9.1 General

9.1.1 The tests carried out and the test methods used shall conform to either:

- a) the material specification; or
- b) the relevant section of this standard; or
- c) the order or inspection schedule.

(See Clause 5.)

9.1.2 The frequency of sampling shall be as specified in the relevant section of this standard.

9.2 Selection and preparation of test samples

9.2.1 Test samples shall be selected and prepared in accordance with the relevant section of this standard, and shall be fully representative of the material in its delivery condition.

9.2.2 Test samples and associated test pieces shall be identified in such a manner that they are traceable to the batch from which they were taken, and their orientation with respect to the product is clear.

9.2.3 Unless otherwise specified in the relevant section of this standard, test samples shall not be mechanically worked after removal from the products they represent.

9.2.4 Test samples representing products in the final heat treated condition specified in the material specification shall not be subjected to further heat treatment.

9.2.5 Test samples representing products to be delivered in a condition other than the condition of use shall be heat treated to the use condition in accordance with the material specification before testing.

9.3 Tensile test

9.3.1 Tensile testing shall be carried out in accordance with BS EN 2002-1.

9.3.2 Unless otherwise specified in the relevant section of this standard, test pieces for tensile testing shall be to the dimensions of the largest practicable size of proportional round test piece specified in BS EN 2002-1.

9.3.3 The tensile test piece direction and location within the product shall be as specified in the relevant section of this standard.

9.4 Hardness test

9.4.1 Hardness testing shall be carried out using one of the methods listed in a) to c) as specified in the material specification:

- a) Brinell hardness testing shall be carried out in accordance with BS EN ISO 6506-1. If not specified in the material specification, the ratio of F/D^2 shall be 10. Periodic checking of the testing machine by the user shall be carried out in accordance with, and at the frequency specified in, BS EN ISO 6506-1.
- b) Vickers hardness testing shall be carried out in accordance with BS EN ISO 6507-1. Periodic checking of the testing machine by the user shall be carried out in accordance with, and at the frequency specified in, BS EN ISO 6507-1.
- c) Rockwell hardness testing shall be carried out in accordance with BS EN ISO 6508-1. Periodic checking of the testing machine by the user shall be carried out in accordance with, and at the frequency specified in, BS EN ISO 6508-1.

9.4.2 All tests on the same batch (including test pieces, where applicable) shall be made by the same method and under the same conditions of loading.

9.5 Other tests

For those tests specific to a particular product form, the test procedure shall be as specified in the relevant section of this standard.

9.6 Retesting procedures

If the test procedure or test piece preparation is found to be faulty, testing shall be repeated using the original sampling frequency after identification of the cause of the failure. When failure cannot be attributed to faulty testing or test piece preparation, additional test samples shall be selected at twice the original sampling frequency, at least one of which shall be from the product or products on which the original results were obtained. If all retest results are satisfactory the batch shall be accepted. If one or more retest results are unsatisfactory the batch shall be:

- a) rejected; or
- b) every product tested, and the products conforming to the relevant requirement accepted; or
- c) in the case of heat-treatable materials, re-heat treated and tested as a new batch.

9.7 Application of values

For the purpose of determining conformity to the limits specified in the material specification, excluding dimensions, an observed or a calculated value obtained from a test shall be rounded in accordance with Annex A.

10 Marking

Products shall bear the following identification marking:

- a) number of the material specification⁴⁾;
- b) delivery condition;
- c) manufacturer's identification and site identification;
- d) inspection stamp;
- e) batch number or unique identification code;
- f) for forgings, any other markings as specified on the drawing or order [see 5.1b8)].

11 Protection and packaging

11.1 The product shall be protected and/or packaged to prevent damage or corrosion during transport.

11.2 If the product is packaged, the outside of the package shall bear the following information:

- a) the name of the purchaser;
- b) the total mass of the package;
- c) the order number and sufficient information to enable the package to be related to the order and other relevant documentation.

12 Certification

12.1 The manufacturer shall supply with each delivery a certificate of conformity, bearing the name and address of the manufacturer and a printed serial number, containing the following minimum information.

