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British Standard Specification for

Steel forgings for pressure purposes

Pièces forgées en avier pour appareils à pression — Spécifications

Schmiedestücke aus Stahl für den Einsatz unter Druck

British Standards Institution

Foreword

This British Standard has been prepared under the direction of the Iron and Steel Standards Policy Committee and replaces the previous edition of BS 1503 published in 1980, which is withdrawn.

The main technical differences between this edition of BS 1503 and the previous edition are the inclusion of steel grades 243-430, 762-690, 225-490, the duplex stainless steel 318S13 and the high nitrogen grades of 304S61, 316S61 and 316S63 steels. Steel grade 245-420 is withdrawn. Attention has been drawn to the requirements of small forgings and more detail given on the non-destructive testing of forgings. Clause **10**, on the number and selection of test samples and the preparation of test pieces, has been extensively revised. Recognition has been given to the advances in steelmaking processes by the reduction of sulphur and/or phosphorus contents in most of the steels in the standard. The options available to the purchaser are shown in appendix B.

The steels included in this British Standard are generally regarded as being weldable. However, care should be taken and, where appropriate, welding should be carried out in accordance with the requirements of the appropriate British Standards for welding (see also option **B.5**).

Elevated temperature proof stress values in this standard represent the results of the most recent assessments. In keeping with the established practice for up-dating the mechanical properties, work continues on the collection and assessment of relevant data. Any resulting new values will be considered for future revisions of this or equivalent standards.

Users of this standard are invited to assist by sending relevant data to the Secretariat of ISM/73/-/1, British Standards Institution, 3 York Street, Manchester, M2 2AT (see appendix M for pro-forma).

This British Standard is one of a series specifying requirements for steels in various product forms for pressure purposes. Other British Standards in this series are:

BS 1501 Steels for pressure purposes : plates, sheet and strip (in three parts)
- Part 1 Specification for carbon and carbon manganese steels
- Part 2 Specification for alloy steels
- Part 3 Specification for corrosion and heat resisting steels

BS 1502 Specification for steels for fired and unfired pressure vessels : sections and bars

BS 1504 Specification for steel castings for pressure purposes

BS 1506 Specification for carbon, low alloy and stainless steel bars and billets for bolting material to be used in pressure retaining applications

Requirements for steel tubes for pressure purposes are specified in BS 3601 to BS 3605 inclusive.

Product certification. Users of this British Standard are advised to consider the desirability of third party certification of product conformity with this British Standard based on testing and continuing surveillance, which may be coupled with assessment of a supplier's quality systems against the appropriate Part of BS 5750.

Enquiries as to the availability of third party certification schemes will be forwarded by BSI to the Association of Certification Bodies. If a third party certification scheme does not already exist, users should consider approaching an appropriate body from the list of Association members.

It is outside the scope of this standard to specify formal qualifications for personnel engaged in testing but it is emphasized that the operation of all equipment should be supervised by competent, trained personnel.

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

Contents

Specification

1 Scope

This British Standard specifies requirements for carbon-manganese, low alloy, ferritic stainless, martensitic stainless, duplex stainless and austenitic stainless steel forgings for pressure purposes. Provision is also made for the supply of semi-finished forged products intended for further processing.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Designation

NOTE. Equivalent designations of steels in BS 1503 : 1989, BS 1503 : 1980, BS 1503 : 1969 and ISO 2604/1-1975 are given in appendix K.

2.1 The steel shall be designated by the number of this standard, the relevant steel grade number as given in table 1, 2 or 3, where appropriate, the relevant following suffix(es).

(a) The suffix 'E' shall follow the steel grade number if minimum room temperature properties and elevated temperature proof stress values are to be verified (see clause **14**).

(b) Materials having verified minimum room temperature tensile properties and verified low temperature impact values shall be designated by the addition to the steel grade number of the suffix 'LT' followed by the temperature below zero, in °C, at which the low temperature impact values are to be verified.

NOTE. When no suffix follows the steel grade number, the minimum room temperature tensile properties only are verified. These will include room temperature impact properties when option **B.8.3** is called up.

2.2 Carbon-manganese and low alloy steels shall be designated by a steel grade number consisting of two parts, the first part representing the nominal analysis, and the second part the minimum room temperature tensile strength in N/mm^2 *.

NOTE. For all the stainless steels, the designation represents the nominal analysis only, with the exception of steel grade 321S51, where, for the same nominal analysis, the additional number 490 or 510 is the minimum room temperature tensile strength in N/mm^2.

Examples:

(a) BS 1501 223-430;

Forging material of niobium-treated carbon-manganese steel 223-430, with verified room temperature properties only.

(b) BS 1503 622-490E;

Forging material of 2.25 % chromium 1 % molybdenum steel type 622-490, with verified room temperature properties and verified elevated temperature proof stress values.

(c) BS 1503 509-690 LT196;

Forging material of 9 % nickel steel 509-690, with verified room temperature properties and verified impact values at a temperature of −196 °C.

(d) BS 1503 420S29;

Forging material of 12 % chromium steel 420S29, with verified room temperature properties only.

(e) BS 1503 347S51E;

Forging material of 18 % chromium 10 % nickel niobium austenitic stainless steel 347S51, with verified room temperature properties and verified elevated temperature proof stress values.

3 Requirements

3.1 Forgings

Forgings shall comply with all the requirements of this standard including the appropriate requirements for the relevant steel specified in table 1, 2 or 3.

3.2 Semi-finished material

Semi-finished material intended for further processing shall comply with the requirements of clauses **4**, **5** and **6**, and shall be suitable for further forging.

3.3 Information to be supplied by the purchaser

Information to be supplied by the purchaser at the time of enquiry and order is detailed in appendix A (see also **3.4**).

3.4 Options

Options available are detailed in appendix B. Where any of the options given are called up at the time of the order, the forgings or semi-finished material shall comply with the requirements of any such options, in addition to the requirements of **3.1** or **3.2**. In the event that the purchaser does not indicate a need to implement any of these options at the time of enquiry and order, the manufacturer or merchant shall supply in accordance with the basic specification.

4 Manufacture of the steel

4.1 Steelmaking process

The steel shall be produced by an electric process or one of the basic oxygen processes.

The purchaser shall be informed of the steelmaking process used.

4.2 Deoxidation

The steel shall be fully killed. The type of deoxidation practice shall be at the option of the manufacturer unless otherwise agreed with the purchaser (see option **B.1**).

*1 N/mm^2 = 1 MPa.

4.3 Casting practice

The steel shall be cast in the form of an ingot or continuously cast material.

5 Chemical composition

5.1 Cast analysis

The chemical composition of the steel shall be determined by cast analysis and shall comply with the relevant requirements specified in table 1, 2 or 3.

Elements not quoted in the individual specification shall not be intentionally added other than for the purpose of finishing the heat in which case the purchaser shall be informed (see **4.2** and option **B.2**).

5.2 Product analysis

When product analysis is carried out, it shall be in accordance with option **B.3**.

5.3 Carbon equivalent values

When forgings are required with maximum carbon equivalent values, they shall be supplied in accordance with option **B.5**.

6 Semi-finished material

6.1 Chemical composition

Semi-finished material intended for further processing shall comply with the composition requirements for the relevant steel as specified in table 1, 2 or 3.

6.2 Mechanical properties and special requirements

When the mechanical properties or special requirements for semi-finished material are specified, they shall comply with options **B.20** and **B.21**.

7 Manufacture of the product

7.1 Hot working

The forgings shall be produced by hammering, drop-forging, pressing, extruding, ring-rolling, or by any combination of these processes.

NOTE 1. It is recommended that forgings should be brought as close as practicable to the finished shape and the size by hot working, and, where practicable, should be so worked as to cause metal flow in the direction most favourable for resisting service stresses.

NOTE 2. It is recommended that the directions of maximum service stress should be made known to the manufacturer by the purchaser.

