

Procedure for

Inspection and testing of wrought heat-resisting alloys

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Foreword

This British Standard covers the general inspection and testing requirements for wrought heat-resisting alloys to be used for aerospace purposes. The procedure set out herein is primarily for use in conjunction with related material specifications in the “HR” series of British Standards and in the Ministry of Defence (Procurement Executive) D.T.D. series.

The first edition of this British Standard was published in December 1968 and a revised edition, which incorporated changes agreed between the manufacturers and users of the materials in the light of working to the provisions of the first edition, was published in December 1971. This further revision has been undertaken to take account of new manufacturing processes and techniques, in particular those for forging stock, and to introduce new requirements, such as those relating to grain size determination and release documentation.

NOTE BS M 46, “*Tubing outside diameters and thicknesses*”¹⁾, lists the outside diameters and thicknesses of tubes to be selected for all uses in aircraft design. Recommended thicknesses for sheet and diameters for wire, in the metric series, are given in Reference Sheets RS 701 and RS 702, respectively, published by the Society of British Aerospace Companies Limited.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 39 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ Implements ISO 2964.

Section 1. General requirements

1 Scope

This British Standard specifies the general requirements for the inspection and testing of materials covered by specifications for wrought heat-resisting alloys (based on iron, nickel, cobalt and other metallic elements) on which the elevated temperature properties are normally verified and which are intended for aerospace and other critical applications.

2 General

2.1 In this standard, whenever agreement between the manufacturer and the purchaser is required, the onus is on the purchaser to obtain the concurrence of the parent design authority. If such concurrence is mandatory the word “purchaser” is marked with an asterisk.

2.2 The “Quality Assurance Authority” referred to throughout this standard shall be as stated in the contract or the accredited representative of the authority stated.

3 References

This standard makes reference to the following standards publications.

BS A 4, *Test pieces and test methods for metallic materials for aircraft*.

BS M 36, *Method for ultrasonic testing of special forgings by an immersion technique using flat-bottomed holes as a reference standard*.

BS M46, *Tubing outside diameters and thicknesses*²⁾.

BS 240, *Method for Brinell hardness test — Part 1: Testing of metals — Part 2: Verification of the testing machine*.

BS 427, *Method for Vickers hardness test — Part 1: Testing of metals — Part 2: Verification of the testing machine*.

BS 891, *Method for Rockwell hardness test — Part 1: Testing of metals — Part 2: Verification of the testing machine*.

BS 1639, *Method for bend testing of metals*.

BS 3923, *Ultrasonic examination of welds — Part 3: Manual examination of nozzle welds*.

BS 4175, *Method for Rockwell superficial hardness test (N and T scales) — Part 1: Testing of metals — Part 2: Verification of the testing machine*.

BS 4331, *Method for assessing the performance characteristics of ultrasonic flaw detection equipment*.

DD 44, *Methods for the determination of grain size of non-ferrous alloys*.

The latest issues of these publications shall be used.

4 Definitions

For the purposes of this British Standard and associated material specifications the following definitions apply.

4.1 Materials

4.1.1 bar

a product of round, square, rectangular or regular polygonal cross section supplied in straight lengths

4.1.2 batch

material that is

- a) form the same cast;
- b) of the same form and manufactured by the same process;
- c) of the same nominal dimensions to within $\pm 10\%$; and
- d) in the same heat treatment condition and from the same heat treatment charge or, in the case of continuous heat treatment, from a run of not more than 8 h.

4.1.3 billet

a rolled, extruded or forged solid or hollow product intended for further working

4.1.4 blade blank

a product with controlled structure, grain size and dimensions such that it is suitable for the direct machining of a turbine blade

4.1.5 cast

the product of the final melting operation

4.1.6 coil

a continuous length of a product wound into a cylindrical or annular form for convenient handling

4.1.7 flash welded ring

a product formed by bending and resistance welding a bar or section

²⁾ Referred to in foreword only.