- a) Purchaser's name and address.
- b) Contract and/or order number.
- c) Quality assurance authority under which the material is supplied and, where appropriate, the registration or approval number.
- d) Manufacturer's internal order number.
- e) Identity of the material specification, including the material designation where appropriate, and the number of this British Standard⁴⁾.
- f) Description of the material supplied, including dimensions, drawing numbers and part numbers if appropriate and any other identification, together with the number(s) of the inspection or manufacturing schedule, where applicable.
- g) Quantity supplied.
- h) Batch number(s) or unique identification.

⁴⁾ Marking a British Standard identifier (e.g. BS 2B 23:2009) on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

- i) Condition of the material as delivered.
- j) Heat treatment details, including details of test sample heat treatment, where appropriate.
- k) Details of all the tests carried out, or the reference numbers of the relevant test reports, copies of which shall be attached.
- l) Inspection stamp.
- m) A certification clause signed by a duly authorized employee of the manufacturer, in the following form unless otherwise required by the quality assurance authority:

“Certified that the whole of the supplies detailed hereon have been inspected and tested and, unless otherwise stated above, conform in all respects to the requirements of the contract and/or order”.

12.2 When certification of the material is issued by a supplier, who is not the manufacturer, the supplier shall hold equivalent certification issued by the manufacturer of the material. All the information required by **12.1**, as provided by the manufacturer, shall be supplied with each delivery.

12.3 If a batch of material consigned by the manufacturer is sub-divided, or the material cut to size by a supplier before re-consignment, the supplier shall carry out any additional dimensional inspection or identification marking and shall certify accordingly.

12.4 Except for cutting to size, material consigned by a supplier who is not the manufacturer shall be in the same condition and to the same specification as originally received from the manufacturer. The supplier shall certify accordingly.

NOTE Where a supplier is required by a purchaser to alter the condition of a material delivered by the manufacturer, this should be the subject of a separate agreement, which is outside the scope of this standard.

Section 2: Rod and sections (including hollow rod and sections)

13 General

This section specifies the inspection and testing procedures for rod and sections (including hollow rod and sections) and shall be used in conjunction with Section 1.

14 Inspection and testing

14.1 Batch sizes for sampling

14.1.1 Batch sizes for rods shall be as specified in Table 1.

14.1.2 Batch sizes for sections shall be those specified in Table 1 for rods of equivalent cross-sectional area.

Table 1 Nominal batch sizes (masses) for sampling of rods

Nominal dimensions of rod (diameter or width across flats)		Nominal batch size (kg)
Over (mm)	Up to and including (mm)	
—	12	300
12	40	600
40	80	1 200
80	—	2 500

14.2 External defects

Each product shall be examined over its whole surface, either visually or by an automatic method, and shall be free from harmful defects.

14.3 Internal defects

If specified in the material specification or on the order, each product shall be ultrasonically tested [see 5.1a4)]. The technique to be used and the acceptance level shall be in accordance with the material specification or as agreed between the manufacturer and the purchaser, as applicable [see 5.2a2)].

14.4 Dimensions and tolerances

14.4.1 The dimensions of the product shall be measured and shall fall within the tolerances specified in the material specification or on the order [see 5.1a5)].

14.4.2 The frequency of measurement shall be at the discretion of the manufacturer.

14.5 Tensile test

14.5.1 One test sample shall be selected from each batch and any remaining part of a batch. Tensile test pieces shall be obtained from the following locations in the test samples.

- a) For test samples from rods up to and including 30 mm in diameter, or minor cross-sectional dimension, the test piece shall be located axially.
- b) For test samples from rods over 30 mm up to and including 75 mm in diameter, or minor cross-sectional dimension, the test piece shall be machined so that the longitudinal axis of the test piece is parallel to, and not less than 15 mm from, the surface of the test sample.
- c) For test samples from rods over 75 mm in diameter, or minor cross-sectional dimension, the test piece shall be machined so that the longitudinal axis of the test piece lies midway between the surface furthest from the centre and the centre of the test sample.
- d) For sections, proportional test pieces shall be machined to the dimensions of one of the standard machined test pieces specified in BS EN 2002-1 such that the longitudinal axis of the test piece is parallel to the extrusion direction of the test sample.

NOTE Rods up to and including 30 mm in diameter, or minor cross-sectional dimension, may be tested without being machined provided a proportional gauge length of $5.65\sqrt{S_0}$ is used.

