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SPECIFICATION FOR

STEELS FOR FIRED AND UNFIRED PRESSURE VESSELS

FORGINGS

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STEELS FOR FIRED AND UNFIRED PRESSURE VESSELS

FORGINGS

BS 1503 : 1969

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THIS BRITISH STANDARD, having been approved by the Iron and Steel Industry Standards Committee, was published under the authority of the Executive Board on 31 March, 1969.

BS 1501–1506 first published November 1950.
First revision, September 1958.
Second revision, BS 1503, published separately, March, 1969.

SBN: 580 05497 7.

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 5000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, price 15s. The BS Yearbook may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 18. Methods for tensile testing of metals.
BS 131. Methods for notched bar tests.
Part 2. Charpy V-notch impact test.
Part 3. The Charpy U-notch impact test on metals.
BS 240. Method for Brinell hardness test.
BS 427. Method for Vickers hardness test.
BS 1113. Water tube boilers.
BS 1121. Methods for the analysis of iron and steel.
BS 1639. Methods for bend testing of metals.
BS 3688. Methods for mechanical testing of metals at elevated temperatures.
Part 1. Tensile testing.
BS 3920. Method of certifying elevated temperature proof or yield stress properties of steel products by selective testing.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following BSI references relate to the work on this standard:
Committee reference ISE/62, ISE/62/2
Draft for comment D64/10246

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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
British Cast Iron Research Association
British Constructional Steelwork Association
British Electrical and Allied Manufacturers' Association
British Ironfounders' Association
British Mechanical Engineering Federation
British Railways Board
British Steel Castings Research Association
*British Steel Industry
Council of Iron Producers
Council of Ironfoundry Associations
Crown Agents for Oversea Governments and Administrations
Department of Employment and Productivity (H.M. Factory Inspectorate)
*Engineering Equipment Users' Association
Federation of Civil Engineering Contractors
Institute of British Foundrymen
Institute of Iron and Steel Wire Manufacturers
*Institute of Marine Engineers
Institution of Civil Engineers
Institution of Mechanical Engineers (Automobile Division)
Institution of Production Engineers
Institution of Structural Engineers
*Iron and Steel Institute
Joint Iron Council
*Lloyd's Register of Shipping
Ministry of Defence, Army Department
*Ministry of Defence, Navy Department
National Association of Drop Forgers and Stampers
National Physical Laboratory (D.S.I.R.)
*Oil Companies Materials Association
Royal Institute of British Architects
Shipbuilders and Repairers National Federation
Society of British Aerospace Companies
Society of Motor Manufacturers and Traders Ltd.
*Stainless Steel Development Association

The Government departments 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 Officers Technical Committee
Association of Shell Boilermakers
British Valve Manufacturers' Association
Council of British Manufacturers of Petroleum Equipment
Electricity Council, the Central Electricity Generating Board and the Area Boards in England and Wales
Institution of Chemical Engineers
National Association of Marine Engine Builders
North East Coast Institution of Engineers and Shipbuilders
Stainless Steel Fabricators Association of Great Britain
Stainless Steel Manufacturers' Association
Tank and Industrial Plant Association
United Kingdom Atomic Energy Authority
Water-tube Boilermakers' Association
Individual manufacturers
Welding Institute

BRITISH STANDARD SPECIFICATION FOR STEELS FOR FIRED AND UNFIRED PRESSURE VESSELS

FORGINGS

FOREWORD

This British Standard has been prepared under the authority of the Iron and Steel Industry Standards Committee.

This edition is written in terms of imperial units and approximate metric, technical unit conversions are included for information. A metric version is shortly to be prepared based on units of the Système International.

The previous edition of BS 1501-6 was specifically related to steels for use in the chemical and petroleum industry, but the scope of this revision has been widened and the standard now relates to steels for all fired and unfired pressure vessels. BS 1503 now incorporates requirements for all pressure vessel and pressure part forgings.

To provide greater flexibility, it has be cided in revising BS 1501-6, to publish these variou of the standard under separate covers which reta isting numbering system except that BS 1501 now y relates to plates and the previously unused number, BS 1502, has been allocated for sections and bars. The separate parts of BS 1501-6 are as follows:

BS 1501. Plates
BS 1502. Sections and bars (other than bolting material)
BS 1503. Forgings
BS 1504. Castings
BS 1506. Bars for bolting material

In addition, the requirements for steels for low temperature applications, which were previously separately specified in BS 1510, have been incorporated in the appropriate parts previously listed.

In preparing this revision full account has been taken of the recommendations of the International Code for Stationary Boilers and, in consequence, elevated temperature properties for the steels have been specified where appropriate. Most of the steels may be ordered with or without proved or certified elevated temperature yield or proof stress properties and, although the manufacturer may not be asked to prove the elevated temperature tensile properties, the method of manufacture of the steel will be essentially the same. In consequence there is no reason to suppose that, if material is ordered without elevated temperature yield or proof stress tests, its properties will necessarily differ from those of material which is certified or hot-tested.

Creep and rupture properties for certain of the materials specified in Section 2 are given in appendices to the relevant material specifications. These data are put forward as representative of the relevant materials and may be relied upon for design purposes.

Where welding is involved, it is assumed that the fabricator will take precautions appropriate to the composition of the steel ar the size and complexity of the weldments concerned.

NOTE. Where metric equivalents are stated, the figures in imperial units are to be regarded as the standard. The metric conversions are approximate. More accurate conversions should be based on the tables in BS 350, 'Conversion factors and tables'.

SPECIFICATION

SECTION 1. GENERAL REQUIREMENTS

1.1 SCOPE

1.1.1 This British Standard specifies requirements for steel forgin , including forgings for drums and headers for fired and unfired pressure vessels, and pressure parts. Where operations other than forging, machining and heat treatment are involved the requirements of the relevant British Standard ll apply (e.g. BS 1113, 'Water tube boilers').

Provision has been made for the supply of material to meet different combinations of service conditions and, where appropriate, requirements are therefore specified for the properties detailed in 1.2.1, 1.2.2 and 1.2.3, which should be coded as indicated in 1.2.4.

1.2 DESIGNATIONS

1.2.1 Room temperature tensile strength and yield stress. These are designated by minimum tensile strength R_m and yield stress R_y in tonf/in². In certain of the material specifications in Section 2, more than one level of tensile strength has been designated.