7.2 Forging reduction

7.2.1 *Forging reduction ratio.* The forging reduction ratio shall be calculated by dividing the cross-sectional area prior to forging by the cross-sectional area after forging. For upset forging the inverse ratio shall be taken. The total forging reduction ratio is the product of the separate forging reduction ratios calculated for each forging operation.

7.2.2 *Hollow forgings.* Hollow forgings shall receive a minimum overall forging reduction of 3 : 1. This shall include a minimum of 2 : 1 in any one forging direction. When the bore diameter is less than one-fifth of overall diameter the requirements for solid forgings shall apply.

7.2.3 *Solid forgings.* Solid forgings produced by forging in one direction only shall receive a minimum overall forging reduction of 3 : 1. Where forging has taken place in more than one direction, the minimum overall forging reduction shall be 4 : 1.

7.2.4 *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. When forging has taken place in more than one direction the minimum overall forging reduction shall be 3 : 1.

7.2.5 *Forgings made from rolled products.* For forgings made from rolled products, the forging reduction from the ingot or concast bar to the finished forging shall be not less than 4 : 1.

7.3 Heat treatment

7.3.1 After hot working, all forgings shall be cooled in such a way that no damage results to the forging.

7.3.2 The forgings shall be heat treated as specified for the relevant steel in table 1, 2 or 3.

NOTE. The influence of size and shape on mechanical properties produced in steel forgings by heat treatment may need to be taken into consideration.

Reference is made to methods of calculating these effects and to the significance of equivalent diameter and ruling section in appendix L.

It is generally impracticable to obtain samples for mechanical tests from positions within the forging where the cooling rate is slowest, and test positions near to the surface are therefore specified in this standard.

Where it is necessary to confirm that the mechanical properties in all parts of the forging will be suitable for the intended application, it is recommended that an agreed programme of testing be carried out on a representative forging and the results compared with those from the test samples to be used in production testing.

8 Surface condition and soundness

8.1 The forgings shall be sound and free from such segregation, cracks, laminations or flaws that preclude their use for the purpose for which they are intended.

See also options **B.9** Hydraulic testing, **B.10** Etching for flow lines, **B.13** Ultrasonic inspection, **B.14** Magnetic particle inspection and **B.15** Dye penetrant inspection.

8.2 The details of any proposed repair procedure, and of the subsequent heat treatment and non-destructive testing, shall be supplied by the manufacturer to the purchaser. Defects in forgings shall not be repaired without prior written permission of the purchaser. The position of such repairs shall be marked on the forging drawing and/or on the forgings themselves and referred to on the test certificate.

9 Inspection

The parties concerned shall have access at all reasonable times to those parts of the manufacturer's works engaged in the production of the forgings and shall be at liberty to observe the manufacture at any stage, to witness the required tests, to inspect dimensionally, to stamp or otherwise identify the forgings and test pieces, and to reject any material that does not comply with this standard.

10 Number and selection of test samples and preparation of test pieces

10.1 General

10.1.1 The minimum number of test samples shall be in accordance with **10.2**, **10.3** or **10.4** according to the mass of the forging. The samples shall be sufficient in size for the required number of test pieces to be taken and as far as practicable in the direction of the principal grain flow (see also options **B.16**, **B.17** and **B.18**).

Test samples shall be provided by one of the following methods.

(a) As separate test samples taken from the initial starting product, i.e. bar, billet or ingot, from which the forgings have been made. The test samples shall have received the same hot working reduction and have the same equivalent diameter as the ruling section of the forgings they represent as defined in appendix L.

(b) From prolongations of the forgings having a diameter or section approximately equal to the ruling section of the forging at the time of heat treatment (see note to **7.3.2**). Integral test samples shall not be parted from the forging until all heat treatment is completed except as in **10.5**.

(c) From additional forgings.

10.1.2 Separate test samples or additional forgings shall be heat treated with the batch they represent. If more than one cast of steel or heat treatment batch is involved in the order, test samples shall be provided for each heat treatment batch and from each cast contributing to each batch.

10.2 Forgings up to 1000 kg mass

For forgings up to 1000 kg mass, test samples shall be provided by methods (a), (b) or (c) of **10.1.1**.

10.3 Forgings between 1000 kg and 3500 kg mass

For forgings between 1000 kg and 3500 kg mass, test samples shall be provided by method **10.1.1**(b). A test sample shall be taken from one end of each forging.

10.4 Forgings over 3500 kg mass

For forgings over 3500 kg mass, test samples shall be provided by method **10.1.1** (b). A test sample shall be taken from each end of each forging.

NOTE. In the case of forgings whose diameter exceeds the length of the axis, the two sets of test samples may be taken 180 ° apart on one end of the forging or from the periphery.

10.5 Forgings for closed hollow vessels

In the case of forgings for closed hollow vessels, the test samples shall be cut off before closing, either by hot working or welding on ends, and shall be subjected to the same heat treatment as the vessels themselves. In the case of open hollow vessels a sample shall be cut off after completion of the heat treatment. The number of test samples taken from these forgings shall comply with the relevant requirements of **10.2**, **10.3** and **10.4**.

10.6 Preparation of test pieces

Unless otherwise agreed, test pieces shall be taken such that no part of the gauge length of the test piece is machined from material located within 12.5 mm of any as-heat treated surface. For impact testing, this requirement shall apply to the complete test piece. In the case of test pieces machined from test samples prepared according to **10.6**(a) the end of the test piece shall be a minimum of 50 mm from the end of the test sample. From each test sample the following test pieces shall be prepared:

(a) one room temperature tensile test piece complying with BS 18.

(b) for steels that are to be impact tested (see option **B.8**), Charpy V-notch test pieces specified in BS 131 : Part 2; the axis of the notch shall be perpendicular to the nearest surface of the forging;

(c) if an elevated temperature tensile test is required (see clause **14**), a test piece cut from a position on the sample adjacent to one of the room temperature tensile test pieces, and prepared in accordance with BS 3688 : Part 1.

See also option **B.19**.

11 Post-weld heat treatment of test samples

NOTE. Design codes or standards include provisions for the application of post-weld heat treatment. Where relevant, reference should be made to such codes or standards.

11.1 Forgings post-weld heat treated by the forgemaster

If the forgings form part of a welded vessel or structure that is given a post-weld treatment by the forgemaster, the test samples shall receive all the heat treatment applied to the forgings as required in **7.3** and shall be subjected with the forgings or fabricated vessel to the post-weld heat treatment.

NOTE. The test samples referred to above exclude test material supplied for welding tests. The welding test material should receive the heat treatments specified in **7.3**.

11.2 Forgings to be post-weld heat treated by the purchaser

See option **B.6**.

12 Mechanical test methods

12.1 Tensile tests at room temperature

Tensile tests at room temperature shall be carried out in accordance with the requirements of BS 18.

12.2 Tensile tests at elevated temperatures

When tensile tests at elevated temperatures are carried out, they shall be in accordance with **B.7.**

12.3 Impact tests

When impact tests are carried out, they shall be in accordance with **B.8.**

13 Mechanical properties at room temperature

The mechanical properties obtained from the test pieces selected, prepared and tested in accordance with clauses **10** and **12** shall comply with the values specified for the relevant steel in table 1, 2 or 3.

14 Mechanical properties at elevated temperatures

14.1 Elevated temperature proof stress values

For forgings whose designation has an 'E' suffix the manufacturer shall either:

(a) satisfy the purchaser in accordance with the procedure given in BS 3920 : Part 1 that the product consistently meets the elevated temperature values specified for the relevant steel as indicated in appendix C, D or E; or

NOTE. Information required for the construction of the lower confidence lines for the elevated temperature proof stress values, necessary for the application of that procedure, is given in appendix F.