**4.1.8
forging**

a product obtained by hot working under a hammer or press. The term includes drop forgings, open die forgings, stampings, pressings, hot rolled rings and forgings made from tubular material

**4.1.9
ingot**

cast material intended for subsequent hot working

**4.1.10
parent cast**

a melt of known chemical composition which is to be subsequently remelted

**4.1.11
plate**

a rolled product of rectangular section, of thickness greater than 3 mm, supplied flat

**4.1.12
section**

a rolled, extruded or forged product not covered by the term “bar” as defined in 4.1.1, nor in the form of plate, sheet, strip, tube or wire

**4.1.13
sheet**

a rolled product of rectangular section, of thickness up to and including 3 mm, supplied flat with sheared or slit edges

**4.1.14
strip**

a rolled product of rectangular section, of thickness up to and including 3 mm, supplied in coil form with slit edges

**4.1.15
test piece**

a test sample as finally prepared for testing

**4.1.16
test sample**

that portion of the material selected for testing

**4.1.17
tube**

a seamless hollow product of uniform thickness

**4.1.18
wire**

a product of round, square or regular polygonal solid section, supplied in coil form

4.2 Heat treatments**4.2.1
precipitation treatment (ageing)**

heat treatment to bring phase(s) out of solution in order to produce the required creep, stress rupture and/or tensile characteristics

**4.2.2
solution treatment**

heat treatment, of alloys normally intended for subsequent precipitation treatment, to ensure adequate solution of the precipitating phase(s), followed by cooling at a rate sufficient to retain the phase(s) in solution

**4.2.3
softening or annealing**

heat treatment designed to give a soft, ductile product

4.3 Melting processes**4.3.1
air melting**

the practice of melting, by an electric process, in air and casting in air

**4.3.2
consumable electrode**

an electrode, for subsequent remelting, produced from air melted, vacuum melted or vacuum refined material

**4.3.3
consumable electrode remelting**

the practice of remelting consumable electrodes of known analysis under one of the following conditions

- a) vacuum arc remelting: in vacuum.
- b) electroflux remelting: through a flux.

**4.3.4
vacuum melting**

the practice of melting, by induction heating, under vacuum and casting in a vacuum chamber

**4.3.5
vacuum refining**

the treatment of an air melted liquid alloy in a vacuum, followed by casting in air or under vacuum

5 Metric and imperial units

The tables governing dimensional tolerances are provided in two forms based on metric or imperial units, respectively. These two sets of requirements are not interchangeable; the relevant set shall be applied, depending on whether the dimensions stated on the order or drawing are expressed in metric or imperial units.

6 Chemical composition

6.1 The chemical composition of the alloy shall comply with requirements of the material specification.

6.2 The samples taken for analysis shall be representative of the melt.

6.3 In the case of remelted material, samples shall be taken from positions as follows.

- a) Vacuum arc remelted ingots: the bottom of each ingot or ingot product.
- b) Electroflux remelted ingots: the top and bottom ends of each ingot product.

6.4 An analysis shall be made of each sample and certificates of analysis shall be supplied to the purchaser. The elements to be determined shall be as required by the material specification or as agreed between the manufacturer, the purchaser(*)³⁾ and the Quality Assurance Authority.

6.5 Elements not quoted in the material specification shall not be intentionally added to the alloy without the agreement of the purchaser(*)³⁾, except for the purpose of finishing the heat; reasonable precautions shall be taken to prevent their inclusion during manufacture. The purchaser(*)³⁾, in agreement with the manufacturer, may set a limit to the amount of one or more such elements and may require the amount of such elements to be stated in the certificate of analysis.

6.6 The specified ranges of chemical composition are based on cast analyses. Any subsequent analytical checks shall take into consideration the heterogeneity normal to the alloy.

6.7 If the material specification makes reference to the control of the chemical composition by means of phase composition (Phacomp) or "Electron vacancy" ($\bar{N}_v$ value) techniques, the value for each cast shall be calculated as described in Appendix A unless otherwise stipulated in the material specification. The value obtained shall comply with the requirements of the material specification and shall be quoted on the test certificate.

