

Specification for

Alloy steel forgings

Co-operating organizations

The Iron and Steel Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Board of Trade*	Institution of Production Engineers
British Cast Iron Research Association	Institution of Structural Engineers
British Constructional Steelwork Association	Joint Iron Council
British Electrical and Allied Manufacturers' Association	Lloyds' Register of Shipping*
British Ironfounders' Association	Ministry of Defence*
British Mechanical Engineering Confederation	Ministry of Defence, Army Department
British Steel Industry*	National Association of Drop Forgers and Stampers
Council of Ironfoundry Associations	National Physical Laboratory (Department of Trade and Industry)
Council of Iron Producers	Oil Companies Materials Association
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Institute of Iron and Steel Wire Manufacturers	Steel Castings Research and Trade Association
Institute of Marine Engineers*	Tank and Industrial Plant Association
Institution of Civil Engineers	Tin Research Institute
Institution of Mechanical Engineers (Automobile Division)	Water-Tube Boiler Makers' Association

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the Committee entrusted with the preparation of this British Standard.

Associated Offices Technical Committee	National Association of Marine Engine Builders
Institution of Engineers and Shipbuilders in Scotland	North East Coast Institution of Engineers and Shipbuilders
Ministry of Defence Navy Department	Royal Institution of Naval Architects

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Foreword

This standard makes reference to the following British Standards

BS 18, *Methods for tensile testing of metals*.

BS 29, *Carbon steel forgings for shipbuilding and general engineering purposes*.

BS 131, *Methods for notched bar tests — Part 2: The Charpy V-notch impact test*.

BS 240, *Method for Brinell hardness test — Part 1: Testing of metals*.

BS 970, *Wrought steels — Part 2: Direct hardening alloy steels, including alloy steels capable of surface hardening by nitriding*.

BS 4124, *Non-destructive testing of steel forgings — Part 1: Ultrasonic flaw detection — Part 2: Magnetic flaw detection — Part 3: Penetrant flaw detection*.

BS, *Equivalent diameters in the selection and heat treatment of steel*¹⁾.

BS Handbook No. 19, *Methods for the sampling and analysis of iron, steel and other ferrous metals*.

PD 6431, *New designation system for alloy steels*.

This British Standard has been prepared under the authority of the Iron and Steel Industry Standards Committee, and has been based on proposals put forward by the Forgemasters of the British Steel Industry.

The specification is an extension of certain of the steels in BS 970-2²⁾ in that alloy steel forgings are covered in this specification having ruling sections above 150 mm and up to and including 1 000 mm. Carbon steel forgings are covered by BS 29³⁾.

The designation system used to identify the steels in Section 4 is based on that given in PD 6431⁴⁾ and alignment with the comparable steels in BS 970-2²⁾ has been implemented.

Section 3 of the specification gives information concerning the equivalent diameter of forgings, ruling sections and the selection of material. This is based on the work being undertaken by a Panel of the Iron and Steel Industry Standards Committee which is preparing BS ⁵⁾.

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 and ii, pages 1 to 22, an inside back cover 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⁾ In course of preparation.

²⁾ BS 970, "Wrought steels", Part 2, "Direct hardening alloy steels, including alloy steels capable of surface hardening by nitriding".

³⁾ BS 29, "Carbon steel forgings for shipbuilding and general engineering purposes".

⁴⁾ PD 6431, "New designation system for alloy steels".

⁵⁾ BS, "Equivalent diameters in the selection and heat treatment of steel" (in course of preparation).

1. General requirements

1.1 Scope

1.1.1 This British Standard specifies requirements for alloy steel forgings for shipbuilding and general engineering purposes, having tensile strengths between the limits of 600 N/mm² and 1 250 N/mm² and ruling sections above 150 mm and up to 1 000 mm.

1.1.2 This specification does not cover the following, but these may be covered by agreement between the manufacturer and the purchaser; suitable additional or amended requirements may be introduced to enable it to be employed:

- 1) Certain specialized forgings, such as monobloc rotor shafts.
- 2) Forgings for elevated temperature applications.
- 3) Steels to be used in welded structures. In the case of these materials, the agreement referred to should cover the chemical composition and the tempering and stress relieving temperatures.