(b) if insufficient data are available to verify compliance with BS 3920 : Part 1 one test shall be made on each cast of steel used for the manufacture of the forging or forgings, the test sample being taken in accordance with clause **10.** The temperature of test shall be chosen by the purchaser from those given in appendix C, D or E. The yield or proof stress values obtained shall comply with the requirements specified for the relevant steel in appendix C, D or E. If forgings of more than one thickness are to be supplied from one cast, then the test shall be made on the thickest forging (see option **B.7.1**).

14.2 Additional elevated temperature tests

When additional elevated temperature tests are required, they shall be carried out in accordance with **B.7.2.**

NOTE. The estimated average stress-rupture values are given in appendices G, H and J. The average stress-rupture values are valid provided that the product has been manufactured strictly in accordance with the technical requirements of this standard.

15 Impact properties

When impact tests are required, they shall be in accordance with option **B.8.**

16 Retests

16.1 Room temperature and elevated temperature tensile tests

If the results from a test piece do not comply with the specified property requirements, two additional tensile tests shall be made, using the same test conditions and test piece dimensions as the one that failed, on test pieces taken from the original or an adjacent test sample. Alternatively, for batch tested forgings, if the forging that failed has been withdrawn by the manufacturer, two further forgings shall be selected from the batch represented and shall be retested.

If the test piece results fail to meet the requirements, the forgings represented shall be deemed not to comply with this British Standard.

16.2 Impact tests at room and at low temperatures

If the average of three impact values is lower than the specified value, or if any one value is lower than 70 % of this specified value, three additional test pieces, taken from the original or an adjacent test sample shall be tested.

The average value from six tests shall be not less than the specified value, not more than two individual values shall be less than the specified value, and not more than one shall be less than 70 % of the specified value, otherwise the forgings represented shall be deemed not to comply with the requirements of this British Standard.

16.3 Re-heat treatment

The manufacturer shall have the right to repeat the heat treatment of any material, including material found not to fulfil the test requirements, and resubmit it for testing. No forging shall be fully re-heat treated more than twice.

17 Manufacturer's certificate

17.1 The manufacturer shall supply a certificate giving:

(a) the complete designation of the steel specification with which the forgings comply, e.g. BS 1503 224-460;

(b) the reference number of each forging;

(c) the steelmaking process used;

(d) the cast analysis in respect of all specified elements;

(e) a statement of the soaking time, temperature and cooling medium for each stage of heat treatment given to the forgings;

(f) the room temperature mechanical properties determined in accordance with this standard;

(g) for forgings whose complete designation contains the suffix 'E', either:

(1) a statement that the material satisfies the verification requirements of BS 3920 : Part 1 (see **14.1**(a)); or

(2) if insufficient data were available to satisfy the requirements of BS 3920 : Part 1, the test temperature of the elevated temperature test and the yield or proof stress values obtained (see **14.1**(b));

(h) for forgings having specified impact properties, the temperature at which impact tests were made and the results obtained;

(i) details of any repairs carried out (see **8.2**). The location of such repairs shall be marked clearly on the drawings and/or the forgings themselves.

In addition, the manufacturer's certificate shall provide details of the following optional requirements:

(j) the incidental element content;

(k) details of any simulated post-weld heat treatment;

(l) if special elevated temperatures tests have been made, the test temperatures used and the yield or proof stress values obtained (see **14.2**);

(m) details and results of any agreed additional tests.

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

18 Marking

18.1 Unless otherwise agreed, each forging, or batch of forgings, as appropriate, shall be legibly marked to show:

(a) the manufacturer's name or trade mark;

(b) the reference numbers or other identification marks by which the forgings can be related to the manufacturer's certificate;

(c) the complete designation of the material* (see clause **2**);

(d) the mark of the inspecting authority, if required (see clause **9**).

18.2 The mark shall be placed in an area on the forging as indicated on the forging drawing.

NOTE. For small forgings that are boxed, the information required by **18.1** may be marked on the box, or on a tag securely attached to the box, in which the forgings are shipped.

18.3 The purchaser shall state if stamping is not permissible. If stamping is permissible, scroll type stamps shall be used. If stamping is not permissible, see option **B.12**.

19 Delivery

No forgings shall be despatched until they have been certified as complying with all the tests and requirements of this standard applicable to the material ordered, and any additional requirements specified in the order.

20 Defects revealed after delivery

In the event of material proving defective during subsequent manufacturing operations such material shall be deemed not to comply with the requirements of this British Standard, notwithstanding any previous certificate of satisfactory testing. The manufacturer shall not be responsible for any defects caused by improper treatment of the material after delivery.

*Marking BS 1503 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 therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

Table 1. Chemical composition, mechanical properties at room temperature and heat treatment of carbon-manganese steels

NOTE. Notes to this table are located after table 3.

Grade	Chemical composition (cast analysis) (see 5.1 and 5.2)															Limiting ruling section (see note 5)	Mechanical properties at room temperature (see note 6)				Heat treatment		
	C	Si (see note 3)		Mn		P	S	Cr (see note 1)	Mo (see note 1)	Ni (see note 1)	Cu (see note 1)	Al		Nb			Yield strength *Re*	Tensile strength *Rm*		Percentage elongation *A*	Treatment (see note 7)	Austenitizing temperature	Tempering temperature
	max.	min.	max.	min.	max.	max.	max.	max.	max.	max.	max.	Total min.	Met. max. (see note 4)	min.	max.		min.	min.	max.	min.			
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	mm	N/mm²	N/mm²	N/mm²	%		°C	°C
164-490	0.25	0.10	0.40	0.80	1.35	0.030	0.025	0.25	0.10	0.40	0.30	0.018	—	—	—	⩽100 >100 ⩽150	305 280	490 490	610 610	16 16	N, N+T or Q+T	880 to 920	580 to 660
221-410	0.20	0.10	0.40	0.80	1.20	0.030	0.025	0.25	0.10	0.40	0.30	—	0.010	—	—	⩽100 >100 ⩽500 >500	215 205 205	410 410 410	530 530 530	20 20 20	Ann, N, N+T or Q+T	890 to 930	580 to 660
221-430	0.20	0.10	0.40	0.80	1.40	0.030	0.025	0.25	0.10	0.40	0.30	—	0.010	—	—	⩽100 >100 ⩽500 >500	225 215 215	430 430 430	550 550 550	19 19 19	Ann, N, N+T or Q+T	890 to 930	580 to 660
221-460	0.23	0.10	0.40	0.80	1.40	0.030	0.025	0.25	0.10	0.40	0.30	—	0.010	—	—	⩽100 >100	245 235	460 460	580 580	18 18	N, N+T or Q+T	890 to 930	580 to 660
221-490	0.25	0.10	0.40	0.90	1.70	0.030	0.025	0.25	0.10	0.40	0.30	—	0.010	—	—	⩽100 >100	265 255	490 490	610 610	16 16	N, N+T or Q+T	880 to 920	580 to 660
221-510	0.25	0.10	0.40	0.90	1.70	0.030	0.025	0.25	0.10	0.40	0.30	—	0.010	—	—	⩽100	285	510	630	16	Q+T	880 to 920	580 to 660
221-530	0.30	0.10	0.40	0.80	1.40	0.030	0.025	0.25	0.10	0.40	0.30	—	0.010	—	—	⩽100	295	530	650	15	Q+T	870 to 910	580 to 660
221-550	0.35	0.10	0.40	0.80	1.40	0.030	0.025	0.25	0.10	0.40	0.30	—	0.010	—	—	⩽100	305	550	670	15	Q+T	870 to 910	580 to 660
223-410	0.20	0.10	0.40	0.80	1.20	0.030	0.025	0.25	0.10	0.40	0.30	—	—	0.01	0.06	⩽100 >100	245 230	410 410	530 530	20 20	N, N+T or Q+T	890 to 930	580 to 660
223-430	0.20	0.10	0.40	0.80	1.40	0.030	0.025	0.25	0.10	0.40	0.30	—	—	0.01	0.06	⩽100 >100	260 245	430 430	550 550	19 19	N, N+T N+T or Q+T	890 to 930	580 to 660
223-460	0.23	0.10	0.40	0.80	1.40	0.030	0.025	0.25	0.10	0.40	0.30	—	—	0.01	0.06	⩽100 >100	290 270	460 460	580 580	18 18	N, N+T or Q+T	880 to 920	580 to 660
223-490	0.25	0.10	0.40	0.90	1.70	0.030	0.025	0.25	0.10	0.40	0.30	—	—	0.01	0.06	⩽100 >100	320 295	490 490	610 610	16 16	N, N+T or Q+T	880 to 920	580 to 660
223-510	0.25	0.10	0.40	0.90	1.70	0.030	0.025	0.25	0.10	0.40	0.30	—	—	0.01	0.06	⩽100	340	510	630	16	Q+T	880 to 920	580 to 660
224-410	0.20	0.10	0.40	0.80	1.20	0.030	0.025	0.25	0.10	0.40	0.30	0.018	—	—	—	⩽100 >100	235 220	410 410	530 530	20 20	N, N+T or Q+T	890 to 930	580 to 660
224-430	0.20	0.10	0.40	0.80	1.40	0.030	0.025	0.25	0.10	0.40	0.30	0.018	—	—	—	⩽100 >100	250 235	430 430	550 550	19 19	N, N+T or Q+T	890 to 930	580 to 660
224-460	0.23	0.10	0.40	0.80	1.40	0.030	0.025	0.25	0.10	0.40	0.30	0.018	—	—	—	⩽100 >100	275 255	460 460	580 580	18 18	N, N+T or Q+T	880 to 920	580 to 660
224-490	0.25	0.10	0.40	0.90	1.70	0.030	0.025	0.25	0.10	0.40	0.30	0.018	—	—	—	⩽100 >100	305 280	490 490	610 610	16 16	N, N+T N+T or	880 to 920	580 to 660
224-510	0.25	0.10	0.40	0.90	1.70	0.030	0.025	0.25	0.10	0.40	0.30	0.018	—	—	—	⩽100	315	510	630	16	Q+T	880 to 920	580 to 660
225-490	0.20	0.10	0.40	0.90	1.70	0.030	0.025	0.25	0.10	0.40	0.30	0.018	—	0.01	0.04	⩽100 >100	340 300	490 490	610 610	16 16	N, N+T or Q+T	890 to 930	580 to 660