14.5.2 Tensile testing shall be carried out in accordance with **9.3**.

14.5.3 The tensile properties shall conform to the material specification.

14.6 Hardness test

14.6.1 If the material specification specifies a hardness requirement, not less than 10% of the rods or sections from each batch shall be hardness tested.

14.6.2 Hardness testing shall be carried out in accordance with one of the methods listed in **9.4**, as required by the material specification.

14.6.3 The hardness of the product shall conform to the material specification.

15 Marking

15.1 Products shall bear the identification marking specified in Clause **10**.

15.2 Each rod or straight section over 20 mm in diameter or major sectional dimension shall be stamped on, or near to, one end with the information specified in **15.1**.

15.3 Rods and straight sections not exceeding 20 mm in diameter or major sectional dimension shall either be marked in accordance with **15.2** or, at the option of the manufacturer, shall be wired together in bundles. Each bundle shall have attached a durable label indelibly marked with the information specified in **15.1**.

15.4 Sections supplied in coils, or on spools, reels or drums shall have firmly attached a durable label indelibly marked with the information specified in **15.1**.

Section 3: Forging stock

16 General

This section specifies the inspection and testing procedures for forging stock and shall be used in conjunction with Section 1.

17 Manufacture

The method of manufacture shall be in accordance with the material specification.

18 Inspection and testing

18.1 Batch sizes for sampling

Forging stock shall be grouped into the batch sizes specified in Table 2.

Table 2 Nominal batch sizes (masses) for sampling of forging stock

Nominal dimensions of forging stock		Nominal batch size (kg)
Over (mm)	Up to and including (mm)	
—	12	300
12	40	600
40	80	1 200
80	—	2 500

18.2 External defects

Each product shall be examined visually over its whole surface and shall be free from harmful defects.

NOTE Surface defects may be removed by local dressing provided the product remains within the specified dimensions.

18.3 Internal defects

If specified in the material specification or on the order, each product shall be ultrasonically tested [see 5.1a4)]. The technique to be used and the acceptance level shall be in accordance with the material specification or as agreed between the manufacturer and the purchaser, as applicable [see 5.2a2)].

18.4 Dimensions and tolerances

18.4.1 The dimensions of the product shall be measured and shall fall within the tolerances specified in the material specification or on the order [see 5.1a5)].

18.4.2 The frequency of measurement shall be at the discretion of the manufacturer.

18.5 Tensile test

18.5.1 One test sample shall be selected from each batch and any remaining part of a batch. Test samples shall, at the option of the manufacturer, be prepared either:

- a) directly from wrought forging stock produced by hot working; or
- b) from wrought or cast forging stock which has been subsequently either hot forged to approximately 65% of its original cross-sectional area, or upset forged to reduce its length by at least 50%.

18.5.2 If required, test samples shall be heat treated in accordance with the material specification.

18.5.3 Tensile test pieces shall be obtained from the following locations in the test samples:

- a) For test samples from forging stock up to and including 30 mm in diameter, or minor cross-sectional dimension, the test piece shall be located axially.
- b) For test samples from forging stock over 30 mm up to and including 75 mm in diameter, or minor cross-sectional dimension, the test piece shall be machined so that the longitudinal axis of the test piece is parallel to, and not less than 15 mm from, the surface of the test sample.
- c) For test samples from forging stock over 75 mm in diameter, or minor cross-sectional dimension, the test piece shall be machined so that the longitudinal axis of the test piece lies midway between the surface furthest from the centre and the centre of the test sample.

18.5.4 Tensile testing shall be carried out in accordance with **9.3**.

18.5.5 The tensile properties shall conform to the material specification or with the inspection schedule or order, as applicable [see **5.1a6**]).

18.6 Hardness test

18.6.1 If the material specification specifies a hardness requirement, not less than 10% of the forging stock from each batch shall be hardness tested.

18.6.2 Hardness testing shall be carried out in accordance with one of the methods specified in **9.4**, as required by the material specification.

18.6.3 The hardness of the product shall conform to the material specification or with the inspection schedule or order, as applicable [see **5.1a7**]).