³⁾ See 2.1.

7 Manufacture

7.1 Melting

7.1.1 General. The alloy shall be made by the process required by the material specification, unless the manufacturer and the purchaser(*)³⁾ agree beforehand to the use of a different process. If a specification permits alternative processes, the manufacturer shall decide which of them shall be used unless the purchaser(*)³⁾ states a particular preference on his order. In all instances, the process by which the alloy was made shall be indicated on the release note.

7.1.2 Consumable electrode remelted material

7.1.2.1 Except as provided in 7.1.2.3, or 7.1.2.4 at no time during remelting shall material of any other composition or type be introduced into the melting chamber, i.e. starter material and electrode stub-ends shall be of the same composition as the material being remelted.

7.1.2.2 Whenever possible and except as provided in 7.1.2.3, weld material used to join electrodes together and to join the electrode to the stub-end shall be of the same composition as the material being remelted. If such weld material is not obtainable, material of a similar composition to or compatible with the material being remelted may be used at the discretion of the manufacturer, unless the purchaser indicates that his prior agreement is required.

7.1.2.3 Alternatively to 7.1.2.1 and 7.1.2.2, for electro-flux and vacuum arc remelting, the stub and any weld material used to join the electrode to the stub-end may be of a different material from that being remelted, provided that the remelted material is not contaminated with material from the stub-ends or weld and that for vacuum arc remelting the stub welding takes place outside the furnace. Remelting shall be terminated not less than 20 mm from the electrode/stub interface and, after completion of the remelting cycle, the electrode/stub interface shall be examined to verify that the stub and weld are intact.

7.1.2.4 For electro-flux remelting, material compatible with the composition of that being remelted shall be permitted to provide electrical contact to the furnace base plate, provided that the chemical composition of the melt is maintained.

7.2 Products

7.2.1 If required by the parent design authority, the process of manufacture of a product shall be approved and shall not be modified significantly except by prior agreement.

7.2.2 At some stage in the manufacture of the products, adequate discard shall be removed to ensure freedom from harmful defects. The purchaser, in agreement with the manufacturer, may set a limit to the amount of such discard.

7.2.3 Processing shall be controlled to avoid changes in composition.

8 Preparation for surface inspection

Unless otherwise agreed between the manufacturer and the purchaser^(*)4), the products shall be machined, ground or descaled to enable the surface to be inspected to the satisfaction of the Quality Assurance Authority.

9 Surface finish

The surface finish of the product shall be in accordance with the requirements of the material specification or as agreed between the manufacturer and the purchaser and stated on the order. If no such requirements are stated, the surface finish shall be at the discretion of the manufacturer.

10 Freedom from defects

10.1 General

10.1.1 All materials shall be free from harmful defects.

10.1.2 Notwithstanding the previous acceptance of material as complying with the requirements of this British Standard, any material that is found at a later stage to contain harmful defects may be rejected.

10.2 Etch test

10.2.1 Etch tests shall be carried out as required by the relevant section of this British Standard.

10.2.2 Except where otherwise stipulated in this British Standard, the material specification, drawing or order, the method of test and standard of acceptance shall be at the discretion of the manufacturer.

10.3 Metallographic examination

10.3.1 Samples for metallographic examination shall be taken at a frequency and from positions as defined in the material specification or as agreed between the manufacturer and the purchaser^(*)4) and stated on the drawing or order.

10.3.2 The method of test and standard of acceptance shall be as stipulated in the material specification or as agreed between the manufacturer and the purchaser^(*)4).

⁴⁾ See 2.1.

10.4 Non-destructive testing

10.4.1 The material shall be non-destructively tested to establish freedom from harmful defects as required by the relevant section of this British Standard.

10.4.2 Except where otherwise stipulated in this British Standard, the material specification, drawing or order, the method of test and standard of acceptance shall be at the discretion of the manufacturer.