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Table 3. Chemical composition, mechanical properties at room temperature and heat trea

NOTE. Notes to this table are located after table 3.

Steel type	Grade	Chemical composition (cast analysis) (see 5.1 and 5.2)										
		C		Si	Mn	P	S	Cr		Mo		Ni
		min.	max.	max.	max.	max.	max.	min.	max.	min.	max.	min.
18 % chromium 10 % nickel	304S11	% —	% 0.030	% 1.00	% 2.00	% 0.040	% 0.025	% 17.00	% 19.00	% —	% 0.70	% 9.00
18 % chromium 10 % nickel	304S31	—	0.07 (see note 10)	1.00	2.00	0.040	0.025	17.00	19.00	—	0.70	8.00
18 % chromium 10 % nickel	304S51	0.04	0.10	1.00	2.00	0.040	0.025	17.00	19.00	—	0.70	8.00
18 % chromium 10 % nickel nitrogen	304S61	—	0.030	1.00	2.00	0.045	0.025	17.00	19.00	—	0.70	8.50
18 % chromium 10 % nickel niobium	347S31	—	0.08	1.00	2.00	0.040	0.025	17.00	19.00	—	0.70	9.00
18 % chromium 10 % nickel niobium	347S51	0.04	0.10	1.00	2.00	0.040	0.025	17.00	19.00	—	0.70	9.00
18 % chromium 10 % nickel titanium	321S31	—	0.08	1.00	2.00	0.040	0.025	17.00	19.00	—	0.70	9.00
18 % chromium 10 % nickel titanium	321S51-490	0.04	0.10	1.00	2.00	0.040	0.025	17.00	19.00	—	0.70	9.00
18 % chromium 10 % nickel titanium	321S51-510	0.04	0.10	1.00	2.00	0.040	0.025	17.00	19.00	—	0.70	9.00
18 % chromium 12 % nickel molybdenum	316S11	—	0.030	1.00	2.00	0.040	0.025	16.50	18.50	2.00	2.50	11.00
18 % chromium 12 % nickel molybdenum	316S13	—	0.030	1.00	2.00	0.040	0.025	16.50	18.50	2.50	3.00	11.50
18 % chromium 12 % nickel molybdenum	316S31	—	0.07	1.00	2.00	0.040	0.025	16.50	18.50	2.00	2.50	10.50
18 % chromium 12 % nickel molybdenum	316S33	—	0.07	1.00	2.00	0.040	0.025	16.50	18.50	2.50	3.00	11.00
18 % chromium 12 % nickel molybdenum	316S51	0.04	0.10	1.00	2.00	0.040	0.025	16.50	18.50	2.00	2.50	10.50
18 % chromium 12 % nickel molybdenum nitrogen	316S61	—	0.030	1.00	2.00	0.045	0.025	16.50	18.50	2.00	2.50	10.50
18 % chromium 12 % nickel molybdenum nitrogen	316S63	—	0.030	1.00	2.00	0.045	0.025	16.50	18.50	2.50	3.00	11.50
18 % chromium 12 % nickel molybdenum titanium	320S33	—	0.08	1.00	2.00	0.040	0.025	16.50	18.50	2.50	3.00	11.50
25 % chromium 20 % nickel	310S31	—	0.15	1.50	2.00	0.040	0.025	24.00	26.00	—	0.70	19.00

eat treatment of austenitic stainless steels

										Mechanical properties at room temperature (see note 6)				Heat treatment		
Ni		Ti		Nb		Cu	B (see option B.22)	Others		Yield strength *Re*	Tensile strength *Rm*		Percentage elongation *A*	Treatment (see note 7)	Solution temperature	Sensitization period (see option B.11)
min.	max.	min.	max.	min.	max.	max.	max.			min.	min.	max.	min.			
%	%	%	%	%	%	%	%	%		N/mm²	N/mm²	N/mm²	%		°C	min
9.00	12.00	—	0.10	—	0.20	0.50	0.005	—		215	480	680	30	q	1000 to 1100	30
8.00	11.00	—	0.10	—	0.20	0.50	0.005	—		230	490	690	30	q	1000 to 1100	15
8.00	11.00	—	0.10	—	0.20	0.50	0.005	—		230	490	690	30	q	1000 to 1125	(see note 11)
8.50	11.50	—	0.10	—	0.20	0.50	0.005	N.12-0.22		305	550	760	35	q	1000 to 1100	30
9.00	12.00	—	—	10xC	1.00	0.50	0.005	—		240	510	710	30	q	1000 to 1100	30
9.00	12.00	—	—	10xC	1.20	0.50	0.005	—		240	510	710	30	q	1050 to 1125	30
9.00	12.00	5xC	0.80	—	—	0.50	0.005	—		235	510	710	30	q	1000 to 1100	30
9.00	12.00	5xC	0.80	—	—	0.50	0.005	—		190	490	690	30	q	1070 to 1150	30
9.00	12.00	5xC	0.80	—	—	0.50	0.005	—		235	510	710	30	q	950 to 1070	30
11.00	14.00	—	0.10	—	0.20	0.70	0.005	—		225	490	690	30	q	1000 to 1100	30
11.50	14.50	—	0.10	—	0.20	0.70	0.005	—		225	490	690	30	q	1000 to 1100	30
10.50	13.50	—	0.10	—	0.20	0.70	0.005	—		240	510	710	30	q	1000 to 1100	15
11.00	14.00	—	0.10	—	0.20	0.70	0.005	—		240	510	710	30	q	1000 to 1100	15
10.50	13.50	—	0.10	—	0.20	0.70	0.005	—		240	510	710	30	q	1000 to 1100	(see note 11)
10.50	13.50	—	0.10	—	0.20	0.70	0.005	N.12-0.22		315	580	780	35	q	1020 to 1120	30
11.50	14.50	—	0.10	—	0.20	0.70	0.005	N.12-0.22		315	580	780	35	q	1020 to 1120	30
11.50	14.50	5xC	0.80	—	—	0.70	0.005	—		245	510	710	30	q	1050 to 1100	30
19.00	22.00	—	0.10	—	0.20	0.50	0.005	—		240	510	710	30	q	1000 to 1100	(see note 11)

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Table 2. Chemical composition, mechanical properties at room temperature and heat treatment of low alloy, fe
NOTE. Notes to this table are located after table 3.