1.2.2 Elevated temperature yield stress or 0·2% proof stress. In certain of the material specifications, minimum values for elevated temperature yield stress or proof stress are given. If required, forgings shall be hot tensile tested to demonstrate that these minimum properties have been achieved or, alternatively, a certification procedure in accordance with 1.17 may be adopted. In either of these cases the forgings shall be ordered as Class B. If hot tensile properties are not required to be verified, the forgings shall be ordered as Class A, see 1.4.1(3).

1.2.3 Impact value. In certain of the material specifications, minimum values for Charpy V or Charpy U-notch tests at room temperature and at lower temperatures are specified. The suffix RT shall be used if tests are required at room temperature. If the tests are required at lower temperatures, the suffix LT shall be used followed by a number representing the temperature below zero in degrees C at which the tests are to be performed. Additionally the letter U or the letter V shall be quoted to indicate the type of notch required.

1.2.4 Examples of coding. (1) BS 1503-161 carbon steel forgings having a tensile strength range of 28-33 tonf/in² and for which no hot tensile test or certification is required shall be coded as BS 1503-161 Grade 28A.

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(2) BS 1503-161 carbon steel forgings having a tensile strength range of 26-31 tonf/in² and for which elevated temperature yield or proof stress properties are to be proved or certified shall be coded as BS 1503-161 Grade 26B.

(3) BS 1503-503 3½ % nickel steel forgings which are to be impact tested at − 75°C with a Charpy U-notch shall be coded as BS 1503-503 LT 75U.

1.3 DEFINITIONS

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

(1) *Certified material.* Forgings for which minimum elevated temperature yield or proof stress values are given in the relevant material specification in Section 2 and which are supplied as having these properties on the basis of data obtained in accordance with the requirements of 1.17.1.

(2) *Hot-tested material.* Forgings for which minimum elevated temperature yield or proof stress values are given in the relevant material specification in Section 2 and which are supplied as having these properties on the basis of representative elevated temperature tensile tests at the temperature or temperatures specified by the purchaser in accordance with 1.17.2.

1.4 INFORMATION TO BE SUPPLIED BY THE PURCHASER

1.4.1 The enquiry and order shall state:

(1) the material specification in Section 2 with which the forgings shall comply (see coding examples in 1.2.4);

(2) the steelmaking process, if a particular process has been agreed, (see 1.6.1) and whether the steelmaking process is to be stated on the manufacturer's certificate (see 1.21.1);

(3) whether any preferred grain flow is required in relation to service stresses;

(4) (i) whether the forgings are to be supplied in a heat-treated condition other than that required by the material specification (for subsequent heat treatment and testing according to the material specification);

(ii) the agreed stress relieving treatment to be applied to the test samples before testing (see 1.14), if, after supply, material is to be fabricated and subsequently stress relieved;

(5)*if Class B forgings having specified elevated temperature yield or proof stress properties are required:

(i) whether the properties may be certified or whether the material is to be hot-tested (see 1.17);

(ii) if the material is to be hot-tested the temperature at which the yield or 0·2% proof stress property is required which, unless otherwise agreed with the manufacturer, shall be one of those tabulated in the relevant material specification;

(6) whether the design involves a creep requirement;

(7)*if forgings having specified impact properties are required:

(i) the temperature at which the impact tests are to be performed, which shall be one of those tabulated in the relevant material specification and

(ii) whether Charpy U-notch or Charpy V-notch tests are to be made.

(8) whether, for austenitic steel forgings, an intercrystalline corrosion test is required (see 1.15.6);

(9) the sampling requirement, A, B or C (see 1.12 and Table 1) and any requirements regarding the position of test pieces and their relationship to the direction of principal grain flow (see 1.13);

(10) whether the forgings are to be inspected during manufacture and tested in the presence of the purchaser's representative;

(11) whether there are any additional inspection requirements, e.g. non-destructive testing;

(12) whether the forgings are to be marked with the number of this British Standard and the appropriate grade letter and number, and whether scroll stamp marking is permitted (see 1.20);

(13) if relevant, the associated application standard or design code (see 1.2.4);

(14) whether additional test samples are required for purchaser's tests (see 1.14.2 Note 2);

(15) whether sample material is required for welding procedure qualification tests, welder or operator performance qualification tests and/or welding production control tests. Where such material is required the purchaser shall agree the dimensions of the samples with the manufacturer and state them on the order.

1.5 GENERAL

1.5.1 The forgings shall comply with the requirements of this section and with the appropriate requirements of Section 2.

1.6 STEELMAKING PROCESS

1.6.1 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 processes shall not be used. If he so desires, the purchaser may agree with the manufacturer the steelmaking process to be used.

1.7 CHEMICAL COMPOSITION

1.7.1 The chemical composition of the steel shall comply with the requirements of the relevant material specification. The specified ranges of analysis are based on ladle analyses.

1.7.2 In cases of doubt regarding the chemical composition of the steel the purchaser or his representative, before accepting the material, shall 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. It is recommended that check analyses should be carried out in accordance with BS 1121†.

1.8 INGOTS

1.8.1 Forgings made from ingots or forged blooms. 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 made therefrom.

1.8.2 Forgings made from rolled products. Unless otherwise specified on the enquiry and order, the forgings may be made from rolled products subject to the requirements of 1.9.2.4.

* Only those forgings for which specified high temperature or impact properties are listed in the relevant material specifications may be so ordered. By agreement certain materials can be supplied with both specified elevated temperature and impact properties.

† BS 1121, 'Methods for the analysis of iron and steel'.

1.9 FORGING

1.9.1 Hot working

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

1.9.1.2 Forgings shall be brought as nearly as practicable to the finished shape and size by hot working and, where practicable, shall be so worked as to cause metal flow in the direction most favourable for resisting the service stresses which it is recommended should be made known to the manufacturer.

1.9.1.3 Alternatively, by agreement between the manufacturer and the purchaser, a cold forging process may be used.

1.9.2 Forging reduction

1.9.2.1 *Hollow forgings.* Hollow forgings shall be made from a solid cast ingot punched, bored or trepanned, or from a hollow cast ingot. The resultant wall of the solid cast ingot or the wall of the hollow ingot as cast shall be reduced in thickness by at least one half in the process of forging. See amdt. 1

1.9.2.2 *Solid forgings.* Unless otherwise agreed, for solid forgings the reduction of area of any part of the forging shall be not less than 3 : 1 where the length at any diameter is greater than the diameter, the original area being that of the ingot, or of the ingot after upsetting if such an operation is involved. Where the length at any diameter is less than the diameter, the forging reduction shall be not less than 1·5 : 1. See amdt. 1

1.9.2.3 *Solid forgings subsequently bored.* For solid forgings subsequently bored with a hole of a diameter greater than one-fifth of the overall diameter of the forging, the reduction of area shall be not less than 2 : 1, the original area being that of the ingot, or of the ingot after upsetting if such an operation is involved. Where the length at any diameter is less than the diameter, the forging reduction shall be not less than 1·5 : 1.

