

BS 6S 100:2010



BSI Standards Publication

AEROSPACE SERIES

Procedure for inspection, testing and acceptance of wrought steels (other than plate, sheet, strip and tube)

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ISBN 978 0 580 67015 2

ICS 49.025.10

The following BSI references relate to the work on this standard:

Committee reference ACE/61

Draft for comment 09/30199785 DC

Publication history

First published February 1945

Second edition, January 1949

Third edition, December 1963

Fourth edition, September 1975

Fifth edition, September 1993

Sixth (current) edition, March 2010

Amendments issued since publication

Date	Text affected
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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 March 2010. It was prepared by Panel ACE/61/-/15, *Steels*, 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This British Standard supersedes BS 5S 100:1993+A2:2003, which is withdrawn.

Information about this document

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

Section 1

- a) Temperature control during heat treatment to BS M 54 replaced by AMS 2750.
- b) Use of polymer quenchant added.
- c) Heat treatment temperature tolerances added.
- d) Requirements for application of values for chemical composition added.
- e) Tensile testing at ambient temperature to BS 4A4:1966, Part 1.1 replaced by BS EN 2002-1.
- f) Tensile testing at elevated temperature to BS 4A4:1966, Part 1.2 replaced by BS EN 2002-2.
- g) Creep and rupture testing to BS 4A4:1966, Part 1.3 replaced by BS EN 2002-005.
- h) Impact testing to BS 4A4:1966, Part 2 replaced by BS 131 and BS EN 10045-1.
- i) Brinell hardness testing to BS EN 10003-1 replaced by BS EN ISO 6506-1.
- j) Rockwell hardness testing to BS EN 10109-1 replaced by BS EN ISO 6508-1.
- k) Grain size test to BS 4490 replaced by BS EN ISO 643.
- l) Hardenability test to BS 4437 replaced by BS EN ISO 642.
- m) Dimensional tolerances to BS 970-1, BS 970-2 and BS 4114 replaced by BS EN 10017, BS EN 10058, BS EN 10059, BS EN 10060, BS EN 10061, BS EN 10092-1, BS EN 10108 and BS EN 10243-1.

Section 8

- n) Requirements for bar and nuts for the manufacture of forged bolts and forged nuts only transferred from Section 9. (In the previous edition Section 8 was unallocated.)
- o) Examination for carburization and decarburization to BS 6617-1 replaced by BS EN ISO 3887.

Section 9

- p) Requirements for spring steel rod and wire for springs transferred from Section 10.
- q) Examination for carburization and decarburization to BS 6617-1 replaced by BS EN ISO 3887.
- r) Mechanical testing to BS 4545 replaced by BS EN 10218-1.

Section 10

- s) Section deleted and requirements transferred to Section 9.

Annex A (was Annex D)

- t) Re-identified as "Rules for application of values for chemical composition and mechanical properties given in material specifications".
- u) Reference to withdrawn BS 1957 replaced by details for rounding of values.

Annex B (was Annex A)

- v) Re-identified as "Cleanness examination procedure".

Annex C (was Annex B)

- w) Re-identified as "Ultrasonic examination procedure".

Annex D (was Annex C)

- x) Re-identified as "Inspection and testing requirements for springs".

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 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 the inspection, testing and acceptance of wrought steel billet, bar, rod and forgings, of parts made from such forms and subsequently heat treated, and of spring steel rod for wire drawing, spring wire and springs, to be used for aerospace purposes.

The standard is applicable to material specifications in the British Standard Aerospace S series.

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, *Notched bar tests – Part 1: The Izod impact test of metals*

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

BS 6200-2.1, *Sampling and analysis of iron, steel and other ferrous metals – Part 2: Sampling and sample preparation – Section 2.1: Methods for iron and steel*

BS 6200-2.2, *Sampling and analysis of iron, steel and other ferrous metals – Part 2: Sampling and sample preparation – Section 2.2: Methods for ferroalloys and other alloying additives*

BS A 100, *Specification for general requirements for bolts and free running nuts of tensile strength not exceeding 1249 MPa*

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 005: Uninterrupted creep and stress-rupture testing*