11 Heat treatment

11.1 If a material specification, drawing or order states a specific temperature, that temperature shall be mandatory. If a temperature range is stated, a suitable temperature within that range shall be selected to give the required properties. The charge shall be maintained at the stipulated or selected temperature, subject to the following tolerances, for the specified period.

Temperature (°C)		Tolerance (°C)
Over	Up to and including	
	750	± 5
750	1 250	± 10
1 250		± 15

11.2 If any material is heat treated in bundles at a temperature exceeding 950 °C and subsequently air cooled, the bundles shall be split after removal from the furnace and the components shall be individually cooled.

12 Mechanical properties

The specified mechanical properties normally refer to test pieces selected and prepared in accordance with the requirements of clause 13. In the event of a departure from those requirements, the properties shall be agreed between the manufacturer and the purchaser^(*)4) and shall be stated on the drawing or order.

13 Selection, preparation and testing of test samples

13.1 Test samples shall be selected and prepared in accordance with the relevant section of this British Standard.

13.2 If any test sample or test piece fails to comply with the requirements of a test as a result of incorrect test procedure or faulty equipment, the test results shall be discarded and a further test sample(s) shall be selected and tested in accordance with the relevant requirements.

14 Tensile tests

14.1 Except as permitted in **14.2**, the test pieces shall be prepared from the test samples (see clause **13**) to the dimensions of one of the test pieces given in BS A 4-1.1 or BS A 4-2.2, as appropriate, and shall be tested in accordance with the requirements of that standard.

14.2 Alternatively to **14.1**, at the option of the manufacturer, bars and sections not exceeding 16 mm in diameter or major sectional dimension may be tested in full section. For material of circular cross section, the elongation shall be measured on a gauge length equal to five times the original diameter of the test piece. For material of other than circular section, the gauge length and elongation value shall be agreed between the manufacturer and the purchaser.

14.3 If a proof stress value is given in the material specification, this shall be obtained from accurately determined load-extension or stress-strain data.

14.4 For both room temperature and elevated temperature testing, the results of each test shall be recorded in accordance with the requirements of BS A 4-1.2.

15 Creep and rupture tests

15.1 The test piece shall be prepared from the test sample (see clause **13**) to the dimensions of one of the test pieces given in BS A 4-1.3 and shall be tested in accordance with the requirements of that standard.

15.2 The duration of the test shall be not less than the minimum required by the material specification.

15.3 A stress higher than that required by the material specification may be used provided that the minimum specified life is attained. Unless otherwise agreed, the stress shall not be increased after the test has been commenced. The actual stress(es) used shall be stated in the release note.

15.4 The results of each test shall be recorded in accordance with the requirements of BS A 4-1.3.

16 Impact test

16.1 The test piece shall be machined from the test sample (see clause **13**) to the dimensions of one of the standard test pieces given in BS A 4-2.

16.2 If the test sample is machined to test piece size before heat treatment either

- a) the notches shall be machined after heat treatment, or
- b) at least 0.1 mm of material shall be removed from the radius of the root of each notch after heat treatment.

16.3 The test piece shall be tested in accordance with the requirements of BS A 4-2.

17 Hardness test

17.1 General

17.1.1 The hardness test shall be carried out in accordance with **17.2**, **17.3**, **17.4** or **17.5**, as appropriate.

17.1.2 Except as provided in **17.1.3**, the hardness shall comply with the requirements of the material specification.

17.1.3 Provided that the hardness of the material in a batch is uniform, the results of the tensile test shall be overriding if both the following conditions apply.

- a) The material specification requires both tensile and hardness tests to be carried out at room temperature and in the same condition.
- b) Both the tensile and hardness requirements are specified as either ranges or minima.

17.2 Brinell hardness test. The Brinell hardness test shall be carried out in accordance with the requirements of BS 240-1, on a machine which has been verified in accordance with the requirements of BS 240-2. The ratio used for F/D^2 shall be 30.

17.3 Vickers hardness test. The Vickers hardness test shall be carried out in accordance with the requirements of BS 427-1, on a machine which has been verified in accordance with the requirements of BS 427-2.