1.9.2.4 *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 in the case of forgings made from products rolled with ingots cast with the larger cross section uppermost and with efficient feeder heads, and not less than 6 : 1 for forgings made from products rolled from other types of ingot.

1.10 FREEDOM FROM DEFECTS

1.10.1 The forgings shall be sound and free from such segregation, cracks, laminations or flaws as might preclude their use for the purpose for which they are intended. They shall be finished to the prescribed dimensions within limits agreed upon between the manufacturer and the purchaser. Defects in forgings shall not be repaired without the previous sanction of the purchaser or his representative.

1.11 HEAT TREATMENT

1.11.1 After hot working and before re-heating for heat treatment in accordance with the relevant material specification, the forgings shall be allowed to cool to a temperature below their transformation range in such a manner that no injury results to the forging.

1.11.2 Unless otherwise agreed and stated on the enquiry and order, the forgings shall be heat-treated as required by the relevant material specification in Section 2.

1.12 NUMBER OF TEST SAMPLES

1.12.1 Test samples shall be selected in accordance with one of the requirements of Table 1 and the provisions of 1.13.1, as agreed between the manufacturer and the purchaser and stated on the order.

1.13 SELECTION AND PREPARATION OF TEST SAMPLES

1.13.1. Selection of test samples

1.13.1.1 If stated on the enquiry and order (see 1.4), all test samples shall be selected by the purchaser or his representative and tested in his presence.

1.13.1.2 Test samples in the form of rings or prolongations of a minimum dimension of 2 in (50 mm) shall be taken from one or both ends of open vessels or from the open end of vessels solid at one end.

In the case of closed hollow vessels including headers, the test samples may be cut off before closing, in which case they shall be heat-treated with the vessels and shall be so positioned with respect to the vessels that they receive representative heat treatment.

In the case of open hollow vessels, the test samples shall be cut off after the completion of the heat treatment.

In other cases, the test sample shall be cut from one of the forgings, or additional material of sufficient size shall be provided. For instance, in the case of punched flanges the punchings may be used as test samples, in which case the identity of the material of the punching with that of the flange shall be evidenced in an adequate manner. Alternatively, a piece of the billet or bar from which the forgings were made can be used, provided it is given approximately the same degree of hot work. If separate test samples are used, they shall be heat-treated with the finished forgings.

If these procedures are not appropriate the method of providing the test samples shall be agreed between the manufacturer and the purchaser and stated on the order.

1.13.1.3 Except as specified in 1.14, or otherwise agreed between the manufacturer and the purchaser, the test samples and test pieces shall not be subjected to any further heat treatment or hot or cold work prior to testing.

1.13.1.4 The test samples shall be cut either in the direction of or transversely to the direction of principal grain flow, as agreed between the manufacturer and the purchaser. In Section 2, the longitudinal test values apply to samples cut in the direction of principal grain flow, and the transverse test values apply to samples cut transversely to the direction of principal grain flow.

Where there is doubt regarding the direction of principal grain flow e.g. in a flange formed by upsetting a billet the direction from which test samples are cut and the elongation and bend test requirement to be met shall be agreed between the manufacturer and the purchaser.

1.13.2 Preparation of test pieces

1.13.2.1 Except as otherwise agreed, the test pieces shall be prepared from the test samples from a sub-surface position, i.e. with the axis of the test piece about ½ inch (12·5 mm) below the outer surface of the forging.

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1.13.2.2 *Room temperature tensile and bend tests.* One test piece for the room temperature tensile test and one test piece for the bend test, if required by the material specification shall be prepared from each test sample.

Eend test pieces shall be smooth machined to a rectangular section of the following dimensions:

1 in wide × ¾ in thick (25 mm × 19 mm) for material having a specified minimum tensile strength of 36 tonf/in² (56·7 kgf/mm²) or under. ¾ in wide × ⅜ in thick (19 mm × 9·5 mm) for material having a specified tensile strength over 36 tonf/in².

The corners of the test piece may be slightly rounded to a radius not exceeding 1/16 in (1·5 mm) by filing or grinding.

1.13.2.3 *Elevated temperature tensile tests.* One test piece shall be prepared from each sample selected in accordance with 1.12 and 1.13.1 except that, if a number of identical forgings are manufactured from the same cast, the number of tests may be reduced by agreement between the manufacturer and the purchaser (see also 1.17.2). The test pieces shall be cut from positions on the samples at positions adjacent to the room temperature tensile test pieces.

1.13.2.4 *Impact tests.* Three test pieces shall be prepared from each test sample. The impact test pieces shall be prepared in accordance with either BS 131, Part 2* or BS 131, Part 3* as appropriate. The notch shall be cut perpendicular to the original surface of the forging. U-notch specimens shall have a 5 mm deep notch unless otherwise agreed between the purchaser and manufacturer†.

* BS 131, 'Methods for notched bar tests', Part 2, 'Charpy V-notch impact test', Part 3, 'The Charpy U-notch impact test on metals'.
† By agreement, a 3 mm deep notch may be used.

TABLE 1. NUMBER OF TEST SAMPLES AND TEST PIECES (See 1.12)

Sampling requirement	Number of test samples	Number of test pieces		
		Room temperature tensile and bend tests	Elevated temperature tests (if required)	Impact tests (if required)
A	Two test samples, one from each end of each forging	One test piece for each test from each test sample	One test piece from each test sample (but see 1.13.2.3)	Three test pieces from each test sample
B	One test sample from each forging			
C	One test sample from one forging selected for test from each batch of forgings from the same cast and of similar section size heat-treated together			

1.14 FURTHER HEAT TREATMENT OF TEST SAMPLES IN RELATION TO WELDING AND STRESS RELIEVING PROCEDURES

NOTE. See the appendices to the individual material specifications in Section 2 for recommended stress relieving and post-weld heat treatments relating to each type of steel.