18.7 Forgeability test

18.7.1 When specified by the material specification, one test sample shall be selected from each batch and any remaining part of a batch to provide a test piece.

18.7.2 The test piece shall have a length not less than the diameter or minor sectional dimension of the forging stock.

18.7.3 When subjected to the forgeability test specified by the material specification, the test piece shall show no visible signs of cracking.

19 Marking

19.1 Products shall bear the identification marking specified in Clause 10.

19.2 Each length of forging stock over 20 mm in diameter or major sectional dimension shall be stamped on, or near to, one end with the information specified in **19.1**.

19.3 Forging stock not exceeding 20 mm in diameter or major sectional dimension shall either be marked in accordance with **19.2** or, at the option of the manufacturer, be wired together in bundles. Each bundle shall have attached a durable label indelibly marked with the information specified in **19.1**.

Section 4: Forgings

20 General

20.1 This section specifies the inspection and testing requirements for forgings and shall be used in conjunction with Section 1.

20.2 This section shall also apply to pre-production forgings intended for the qualification of the method of manufacture, inspection and testing.

21 Manufacture

21.1 Forgings shall be manufactured from forging stock conforming to Section 3.

NOTE When the manufacturer of the forging stock and the forgings is the same, the tests on the forging stock specified in Section 3 may be waived subject to agreement with the quality assurance authority.

21.2 The method of manufacture of production forgings shall be the same as the method of manufacture of the pre-production forgings, except by agreement between the manufacturer and the purchaser and following written approval by the design authority including any requirement for re-qualification of the forgings.

22 Pre-production forgings

22.1 General

22.1.1 The following information to be supplied by the purchaser shall be fully documented on the order, drawing or inspection schedule:

- a) the number of forgings to be selected from initial production for evaluation;
- b) the location, size and form of any test pieces to be cut from the forgings and the test properties required at each location;
- c) any other test requirements such as grain flow, macrostructure, microstructure; and
- d) the condition of the forgings on which the tests are to be carried out.

22.1.2 The inspection and testing of pre-production forgings shall be carried out and the inspection and test conditions shall be recorded, to allow the definition of the optimum techniques to be used for production forgings, including, where appropriate, the ultrasonic test method (probe, frequency, angle of incidence, etc.).

22.1.3 The inspection and tests carried out on pre-production forgings shall include those which will be carried out on production forgings (see Clause 23).

22.2 Inspection and testing report

In addition to any information specified by Section 1, the inspection and testing report on the pre-production forgings shall include all the technical information that has been obtained on these forgings, e.g. photographs taken during macroscopic and microscopic examination and results of dimensional measurements.

22.3 Acceptance of pre-production forgings

When all inspection and test results relating to pre-production forgings have been reported, and accepted as satisfactory by the purchaser, written agreement for series production shall be obtained from the design authority.

23 Inspection and testing of production forgings

23.1 General

Inspection and testing carried out on production forgings shall be under the same conditions as those applied to the pre-production forgings (see 22.1.2 and 22.1.3).

23.2 Batch sizes for sampling

The forgings shall be grouped into the batch sizes specified in Table 3.

Table 3 Nominal batch sizes (masses) for sampling of production forgings

Mass of individual forging		Nominal batch size (kg)
Over (kg)	Up to and including (kg)	
—	0.5	300
0.5	2.0	600
2.0	10.0	1 200
10.0	—	2 500

23.3 Surface preparation

Inspection shall be carried out after chemical and/or mechanical surface preparation. The method of surface preparation shall be at the discretion of the manufacturer.

23.4 External defects

23.4.1 Visual examination of all surfaces of each forging shall be carried out using the procedure stated on the order or inspection schedule [see 5.1b1)]. If no procedure is stated, the procedure used shall be at the discretion of the manufacturer.

23.4.2 The surfaces of the forgings shall be free from harmful defects. Local dressing to remove defects shall be permitted provided the dimensions remain within the specified limits. Visual examination shall be repeated on dressed areas.

23.5 Internal defects

23.5.1 If specified on the drawing or the inspection schedule, each forging shall be subjected to ultrasonic testing [see 5.1a4)]. The technique, which shall be defined during qualification of the pre-production forgings, and the acceptance level, shall be as agreed between the manufacturer and the purchaser [see 5.2a2)].