17.4 Rockwell hardness test. The Rockwell hardness test shall be carried out in accordance with the requirements of BS 891-1, on a machine which has been verified in accordance with the requirements of BS 891-2.

17.5 Rockwell superficial hardness test. The Rockwell superficial hardness test (N and T scales) shall be carried out in accordance with the requirements of BS 4175-1, on a machine which has been verified in accordance with the requirements of BS 4175-2.

18 Retests

Where a retest procedure permits a batch or individual product to be reheat treated and retested, the batch or product shall be subjected, in accordance with the relevant section of this British Standard, to ALL the tests required by the material specification.

19 Grain size determination

19.1 Except as stipulated in section 9, samples for the determination of grain size shall be taken at a frequency and from positions as defined in the material specification or as agreed between the manufacturer and the purchaser(*)⁵⁾ and stated on the drawing or order.

19.2 The determination shall be carried out in accordance with the requirements of DD 44.

19.3 The grain size shall comply with the requirements of the material specification, drawing or order.

20 Maintenance of identity

20.1 The material shall be kept identifiable as to its cast, its batch and, if required, its ingot and position in the ingot, to enable final identification marking to be made in accordance with clause 21.

20.2 Immediately before despatch, every product shall be checked for its alloy type by a method agreed with the Quality Assurance Authority.

20.3 Test samples and test pieces shall be kept identifiable with the material that they represent.

21 Final marking

21.1 Each billet and each bar, section and tube over 20 mm diameter or major sectional dimension, passed by the inspector, shall be stamped on or near to one end, or roller marked, or both, with the mark of the inspector, the specification number and such other markings as shall ensure full traceability of the material.

21.2 Bars, sections, tubes and wires not exceeding 20 mm diameter or major sectional dimension, passed by the inspector, shall be individually marked as required by 21.1 or, at the option of the manufacturer, bars, sections, tubes or wires from the same batch shall be wired in bundles, each of which shall have attached a durable label bearing the mark of the inspector, the specification number and such other markings as shall ensure full traceability of the material.

21.3 Unless otherwise required by the drawing or order or agreed with the purchaser(*)⁵⁾, each forging, passed by the inspector, shall bear the mark of the inspector, the specification number and such other marking as shall ensure full traceability of the material. The drawing for the forging shall state the position in which the identification marks are to be applied and, if incised marking is unsuitable, the method of marking to be used shall also be stated. If individual forging identification is not required, the items shall be made up into parcels, each of which shall have attached a durable label bearing the mark of the inspector, the specification number and such other markings as shall ensure full traceability of the material.

21.4 Each sheet over 20 mm wide and each coil of strip, passed by the inspector, shall be stamped or roller marked, or both, with the mark of the inspector, the specification number and such other markings as shall ensure full traceability of the material. Sheet not exceeding 20 mm wide shall be either individually marked or, at the option of the manufacturer, those from the same batch shall be wired in bundles, each of which shall have attached a durable label bearing the mark of the inspector, the specification number and such other markings as shall ensure full traceability of the material.

21.5 Each coil of wire, passed by the inspector, shall have attached a durable label bearing the mark of the inspector, the specification number and such other markings as shall ensure full traceability of the material.

21.6 If roller marking is employed, the ink shall be non-corrosive during any subsequent treatment and shall be capable of being completely removed without detriment to or witness on the material.

22 Release documentation

22.1 The manufacturer shall supply with each delivery a release note (acceptance certificate, certificate of conformity) bearing a printed serial number, his name and address, and stating the following information.

- a) All the details relevant to the delivery including
 - 1) purchaser's name and address;
 - 2) contract and/or order number;
 - 3) description of the supplies with drawing or part numbers, if appropriate;
 - 4) quantity;
 - 5) specification reference(s);

⁵⁾ See 2.1.