1.14.1 Forgings stress-relieved by the forgemaster. If the forgings form part of a welded vessel or structure, which is stress-relieved by the forgemaster, the test samples shall receive all the heat treatments applied to the forgings as required in 1.11 and shall either:

(1) be subjected with the forgings or fabricated vessel to the stress relieving heat treatment, or

(2) be separately subjected to a stress relieving treatment which is calculated to produce a similar effect on the mechanical properties as that applied to the vessel or structure.

1.14.2 Forgings to be stress-relieved by the purchaser. Where the purchaser intends to incorporate the forging or fabrication in a welded vessel or structure and will apply a stress-relief heat treatment, test samples which have received heat treatments referred to in 1.11 or 1.11 plus 1.14.1 shall also be subjected by the forgemaster to a stress-relief heat treatment which is calculated to produce a similar effect on the mechanical properties as the stress-relief heat treatment to be applied to the welded vessel or structure by the purchaser.

NOTE 1. If any additional or unforeseen stress-relief heat treatment has to be applied by the purchaser the stress-relief heat treatment temperature should not exceed the temperature of the final heat treatment, i.e. either tempering or stress-relief applied by the forgemaster to the test samples.

NOTE 2. If so desired, the purchaser may be supplied with additional test samples, which have been cut from the forging after heat treatment in accordance with 1.11 and, if applicable, 1.14.1, with a view to subjecting these test samples to the final stress-relief heat treatment and subsequent mechanical testing for information purposes.

NOTE 3. The test samples referred to above exclude test material supplied for welding tests (see 1.4.1(15)). This material should receive the heat treatments prescribed in 1.11 and, if applicable, 1.14.1.

1.15 MECHANICAL TESTS

1.15.1 Tensile tests at room temperature. Tensile tests at room temperature shall be performed, and the proof or yield stress shall be determined, in accordance with BS 18‡.

‡ BS 18, 'Methods for tensile testing of metals'.

1.15.2 Tensile tests at elevated temperatures. Tensile tests at elevated temperatures shall be performed in accordance with BS 3688, Part 1* on Class B forgings.

The tests shall be made at the temperature specified on the order; this shall be selected by the purchaser from those listed in the relevant material specification in Section 2.

1.15.3 Bend tests. The bend test piece shall, at room temperature, be bent through 180°, without fracture, to the internal radius, or round a former having the radius specified in the relevant material specification. The bend test shall be performed in accordance with the relevant requirements of BS 1639†.

Bend tests may be made either by pressure or by blows.

1.15.4 Impact tests. The impact tests shall be performed in accordance with:

(1) BS 131, Part 2 'Charpy V-notch impact test', or

(2) BS 131, Part 3 'The Charpy U-notch impact test on metals'

as required by the material specification.

Low temperature impact tests shall be made at the temperature stated on the enquiry and order and selected by the purchaser from those specified in the relevant material specification in Section 2.

1.15.5 Hardness test. If required by the material specification, hardness tests shall be performed in accordance with BS 240‡ or BS 427§ as appropriate.

1.15.6 Intercrystalline corrosion test. If specified in the relevant material specification, and required by the order, a special bend test shall be carried out as follows:

Each bend test piece shall be not larger than ½ in diameter or thickness and, unless otherwise specified, before being tested shall be heated for 30 minutes at a temperature of 650 °C (1200 °F) and cooled in air. It shall then be immersed for 72 hours in a boiling solution having the following composition:

111 g copper sulphate ($CuSO_4 \cdot 5H_2O$)
98 g sulphuric acid (relative density 1·84)
all made up to 1 litre with distilled water.

Precautions shall be taken during the boiling to prevent concentration of the solution due to evaporation. After this preparation each test piece shall be capable of being bent without cracking through 90° round a radius equal to three times the diameter or thickness of the test piece.

1.16 MECHANICAL PROPERTIES AT ROOM TEMPERATURE

The mechanical properties obtained from the test pieces selected, prepared and tested in accordance with 1.12, 1.13, 1.14, and 1.15, shall comply with the requirements of the relevant material specification in Section 2.

1.17 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURES

1.17.1 Certified material. For certified material, representative elevated temperature tests at the temperature or temperatures specified by the purchaser shall not be required for material supplied to the order, provided the manufacturer has obtained certification approval for the supply of material covered by the relevant material specification, following the procedure described in BS 3920¶, which lays down conditions under which he shall demonstrate that the steel in question consistently has the indicated properties.

1.17.2 Hot-tested material. For hot-tested material, elevated temperature tests shall be made in accordance with the requirements specified in 1.12, 1.13, 1.14 and 1.15.2 at the temperature or temperatures specified by the purchaser, and the yield or proof stress values obtained shall comply with the requirements of the relevant material specification in Section 2.

If tests at the appropriate temperature or temperatures have been made on samples taken from forgings of the same dimensions made from the same cast and of section size equal to or greater than those ordered, the results of such tests may, if agreed by the purchaser, be adduced as evidence that the forgings ordered have the required properties.

1.18 IMPACT PROPERTIES

1.18.1 The impact properties obtained from standard test pieces (10 mm square), selected and prepared in accordance with 1.12, 1.13 and 1.14, and tested in accordance with 1.15.4, shall comply with the requirements of the relevant material specification.

1.18.2 For subsidiary standard test pieces, the values to be obtained shall be agreed between the manufacturer and the purchaser.

1.19 RETESTS

1.19.1 General. If any test fails, the manufacturer shall either undertake retesting in accordance with 1.19.2, or 1.19.3 as appropriate, or re-heat-treat the material represented in accordance with 1.19.4, and re-submit it for testing.

Any additional test samples required for retesting shall be taken from a position on the forging similar to that from which the original test sample was taken.

1.19.2. Room and elevated temperature tensile tests and bend tests. Should a test piece not fulfil the test requirements, two additional tests shall be made on test pieces of the same type as the one which failed, taken from the original or an adjacent test sample. Alternatively, for batch tested forgings, if the forging which failed has been withdrawn by the manufacturer, two further forgings shall be selected from the batch represented and shall be submitted for testing. Should either of these additional tests fail, the forgings represented shall be deemed not to comply with this British Standard.

1.19.3 Impact tests. If the average of three impact tests equals or exceeds the specified minimum average value but one test piece fails to give the specified minimum individual value, two more impact test pieces shall be cut from the same forgings and tested. If both these pieces give not less than the specified minimum average value, the material represented shall be deemed to comply with this British Standard.