1.2 Definitions

For the purposes of this British Standard, the following definitions apply:

1.2.1

electric quality steel

electric quality steel is steel melted in an induction furnace or in a basic lined electric arc furnace. When produced in the arc furnace, the conventional double slag process is used. The steel is characterized by a high standard of cleanness and by low sulphur and phosphorus contents

1.2.2

electrically melted steel

electrically melted steel is steel made in an electric furnace under conditions not necessarily conforming with the above requirements and which complies with standards similar to those required of open hearth steel

1.3 Information to be supplied by the purchaser

The following information should be given on the enquiry and order:

- 1) The material specifications in Section 4 with which the forgings shall comply after consideration has been given to the assessment of the equivalent diameter of the forging in relation to the limiting ruling section of the specification (see Section 3).
- 2) Whether electric quality steel is required (see maxima for sulphur and phosphorus at foot of each material specification, included in Section 4), or whether any other specific steelmaking process is required (see 1.5).

NOTE The supplier may decide that it is necessary to supply electric quality steel in order to meet the mechanical properties quoted in certain of the material specifications in Section 4.

- 3) Which of the five conditions of supply, given in 1.14.1, is required, and in the case of conditions 3, 4 and 5, whether the 0.2 % proof stress is to be determined (see individual material specifications in Section 4).
- 4) Which of the tensile strength ranges, given in the appropriate material specification in Section 4, is required.
- 5) A drawing of the part or forging shall be included with the enquiry and order indicating:
 - a) the positions on the forging from which tests are required;
 - b) special requirements as regards grain flow (see 1.9.1) and whether the forging may be made from a rolled product (see 1.7.2);
 - c) the finished machined dimensions in the case of forgings ordered in the unmachined condition.

- 6) Whether a sketch, showing the shape of the rough forging before machining, is to be submitted for approval to the parties concerned⁶⁾ (see 1.9.6).
- 7) Whether the application involves a welding operation (see 1.1).
- 8) Details of non-destructive tests which the parties concerned require (see 1.12.2).
- 9) The name of the inspecting and/or regulating authorities, together with details of any special requirements of those organizations.

1.4 General

1.4.1 The limiting ruling section of a forging shall be assessed in relation to equivalent diameter as defined in Section 3.

1.4.2 The forgings shall comply with the requirements of this section and with those of the appropriate material specification, limiting ruling section, and, for the determination of elongation and impact values, the test value number.

1.5 Steelmaking process

Forgings shall be made from fully killed steel, which may be made by any process except that the air, and mixed air-oxygen bottom blown basic converter process shall not be used. If the purchaser so desires, he may state on his enquiry and order the process of manufacture to be used.

NOTE Reference should be made to the individual material specifications in Section 4, in which the maxima for sulphur and phosphorus are specified for electric quality steel as defined in 1.2 1).

The steel shall be fully killed by the addition of suitable deoxidants and/or by the use of vacuum degassing processes. Where deoxidants other than silicon or vacuum degassing processes are used, the minimum silicon content specified in the appropriate material specification in Section 4 shall not apply.

1.6 Chemical composition

1.6.1 Unless otherwise agreed, the chemical composition of the steel shall comply with the requirements of the relevant material specification in Section 4, except that slight deviation from the composition specified will be acceptable provided that the specified mechanical properties are obtained (i.e. the mechanical properties are the governing criteria for acceptance). The specified ranges of composition are based on ladle analysis.

1.6.2 In cases of doubt regarding the chemical composition of the steel, the parties concerned, before accepting the material, have the right to obtain chemical analyses in respect of one or more elements from mechanical test pieces representative of each cast. Consideration of such check analyses shall take into account the heterogeneity of the steel. Check analysis shall be carried out in accordance with the appropriate method in BS Handbook No. 19⁷⁾, or by an instrumental method agreed between the manufacturer and the parties concerned.

1.6.3 Elements other than those listed in the specification shall not be added deliberately except for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent contamination by incidental elements from scrap. Analyses for incidental elements shall not be required unless requested by the parties concerned or unless reason exists to suspect their presence in excessive amounts.

1.7 Ingots

1.7.1 Forgings made from ingots or forged blooms and billets. The forgings shall be made from ingots cast in chill moulds with the larger cross section uppermost and with efficient feeder heads or from forged blooms and billets made therefrom.

1.7.2 Forgings made from rolled products. Unless otherwise specified on the enquiry or order, and subject to the requirements of 1.9.3, the forgings may be made from rolled products produced from ingots cast in chill moulds with the larger section uppermost, and with efficient feeder heads.

⁶⁾ For the purposes of this specification, the term "parties concerned" is intended to include the purchaser, his representative, the user, the inspecting authority and the regulating authority acting on their own behalf.

⁷⁾ BS Handbook No. 19, "Methods for the sampling and analysis of iron, steel and other ferrous metals".

1.8 Discard

Sufficient discard shall be made from the top and bottom of each ingot to ensure freedom from piping and harmful segregation in the finished forging.