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

BS EN 10017, *Steel rod for drawing and/or cold rolling – Dimensions and tolerances*

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

BS EN 10058, *Hot rolled flat steel bars for general purposes – Dimensions and tolerances on shape and dimensions*

BS EN 10059, *Hot rolled square steel bars for general purposes – Dimensions and tolerances on shape and dimensions*

BS EN 10060, *Hot rolled round steel bars for general purposes – Dimensions and tolerances on shape and dimensions*

BS EN 10061, *Hot rolled hexagon steel bars for general purposes – Dimensions and tolerances on shape and dimensions*

BS EN 10092-1, *Hot rolled spring steel flat bars – Part 1: Flat bars – Dimensions and tolerances on shape and dimensions*

BS EN 10108, *Round steel rod for cold heading and cold extrusion – Dimensions and tolerances*

BS EN 10218-1, *Steel wire and wire products – General – Part 1: Test methods*

BS EN 10243-1, *Steel die forgings – Tolerances on dimensions – Part 1: Drop and vertical press forgings*

BS EN 10243-2, *Steel die forgings – Tolerances on dimensions – Part 2: Upset forgings made on horizontal forging machines*

BS EN 10278, *Dimensions and tolerances of bright steel products*

BS EN 12668, *Non-destructive testing – Characterization and verification of ultrasonic examination equipment*

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

BS EN ISO 642, *Steel hardenability test by end quenching (Jominy test)*

BS EN ISO 643, *Steels – Micrographic determination of the apparent grain size*

BS EN ISO 3887, *Steels – Determination of depth of decarburization*

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)*

AMS 2301, *Aircraft quality steel cleanliness – Magnetic particle inspection procedure*¹⁾

AMS 2750, *Pyrometry*¹⁾

AMS-STD-2154, *Process for ultrasonic inspection of wrought materials*¹⁾

ASTM E45, *Standard test methods for determining the inclusion content of steel*²⁾

3 Terms and definitions

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

3.1 bars

3.1.1 bar

wrought product with a consistent solid cross-section supplied in straight lengths

3.1.2 black bar

bar which has not had its finished surface improved by descaling or by either of the methods applicable to bright bar

¹⁾ Available from www.sae.org.

²⁾ Available from www.astm.org.

- 3.1.3 bright bar**
bar which has been finish ground or machined
- 3.1.4 bright drawn bar**
bar which has been descaled and cold drawn
- 3.2 batch**
products which are from the same cast; of the same form and manufactured under the same processing conditions; of the same nominal dimensions to within $\pm 10\%$ or of similar ruling section; and 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 except in the case of coil when the maximum time is that required to heat treat one full coil
- 3.3 billet**
rolled, extruded, forged or continuously cast product which may be solid or hollow and which is intended for further hot working
- 3.4 cast**
mass of solid metal all resulting from the same final melting operation
- 3.5 continuous casting**
process whereby molten metal from a single melt is poured into a water cooled mould, through which it is passed slowly and continuously to emerge as solid metal in a regular shape ready for subsequent hot working
- 3.6 design authority**
organization responsible for the detailed design of matériel and for certifying designs and/or for sealing drawings and specifications
- 3.7 equivalent diameter**
diameter at the time of heat treatment of a hypothetical very long bar (effectively of infinite length) of uniform circular cross-section, which, if subjected to the same cooling conditions as the product being heat treated, i.e. same initial and final temperatures and same cooling medium, would have a cooling rate at its axis equivalent to that at the slowest-cooling position in the product being heat treated
NOTE Further information is given in BS 5046.
- 3.8 forgemaster**
company responsible for producing forgings
- 3.9 forging**
product obtained by hot working under a press or hammer (including rolled rings) and not intended for further hot working
- 3.10 forging stock**
cast or wrought steel intended for the production of forgings
- 3.11 ingot**
material cast into static moulds prior to subsequent hot working or, in the case of continuously cast material, an individual continuously cast strand
- 3.12 limiting ruling section**
largest diameter, for any given composition of steel, in which certain specified mechanical properties can be expected after a specified heat treatment
NOTE Further information is given in BS 5046.