* BS 3688, 'Methods for mechanical testing of metals at elevated temperatures', Part 1, 'Tensile testing'.
† BS 1639, 'Methods for bend testing of metals'.
‡ BS 240, 'Method for Brinell hardness test'.
§ BS 427, 'Method for Vickers hardness test'.
¶ BS 3920, 'Method of certifying elevated temperature proof or yield stress properties of steel products by selective testing'.

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If the average of the three impact tests fails to attain the specified minimum average value, or if two of the tests fall below the specified minimum individual value, the material represented shall be deemed not to comply with this British Standard.

1.19.4 Re-heat treatment. The manufacturer shall have the right to re-heat-treat any material, including material already found not to fulfil the test requirements, and re-submit it for testing. Unless otherwise agreed, no forging shall be fully re-heat-treated more than twice.

1.20 MARKING

1.20.1 Unless otherwise agreed, each forging or batch of forgings as appropriate shall be legibly marked with the manufacturer's name or trade mark and with numbers or other identification marks by which they can be traced to the cast of steel from which they were made. The purchaser shall state whether or not stamp marking is permitted. If stamp marking is permitted then scroll type stamps shall be used and the marking shall be placed in the area indicated on the forging drawing. Paint containing lead, zinc, copper or tin shall not be used.

1.21 MANUFACTURER'S CERTIFICATE

1.21.1 The manufacturer shall supply a certificate stating:

(1) the individual material specification with which the forgings comply, the ladle analysis, the room temperature mechanical properties determined in accordance with this British Standard and details of the heat treatment given to the forgings and test samples;

(2) if required, the steelmaking process used;

(3) for hot-tested material, the temperature or temperatures at which the tests were made and the yield or proof stress values obtained;

(4) for certified material, the elevated temperature properties with which the forgings are certified as complying;

(5) for material having low temperature properties, the temperature at which the impact tests were made, the type of notch, and the results of the tests.

The test certificate shall be signed by the person responsible for the supervision of the inspection and testing of the forgings.

1.22 DELIVERY

1.22.1 No forgings shall be despatched until they have been tested and shown to comply with, or have been certified as complying with all the tests and requirements of this standard applicable to the material required or specified.

1.23 DEFECTS REVEALED AFTER DELIVERY

1.23.1 In the event of material proving defective during subsequent manufacturing operations, such material shall be regarded as not complying with this British Standard, notwithstanding any previous certificate of satisfactory testing.

1.24 INSPECTION

1.24.1 The purchaser or his representative shall have access at all reasonable times to that part of the manufacturer's works engaged on the order; he shall be at liberty to inspect the manufacture at any stage and to witness the required tests. If the material is to be inspected and tested in the presence of the purchaser's representative, this shall be stated on the enquiry and order. (See 1.4.1 (7) and 1.13.1.1.)

1.25 TESTING FACILITIES

1.25.1 The manufacturer shall supply the material required for testing and shall furnish and prepare the necessary test pieces and supply the labour and appliances for such testing as may be carried out on his premises in accordance with this British Standard. Failing facilities at his own works, the manufacturer shall arrange for the tests to be carried out.

SECTION 2. SPECIFIC REQUIREMENTS

(To be read in conjunction with Section 1. General Requirements)

NOTE. Individual material specifications for stainless steels will be added to this section by amendment action at a future date.

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BS 1503-161

CARBON STEEL FORGINGS (SILICON-KILLED)

2.1 SCOPE

2.1.1 This specification states requirements for silicon-killed carbon steel forgings in three tensile grades. If required, the forgings can be supplied having proved or certified elevated temperature yield or proof stress properties.

2.2 DESIGNATIONS

2.2.1 Tensile grades. Three tensile grades are specified, namely:

Grade 26: 26–31 tonf/in² tensile strength

Grade 28: 28–33 tonf/in² tensile strength

Grade 32: 32–36 tonf/in² tensile strength (primarily intended for valves and fittings).

2.2.2 Suffix letters

Class A: the suffix 'A' to the grade number shall be used, if the purchaser does not require the material to be hot-tested or certified.

Class B: the suffix 'B' to the grade number shall be used if the purchaser requires the material to be hot-tested or certified.

The purchaser shall state on the enquiry and order the grade of steel required and the suffix letters.

2.2.3 Elevated temperature properties. (Class B forgings) If Class B forgings are required by the order, the material shall be supplied with the properties either certified or hot-tested in accordance with 1.17 as agreed between the manufacturer and the purchaser and stated on the order. If the forgings are to be supplied hot-tested the purchaser shall also state at which temperature in Table 4 the tests are to be made.

2.2.4 Examples of coding

28–33 tonf/in² tensile strength forgings to this British Standard, for which hot tensile tests or certification are not required, shall be coded as:

BS 1503–161 Grade 28A

26–31 tonf/in² tensile strength forgings to this British Standard, for which specified elevated temperature yield or proof stress properties are to be proved or certified, shall be coded as:

BS 1503–161 Grade 26B

2.3 CHEMICAL COMPOSITION

2.3.1 The ladle analysis shall comply with the appropriate requirements of Table 2.

TABLE 2. CHEMICAL COMPOSITION

Element		Grade 26 %		Grade 28 %		Grade 32* %	
Carbon	max.	0·20		0·25		0·25	
Silicon	min.	0·15		0·15		0·15	
	max.	0·35		0·35		0·35	
Manganese	min.	0·65		0·65		0·65	
	max.	1·20		1·20		1·20	
Sulphur	max.	0·050		0·050		0·050	
Phosphorus	max.	0·050		0·050		0·050	
Nickel	max.	0·40	Total 0·80 max.	0·40	Total 0·80 max.	0·40	Total 0·80 max.
Chromium	max.	0·25		0·25		0·25	
Molybdenum	max.	0·10		0·10		0·10	
Copper	max.	0·30		0·30		0·30	

NOTE. If aluminium is used for deoxidation purposes, the total aluminium content of the steel shall not exceed 0·010%.

2.4 HEAT TREATMENT

2.4.1 Unless otherwise agreed and stated on the enquiry and order, all forgings shall be supplied in the normalized, or normalized and tempered condition.

The normalizing temperature shall be within the range 870–920°C.

The tempering temperature shall be within the range 580–660°C. If stress rupture or creep properties are a design requirement, the tempering temperature shall not exceed 620°C.

2.5 MECHANICAL PROPERTIES AT ROOM TEMPERATURE

2.5.1. The mechanical properties obtained from test pieces, selected, prepared and tested in accordance with the requirements of 1.12, 1.13 and 1.15, shall comply with the requirements of Table 3.