6) cast and/or batch number(s) and, if required, identity of and position in the ingot;
7) process by which the alloy was melted;
8) condition of the material as delivered;
9) heat treatment details, if appropriate;
10) inspector's stamp;
11) details of all the tests carried out, as required by the material specification, or a reference to the numbers of the relevant test reports containing this information, copies of which shall be attached to the release note.

b) A certificate 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 manufactured, tested and inspected to the requirements of the Quality Assurance Authority and, unless otherwise stated, conform in all respects to the specification(s), drawing(s), and contract/order relative thereto.”

22.2 In the case of material supplied by a stockist, all the information required by **22.1**, except **22.1** a) 1) and 2), as provided by the manufacturer, shall be supplied with each delivery.

Section 2. Bars for machining and sections

23 Condition

The material shall be supplied in the condition required by the material specification unless the manufacturer and the purchaser(*)⁶⁾ agree otherwise, in which case the condition in which the material is to be supplied shall be stated on the drawing or order.

24 Dimensional tolerances

24.1 The dimensions of bars, other than hot rolled bars, shall comply with the requirements of Table 1, Table 2 or Table 3, as appropriate.

24.2 Tolerances on the dimensions of sections and hot rolled bars, if required, shall be stated on the order.

24.3 Tolerances on the straightness of bars, if required, shall be stated on the order.

25 Heat treatment

25.1 The bars and sections shall be heat treated in accordance with the requirements of the material specification.

25.2 No bar, section or test sample shall be subjected to the specified heat treatment more than twice.

26 Mechanical tests

26.1 Selection and preparation of test samples

26.1.1 The inspector shall select one test sample from each batch (see 4.1.2) to provide test pieces for the tests required by the material specification.

26.1.2 Test samples shall consist of lengths of the full cross section of the product.

26.1.3 Test samples representing material which is not supplied in the finally heat treated condition shall be finally heat treated in accordance with the requirements of the material specification.

26.1.4 Test samples representing material which has been finally heat treated, as required by the material specification, shall not be further heat treated.

26.1.5 Test samples shall not be further mechanically worked after they have been separated from the material they represent.

26.2 Location of test pieces. Unless otherwise stipulated in the material specification or order, the following requirements govern the preparation of test pieces from the test samples selected and prepared in accordance with 26.1.

26.2.1 *Samples up to and including 30 mm in diameter or minor sectional dimension.* Except as permitted by 14.2, the test piece shall be machined coaxially from the test sample.

26.2.2 *Samples over 30 mm up to and including 75 mm in diameter or minor sectional dimension.* The longitudinal axis of the test piece shall be not less than 15 mm from the surface of the test sample.

26.2.3 *Samples over 75 mm in diameter or minor sectional dimension.* The test piece shall be prepared in accordance with 26.2.2 or, at the option of the manufacturer, shall be taken in the transverse direction not less than 15 mm from the surface of the product. The location and direction of the test piece shall be stated in the release note.

26.3 Initial tests. The mechanical properties obtained from the test pieces shall comply with the requirements of the material specification.

26.4 Retests. If any test piece fails to comply with the requirements of a specified mechanical test, the inspector shall adopt one or both of the following procedures, as requested by the manufacturer.

a) Select for test from the same batch two further samples, one of which shall be from the bar or section from which the original test sample was taken, unless that bar or section has been withdrawn by the manufacturer. The mechanical properties obtained from the test pieces prepared from both these further test samples shall comply with the requirements of the material specification.

b) Allow the batch to be reheat treated and retested (see clause 18).

27 Hardness test

27.1 Initial tests. Hardness testing shall be carried out at the following frequency.

27.1.1 *Material in other than the finally heat treated condition.* If the material specification states a maximum hardness value for bar or section in other than the finally heat treated condition, not less than 10 % of the bars or sections in each heat treatment batch shall be hardness tested.

27.1.2 *Material in the finally heat treated condition.* If the material specification states a hardness value for bar or section in the heat treated condition, each bar or section and each representative test sample shall be hardness tested after heat treatment.

⁶⁾ See 2.1.