3.13 manufacturer

company that produces the material in the form and condition in which it is supplied to the purchaser

3.14 melting processes**3.14.1 air melting**

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

3.14.2 consumable electrode

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

3.14.3 consumable electrode remelting

process of remelting consumable electrodes of known analysis by one of the methods defined in 3.14.4, 3.14.5, 3.14.7 or 3.14.9

3.14.4 electroflux remelting

process of remelting consumable electrodes through a flux

3.14.5 electroslog remelting

process of remelting consumable electrodes under a protective slag layer

3.14.6 secondary refining

process of carrying out a further refining operation in a separate vessel to that in which initial melting/converting was carried out, without intermediate solidification of the steel

NOTE The operation is carried out under vacuum and/or with inert gas bubbling facilities.

3.14.7 vacuum arc remelting

process of remelting consumable electrodes under vacuum

3.14.8 vacuum degassing

treatment of an air melted liquid alloy in a vacuum for the purpose of removing volatile constituents, followed by casting in air or under vacuum

3.14.9 vacuum induction melting

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

NOTE See also vacuum arc remelting (3.14.7).

3.15 parent cast

melt of known chemical composition which is to be subsequently remelted

3.16 procedure X

procedure for the initial approval and process control of forgings in which test samples are machined from specified locations in forgings and tested to establish the initial quality and demonstrate that the forgings continue to conform to specified requirements

NOTE 1 The forgings from which the samples are taken are destroyed.

NOTE 2 This procedure is used in conjunction with procedures A or C (see 45.1).

3.17 purchaser

company which orders and purchases the product

3.18 quality assurance authority

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

3.19 rod

hot rolled wrought product with a consistent solid cross-section supplied in coil form

NOTE It may be a finished product or subsequently further processed.

3.20 ruling section

equivalent diameter of that portion of the product or part at the time of heat treatment that is most important in relation to mechanical properties

NOTE Further information is given in BS 5046.

3.21 strand

product of an individual continuous casting mould

3.22 supplier

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

3.23 test piece

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

3.24 test sample

portion of the material selected for testing

3.25 tests**3.25.1 acceptance tests**

tests carried out by the manufacturer on material which is to be delivered in the final heat-treated condition to show that the material conforms to the material specification

3.25.2 proving tests

mechanical tests carried out by the manufacturer on material which is to be delivered in a condition other than the final heat-treated condition

NOTE Suitable test samples are subjected to the specified final heat treatment to show that the material conforms to the material specification.

3.26 wire

product with a regular or consistent solid section obtained by the cold working of rod and normally supplied in coils

4 General

This standard details the basic requirements for the inspection and testing of British Standard Aerospace series wrought steels (other than plate, sheet, strip and tube).

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 manufacturer and the purchaser 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 standard³⁾ can be made and verified.

a) General:

- 1) the identity of the material specification with which this standard is to be used;
- 2) the heat treatment condition in which the material and parts are to be supplied, if different from the material specification (see 7.1);
- 3) the required heat treatment temperature (and tolerance) if different from the material specification (see 7.4);
- 4) if the use of polymer quenching is to be precluded where it is not precluded by the material specification (see 7.7);
- 5) if a particular method is required for surface inspection (see 12.1);
- 6) if sulfur printing and/or deep etching tests are required also on samples corresponding to the bottoms of ingots (see 14.1);
- 7) the required sampling frequency for sulfur printing and/or deep etching tests if different from the material specification and this standard (see 14.2);
- 8) if a particular method of ultrasonic examination and level of acceptance are required (see 17.3);
- 9) if the higher acceptance grade for ultrasonic testing given in Annex C is required (see 17.5 and C.6);
- 10) if the determination of transverse properties is required (see 18.2.2);
- 11) the required condition of supply, if different from the material specification (see Clause 19);

³⁾ Marking a British Standard identifier (e.g. BS S 164:2002) 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.