TABLE 3. MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Grade	26	28	32*
Tensile strength tonf/in² min.	26	28	32
Tensile strength tonf/in² max.	31	33	36
Yield stress tonf/in², min.	13·0	14·0	16·0
Elongation %, min., on $L_o = 5{\cdot}65\sqrt{S_o}$ For longitudinal tests	23	22	20
Elongation %, min., on $L_o = 5{\cdot}65\sqrt{S_o}$ For transverse tests	20	19	17
Bend test Maximum radius of bend in terms of thickness t Longitudinal tests	⅓t	⅓t	—
Bend test Maximum radius of bend in terms of thickness t Transverse tests	⅔t	⅔t	—

* Primarily intended for valves and fittings of small ruling sections.

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TABLE 3M. METRIC EQUIVALENT OF TABLE 3

Grade	26	28	32
Tensile strength kgf/mm²			
min.	40·9	44·1	50·4
max.	48·8	52·0	56·7
Yield stress kgf/mm², min.	20·5	23·0	25·2
Elongation % min., on $5{\cdot}65\sqrt{S_o}$			
For longitudinal tests	23	22	20
For transverse tests	20	19	17
Bend test Maximum radius of bend in terms of thickness t			
Longitudinal tests	⅓t	⅓t	—
Transverse tests	⅔t	⅔t	—

2.6 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURES

(See also 2.2.3)

2.6.1 If forgings having elevated temperature properties are ordered, the manufacturer shall, as required by the order, either:

(1) certify that the forgings have the properties specified in Table 4 in accordance with the requirements of 1.17.1; or

(2) hot-test the material in accordance with the requirements of 1.17.2 at the temperature stated on the order, in which case the yield stress or 0·2% proof stress values obtained shall comply with the relevant requirements of Table 4.

TABLE 4. MECHANICAL PROPERTIES AT ELEVATED TEMPERATURES

Grade	Minimum yield stress or 0·2% proof stress, tonf/in², determined in accordance with BS 3688*, at temperature of:							
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C
26B	12·1	11·6	11·0	10·4	9·6	9·0	8·5	8·2
28B	12·9	12·3	11·6	11·2	10·5	10·0	9·5	9·2
32B	14·9	14·3	13·6	13·1	12·5	12·0	11·5	11·2

TABLE 4M. METRIC EQUIVALENT OF TABLE 4

Grade	Minimum yield stress or 0·2% proof stress, kgf/mm², determined in accordance with BS 3688* at temperature of:							
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C
26B	19·1	18·3	17·3	16·4	15·1	14·2	13·4	12·9
28B	20·3	19·4	18·3	17·6	16·5	15·7	15·0	14·5
32B	23·5	22·5	21·4	20·6	19·7	18·9	18·1	17·6

* BS 3688, 'Methods for mechanical testing of metals at elevated temperatures', Part 1, 'Tensile testing'.

BS 1503-161 APPENDIX A

CREEP AND CREEP RUPTURE PROPERTIES

The creep and creep rupture values given in Table 5 have been determined from data from tests upon a large number of samples of steel representative of commercial production.

It is considered that these values may reliably be used for design purposes. Mean values are listed but it is estimated that the scatter will not exceed ±20%.

TABLE 5. CREEP AND CREEP RUPTURE VALUES

Grades	Temperature °C	Stress, lbf/in², for: 1% creep strain in 10 000 hours	1% creep strain in 30 000 hours	1% creep strain in 100 000 hours	1% creep strain in 200 000 hours	Rupture in 10 000 hours	Rupture in 30 000 hours	Rupture in 100 000 hours	Rupture in 200 000 hours
26A and B 28A and B 32A and B	380	See note				42 100	37 000	31 100	27 300
	390					38 500	33 400	27 600	24 000
	400					34 900	29 800	24 200	20 800
	410					31 600	26 400	21 100	17 900
	420					28 200	23 300	18 100	15 200
	430					25 100	20 400	15 500	12 800
	440					22 200	17 500	13 000	10 800
	450					19 300	15 000	10 800	8 700
	460					16 600	12 500	9 000	7 400
	470					14 300	10 800	7 400	6 000
	480					12 300	9 200	6 300	4 900
	490					10 500	7 600	5 400	4 300
	500					9 000	6 700	4 700	3 600

NOTE. Stresses corresponding to 1% total strain in 10 000 hours to 200 000 hours are still under consideration but may be assumed to be not less than two thirds of the stresses corresponding to creep rupture under the same conditions of time and temperature.

BS 1503-161 APPENDIX B

STRESS-RELIEVING

If a stress-relieving heat treatment is employed, the temperature shall be within the range 580–660°C. If the design is based on stress rupture or creep properties the stress relieving temperature shall not exceed 620°C.

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BS 1503-221

CARBON MANGANESE STEEL FORGINGS (SILICON-KILLED)

2.1 SCOPE

2.1.1 This specification states requirements for silicon-killed carbon manganese steel forgings in two tensile grades. If required, the forgings can be supplied having proved or certified elevated temperature yield or proof stress properties.

2.2 DESIGNATIONS

2.2.1 Tensile grades. Two tensile grades are specified, namely:

Grade 32: 32–37 tonf/in² tensile strength

Grade 34: 34–39 tonf/in² tensile strength

2.2.2 Suffix letters

Class A: the suffix 'A' to the grade number shall be used if the purchaser does not require the material to be hot-tested or certified.

Class B: the suffix 'B' to the grade number shall be used if the purchaser requires the material to be hot-tested or certified.

The purchaser shall state on the enquiry and order the grade of steel required and the suffix letter.

2.2.3 Elevated temperature properties. (Class B forgings). If Class B forgings are required by the order, the material shall be supplied with the properties either certified or hot-tested in accordance with 1.17 as agreed between the manufacturer and the purchaser and stated on the order. If the forgings are to be supplied hot-tested the purchaser shall also state at which temperature in Table 4 the tests are to be made.