Steel type	Grade	Chemical composition (cast analysis) (see 5.1 and 5.2)														
		C		Si (see note 3)		Mn		P	S	Cr (see note 2)		Mo (see note 2)		Ni (see note 2)		Cu (see note
		min.	max.	min.	max.	min.	max.	max.	max.	min.	max.	min.	max.	min.	max.	max.
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0.3 % molybdenum	243-430	0.12	0.20	0.15	0.40	0.50	0.80	0.030	0.025	—	0.25	0.25	0.35	—	0.40	0.30
1 % chromium 0.5 % molybdenum	620-440	—	0.18	0.15	0.40	0.40	0.70	0.030	0.025	0.85	1.15	0.45	0.65	—	0.40	0.30
1 % chromium 0.5 % molybdenum	620-540	—	0.18	0.15	0.40	0.40	0.70	0.030	0.025	1.10	1.40	0.45	0.65	—	0.40	0.30
1.25 % chromium 0.5 % molybdenum	621-460	—	0.18	0.15	0.40	0.40	0.70	0.030	0.025	1.10	1.40	0.45	0.65	—	0.40	0.30
0.5 % chromium 0.5 % molybdenum 0.25 % vanadium	660-460	0.10	0.18	0.15	0.40	0.40	0.70	0.030	0.025	0.30	0.60	0.50	0.70	—	0.40	0.30
manganese chromium molybdenum vanadium	271-560	—	0.17	0.15	0.40	1.00	1.50	0.030	0.025	0.50	1.00	0.20	0.35	0.30	0.70	0.30
2.25 % chromium 1 % molybdenum	622-490	—	0.15	0.15	0.40	0.40	0.70	0.030	0.025	2.00	2.50	0.90	1.20	—	0.40	0.30
2.25 % chromium 1 % molybdenum	622-560	—	0.15	0.15	0.40	0.40	0.70	0.030	0.025	2.00	2.50	0.90	1.20	—	0.40	0.30
2.25 % chromium 1 % molybdenum	622-650	—	0.15	0.15	0.40	0.40	0.70	0.030	0.025	2.00	2.50	0.90	1.20	—	0.40	0.30
5 % chromium 0.5 % molybdenum	625-520	—	0.15	0.15	0.40	0.30	0.80	0.030	0.025	4.00	6.00	0.45	0.65	—	0.40	0.30
5 % chromium 0.5 % molybdenum	625-590	—	0.18	0.15	0.40	0.30	0.80	0.030	0.025	4.00	6.00	0.45	0.65	—	0.40	0.30
12 % chromium 1 % molybdenum 0.3 % vanadium	762-690	0.17	0.23	0.15	0.40	0.30	1.00	0.040	0.025	11.00	12.50	0.70	1.20	0.30	0.80	0.30
12 % chromium	410S21	0.09	0.15	—	0.80	—	1.00	0.040	0.025	11.50	13.50	—	0.30	—	1.00	0.30
12 % chromium	420S29	0.14	0.20	—	0.80	—	1.00	0.040	0.025	11.50	13.50	—	0.30	—	1.00	0.30
12 % chromium	403S17	—	0.08	—	0.80	—	1.00	0.040	0.025	12.00	14.00	—	0.30	—	0.50	0.30
12 % chromium	405S17	—	0.08	—	0.80	—	1.00	0.040	0.025	12.00	14.00	—	—	—	0.50	0.30
22 % chromium 5 % nickel	318S13	—	0.030	—	1.00	—	2.00	0.025	0.020	21.00	23.00	2.50	3.50	4.50	6.50	0.50
3.5 % nickel	503-490	—	0.15	0.15	0.40	—	0.80	0.025	0.020	—	0.25	—	0.10	3.25	3.75	0.30
9 % nickel	509-690	—	0.10	0.15	0.40	—	0.80	0.025	0.020	—	0.25	—	0.10	8.50	10.00	0.30

ritic stainless, martensitic stainless and duplex stainless steels

Al		V		Others	Limiting ruling section (see note 5)	Mechanical properties at room temperature (see note 6)				Heat treatment		
Total min.	Met. max. (see note 4)	min.	max.	max.		Yield strength *Re* min.	Tensile strength *Rm* min.	Tensile strength *Rm* max.	Percentage elongation *A* min.	Treatment (see note 7)	Austenitizing temperature	Tempering temperature
%	%	%	%	%	mm	N/mm²	N/mm²	N/mm²	%		°C	°C
—	0.012	—	—	—	200	250	430	580	19	N+T or Q+T	880 to 930	630 to 720
—	0.020	—	—	—	—	275	440	590	19	N+T or Q+T	900 to 950	620 to 720
—	0.020	—	—	—	200	375	540	690	18	Q+T	900 to 950	620 to 720
—	0.020	—	—	—	—	275	460	610	18	Q+T	900 to 950	620 to 720
—	0.020	0.22	0.28	Sn 0.025	—	300	460	610	18	N+T or Q+T	900 to 990	680 to 720
—	0.020	0.05	0.10	—	—	370	560	710	17	N+T or Q+T	900 to 950	625 to 675
—	0.020	—	—	—	—	275	490	640	18	N+T or Q+T	930 to 980	650 to 750
—	0.020	—	—	—	—	370	560	710	17	N+T or Q+T	930 to 980	650 to 750
—	0.020	—	—	—	—	475	650	800	16	Q+T	930 to 980	620 to 700
—	0.020	—	—	—	—	365	520	670	18	N+T or Q+T	925 to 975	700 to 775 (see note 8)
—	0.020	—	—	—	—	450	590	740	18	N+T or Q+T	925 to 975	650 to 725
—	0.020	0.20	0.35	—	250	490	690	840	14	N+T or Q+T	1020 to 1070	750 to 780
—	—	—	—	—	—	395	590	740	17	Q+T	950 to 1020	620 to 750
—	—	—	—	—	—	515	700	850	16	Q+T	950 to 1020	620 to 750
—	—	—	—	—	—	265	470	620	18	N+T or Q+T	950 to 1020	700 to 780
0.10	0.30	—	—	—	—	210	420	570	19	N+T or Q+T	950 to 1020	700 to 780
—	—	—	—	—	350	450	640	880	25	Q	1050 to 1100	—
0.018	—	—	—	—	100	300	490	640	17	Q+T	840 to 900	580 to 630
0.018	—	—	—	—	150	490	690	840	16	(see note 9)	(see note 9)	560 to 600

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Notes to tables 1 to 3.

NOTE 1. The total content of chromium, molybdenum, nickel and copper shall not exceed 0.80 %.

NOTE 2. For the low alloy steels in table 2 where the values of chromium, copper, molybdenum, or nickel are shown as maximum only, the total content of these elements shall not exceed 0.80 %.

NOTE 3. If the steel is vacuum-deoxidized, the lower limit of the silicon range is not applicable (see **4.2**).

NOTE 4. Where a maximum metallic aluminium content (Almet) of 0.010 %, 0.012 % or 0.020 % is specified, determination of the total aluminium content, provided that it does not exceed the specified value, shall be deemed to meet this requirement. In cases of dispute, the metallic aluminium content shall be determined.