23.5.2 The manufacturing stage at which the forgings are tested shall be as stated on the drawing or inspection schedule [see 5.1b2)].

23.6 Dimensions and tolerances

23.6.1 The dimensions of the forgings shall be measured and shall fall within the limits agreed between the manufacturer and the purchaser and indicated on the drawing, order or inspection schedule [see 5.2b1)].

23.6.2 The dimensions specially designated by the purchaser [see 5.1b3)] shall be measured on each forging.

23.6.3 For other dimensions the frequency of measurement shall be at the discretion of the manufacturer.

23.7 Tensile test

23.7.1 Batch release tensile test samples shall be prepared by one of the following procedures as stated on the drawing, order or inspection schedule [see 5.1b4)]. Where no procedure is stated, the choice of procedure shall be at the discretion of the manufacturer:

- a) test samples cut from forgings;
- b) test samples forged integrally with the forgings;
- c) test samples forged separately from the same batch of forging stock as the forgings they represent.

23.7.2 One test sample shall be selected from each batch and from any remaining part of a batch, unless otherwise specified on the drawing or inspection schedule [see 5.1b5)].

23.7.3 In the case of test samples taken from forgings [see 23.7.1a) and b)] the test piece shall be machined from the test sample so that the axis of the test piece is parallel to the major dimension of the forging, unless a specific location is specified on the drawing, order or inspection schedule [see 5.1b6)]. The test piece shall conform to the dimensions of the largest test piece specified in BS EN 2002-1 that is practicable to take from a particular product.

23.7.4 Test samples forged separately from forging stock [see 23.7.1c)] shall be prepared in accordance with 18.5.1 and 18.5.2, and tensile test pieces shall be prepared from these samples in accordance with 18.5.3.

23.7.5 Tensile testing shall be carried out in accordance with 9.3.

23.7.6 The tensile properties shall conform to the material specification, or with the drawing or inspection schedule, as applicable [see 5.1a6)].

23.8 Hardness test

23.8.1 All forgings and tensile test samples shall be hardness tested unless otherwise agreed by the quality assurance authority. Hardness testing shall be carried out in accordance with one of the methods listed in 9.4, as required by the material specification.

23.8.2 The hardness of the material shall conform to the material specification.

23.8.3 If any hardness result fails to conform to the material specification the following procedure shall be followed.

- a) Provided that the hardness of the forgings and test samples in the batch is uniform and the tensile properties conform to those specified in the material specification, drawing or inspection schedule, the batch shall be accepted subject to written agreement from the design authority.
- b) Where the hardness is not uniform, the forgings of incorrect hardness, together with the appropriate tensile test samples, shall be heat treated or re-heat treated as appropriate and retested.

23.9 Grain flow

23.9.1 If grain flow examination is specified on the order, drawing or inspection schedule [see 5.1b7)], macroscopic and microscopic examination shall be carried out. The type of examination and the sampling frequency shall be as specified on the order, drawing or inspection schedule.

23.9.2 The grain flow shall be the same as that obtained on the pre-production forgings and shall conform to the order, drawing or inspection schedule [see 5.1b7)].

23.10 Residual stress

23.10.1 Whole, finished forgings shall be tested for residual stress in accordance with BS EN ISO 196.

23.10.2 The frequency of sampling for testing shall be as agreed between the manufacturer and the purchaser [see 5.2b2)]. The sample forgings, which constitute the test specimens, shall not be subjected to additional preparation before testing and shall not be marked for identification by indenting.

23.10.3 After testing, the forgings shall show no evidence of visible cracks.

24 Marking

24.1 Products shall bear the identification marking specified in Clause 10.

24.2 Forgings with a large enough surface area to accommodate the markings specified in 24.1 shall be individually marked. The position of the markings shall be as stated on the drawing or order [see 5.1b9)].

24.3 Forgings with too small a surface to accommodate the markings specified in 24.1 shall be tied in bundles or otherwise packaged. Each bundle or package shall have attached a durable label indelibly marked with the information required by 24.1.

Section 5: Seamless tube

25 General

This section specifies the inspection and testing procedures for seamless tube for hydraulic and structural applications and shall be used in conjunction with Section 1.

