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AEROSPACE SERIES

Procedure for inspection, testing and acceptance of iron, nickel, copper, cobalt and refractory metal base alloy castings

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Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 January 2010. It was prepared by Panel ACE/61/-/15, *Steels*, and Panel ACE/61/-/48, *Heat resisting 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This standard supersedes BS HC 100:1972, which is withdrawn.

Information about this document

This is a full revision of BS HC 100, and introduces the following principal changes.

Section 1: General requirements

- a) Definitions have been amended.
- b) Information to be supplied by purchaser has been added.
- c) Information to be agreed by contracting parties has been added.
- d) Qualification of foundry technique requirements has been added.
- e) Reference to AMS 2750 has been added for heat treatment temperature control.
- f) Heat treatment temperature tolerances have been added.
- g) Tensile testing at ambient temperature to BS 4A 4 has been replaced by BS EN 2002-1.
- h) Tensile testing at elevated temperature to BS 4A 4-1.2 has been replaced by BS EN 2002-2.
- i) Creep and stress-rupture testing to BS 4A 4-1.3 has been replaced by BS EN 2002-005.
- j) Impact testing to BS 4A 4 has been replaced by BS 131 and BS EN 10045.
- k) Brinell hardness testing to BS 240 has been replaced by BS EN ISO 6506-1.
- l) Vickers hardness testing to BS 427 has been replaced by BS EN ISO 6507-1.
- m) Rockwell hardness testing to BS 891 has been replaced by BS EN ISO 6508-1.
- n) Bend testing to BS 4A 4 has been replaced by BS EN ISO 7438.
- o) Depth of case test method BS EN ISO 2639 has been added.
- p) Intercrystalline corrosion test method BS EN ISO 3651-2 has been added.
- q) Rules for application of values have been added.
- r) Penetrant flaw detection test method EN 2002-16 has been added.
- s) Penetrant dye sensitivity requirements have been added.

- t) Magnetic particle flaw detection test method BS EN ISO 9934 has been added.
- u) Radiological examination test method EN 2002-021 has been added.
- v) Reference to ASTM E192 has been added for defect acceptance standards.
- w) Protection and packaging requirements have been added.
- x) Certification requirements have been amended.

Section 2: Re-melting stock

Internal and external defects requirements have been added.

Section 3: Precision castings

Internal and external defects requirements have been added.

Section 4: Sand castings

Internal and external defects requirements have been added.

Section 5: Centrifugal castings

Internal and external defects requirements have been added.

New Annex A added – rules for application of values for chemical composition and mechanical properties given in material specifications.

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 methods are expressed as a set of instructions, a description, 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 requirements

1 Scope

This British Standard specifies procedures for inspection, testing and acceptance of iron, nickel, copper, cobalt and refractory metal base alloy castings for aerospace purposes.

The standard is applicable to material specifications in the British Standard Aerospace HC series and also to other British Standard material specifications for iron, nickel, copper, cobalt and refractory metal base alloy castings 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 131-1, *Methods for notched bar tests – Part 1: The Izod impact test on metals*

BS 131-4, *Methods for notched bar tests – Part 4: Calibration of Izod pendulum impact testing machines for metals*

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

BS EN 2002-2, *Metallic materials – Test methods – Part 2: Tensile testing at elevated temperature*

BS EN 2002-005, *Metallic materials – Test methods – Part 5: Uninterrupted creep and stress-rupture testing*

BS EN 2103-3, *Steel, nickel base and cobalt base alloy remelting stock and castings – Technical specification – Part 3: Pre-production and production castings*

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

BS EN 10045-1, *Charpy impact test on metallic materials – Part 1: Test method (V- and U-notches)*

BS EN ISO 148-2, *Metallic materials – Charpy pendulum impact test – Part 2: Verification of testing machines*

BS EN ISO 2639, *Steels – Determination and verification of the depth of carburized and hardened cases*

BS EN ISO 3452-2, *Non-destructive testing – Penetrant testing – Part 2: Testing of penetrant materials*

BS EN ISO 3651-2, *Determination of resistance to intergranular corrosion of stainless steels – Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels – Corrosion test in media containing sulfuric acid*

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 9934 (all parts), *Non-destructive testing – Magnetic particle testing*

EN 2002-16, *Metallic materials – Test methods – Part 16: Non-destructive testing – Penetrant testing*¹⁾

EN 2002-021, *Metallic materials – Test methods – Part 21: Radiographic testing of castings*¹⁾

AMS 2750, *Pyrometry*²⁾

ASTM E192, *Standard Reference Radiographs of Investment Steel Castings for Aerospace Applications*³⁾

3 Terms and definitions

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

3.1 batch

batch of ingots for re-melting or castings, each of which is:

- a) castings of similar dimensions, (see Note 1), produced from the same melt and, if heat treated, heat treated together; or
- b) precision castings of similar dimensions (see Note 2), poured from a melt made up of re-melt stock or re-melt stock plus the same amount of alloying additions [see 30.1a), 30.1b) and 30.2] and, if heat treated, heat treated together

NOTE 1 For centrifugal castings, similar dimensions only apply to the cross-section dimension, i.e. length can be ignored.