NOTE 5.

(a) If a solid forging has a reasonably cylindrical section at the position from which test samples are to be taken, the diameter at the position is the dimension referred to in tables 1, 2, 9 and 10.

(b) If a solid forging is not cylindrical, or is hollow, the tables 1, 2, 9 and 10 refer to the equivalent diameter, which should be estimated for the similar position on the forging using the rules given in BS 5046, a hollow cylinder being considered as a tube for the purposes of that standard (see note to **7.3.2** and appendix L).

NOTE 6.

A is the percentage elongation after fracture on gauge length L_o;

L_o is the original gauge length and is given by the expression:

$$L_o = 5.65 \sqrt{S_o}$$

where S_o is the original cross-sectional area of the gauge length;

The tensile strength R_m, the yield strength R_e and the percentage elongation after fracture A shall be determined and the results obtained shall comply with the values specified for the relevant steel in table 1, 2 or 3. For the yield strength for carbon-manganese, low alloy, ferritic stainless, martensitic stainless, and duplex stainless steels, either the 0.2 % proof stress $R_{p0.2}$ or the upper yield stress R_{eH} shall be determined. For austenitic stainless steels the 1 % proof stress $R_{p1.0}$ shall be determined.

Elongation values shall be reported with reference to a gauge length $L_o = 5.65 \sqrt{S_o}$, where L_o is the original gauge length and S_o is the original cross-sectional area of the gauge length. If other gauge lengths are used the corresponding elongation on a gauge length $L_o = 5.65 \sqrt{S_o}$ shall be obtained by reference to conversion tables in BS 3894 : Part 1 or BS 3894 : Part 2. In cases of dispute, the elongation shall be measured on a $5.65 \sqrt{S_o}$ gauge length.

NOTE 7.

Ann = annealed;
N = normalized;
Q = quenched;
q = cooled in oil, water or air (rapidly);
T = tempered.

NOTE 8. See note 3 to appendix H.

NOTE 9. Forgings of steel grade 509 shall be given either a double-refining or single-refining heat treatment as specified below.

Forgings of greater than 75 mm ruling section shall be quenched in oil or water at the final refining stage.

The double-refining heat treatment shall consist of:

(a) normalizing or quenching in oil or water from a temperature within the range 880 °C to 920 °C; followed by

(b) normalizing or quenching in oil or water from a temperature within the range 780 °C to 820 °C; followed by

(c) tempering at a temperature within the range 560 °C to 600 °C. The forgings shall be held at the tempering temperature for not less than 1 h for each 25 mm of thickness and quenched in air, oil or water. The rate of cooling shall be as fast as is practicable and not less than 170 °C/h down to a temperature of 200 °C.

The single-refining heat treatment shall consist of:

(1) normalizing or quenching in oil or water from a temperature within the range 780 °C to 820 °C; followed by

(2) temperating at a temperature within the range 560 °C to 600 °C. The forgings shall be held at the tempering temperature for not less than 1 h for each 25 mm of thickness and quenched in air, oil or water. The rate of cooling shall be as fast as is practicable and not less than 170 °C/h down to a temperature of 200 °C.

NOTE 10. If required to meet an intergranular corrosion test the carbon content may need to be restricted to a lower level.

NOTE 11. Intergranular corrosion tests are not applicable to steel grades 304S51, 316S51, 310S31 and duplex stainless steels.

Appendices

Appendix A. Information to be supplied by the purchaser

A.1 Forgings

For forgings the purchaser shall state the following on the enquiry and order:

(a) the forging dimensions, or the drawing number(s), containing the dimensions, tolerances and surface finishes, with which the forgings shall comply;

(b) the quantity of forgings required;

(c) the complete designation of the steel of which the forgings are to be made (see clause **2**);

(d) whether production and testing of the forgings is to be witnessed by the purchaser's representative, and if so, the particular stages in production and testing at which the purchaser's representative may require to be present (see clause **9**);

(e) the required options, with limits where appropriate (see appendix B).

A.2 Semi-finished material

If semi-finished material intended for further processing is to be supplied the purchaser shall state the following on his enquiry and order:

(a) the quantity and size required and condition of supply;

(b) the complete designation of the steel;

(c) whether mechanical properties are to be determined, and if so, the details of the test procedures and results to be obtained (see **6.2**);

(d) the required options with limits where appropriate (see appendix B).

Appendix B. Options (see 3.4)

B.1 Deoxidation

The type of deoxidation practice shall be agreed between purchaser and manufacturer (see **4.2**).

B.2 Limits on unspecified elements

Any limits on elements other than those specified in tables 1, 2 and 3, shall be agreed between purchaser and manufacturer (see **5.1**).

B.3 Product analysis

The number of samples for product analysis shall be stated by the purchaser. The samples shall be taken either from the test pieces used for the verification of the mechanical properties or from drillings from those test pieces.
The composition shall not vary from the values specified for the relevant steel in table 1, 2 or 3 by more than the permissible deviations given in tables 4, 5 or 6 (see also **5.2** and **B.4**). In cases of dispute, product analyses shall be in accordance with British Standard Handbook 19 or BS 6200.

Table 4. Permissible deviation from the specified composition for carbon-manganese steels

Element	Maximum of specification range	Permissible deviation* from the specified range (see option B.3)
	%	%
Carbon	≤0.35	+0.03
Silicon	≤0.50	±0.05
Manganese	≤2.0	+0.10
Sulphur	≤0.050	+0.005
Phosphorus	≤0.050	+0.005
Niobium	≤0.10	+0.01

*The deviations, other than when maxima only are specified, apply either above or below the specified limits of the range but not both above and below for the same element from different products for the same cast.

Table 5. Permissible deviation from the specified composition for low alloy steels

Element	Maximum of specification range	Permissible deviation* from the specified range (see option B.3)
	%	%
Carbon	≤0.35	±0.03
Silicon	≤0.50	±0.05
Manganese	≤2.0	±0.10
Sulphur	≤0.050	+0.005
Phosphorus	≤0.050	+0.005
Nickel	≤5.0	±0.07
	>5.0, ≤10.0	±0.10
Chromium	≤10.0	±0.10
Molybdenum	≤0.35	±0.04
	>0.35, ≤1.0	±0.05
Vanadium	≤0.20	±0.01
	>0.20, ≤0.35	±0.03

*The deviations, other than when maxima only are specified, apply either above or below the specified limits of the range but not both above and below for the same element from different products for the same cast.

B.4 Product analysis from different locations

The location of samples if different from that in **B.3** shall be agreed between purchaser and manufacturer, as shall also the permissible deviations in analyses, taking into account the heterogeneity of the product.

B.5 Maximum carbon equivalent values for weldability

As agreed between the manufacturer and purchaser, forgings shall be supplied with a specific maximum carbon equivalent value. These maximum values which are based upon cast analysis, shall be as given in table 7. The carbon equivalent value shall be calculated using the following formula:

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

Table 6. Permissible deviation from the specified composition for ferritic stainless, martensitic stainless, duplex stainless and austenitic stainless steels

Element	Maximum of specification range	Permissible deviation* from the specified range (see option B.3)
	%	%
Carbon	≤0.03	+0.005
	>0.03, ≤0.25	±0.01
Manganese	≤1.0	+0.04
	>1.0, ≤2.0	+0.05
Silicon	≤1.0	+0.05
Sulphur	≤0.030	+0.003
	>0.030, ≤0.040	+0.004
Phosphorus	≤0.030	+0.003
	>0.030, ≤.040	+0.004
Nickel	≤1.0	±0.03
	>1.0, ≤2.0	±0.05
	>2.0, ≤5.0	±0.07
	>5.0, ≤10.0	±0.10
	>10.0, ≤20.0	±0.15
	>20.0	±0.20
Chromium	≤10.0	±0.10
	>10.0, ≤15.0	±0.15
	>15.0, ≤20.0	±0.20
	>20.0	±0.25
Molybdenum	≤1.0	+0.04
	>1.0, ≤2.0	±0.05
	>2.0, ≤3.0	±0.08
Titanium	All ranges	±0.05
Niobium	All ranges	±0.05

*The deviations, other than when maxima only are specified, apply either above or below the specified limits of the range but not both above and below for the same element from different example products for the same cast.