26 Inspection and testing

26.1 Batch sizes for sampling

Tubes shall be grouped into the batch sizes specified in the material specification.

26.2 All tube

Each tube shall be examined visually on the internal and external surfaces and shall be free from harmful defects.

26.3 Hydraulic tube

26.3.1 Each tube shall be eddy current tested in accordance with BS EN 1971 and shall conform to the material specification.

26.3.2 Testing shall only be undertaken and/or supervised by personnel who comply with BS EN 4179 or an equivalent scheme acceptable to the quality assurance authority.

26.3.3 Unless otherwise stated in the material specification, the diameter of drilled holes in the reference standard tube shall be as specified in Table 4.

Table 4 Diameter of drilled holes in reference standard tube

Outside diameter of tube (D)	Diameter of drilled holes in reference standard tube	Tolerance on diameter of drilled holes in reference standard tube
$D \leq 19$	0.6	
$19 < D \leq 25$	0.8	
$25 < D \leq 32$	0.9	
$32 < D \leq 38$	1.05	± 0.05
$38 < D \leq 45$	1.15	
$45 < D \leq 50$	1.3	
$D > 50$	by agreement	

NOTE All dimensions are in mm.

26.3.4 Each tube shall be bore tested. A bob or wire shall be passed through the bore of the tube. The diameter of the bob or wire shall be 80% of the nominal internal diameter of the tube. The length of the bob shall not be less than twice its diameter.

26.3.5 The bob or wire shall pass through the bore of the tube freely.

26.3.6 Alternatively, if the tube can be mounted to ensure full end-to-end visibility, it shall be examined visually and be free from constriction.

26.4 Dimensions and tolerances

26.4.1 The dimensions of the product shall be measured and shall fall within the tolerances specified in the material specification or on the order [see 5.1a5)].

26.4.2 The frequency of measurement shall be at the discretion of the manufacturer.

26.5 Tensile test

26.5.1 One test sample shall be selected from each batch and any remaining part of a batch. The test pieces shall be full sections or longitudinal strips cut from any part of the tube, and shall conform to 9.3.2.

26.5.2 Tensile testing shall be carried out in accordance with 9.3.

26.5.3 The tensile properties shall conform to the material specification.

26.6 Hardness test

26.6.1 10% of the tubes from each batch and any remaining part of a batch shall be hardness tested.

26.6.2 Hardness testing shall be carried out in accordance with one of the methods listed in 9.4, as required by the material specification.

26.6.3 The hardness of the product shall conform to the material specification.

26.7 Drift-expanding test

26.7.1 Drift-expanding testing shall be carried out in accordance with BS EN ISO 8493.

26.7.2 The angle (β) of the conical mandrel shall be as specified in the material specification.

26.7.3 The maximum outside diameter of the expanded part of the test piece, D_u , or relative expansion as a percentage of the original diameter, D , shall be as specified in the material specification.

26.8 Flattening test

26.8.1 Flattening testing shall be carried out in accordance with BS EN ISO 8492.

26.8.2 The distance between platens measured under load in the direction of flattening shall be as specified in the material specification.

26.9 Distension test

26.9.1 The test piece shall be not less than 600 mm in length.

26.9.2 The mean outside diameter shall be determined at the mid-point of the length of the test piece by measurement of two diameters at right angles with an instrument having a sensitivity of 0.0025 mm.

26.9.3 The test pressure shall be as specified in the material specification. If not specified in the material specification it shall be calculated from the equation:

$$P = R_{p0.2} \frac{D^2 - d^2}{D^2 + d^2}$$

where:

P is the test pressure (in MPa);

D is the maximum outside diameter (i.e. nominal diameter plus ovality tolerance) (in mm);

d is the maximum inside diameter (i.e. D minus twice the minimum thickness at any point) (in mm);

$R_{p0.2}$ is the minimum 0.2% proof stress specified in the material specification (in MPa).

26.9.4 The test pressure shall be applied and maintained for not less than 30 s.

26.9.5 After release of the pressure, the mean outside diameter shall be determined by measurement of two diameters at right angles at the original position.