- 12) the required dimensional tolerances for parts [see Clause 20c)];
- 13) if the material is required to be identifiable to the ingot and position within the ingot from which it came (see 21.1);
- b) Forging stock, billet and bar:
 - 1) the ruling section of heat treatment test samples, if required (see 36.1.2 and 36.3.2);
- c) Forgings:
 - 1) the method of ultrasonic examination to be used and the level of acceptance (see 17.3);
 - 2) if the identification marking is to be stamped in a particular position (see 22.4);
 - 3) whether procedure X is to be invoked, and if so the number of forgings to be selected for evaluation, the location, size and form of the test pieces, the minimum test properties, any additional test requirements and the procedure for selection of forgings during production (see 44.1);
 - 4) the sampling procedure for batch release testing, including details of integral test samples or test samples machined from the body of forgings, as applicable (see 45.1);
 - 5) the number of test samples to be heat treated with each batch of forgings, if applicable (see 45.2);
 - 6) if a heat treatment proving test is required (see 45.3), and the retest procedure, if applicable (see 46.2.2);
 - 7) the number of test samples to be supplied for heat treatment with each batch of forgings, if applicable (see 45.5);
 - 8) the mechanical tests to be carried out and the mechanical properties required, if different from the material specification (see 46.1);
 - 9) if more than one hardness test is to be carried out per forging, the required test positions and required hardness values (see 47.1.2 and 47.1.3);
- d) Parts finally heat treated after machining:
 - 1) the mechanical tests to be carried out and the mechanical properties required, if different from the material specification (see 49.4.1);
 - 2) the position for hardness testing, if applicable (see 49.5.1 and 52.5.1) and any special hardness requirements (see 49.5.1);
 - 3) the carburizing process to be applied, if applicable, the depth of case required and the final heat treatment to be applied (see 50.2);
 - 4) if a particular method is required for measuring the depth of case (see 50.3.2);
 - 5) if hardness testing is to be carried out on the core of each part, and the hardness required (see 50.3.6);
 - 6) the depth of case to be obtained from nitriding (see 51.2), and if a particular method is to be used for measuring depth of case (see 51.3.2);
 - 7) if a hardness test is required on the core, and if a particular test position is required (see 51.5);

- e) Spring steel rod and wire for springs:
 - 1) if ductility tests are required for wire (see 62.7.4);
- f) Springs:
 - 1) the required frequency of insertion of test lengths with springs heat treated in a continuous furnace or oven [see D.4b)];
 - 2) the maximum permitted amount of decarburization if different from the material specification (see D.6.1).

5.2 Item to be agreed between the contracting parties

The following item 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 item shall be satisfied before a claim of compliance with the standard⁴⁾ can be made and verified:

- a) the method of temperature control if other than AMS 2750 (see 7.3).

6 Manufacture

6.1 The steel shall be made by the melting process specified in the material specification. If, in addition to air melting, vacuum degassing and/or secondary refining is carried out by the manufacturer, and that treatment is not a requirement of the material specification or order, the release documentation shall state that vacuum degassing and/or secondary refining has been employed.

6.2 Except as permitted in 6.3 for vacuum arc remelted casts, 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 conform to the same material specification as the steel being remelted. Not more than one parent cast shall be used to produce a single electrode or remelted ingot.

6.3 For vacuum arc remelted casts produced under automated conditions with equipment enabling quantitative control of electrode consumption, it is permissible to use electrode stubs which differ in composition from the material being re-melted, provided that the welding of the stub to the electrode takes place outside the furnace and sufficient unmelted electrode remains on the stub after completion of remelting to ensure freedom from contamination of the ingot by the stub material. 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.

⁴⁾ Marking a British Standard identifier (e.g. BS S 164:2002) 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.

6.4 For electroslag remelted casts, the use of electrode stub ends of different material to the steel being remelted shall be permitted provided that the remelted steel is not contaminated with material from the stub ends. Not more than one parent cast shall be used to produce a single electrode or remelted ingot.

6.5 The size, shape and method of production of the ingots shall be so selected as to minimize segregation and axial unsoundness.

6.6 The ingots, unless charged hot into the mill or forge reheating furnace, shall be cooled in a manner that prevents cracking.

6.7 Re-heating for hot working and cooling after hot working shall be controlled to avoid deleterious effects.

6.8 At some stage, or stages, in the manufacture of the product, adequate discard shall be removed from the portions corresponding to the top and the bottom of each ingot or the beginning and end of each strand.