1.9 Forging

1.9.1 Hot working. Forgings shall be brought, as nearly as practicable, to the finished shape and size by hot working. Where grain flow in any particular direction is required, the purchaser shall advise of this in the enquiry and agreement with the manufacturer shall be reached prior to ordering.

The amount of hot working shall be such as to ensure satisfactory soundness and uniformity of structure and mechanical properties.

1.9.2 Forging reduction

1.9.2.1 Solid forgings. Typical solid forgings are represented in Figure 1 to Figure 8 in Section 2. For forgings made directly from ingots, blooms or forged billets, i.e. where the forging work is mainly longitudinal, the reduction of area by forging shall be not less than 2 : 1 or not less than 1.5 : 1 for a portion of a forging, the length of which is less than its diameter (e.g. the collars in Figure 2 and Figure 3); the original area being the mean area of the ingot, or of the ingot or billet after upsetting, if such an operation is involved.

In the case of upset discs or blanks, the thickness of any part of the disc shall not be more than one half of the length of the billet from which it was formed (see Figure 5 and Figure 6), if the billet has received a forging reduction of not less than 1.5 : 1 or one third of the original length of the piece if this has been cut from an ingot, or of the billet if the billet has received an initial forging reduction of less than 1.5 : 1.

1.9.2.2 Hollow forgings. Hollow forgings shall be made from a solid cast ingot punched, bored or trepanned, or a partly forged ingot punched, bored or trepanned or from a hollow cast ingot. The resultant wall from the solid cast ingot or prepared billet or the wall of the hollow ingot as cast shall, except as permitted in the following paragraph, be reduced in thickness by at least one half in the process of hollow forging.

Where it is not practicable to give a 2 : 1 reduction in hollow forging, the forging procedure shall be such as to ensure adequate work is given to the billet prior to trepanning (or punching) and hollow forging. This may be either a 2 : 1 minimum reduction from the ingot to the billet or a 2 : 1 minimum upsetting operation to form the billet from the ingot.

1.9.2.3 Forgings made from rolled products. For forgings made from rolled products, the reduction in area from the ingot to the finished forging shall be not less than 4 : 1, or not less than 2 : 1 for a portion of a forging the length of which is less than its diameter (e.g. the collars in Figure 2 and Figure 3).

1.9.3 Special conditions. Any departure from these conditions shall be a matter for prior agreement between the manufacturer and the parties concerned.

1.9.4 Sketch of rough forging. If specified on the enquiry and order, the manufacturer shall submit, for the approval of the parties concerned, a sketch showing the shape of the rough forging before machining.

1.10 Freedom from defects

Forgings shall be sound and free from defects of a harmful nature which might preclude their use for the purpose for which they were intended. Defects in forgings shall not be repaired without the previous sanction of the parties concerned. The procedure for the repair of defects and the subsequent inspection of forgings shall also be the subject of an agreement between the same parties.

1.11 Dimensions

Forgings shall be finished to the prescribed dimensions within limits agreed upon between the manufacturer and the parties concerned.

1.12 Non-destructive testing

1.12.1 The manufacturer shall carry out such non-destructive tests that are necessary to satisfy himself that the forgings are free from harmful defects (see **1.10**).

1.12.2 Any ultrasonic, magnetic or penetrant flaw detection tests required by the parties concerned shall be undertaken in accordance with BS 4124⁸⁾. The sulphur printing test method may be used either independently or in conjunction with the tests carried out in accordance with BS 4124⁸⁾. All non-destructive tests required (and where applicable appropriate acceptance standards) shall be specified on the enquiry form and be the subject of an agreement at the time of ordering.

1.13 Thermal treatment

1.13.1 The thermal treatment of the steel at all stages of manufacture shall be such as to avoid the formation of harmful defects in the finished product.

1.13.2 Forgings shall be heat-treated in suitably designed furnaces which permit the whole forging to be uniformly heated to the desired temperature.

1.13.3 At an appropriate stage of manufacture after completion of hot working operations, each forging shall be suitably heat treated to refine the structure and to obtain the desired mechanical properties. The final heat treatment shall consist of heating to a uniform temperature above the upper critical point, and hardening by cooling as appropriate in air, oil, water or other quenching medium, followed by tempering. The hardening and tempering temperatures shall be in accordance with the requirements of the appropriate steel specification in Section 4.

If any straightening operation is performed after the final heat treatment, the procedure shall be such as to ensure that the forging will be free from harmful residual stress (see **1.14.3**).