26.9.6 The test piece used for the test shall be discarded.

26.10 Tube leakage (hydraulic pressure test)

26.10.1 The test pressure shall be as specified in the material specification. If not specified in the material specification it shall be calculated from the equation:

$$P = 0.65 R_{p0.2} \frac{D^2 - d^2}{D^2 + d^2}$$

where:

P is the test pressure (in MPa);

D is the maximum outside diameter (i.e. nominal diameter plus ovality tolerance) (in mm);

d is the maximum inside diameter (i.e. D minus twice the minimum thickness at any point) (in mm);

$R_{p0.2}$ is the minimum 0.2% proof stress specified in the material specification (in MPa).

26.10.2 The test pressure shall be applied and maintained for not less than 30 s.

NOTE Care should be taken to ensure that air in a tube being tested is completely replaced by hydraulic fluid before the specified pressure is applied.

26.10.3 The frequency of sampling for testing shall be in accordance with the material specification.

26.10.4 The results shall conform to the material specification.

27 Marking

27.1 Products shall bear the identification marking specified in Clause 10.

27.2 Each straight length of tube over 20 mm in diameter shall be indelibly marked (e.g. electro-etched) on, or near to, the end with the information required by 27.1.

27.3 Straight tubes not exceeding 20 mm in diameter shall either be marked in accordance with 27.2 or, at the option of the manufacturer, be wired together in bundles. Each bundle shall have attached a durable label indelibly marked with the information required by 27.1.

27.4 Tubes supplied in coil or on spools, reels or drums shall have firmly attached a durable label indelibly marked with the information required by 27.1.

Section 6: Sheet, strip and foil

28 General

This section specifies the inspection and testing procedures for sheet, strip and foil and shall be used in conjunction with Section 1.

29 Inspection and testing

29.1 External defects

Each sheet or coil shall be examined visually and shall be free from harmful defects.

29.2 Dimensions and tolerances

29.2.1 The dimensions of the product shall be measured and shall fall within the tolerances specified in the material specification or on the order [see 5.1a5)].

29.2.2 The frequency of measurement shall be at the discretion of the manufacturer.

29.3 Batch sizes for sampling and frequency of sampling for mechanical tests – all materials except copper-beryllium

29.3.1 Sheet, strip or foil of the same width, thickness and condition shall be batched together and from each batch the number of samples taken shall be as specified in **29.3.2** to **29.3.6**.

29.3.2 From batches with a mass of less than 500 kg, one sample shall be taken to provide the necessary test pieces.

29.3.3 From batches with a mass of 500 kg and not more than 2 000 kg, one sample shall be taken from each 500 kg of material, and one sample from any remaining fraction.

29.3.4 Where strip is supplied in coils with a mass of more than 500 kg, one sample shall be taken from each coil to provide the necessary test pieces. Where sheet or strip is cut from coils with a mass of more than 500 kg, one sample shall be taken from each original coil to provide the necessary test pieces.

29.3.5 If the purchaser requires more than one sample to be taken from any coil [see 5.1c1)], the method of taking the additional sample or samples shall be agreed between the manufacturer and the purchaser [see 5.2c1)].

29.3.6 Batches exceeding 2 000 kg shall be subdivided into smaller batches of not less than 500 kg and not more than 2 000 kg, to which the provisions of **29.3.3** shall then apply.

29.4 Batch sizes for sampling and frequency of sampling for mechanical tests – copper-beryllium

29.4.1 Strip and foil shall be grouped into batches as defined in the material specification.

29.4.2 From each batch, one sample shall be taken to provide the necessary test pieces.

29.5 Tensile test

29.5.1 Tensile testing shall be carried out in accordance with 9.3. Tests shall be carried out on flat specimens of full product thickness. The longitudinal axis of symmetry of the test piece shall be in the direction of rolling.

29.5.2 Tensile tests shall not be applied to material 0.50 mm thick or less, with the exception of copper-beryllium, where it shall be applied to material down to 0.10 mm thickness. The elongation test shall not be applied to material thinner than 0.80 mm when less than 12.5 mm wide, with the exception of copper-beryllium, where it shall be applied to strip down to 0.25 mm thickness.

29.5.3 The tensile properties shall conform to the material specification.

29.6 Hardness test

29.6.1 Hardness testing shall be carried out in accordance with one of the methods listed in 9.4, as required by the material specification.