6.9 For products made by continuous casting, the minimum hot working reduction ratio from as cast bloom or billet to finished product shall be 6:1.

7 Heat treatment

7.1 Material and parts shall be supplied in the heat treatment condition specified in the material specification, drawing or order [see 5.1a2)].

7.2 No material, part or test sample shall be subjected to refining, hardening, normalizing, softening, solution treatment, primary hardening or precipitation, or a combination thereof, more than three times in total.

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

7.4 If a specific temperature (value and tolerance) is given in the material specification, drawing or order [see 5.1a3)], 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.

7.5 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) $750\text{ }^{\circ}\text{C} \leq \theta \leq 1\,250\text{ }^{\circ}\text{C}$: $\pm 10\text{ }^{\circ}\text{C}$
- c) $\theta > 1\,250\text{ }^{\circ}\text{C}$: $\pm 15\text{ }^{\circ}\text{C}$

7.6 If no period or temperature are given in the material specification these shall be at the discretion of the manufacturer.

NOTE Special provisions for the heat treatment of test samples are given in 18.2.3 and 18.2.4.

7.7 Unless specifically precluded by the material specification or order [see 5.1a4)], where the material specification specifies the use of an oil quenchant, it is permissible for material to be quenched in a polymer quenchant.

7.8 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.

8 Chemical composition

8.1 The chemical composition of the steel shall conform to the material specification. An analysis of every cast shall be made for the specified elements and a certificate of analysis shall be supplied to the purchaser unless the whole of the cast is to be remelted (see 8.2).

8.2 Each consumable electrode remelted cast shall be analysed. Samples shall be taken from the top and bottom of each remelted ingot. The elements to be determined in each cast shall be as specified in the material specification.

NOTE If the manufacturer can show by statistical analysis that there is no significant difference between the top and bottom locations, only one position need be analysed.

8.3 Analytical samples shall be selected and prepared in accordance with the relevant requirements specified in BS 6200-2.1 and BS 6200-2.2. In the case of continuously cast material, if it is impracticable to sample the liquid steel, samples shall be taken from the cast product at positions corresponding to the beginning, middle and end of the cast.

8.4 Elements not quoted in the material specification shall not be intentionally added to the steel except for the purpose of finishing the melt. Reasonable precautions shall be taken to prevent their inclusion during manufacture. The maximum limits on residual elements shall be as given in Table 1.

8.5 The deliberate addition of lead shall be permitted in certain low strength steels if it is specified as an alloying element in the material specification. Lead shall not be added to other steels.

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

Table 1 Maximum limits on residual elements

Element	Carbon and carbon-manganese, boron and alloy grades	Non-austenitic, corrosion-resisting grades	Austenitic, corrosion-resisting grades
	Wt %	Wt %	Wt %
Nickel	0.40	—	—
Chromium	0.30	—	—
Molybdenum	0.15	0.30	1.00
Niobium	—	—	0.20
Titanium	—	—	0.10
Copper	0.30	0.30	0.70

9 Product analysis and permitted variations

Product analysis may differ from the cast analysis due to heterogeneity arising during casting and solidification. Table 2 shows the variations from the range specified for cast analysis permitted on product analysis.

The variation may occur either above or below the individual element ranges but shall not apply both above and below the specified range for any one element in any one cast of steel.

Test specimens for product analysis shall be taken in accordance with BS 6200-2.1 and BS 6200-2.2.