Table 7. Maximum carbon equivalent values

Steel grade	Maximum carbon equivalent
	%
164-490	0.47
221-410	0.39
221-430	0.41
221-460	0.45
221-490	0.47
223-410	0.39
223-430	0.41
223-460	0.45
223-490	0.47
224-410	0.41
224-430	0.43
224-490	0.47
225-490	0.47

B.6 Simulated post-weld heat treatment of test samples

If the purchaser intends to incorporate the forging or fabrication in a welded vessel or structure and apply a post-weld heat treatment, test samples shall have received heat treatments referred to in **7.3** and, if applicable, **11.2** shall also be subjected to a heat treatment that simulates the post-weld heat treatment to be applied to the welded vessel or structure by the purchaser. The post-weld heat treatment, and the mechanical properties to be obtained after testing these samples in accordance with clause **12** shall be agreed between the purchaser and the manufacturer.

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

NOTE 2. If he desires, the purchaser may be supplied with additional test samples cut from the forging after heat treatment in accordance with **7.3** and, if applicable **11.2**, with a view to subjecting these test samples to additional heat treatment and subsequent mechanical testing for information purposes.

NOTE 3. The test samples referred to above exclude test materials supplied for welding tests. The test material should receive the heat treatments prescribed as in **7.3** and if applicable, **11.2**.

B.7 Elevated temperature properties and testing

B.7.1 Forgings shall be supplied with elevated temperature properties as in **14.1**. Should testing be required (see **14.1**(b) this shall be carried out in accordance with BS 3688 : Part 1.

B.7.2 Should additional elevated temperature testing be required (see **14.2**) this shall be carried out in accordance with BS 3688 : Part 1. The number, position and temperatures of such tests shall be agreed between the purchaser and the manufacturer from those temperatures for which elevated temperature proof or yield stress values are specified for the relevant steel in appendix C, D or E. The yield stress values obtained shall comply with the requirements for the relevant steel.

B.8 Impact tests and properties

B.8.1 General

B.8.1.1 The purchaser shall state whether impact testing is required at room temperatures (see **B.8.3**), below room temperature (see **B.8.4**) or on samples subjected to a stress-relieving post-weld heat treatment (see **B.8.2**). In the last case values required shall be agreed between the purchaser and supplier. The Charpy V-notch impact tests shall be carried out in accordance with the requirements of BS 131 : Part 2. 1

B.8.1.2 Impact tests shall be made on samples selected and prepared in accordance with the requirements of clause **10**. The direction of the test piece in relation to the direction of metal flow in the forging, longitudinal or transverse, shall be specified.

NOTE. If the impact properties fail to meet the specified requirements, retests may be carried out in accordance with **16.2**.

B.8.2 Impact tests on heat treated samples

If required, impact values shall be obtained on samples subjected to a stress relieving or post-weld heat treatment (see clause **11**).

B.8.3 Impact tests at room temperature

Tests shall be made on three impact test pieces from each sample, and the average of the Charpy V-notch impact values (KV) obtained in these tests at room temperature shall not be less than the value specified in table 9 or 10

for the appropriate limiting ruling section (see appendix L) of the relevant steel. One individual value may be below the specified value but no individual value shall be less than 70 % of the specified value.

B.8.4 Impact tests below room temperature

Tests shall be made on three impact test pieces from each sample. The average of the Charpy V-notch impact values (KV) obtained in these tests at below room temperature for carbon-manganese, 3.5 % nickel, 9 % nickel and austenitic stainless steels, shall not be less than the value specified in table 8 for the appropriate test temperature and limiting ruling section (see appendix L) of the relevant steel. One individual value may be below the specified value but no individual value shall be less than 70 % of the specified value.

Table 8. Low temperature impact properties of carbon-manganese, 3.5 % nickel, 9 % nickel and austenitic stainless steels

Grade	Limiting ruling section max.	Temperature of test	Impact value KV min.
	mm	°C	J
223-410	No limit	−10	27
	150	−20	27
	100	−50	27
223-430	No limit	−10	27
	150	−15	27
	100	−40	27
223-460	No limit	0	41
	150	−10	41
	100	−20	41
223-490	150	0	41
	100	−10	41
223-510	150	0	41
224-410	No limit	−10	27
	150	−20	27
	100	−50	27
224-430	No limit	−10	27
	150	−15	27
	100	−40	27
224-460	No limit	0	41
	150	−10	41
	100	−20	41
224-490	150	0	41
	100	−10	41
224-510	150	0	41
503-490	150	−80	27
509-690	150	−196	34
304S11 and 304S31	No limit	−196	50
316S11, 316S13, 316S31 & 316S33	No limit	−196	50
321S31	No limit	−196	40
347S31	No limit	−196	40

NOTE. Heat treatment(s) for the relevant steel are as specified in table 1, 2 or 3.

B.9 Hydraulic testing

Forgings shall be hydraulically tested. In no case shall the nominal stress produced by the hydraulic test exceed 90 % of the specified room temperature yield strength of the steel.

NOTE. Every forging is to be tested unless otherwise agreed between the purchaser and the manufacturer. Details of the test procedure, including the test temperature, and the value and duration of the test pressure, are to be agreed between the purchaser and the manufacturer.

Table 9. Room temperature impact properties of carbon-manganese steels

Grade	Limiting ruling section (see note 5 to tables 1,2 & 3)	Impact Value KV min (see option B.8.3)
	mm	J
164-490	≤100	41
	>100 ≤150	41
221-410	≤100	27
	>100 ≤500	27
	>500	—
221-430	≤100	27
	>100 ≤500	27
	>500	—
221-460	≤100	41
	>100	—
221-490	≤100	41
	>100	—
221-510	≤100	—
221-530	≤100	—
221-550	≤100	—
221-550	≤100	—
223-410	≤100	27
	>100	27
223-430	≤100	27
	>100	27
223-460	≤100	41
	>100	41
223-490	≤100	41
	>100	41
223-510	≤100	41
224-410	≤100	27
	>100	27
224-430	≤100	27
	>100	27
224-460	≤100	41
	>100	41
224-490	≤100	41
	>100	41
224-510	≤100	41
225-490	≤100	41
	>100	41

NOTE. Heat treatment(s) for the relevant steel are as given in table 1.

Table 10. Room temperature impact properties of low alloy, ferritic stainless and martensitic stainless steels

Grade	Limiting ruling section (see note 5 to tables 1,2 & 3)	Impact value KV min (see option B.8.3)
	mm	J
243-430	200	27
620-440	—	27
620-540	200	41
621-460	—	41
660-460	—	—
271-560	—	41
622-490	—	41
622-560	—	41
622-650	—	41
625-520	—	27
625-590	—	41
503-490	100	—
509-690	150	—
410S21	—	27
420S29	—	27

B.10 Etching for flow lines

When the purchaser calls up this option, a sample forging shall be etched to show flow lines. Details of etching procedure, as well as the criteria of acceptance shall be the subject of agreement between purchaser and supplier.

B.11 Intergranular corrosion test for austenitic stainless steels

An intergranular corrosion bend test shall be carried out on austenitic stainless steels in accordance with BS 5903. One test shall be made per cast per heat treatment batch on the forging having the largest equivalent diameter in the batch.

NOTE. Intergranular corrosion tests are not applicable to steel grades 304S51, 316S51, 310S31 and duplex stainless steels.