NOTE 2 If mechanical test samples are cut from actual castings, a batch comprises castings to the same pattern. Castings to the left-hand and right-hand version of any pattern are considered as being to the same pattern.

3.2 cast

product of a single furnace charge, or more than one furnace charge mixed prior to pouring, used to produce re-melting stock

3.3 centrifugal castings

process in which a mould in metal or sand rotates around the pouring axis

3.4 designated area

highly stressed or otherwise important region of a casting, the location of which is determined by the design authority and stated on the drawing or associated documents

3.5 design authority

organization responsible for the detailed design of matériel and which has the responsibility of certifying designs and/or sealing drawings and specifications

¹⁾ Published as ASD Prestandard at the date of publication of this standard.

²⁾ Available from www.sae.org.

³⁾ Available from www.astm.org.

3.6 melt

product of a single furnace charge, or more than one furnace charge mixed prior to pouring, used to produce castings

3.7 precision castings

process involving a ceramic mould formed around a disposable pattern (e.g. lost wax process)

3.8 pre-production castings

castings produced to a particular design which qualify the method of manufacture and mould configuration and demonstrate that the purchaser's requirements can be met

3.9 quality assurance authority

body responsible for authorizing the founder or supplier to issue certification, when to certify means to attest as meeting a standard

3.10 re-melting stock

metal, supplied in cast or wrought form, the chemical composition of which has been established by analysis

NOTE This is also known as "master melt" in connection with investment castings.

3.11 sand castings

process involving the moulding of a re-usable pattern with a bonded sand (excluding castings made by the centrifugal process)

3.12 undesignated area

all regions within a casting which have not been designated

3.13 vacuum melting

practice of melting and casting under vacuum

4 General

This standard details the basic requirements for the inspection and testing of British Standard Aerospace HC series, wrought heat-resisting 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 standard⁴⁾ can be made and verified.

a) General:

- 1) the number of the material specification with which this standard is to be used;
- 2) the heat treatment required if different from that specified in the material specification (see 9.1);
- 3) if the use of polymer quenching is to be precluded where it is not precluded by the material specification (see 9.7);
- 4) when test samples are cut from castings, the number of castings to be tested in each batch (see 12.2.2);
- 5) for castings supplied in other than the finally heat treated condition, the number of additional test samples required [see 12.3.2a) and 12.3.2b)];
- 6) the technique for magnetic particle flaw detection (see Clause 16);
- 7) the technique for radiological examination (see 17.1);
- 8) the nature and colour of the marking ink and type of characters if other than at the discretion of the manufacturer (see 19.1);
- 9) if the product is not to be protected by a coating of corrosion preventative (see 20.1);

b) Re-melting stock:

- 1) the manufacturing method if other than by the use of pure materials, added elements and approved scrap (see Clause 23);
- 2) if mechanical tests are required where this is not specified by the material specification (see 27.1);
- 3) the mechanical properties where they are not specified in, or are different from, those specified in the material specification (see 28.2);

⁴⁾ Marking a British Standard identifier (e.g. BS HC 202:1973) 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.

- c) Precision castings:
 - 1) the required frequency of chemical analysis for melts produced in accordance with 30.1a) or 30.1b) where this is not specified by the material specification or is not to be determined by the quality assurance authority (see 32.2.1);
 - 2) the required properties if other than in accordance with the material specification (see 36.1 and 36.2);
- d) Sand castings:
 - 1) the required properties if other than in accordance with the material specification (see 47.1 and 47.2).

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 standard⁵⁾ can be made and verified.

- a) The method of temperature control if other than AMS 2750 (see 9.2).
- b) The form, mass, dimensions and tolerances of re-melting stock (see 11.1).
- c) The method of selection and preparation of test samples if not specified elsewhere in the standard (see 12.2.1).
- d) For precision castings, if cast-to-size test pieces may be used (see 12.2.3).
- e) If flaw detection using non-fluorescent penetrants is permitted (see Clause 15).
- f) The acceptance criteria for castings with a wall thickness greater than 25 mm (see 17.4).
- g) For re-melting stock, the test methods and acceptance criteria for internal defects if not at the manufacturer's option (see Clause 25).
- h) For re-melting stock, the method of casting the test samples if not at the manufacturer's option (see 27.2).
- i) The condition of the castings if not in accordance with the material specification (see Clause 31, Clause 42 and Clause 53).
- j) If all castings are not required to be examined for internal defects (see 33.2, 44.2 and 55.2).
- k) The acceptance standard for other than cracks and crack-like defects (see 34.3, 45.3 and 56.3).
- l) For centrifugal castings, the method of obtaining the test samples (see 57.2).

⁵⁾ Marking a British Standard identifier (e.g. BS HC 202:1973) 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 Pre-production castings – qualification of foundry technique

6.1 Prior to commencing series production of a design, pre-production castings shall be produced in order to optimize and qualify the method of manufacture and mould configuration and to demonstrate that the design authority's requirements can be met.

NOTE It is strongly recommended that the technical representative of the founder should be given the opportunity to examine the casting drawing at the initial stages of design and to advise on the optimum design which will enable acceptable castings to be produced consistently.