Table 2 Permitted variation of product analysis from specified range

Element	Range in which maximum of specified element falls Weight (W) %	Variation on specified range	
		Under min. Weight %	Over max. Weight %
Carbon	$W \leq 0.010$	0.002	0.002
	$0.010 < W \leq 0.03$	0.005	0.005
	$0.03 < W \leq 0.25$	0.01	0.01
	$0.25 < W \leq 0.50$	0.02	0.02
	$0.50 < W \leq 1.0$	0.03	0.03
	$1.0 < W \leq 1.3$	0.04	0.04
Silicon	$W \leq 0.1$	—	0.01
	$0.1 < W \leq 0.25$	0.02	0.02
	$0.25 < W \leq 0.45$	0.03	0.03
	$0.45 < W \leq 1.0$	0.05	0.05
	$1.0 < W \leq 2.0$	0.10	0.10
Manganese	$W \leq 0.70$	0.03	0.03
	$0.70 < W \leq 1.0$	0.04	0.04
	$1.0 < W \leq 2.0$	0.05	0.05
Phosphorus	$W \leq 0.030$	0.003	0.003
	$0.030 < W \leq 0.045$	0.004	0.004
	$W > 0.045$	0.005	0.005
Sulfur	$W \leq 0.030$	—	0.003
Chromium	$W \leq 0.60$	0.03	0.03
	$0.60 < W \leq 1.25$	0.04	0.04
	$1.25 < W \leq 2.5$	0.05	0.05
	$2.5 < W \leq 10.0$	0.10	0.10
	$10.0 < W \leq 15.0$	0.15	0.15
	$15.0 < W \leq 20.0$	0.20	0.20
	$W > 20.0$	0.25	0.25
Molybdenum	$W \leq 0.20$	0.01	0.01
	$0.20 < W \leq 0.50$	0.02	0.02
	$0.50 < W \leq 1.0$	0.03	0.03
	$1.0 < W \leq 2.0$	0.05	0.05
	$2.0 < W \leq 3.0$	0.08	0.08

Table 2 Permitted variation of product analysis from specified range (*continued*)

Element	Range in which maximum of specified element falls Weight (W) %	Variation on specified range	
		Under min. Weight %	Over max. Weight %
Nickel	$W \leq 1.0$	0.03	0.03
	$1.0 < W \leq 3.0$	0.05	0.05
	$3.0 < W \leq 5.0$	0.07	0.07
	$5.0 < W \leq 10.0$	0.10	0.10
	$10.0 < W \leq 20.0$	0.15	0.15
	$20.0 < W \leq 30.0$	0.20	0.20
Aluminium	$W \leq 0.15$	0.005	0.01
	$0.15 < W \leq 0.50$	0.03	0.03
	$0.50 < W \leq 1.0$	0.04	0.04
Boron	$0.0001 < W \leq 0.01$	0.0004	0.001
	$0.01 < W \leq 0.05$	0.005	0.005
Cobalt	$W \leq 0.05$	0.01	0.01
	$0.05 < W \leq 1.0$	0.03	0.03
	$1.0 < W \leq 5.0$	0.05	0.05
	$5.0 < W \leq 10.0$	0.10	0.10
	$10.0 < W \leq 15.0$	0.15	0.15
Copper	$W \leq 0.50$	0.03	0.03
	$0.50 < W \leq 5.0$	0.04	0.04
	$5.0 < W \leq 10.0$	0.05	0.05
Nitrogen	$W \leq 0.02$	0.005	0.005
	$0.02 < W \leq 0.20$	0.01	0.01
	$0.20 < W \leq 0.25$	0.02	0.02
Niobium	$W \leq 1.0$	0.05	0.05
	$1.0 < W \leq 3.0$	0.10	0.10
	$3.0 < W \leq 5.0$	0.15	0.15
Tin	$W \leq 0.05$	0.005	0.01
Titanium	$W \leq 1.0$	0.05	0.05
	$1.0 < W \leq 3.0$	0.07	0.07
Vanadium	$W \leq 0.01$	0.01	0.01
	$0.01 < W \leq 0.25$	0.02	0.02
	$0.25 < W \leq 0.50$	0.03	0.03
	$0.50 < W \leq 1.0$	0.04	0.04
	$1.0 < W \leq 1.5$	0.05	0.05
	$1.5 < W \leq 5.0$	0.10	0.10
Tungsten	$W \leq 1.0$	0.03	0.03
	$1.0 < W \leq 2.0$	0.05	0.05
	$2.0 < W \leq 5.0$	0.07	0.07
Zirconium	$W \leq 0.1$	—	0.01
	$0.1 < W \leq 0.2$	0.02	0.02

10 Temporary identification up to the cast approval stage

10.1 Ingots from each cast shall be identified serially. Wrought products shall be identifiable to the particular ingots from which they were made and shall be marked to maintain their identity relative to the tops and bottoms of the ingots (beginnings and ends of strands). These markings shall be maintained until it has been shown that the cast conforms to Clause 14, Clause 15, Clause 16 and Clause 17.