29.6.2 The hardness of the product shall conform to the material specification.

29.7 Bend test

29.7.1 Bend testing shall be carried out in accordance with BS EN ISO 7438.

29.7.2 The angle of bend (α) shall be as specified in the material specification.

29.7.3 In cases of dispute, the test shall be carried out with testing machines or presses equipped with a bending device with two supports and a former as specified in BS EN ISO 7438.

29.7.4 For material 50 mm wide or less the bend axis shall be at right angles to the rolling direction (longitudinal bend).

29.7.5 For material greater than 50 mm wide the bend axis shall be parallel to the rolling direction (transverse bend).

29.7.6 Both surfaces shall be tested.

29.7.7 The test pieces shall not crack when bent once through the angle specified in the material specification.

30 Marking

30.1 Products shall bear the identification marking specified in Clause 10.

30.2 Sheet, strip and foil supplied flat or folded shall be indelibly marked with the information required by 30.1.

30.3 Strip and foil supplied in coil or on reels or drums shall have firmly attached, to each coil, reel or drum, a durable label indelibly marked with the information required by 30.1.

Section 7: Wire

31 General

This section covers the inspection and testing procedures for wire and shall be used in conjunction with Section 1.

32 Inspection and testing

32.1 Batch sizes for sampling

Wire shall be grouped into the batch sizes specified in the material specification.

32.2 External defects

All wire shall be examined, either visually or by an automatic method, and shall be free from harmful defects.

32.3 Dimensions and tolerances

32.3.1 The dimensions of the product shall be measured and shall fall within the tolerances specified in the material specification or on the order [see 5.1a5)].

32.3.2 The frequency of measurement shall be at the discretion of the manufacturer.

32.4 Tensile test

32.4.1 One test sample shall be selected from each batch.

32.4.2 Tensile testing shall be carried out in accordance with 9.3.

32.4.3 The tensile properties shall conform to the material specification.

32.5 Hardness test

32.5.1 If the material specification states a hardness requirement, one test sample per batch shall be hardness tested.

32.5.2 Hardness testing shall be carried out in accordance with one of the methods listed in 9.4, as required by the material specification.

32.5.3 The hardness of the product shall conform to the material specification.

32.6 Wrapping test

32.6.1 The wire shall be wound around a mandrel to form a closely wrapped helix. The number of turns and the mandrel diameter shall be as specified in the material specification.

32.6.2 The results shall conform to the material specification.

33 Marking

Wires in coils or on spools, reels or drums shall be securely tied and each coil, spool, reel or drum shall have firmly attached a durable label indelibly marked as specified in Clause 10.

Annex A (normative)

Rules for application of values for chemical composition and mechanical properties given in material specifications

For the purpose of determining conformity to the limits specified in the material specification, excluding dimensions, an observed or a calculated value obtained from a test shall be rounded in one step to the same number of figures used to express the specified limit in the material specification in accordance with the following procedures.

- a) For units of stress tensile strength and proof stress values shall be rounded as follows:
 - 1) stresses up to 250 MPa: to the nearest even number;
 - 2) stresses over 250 MPa up to and including 1 000 MPa: to the nearest multiple of 5;
 - 3) stresses over 1 000 MPa: to the nearest multiple of 10.
- b) For numerical values and other units:
 - 1) when the value immediately after the last value to be retained is less than 5, the last value to be retained shall remain unchanged;
 - 2) when the value immediately after the last value to be retained is greater than or equal to 5, and followed by at least one value other than zero, the last value to be retained shall be increased by one;
 - 3) when the value immediately after the last value to be retained is equal to 5 and followed by zeros only, the last value to be retained shall remain unchanged if even and be increased by one if odd.

Bibliography

Standards publications

For dated references only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 2B 23, *Specification for copper-aluminium-nickel-iron alloy rods, bars, sections, forging stock and forgings*

BS B 27, *Specification for copper-zinc-aluminium-nickel-silicon alloy tube*⁵⁾

BS 6931, *Glossary of terms for copper and copper alloys*

BS EN 12451, *Copper and copper alloys – Seamless, round tubes for heat exchangers*⁵⁾

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⁵⁾ Referred to in the foreword only.

⁶⁾ Referred to in the foreword only. Available from www.astm.org.

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