1.14 Selection and preparation of test samples

1.14.1 The amount of testing, in accordance with one of the alternatives given below and the location of the test samples in accordance with **1.14.2**, shall be agreed at the enquiry stage between the manufacturer and the parties concerned, taking into consideration the size and importance of the forging. This information shall be specified on the order:

- 1) Forgings to be supplied to chemical composition only, i.e. no mechanical testing.
- 2) No mechanical testing except that each forging or an agreed proportion of forgings are to be Brinell hardness tested.
- 3) Mechanical tests to be carried out on an agreed proportion of forgings made from one cast, heat treated together as a batch.
- 4) Mechanical tests to be carried out on each forging.
- 5) A combination of 2) and 3) or 2) and 4).

Sufficient material shall be left on each forging or multiple forging to be tested to enable the agreed test samples to be obtained. The diameter at the position of each test sample shall be not less than that of the part of the forging represents.

1.14.2 Unless otherwise agreed between the manufacturer and the parties concerned, the test position(s) shall be selected from those typified in Section 2.

Test samples shall be cut close to the exterior of the forging. The mechanical properties specified in Section 4 apply to these test positions. Where other test positions are agreed, and/or the limitations laid down in Section 2 are not complied with, adjusted mechanical properties may be specified by agreement between the manufacturer and the parties concerned.

1.14.3 Test samples shall not be detached from the forgings until all heat treatment has been completed, except by agreement between the manufacturer and the parties concerned. In such cases, the sample pieces shall be heat treated with the forgings they represent.

No sample or test piece shall receive any additional hot or cold working or heat treatment.

⁸⁾ BS 4124, "Non-destructive testing of steel forgings", Part 1, "Ultrasonic flaw detection", Part 2, "Magnetic flaw detection", Part 3, "Penetrant flaw detection".

1.15 Mechanical tests

1.15.1 Tensile tests

1.15.1.1 Where applicable, the tensile tests shall be carried out in accordance with BS 18⁹⁾. The dimensions of the test pieces shall conform with Table 1 of BS 18, having a gauge length of $L_0 = 5.65 \sqrt{S_0}$ ¹⁰⁾. Where dimensions of the forging permit, the diameter d should be 11.3 mm with a gauge length of 56.5 mm. In other cases, the nearest smaller standard diameter/gauge length from Table 1, permitted by the dimensions of the forging, shall be used.

Should a test piece break outside the middle third of its gauge length, the test may, at the option of the manufacturer, be discarded and another test made on a test piece from a position similar to that from which the defective test piece was obtained.

1.15.1.2 Unless otherwise agreed between the manufacturer and the parties concerned, the tensile strength of a forging shall be within the range of 150 N/mm² specified in the relevant table of Section 4. If more than one tensile test is taken, the variation in tensile strength for any one forging shall be not greater than 100 N/mm².

1.15.2 Impact tests. Where applicable: the impact tests shall be carried out in accordance with BS 131-2¹¹⁾. The value obtained shall be in accordance with the requirements of the relevant material specification in Section 4.

1.15.3 Hardness test. Where applicable, the hardness test shall be carried out in accordance with BS 240-1¹²⁾, by the application of 3 000 kgf to a ball of 10 mm diameter.

If this method is not practicable an alternative method of hardness testing together with the acceptable conversion limits based on the Brinell hardness ranges may be the subject of an agreement between the manufacturer and the parties concerned.

The values obtained shall be in accordance with the requirements of the appropriate material specification in Section 4.

1.16 Retests

In cases where a test piece selected by the parties concerned does not fulfil the test requirements, the manufacturer may adopt either or both of the following procedures, always provided that the forging is not re-hardened more than twice:

- 1) Where it is agreed that the results obtained may not fairly represent the quality of the forging, two further test samples shall be selected from the same forging and from a position similar to that from which the test piece which failed was obtained, and two further tests made. Results of tests on both these further test pieces shall comply with the specified requirements.
- 2) The forging(s) or multiple forging(s), represented by the test piece which failed, shall be fully reheat-treated in accordance with 1.13.3 or retempered at the discretion of the manufacturer before resubmitting for testing in accordance with 1.14.

1.17 Marking and identification

Each forging shall be clearly marked by the manufacturer with a number or identification mark by which it can be traced to the cast of steel, and if practicable, the ingot and the position therein from which the forging was made.

It required, each forging, after satisfying the prescribed test requirements, shall be clearly marked to indicate that the forging is to the satisfaction of the parties concerned.

⁹⁾ BS 18, "Methods for tensile testing of metals".

¹⁰⁾ S_0 = Original cross sectional area of test piece.

¹¹⁾ BS 131, "Methods for notched bar tests", Part 2, "The Charpy V-notch impact test".

¹²⁾ BS 240, "Method for Brinell hardness test", Part 1, "Testing of metals".