NOTE The identification of ingots within a cluster is arbitrary. In the case of directly rolled small section bar (i.e. < 100 mm section), it is not necessary to identify every piece to its location in the ingot provided that sufficient lengths from the top and bottom of the ingot are identified to ensure adequate discard.

10.2 Continuously cast products shall be identified serially and shall be identifiable to the strand from which they were made. The position corresponding to the beginning and end of each strand shall be marked.

11 Surface dressing

11.1 Overall dressing

When overall dressing is specified in the material specification, the material shall be machined, ground or scarfed all over at a suitable stage. Sufficient material shall be taken off to remove surface imperfections which might produce any defect likely to be detrimental to the end use.

11.2 Local dressing

When local dressing is specified in the material specification, surface defects shall be removed by local machining, chipping, grinding or scarfing.

12 Surface inspection

12.1 The surfaces of bars and forgings shall be inspected for defects which might be detrimental to the end use, using the method specified on the order [see 5.1a5)]. If not specified on the order, the method of inspection shall be at the discretion of the manufacturer.

12.2 Forgings and black bar for machining shall be descaled by a suitable method to enable the surface to be inspected. If acid pickling is used, the release documentation shall be endorsed to that effect.

12.3 The presence of any surface defect which is likely to be detrimental to the end use shall be a cause for rejection.

12.4 Bar supplied for the manufacture of aerospace fasteners shall be such that when processed in accordance with BS A 100, the bar conforms to the surface defect requirements specified in BS A 100.

13 Freedom from defects

13.1 All material shall be free from any defects which are likely to be detrimental to the end use.

13.2 Certain defects (e.g. “fish tailing”) can occur at the ends of bars due to rolling. Appropriate steps shall be taken to ensure that such end defects are completely removed.

13.3 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.

14 Sulfur printing and deep etching tests

14.1 Sulfur printing and/or deep etching tests shall be carried out, at a suitable stage during manufacture, on full section samples corresponding to the top of ingots (or both ends of each strand) and, when required by the material specification or order [see 5.1a6)] to the bottoms of ingots selected from each cast in accordance with 14.2. Additionally for narrow end-up ingots, samples corresponding to the middle portions of the ingots shall be selected from each cast in accordance with 14.2.

NOTE Suitable methods for sulfur printing and deep etching tests are given in BS 6285 and BS 6533, respectively.

The tests shall reveal no feature likely to be detrimental to the end use.

14.2 Samples shall be selected as specified in the material specification, or order [see 5.1a7)]. If not specified, samples shall be selected as follows.

- For ingots cast individually up to 5 000 kg each, the minimum number of samples to be selected shall be as given in Table 3. The selected ingots shall be as widely separated in order of casting as is practicable.
- For ingots cast individually over 5 000 kg each, one sample shall be taken from each ingot.
- For ingots cast in clusters, one sample shall be taken from one ingot in each cluster.
- For continuously cast material, one sample shall be selected from each end of each strand.

Table 3 Sampling of ingots of up to 5 000 kg mass for sulfur printing and deep etching tests

Number of ingots in case	Number of ingots to be selected
Up to 5	1
6 to 11	2
11 to 25	3
26 to 40	4
Over 40	5

15 Lead segregation

If lead is added to the steel (see 8.5), the billet adjacent to the bottom discard of each ingot, or each end of each continuously cast strand shall be shown to be free from lead segregation. Where ingots are cast in a cluster, one ingot shall be shown to be free from lead segregation.

16 Cleanliness

When applicable (see Note), the material shall be assessed for cleanliness by measurement of the non-metallic inclusion content using the method specified in the material specification. If the material specification does not specify a method, the assessment shall be carried out in accordance with Annex B.

The material shall meet the acceptance criteria given in the material specification or the relevant acceptance criteria given in Annex B, as applicable.

NOTE Cleanliness assessment is only applicable to certain steels (see **B.1**).