The following requirements shall be specified on the order, drawing and/or inspection schedule:

- a) number of pre-production castings to be produced for evaluation/qualification;
- b) heat treatment condition of the pre-production castings including any requirements for machining prior to heat treatment;
- c) any areas on the castings which are critical and for which a high internal and/or external defect standard is required;
- d) type, number and locations of tests/inspections necessary to evaluate and qualify the method of manufacture such as dimensions, mechanical properties, microstructure, macrostructure, etc;
- e) whether the method of manufacture needs to be agreed with the design authority or is at the founder's discretion;
- f) who is to perform the evaluation/qualification.

6.2 Qualification of the pre-production castings shall be carried out and include those inspections and tests which will be performed on production castings. All manufacturing parameters shall be recorded with the following foundry techniques in particular being noted:

- a) position of runners and risers;
- b) position and nature of chills;
- c) type of moulding material and details of mould manufacturing parameters;
- d) mould temperature;
- e) maximum amount of approved scrap which may be added to the melt (at the founder's discretion);
- f) casting temperature range;
- g) heat treatment details;
- h) method of surface finishing.

6.3 Unless otherwise agreed with the design authority, it shall be demonstrated that the casting procedure developed is capable of consistently producing castings fully conforming to drawing requirements, without the need for weld repair.

6.4 When all inspection and test results relating to pre-production castings have been reported and are considered as satisfactory by the design authority, the founder shall compile a manufacturing schedule defining the foundry technique and inspection requirements, including any radiographic techniques to be used. This shall be made available to and/or be subject to written agreement with the design authority as

required. Series production shall commence when written agreement or an order has been received from the design authority or purchaser.

7 Manufacture of production castings

7.1 General

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

7.2 Correction of distortion

Correction of distortion shall be carried out only by agreement between the founder and design authority. The founder shall be responsible for specifying the conditions under which such correction shall be carried out, subject to any requirements of the design authority. The method agreed shall be incorporated in the manufacturing schedule. After correction of distortion, all castings so treated shall be examined by magnetic or penetrant flaw detection, as applicable (see Clause 15).

7.3 Repair of castings

7.3.1 Castings shall be repaired only as permitted by the design authority. Unless the design authority stipulates a particular method of repair, the founder shall submit the proposed method to the design authority. All repairs shall be carried out before impregnation and/or sealing.

7.3.2 Prior to weld repair, defects shall be completely dressed out. Each weld preparation area shall be subject to magnetic or penetrant flaw detection, as applicable (see Clause 15 and Clause 16) to ensure that defects have been completely removed.

7.3.3 If castings are pre-heated prior to weld repair, the pre-heating shall be carried out in such a manner that the mechanical properties of the finally heat treated castings are not adversely affected.

7.3.4 Weld repair of castings shall be carried out by a welder whose competence has been satisfactorily demonstrated. The founder shall devise a scheme for demonstrating the competence of the welder and, if required by the order, specification or associated document, shall submit details of the scheme and the results of any competence tests to the design authority for approval.

8 Re-qualification requirements

At the discretion of the design authority, re-qualification of serial production castings shall be required in the following instances:

- a) modification to the drawing;
- b) use of re-melt stock from a different source;
- c) modifications to the approved casting route;
- d) use of a new casting founder;

- e) when a significant time interval (usually several years) has elapsed between casting campaigns for a specific part;
- f) if new tooling is used;
- g) when required by the design authority for any other reason.

Re-qualification testing requirements, especially location/type of test samples, shall be identical to those used for the initial qualification of the pre-production castings unless otherwise specified on the order, drawing or inspection schedule.

9 Heat treatment

9.1 Heat treatment shall be carried out in accordance with the material specification or order [see 5.1a2)].

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

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

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

- a) $\theta < 750\text{ }^{\circ}\text{C}$: $\pm 5\text{ }^{\circ}\text{C}$.
- b) $750\text{ }^{\circ}\text{C} \leq \theta \leq 1250\text{ }^{\circ}\text{C}$: $\pm 10\text{ }^{\circ}\text{C}$.
- c) $\theta > 1250\text{ }^{\circ}\text{C}$: $\pm 15\text{ }^{\circ}\text{C}$.

9.5 If no period or temperature is given in the material specification for a particular heat treatment, these and their tolerances shall be at the discretion of the manufacturer.

9.6 No castings shall be subjected to the specified final heat treatment (other than tempering) more than three times.

9.7 Unless specifically precluded by the material specification or order [see 5.1a3)], where the material specification specifies the use of an oil quenchant, it is permissible for material to be quenched in a polymer quenchant.

9.8 When substituting a polymer quenchant for an existing oil quenchant, the polymer and concentration being substituted shall achieve cooling characteristics that are similar to the existing oil quenchant and the properties being produced shall be equivalent to those for oil quenched parts.

10 Chemical composition

10.1 The chemical composition shall conform to the material specification.

10.2 The frequency of chemical analysis shall be as specified in the relevant section of this standard. The samples taken for analysis shall be representative of the cast. The method of analysis shall be at the