2.2.4 Examples of coding

32–37 tonf/in² tensile strength forgings to this British Standard, for which hot tensile tests or certification are not required, shall be coded as:

BS 1503-221 Grade 32A

34–39 tonf/in² tensile strength forgings to this British Standard, for which specified elevated temperature yield or proof stress properties are to be proved or certified, shall be coded as:

BS 1503-221 Grade 34B

2.3 CHEMICAL COMPOSITION

2.3.1 The ladle analysis shall comply with the appropriate requirements of Table 2.

TABLE 2. CHEMICAL COMPOSITION

Element		Grade 32 %	Grade 34 %
Carbon	max.	0·25	0·27
Silicon	min.	0·15	0·15
	max.	0·35	0·35
Manganese	min.	0·90	0·90
	max.	1·50	1·50
Nickel	max.	0·50	0·50
Sulphur	max.	0·050	0·050
Phosphorus	max.	0·050	0·050
Chromium	max.	0·25 } Total	0·25 } Total
Molybdenum	max.	0·10 } 0·50	0·10 } 0·50
Copper	max.	0·30 } max.	0·30 } max.

NOTE. If aluminium is used for deoxidation purposes, the total aluminium content of the steel shall not exceed 0·010%.

2.4 HEAT TREATMENT

2.4.1 Unless otherwise agreed and stated on the enquiry and order, all forgings shall be supplied in the normalized, or normalized and tempered condition.

The normalizing temperature shall be within the range 860–910°C.

The tempering temperature shall be within the range 580–660°C. If stress rupture or creep properties are a design requirement, the tempering temperature shall not exceed 620°C.

2.5 MECHANICAL PROPERTIES AT ROOM TEMPERATURE

2.5.1 The mechanical properties obtained from test pieces, selected, prepared and tested in accordance with the requirements of 1.12, 1.13 and 1.15, shall comply with the requirements of Table 3.

TABLE 3. MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Grade	32	34
Tensile strength tonf/in²		
min.	32	34
max.	37	39
Yield stress tonf/in², min.	16·0	17·0
Elongation % min. on $5{\cdot}65\sqrt{S_0}$		
For longitudinal tests	19	18
For transverse tests	16	15
Bend test Maximum radius of bend in terms of thickness t		
Longitudinal tests	½t	⅔t
Transverse tests	1t	1⅓t

TABLE 3M. METRIC EQUIVALENT OF TABLE 3

Grade	32	34
Tensile strength kgf/mm²		
min.	50·3	53·5
max.	58·3	61·4
Yield stress kgf/mm², min.	25·2	26·8
Elongation % min. on $5{\cdot}65\sqrt{S_o}$		
For longitudinal tests	19	18
For transverse tests	16	15
Bend test Maximum radius of bend in terms of thickness t		
Longitudinal tests	½t	⅔t
Transverse tests	1t	1⅓t

2.6 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURES
(See also 2.2.3)

2.6.1 If forgings having elevated temperature properties are ordered, the manufacturer shall, as required by the order, either:

(1) certify that the forgings have the properties specified in Table 4 in accordance with the requirements of 1.17.1; or

(2) hot-test the material in accordance with the requirements of 1.17.2 at the temperature stated on the order, in which case the yield stress or 0·2% proof stress values obtained shall comply with the relevant requirements of Table 4.

TABLE 4. MECHANICAL PROPERTIES AT ELEVATED TEMPERATURES

Grade	Minimum yield stress or 0·2% proof stress, tonf/in², determined in accordance with BS 3688* at temperature of:							
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C
32B	14·9	14·3	13·6	13·1	12·5	12·0	11·5	11·2
34B	15·9	15·3	14·6	14·1	13·5	13·0	12·5	12·2

TABLE 4M. METRIC EQUIVALENT OF TABLE 4

Grade	Minimum yield stress or 0·2% proof stress, kgf/mm², determined in accordance with BS 3688* at temperature of:							
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C
32B	23·5	22·5	21·4	20·6	19·7	18·9	18·1	17·6
34B	25·0	24·1	23·0	22·2	21·3	20·5	19·7	19·2

* BS 3688, 'Methods for mechanical testing of metals at elevated temperatures', Part 1, 'Tensile testing'.

BS 1503-221 APPENDIX A

CREEP AND CREEP RUPTURE PROPERTIES

The creep and creep rupture values given in Table 5 have been determined from data from tests upon a large number of samples of steel representative of commercial production.

It is considered that these values may reliably be used for design purposes. Mean values are listed but it is estimated that the scatter will not exceed ±20%.

TABLE 5. CREEP AND CREEP RUPTURE VALUES

Grades	Temperature °C	Stress, lbf/in², for: 1% creep strain in				Rupture in			
		10 000 hours	30 000 hours	100 000 hours	200 000 hours	10 000 hours	30 000 hours	100 000 hours	200 000 hours
32A and B 34A and B	380	See note				43 900	35 800	32 300	28 200
	390					40 300	34 900	29 100	25 300
	400					37 000	31 800	26 000	22 400
	410					33 600	28 700	23 000	19 700
	420					30 200	25 500	20 400	17 200
	430					27 100	22 600	17 700	14 800
	440					24 200	19 700	15 200	12 800
	450					21 300	17 200	13 000	10 800
	460					18 600	15 000	11 000	9 000
	470					16 100	12 800	9 200	7 400
	480					14 100	10 800	7 600	6 000
	490					12 100	9 200	6 300	4 900
	500					10 500	7 800	5 400	4 300

NOTE. Stresses corresponding to 1% total strain in 10 000 hours to 200 000 hours are still under consideration but may be assumed to be not less than two-thirds of the stresses corresponding to creep rupture under the same conditions of time and temperature.

BS 1503-221 APPENDIX B

STRESS-RELIEVING

If a stress-relieving heat treatment is employed, the temperature shall be within the range 580–660°C. If the design is based on stress rupture or creep properties the stress relieving temperature shall not exceed 620°C.

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BS 1503-223

CARBON MANGANESE STEEL FORGINGS (SILICON-KILLED, NIOBIUM-TREATED)

2.1 SCOPE

2.1.1 This specification states requirements for silicon-killed niobium-treated steel forgings in two tensile grades. If required, the forgings can be supplied having proved or certified elevated temperature yield or proof stress properties. The forgings can also be supplied having specified low temperature impact properties.

2.2 DESIGNATIONS

2.2.1 Tensile grades. Two tensile grades are specified namely:

Grade 28: 28–33 tonf/in² tensile strength
Grade 32: 32–37 tonf/in² tensile strength

2.2.2 Suffix letters

Class A: the suffix 'A' to the grade number shall be used if the purchaser does not require the material to be hot-tested or certified.

Class B: the suffix 'B' to the grade number shall be used if the purchaser requires the material to be hot-tested or certified.

Material having specified impact properties shall be designated by the suffix 'LT' followed by a number representing the testing temperature below zero in degrees C together with the letter 'V' indicating the type of notch required.