17 Ultrasonic examination

17.1 All materials, except continuously cast material which is manufactured directly into coil, shall be subjected to ultrasonic examination and shall meet the requirements of Annex C. Testing shall be carried out at an intermediate (billet) stage with diameter or minor sectional dimension less than or equal to 200 mm or, when this is not practicable, at a suitable subsequent stage of manufacture.

17.2 In the case of continuously cast steel which is manufactured directly into coil, an alternative means of assessing the material for internal defects shall be employed. This shall be at the discretion of the manufacturer and acceptable to the quality assurance authority.

17.3 For bar exceeding 200 mm in diameter or minor sectional dimension and for all products in austenitic corrosion resisting steel and free-machining steels, irrespective of the melting route, the method of examination and level of acceptance shall be as stated on the order or inspection schedule [see **5.1a8**]. If not stated on the order or inspection schedule, the method of examination and level of acceptance shall be at the discretion of the manufacturer. For forgings, the method of examination and the level of acceptance shall be as stated on the order [see **5.1c1**].

17.4 If the form and/or surface condition of billet or bar supplied for subsequent hot working does not permit ultrasonic examination in accordance with the full requirements of Annex C, the manufacturer shall endorse the release documentation with the details of the level to which the product has been examined. It shall then be the responsibility of the company producing the product in its final form to demonstrate conformity to the ultrasonic requirements of this standard.

17.5 If the higher grade acceptance standard given in Annex C (see Table C.1) is specified in the material specification or on the drawing or order [see **5.1a9**] the material shall meet the acceptance criteria for this grade as given in Annex C. If the higher grade is not specified, the material shall meet the acceptance criteria for the standard grade as given in Annex C.

NOTE Attention is drawn to the limitations which class AA imposes regarding the type of product which can be examined to this level (see **C.6**).

18 Testing

18.1 General

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

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

NOTE See Clause 5.

18.1.2 The minimum frequency of sampling for mechanical testing shall be one sample per batch.

18.2 Selection and preparation of test samples for mechanical tests

18.2.1 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. Where test samples represent products in the final heat treatment condition specified in the material specification, they shall not be subjected to further heat treatment. Where test samples represent products to be delivered in a condition other than the condition of use, they shall be heat treated to the use condition in accordance with the material specification before testing.

18.2.2 If transverse properties for billet or bar are specified in the material specification or order [see 5.1a10)], test samples shall be cut in the form of transverse slices. This shall only apply to billet and bar not less than 75 mm in diameter or major sectional dimension. The results of transverse testing shall be identified as such on the release documentation.

18.2.3 Except for precipitation-hardening steels (see 18.2.4), it is permissible for test samples for steels for which the specified minimum tensile strength is 1 300 MPa or more to be machined to test piece size, plus a grinding allowance if required, and heat treated at that size.

18.2.4 It is permissible for test samples for precipitation-hardening steels for which the specified minimum tensile strength is 1 250 MPa or more to be machined after solution treatment (and primary hardening if applicable) to test piece size, plus a grinding allowance if required, and precipitation hardened at that size.

18.2.5 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.

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

NOTE 1 In the material specifications which make reference to this standard, the specified mechanical properties refer to tests taken in the longitudinal direction, except where transverse properties are specified. The specified properties relate to test pieces machined from defined positions and they will not necessarily be realized when tests are carried out on test pieces selected from other positions in the material (see 3.7, 3.12 and 3.20).

NOTE 2 Where the material specification specifies only the mechanical properties for the longitudinal direction, it is permissible to release material tested in the transverse direction, provided that the test results conform to the requirements specified for the longitudinal direction (see 18.2.2).

18.3 Location of longitudinal test pieces for mechanical tests

18.3.1 For products and test samples up to and including 30 mm in diameter or minor sectional dimension, the test pieces shall be machined coaxially with the test sample.

18.3.2 For products and test samples over 30 mm in diameter or minor sectional dimension the longitudinal axis of the test pieces shall be 12.5 mm from the surface of the product or test sample.

18.4 Location of transverse test pieces for mechanical tests

The test pieces shall be located as shown in Figure 1 or, if specified in the material specification, the longitudinal axis of the test piece shall intersect the longitudinal axis of the product or test sample.

Figure 1 Location of transverse test piece