The purchaser shall state on the enquiry and order the grade of steel required and the suffix letters.

2.2.3 Elevated temperature properties (Class B forgings). If Class B forgings are required by the order the material shall be supplied with the properties either certified or hot-tested in accordance with 1.17 and the purchaser shall state on which basis the forgings are to be supplied on his enquiry and order. If the forgings are to be supplied hot-tested the purchaser shall also state at which temperature in Table 4 the tests are to be made.

2.2.4 Impact properties. If forgings having specified impact properties are required by the order, the purchaser shall also state the temperature in Table 5 at which the tests are to be made.

2.2.5 Examples of coding

28–33 tonf/in² tensile strength forgings to this British Standard for which hot tensile tests or certification are not required shall be coded as:

BS 1503-223 Grade 28A

32–37 tonf/in² tensile strength forgings to this British Standard for which specified elevated temperature yield or proof stress properties are to be proved or certified shall be coded as:

BS 1503-223 Grade 32B

32–37 tonf/in² tensile strength forgings to this British Standard, for which hot tensile tests or certification are not required, but having specified Charpy V-notch impact tests at − 10° C shall be coded as:

BS 1503-223 Grade 32A LT 10V

2.3 CHEMICAL COMPOSITION

2.3.1 The ladle analysis shall comply with the appropriate requirements of Table 2.

TABLE 2. CHEMICAL COMPOSITION

Element		Grade 28 %	Grade 32 %
Carbon	max.	0·20	0·25
Silicon	min.	0·15	0·15
	max.	0·35	0·35
Manganese	min.	0·90	0·90
	max.	1·60	1·60
Niobium	min.	0·01	0·01
	max.	0·06	0·06
Sulphur	max.	0·050	0·050
Phosphorus	max.	0·050	0·050
Nickel	max.	0·40 } Total	0·40 } Total
Chromium	max.	0·25 } 0·80	0·25 } 0·80
Molybdenum	max.	0·10 } max.	0·10 } max.
Copper	max.	0·30	0·30

2.4 HEAT TREATMENT

2.4.1 Unless otherwise agreed and stated on the enquiry and order, all forgings shall be supplied in the normalized, normalized and tempered, or quenched and tempered condition (see 1.3.2).

The normalizing or quenching temperature shall be within the range 900–950°C.

The tempering temperature shall be within the range 580–660°C. If stress rupture or creep properties are a design requirement, the tempering temperature shall not exceed 620°C.

2.5 MECHANICAL PROPERTIES AT ROOM TEMPERATURE

2.5.1 The mechanical properties obtained from test pieces, selected, prepared and tested in accordance with the requirements of 1.12, 1.13 and 1.15, shall comply with the requirements of Table 3.

TABLE 3. MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Grade		28	32
Tensile strength tonf/in²	min.	28	32
	max.	33	37
Yield stress tonf/in²	min.	16	18
Elongation %min. on $5{\cdot}65\sqrt{S_o}$			
For longitudinal tests		22	19
For transverse tests		19	16
Bend test Maximum radius of bend in terms of thickness t			
Longitudinal tests		$\frac{1}{3}t$	$\frac{2}{3}t$
Transverse tests		$\frac{2}{3}t$	$1t$

TABLE 3M. METRIC EQUIVALENTS OF TABLE 3

Grade		28	32
Tensile strength kgf/mm²	min.	44·1	50·4
	max.	52·0	58·3
Yield stress kgf/mm²	min.	25·2	28·3
Elongation % min. on $5{\cdot}65\sqrt{S_o}$			
For longitudinal tests		22	19
For transverse tests		19	16
Bend test Maximum radius of bend in terms of thickness t			
Longitudinal tests		½t	⅝t
Transverse tests		⅝t	1t

2.6 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURES

(See also 2.2.3)

2.6.1 If forgings having elevated temperature properties are ordered, the manufacturer shall, as required by the order, either:

(1) certify that the forgings have the appropriate properties specified in Table 4 in accordance with the requirements of 1.16.1; or

(2) hot-test the material in accordance with the requirements of 1.16.2 at the temperature stated on the order, in which case the yield stress or 0·2 % proof stress values obtained shall comply with the relevant requirements of Table 4.

TABLE 4. MECHANICAL PROPERTIES AT ELEVATED TEMPERATURES

Grade	Minimum yield stress or 0·2 % proof stress, tonf/in², determined in accordance with BS 3688* at a temperature of:							
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C
28B	14·5	13·6	12·7	11·8	10·9	10·0	9·5	9·2
32B	16·5	15·6	14·7	13·8	12·9	12·0	11·5	11·2

TABLE 4M. METRIC EQUIVALENT OF TABLE 4

Grade	Minimum yield stress or 0·2 % proof stress, kgf/mm², determined in accordance with BS 3688* at a temperature of:							
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C
28B	22·8	21·4	20·0	18·6	17·2	15·7	15·0	14·5
32B	26·0	24·6	23·2	21·7	20·3	18·9	18·1	17·6

* BS 3688, 'Methods for mechanical testing of metals at elevated temperatures', Part 1, 'Tensile testing'.

2.7 IMPACT PROPERTIES

2.7.1 If forgings having specified impact properties are required by the order the values obtained from test pieces, cut parallel to the direction of principal grain flow, and selected, prepared and tested in accordance with the requirements of 1.12, 1.13 and 1.15 shall comply with the appropriate requirements of Table 5.

TABLE 5. CHARPY V IMPACT TESTS

Grade	Impact test value, ft lbf, at temperature of:					
	0°C*		−10°C (4 in ruling section max.)		−30°C (4 in ruling section max.)	
	Min. average value	Min. individual value	Min. average value	Min. individual value	Min. average value	Min. individual value
28	20	15	20	15	20	15
32	20	15	20	15	—	—

TABLE 5M. METRIC EQUIVALENT OF TABLE 5

Grade	Impact test value, kgf m, at temperature of:					
	0°C*		−10°C (100 mm ruling section max.)		−30°C (100 mm ruling section max.)	
	Min. average value	Min. individual value	Min. average value	Min. individual value	Min. average value	Min. individual value
28	2·8	2·1	2·8	2·1	2·8	2·1
32	2·8	2·1	2·8	2·1	—	—

* These properties may not be obtainable in the case of very large forgings and for such forgings the values to be obtained shall be agreed between the manufacturer and the purchaser.

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