B.12 Marking by use of paint or ink

Marking shall be by use of paint or ink in lieu of stamping. When paint or ink marking is used, the dried film shall contain not more than 250 ppm (0.025 %) of any of the following metals: lead, tin, copper, zinc. Any special colour shall be indicated by the purchaser.

NOTE. For certain applications, limits may also be required on the levels of sulphur and halogens in the paint. These limits should be the subject of agreement between the supplier and the purchaser.

B.13 Ultrasonic inspection

Testing shall be carried out in accordance with BS 4124. The acceptance standard shall be the subject of agreement between purchaser and supplier. The quantity of forgings tested shall be statistically controlled sample or 100 % as agreed between purchaser and supplier.

B.14 Magnetic particle inspection

Testing shall be carried out in accordance with BS 6072. The acceptance standard shall be the subject of agreement between purchaser and supplier. The quantity of forgings tested shall be a statistically controlled sample or 100 % as agreed between purchaser and supplier.

B.15 Dye penetrant inspection

Testing shall be carried out in accordance with BS 6443. The acceptance standard shall be the subject of agreement between purchaser and supplier. The quantity of forgings tested shall be a statistically controlled sample or 100 % as agreed between purchaser and supplier.

B.16 Transverse tensile tests

Room temperature tensile testing with the direction of the test piece transverse to the direction of metal flow in the forging, shall be carried out in accordance with the requirements of clause **10** and **12.1**. The properties obtained shall comply with clause **13**.

B.17 Position of test pieces

For mechanical testing, test pieces shall be selected from a position of one-quarter section thickness of the forging, with the direction of the test piece parallel to the grain flow of the material.

The required test properties shall be subject to agreement between purchaser and supplier.

B.18 Mechanical testing of test pieces selected from other positions

Testing at other positions may be agreed between the parties concerned at the time of the enquiry and order. The required test properties shall be subject to agreement between the purchaser and supplier.

B.19 Test sample thickness

Where the forging is not covered by BS 5046, the thickness of the test sample shall be agreed between the purchaser and the supplier.

B.20 Special requirements for semi-finished material

Any special requirements, e.g. control of rolling and of forging reduction, to ensure that finished forgings comply with the requirements of this specification shall be agreed between purchaser and supplier.

B.21 Mechanical properties for semi-finished material

When it is required to demonstrate that particular mechanical properties can be achieved in the finished forgings, the supplier shall provide details of their equivalent diameter and heat treatment. The details of the procedures to be followed, the tests to be made and the results to be obtained shall be agreed between the purchaser and supplier. A test certificate shall be provided if requested by the purchaser.

B.22 Reduced boron content

The purchaser may request a lower maximum boron content than that given in table 3. The maximum value shall be agreed with the supplier.

Appendix C. Minimum lower yield stress (R_{eL}) or minimum 0.2 % proof stress ($R_{p0.2}$) values at elevated temperatures for carbon manganese steels

Grade	Diameter or equivalent diameter	R_{eL} min. or $R_{p0.2}$ min.* at a temperature of:							
		100 °C	150 °C	200 °C	250 °C	300 °C	350 °C	400 °C	450 °C
	mm	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
164-490	≤100	272	256	234	213	192	182	173	168
	>100 ≤150	253	238	218	205	192	182	173	168
221-410	≤100	192	188	181	168	150	142	138	136
	>100	178	175	170	162	150	142	138	136
221-430	≤100	204	200	193	178	160	153	148	145
	>100	189	186	181	172	160	153	148	145
221-460	≤100	222	218	210	194	176	168	162	158
	>100	206	203	197	188	176	168	162	158
221-490	≤100	240	236	227	210	192	183	177	172
	>100	222	219	212	203	192	183	177	172
221-510	≤100	253	248	239	221	202	193	186	180
221-530	≤100	264	260	250	232	212	204	196	189
221-550	≤100	276	272	262	243	223	213	204	198
223-410	≤100	216	207	195	180	159	148	138	133
	>100	201	193	181	173	159	148	138	133
223-430	≤100	234	222	208	192	171	160	150	144
	>100	218	201	193	184	171	160	150	144
223-460	≤100	261	246	227	210	190	178	167	161
	>100	243	229	211	202	190	178	167	161
223-490	≤100	288	269	247	228	208	196	184	177
	>100	263	250	230	219	208	196	184	177
223-510	≤100	305	285	259	239	220	207	196	188
224-410	≤100	215	204	188	171	152	141	134	130
	>100	200	190	175	164	152	141	134	130
224-430	≤100	229	217	199	182	162	151	144	139
	>100	213	202	185	175	162	151	144	139
224-460	≤100	251	236	217	198	177	167	158	153
	>100	233	220	202	190	177	167	158	153
224-490	≤100	272	256	234	213	192	182	173	168
	>100	253	238	218	205	192	182	173	168
224-510	≤100	287	268	245	224	202	192	183	177
225-490†	≤100	305	285	259	239	220	206	195	187
	>100	272	260	245	231	220	206	195	187

*At any test temperature the greater of R_{eL} min. or $R_{p0.2}$ min. shall be taken as the criterion of acceptance.

†Values for 225-490 are based on a comparison with values for 223-490 and 224-490. No data analysis is available for 225-490 and a table showing parameters for lower confidence lines has therefore not been included.

Appendix D. Minimum lower yield stress (R_{eL}) or minimum 0.2 % proof stress ($R_{p0.2}$) values at elevated temperatures for low alloy, ferritic stainless, martensitic stainless, and duplex stainless steels

Grade	R_{eL} min. or $R_{p0.2}$ min.* at a temperature of:										
	100 °C	150 °C	200 °C	250 °C	300 °C	350 °C	400 °C	450 °C	500 °C	550 °C	600 °C
	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
243-430	237	232	218	200	167	153	148	143	139	—	—
620-440	241	224	213	197	184	170	162	157	151	146	145
620-540	340	328	315	303	294	284	279	273	265	251	240
621-460	260	245	234	218	205	191	183	176	167	163	162
660-460	282	276	267	241	225	216	209	203	200	197	164
271-560	341	330	322	312	306	298	288	282	269	255	221
622-490	261	253	245	236	230	224	218	205	189	167	145
622-560	347	336	329	320	313	302	295	289	259	226	193
622-650	455	441	435	427	420	403	393	375	349	302	255
625-520	345	335	327	323	322	316	306	285	256	—	—
625-590	414	402	394	389	385	374	359	333	297	—	—
762-690	407	388	374	360	349	340	328	309	280	243	177
410S21	339	321	313	303	299	288	275	249	219	169	112
420S29	453	440	431	419	413	396	379	340	301	227	146
403S17	211	197	188	182	179	172	165	149	133	107	78
405S17	160	144	137	132	129	124	116	107	96	80	65
318S13†	360	335	310	295	285	—	—	—	—	—	—

*At any test temperature the greater of R_{eL} min. or $R_{p0.2}$ min. shall be taken as the criterion of acceptance.
†Values for steel 318S13 based on the Stahl-Eisen Werkstoffblatt 400 : 1986.

Appendix E. Minimum 1 % proof stress $R_{p1.0}$ values at elevated temperatures for austenitic stainless steels

Grade*	$R_{p1.0}$ min. at a temperature of:												
	100 °C	150 °C	200 °C	250 °C	300 °C	350 °C	400 °C	450 °C	500 °C	550 °C	600 °C	650 °C	700 °C
	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
304S11†	168	150	137	128	122	116	110	108	106	102	100	96	93
304S31†	178	160	147	139	132	125	120	117	115	112	109	104	99
304S51	178	160	147	139	132	125	120	117	115	112	109	104	99
304S61‡	230	201	182	172	163	156	149	144	140	136	131	128	124
347S31†	204	192	182	172	166	162	159	157	155	153	151	—	—
347S51	204	192	182	172	166	162	159	157	155	153	151	—	—
321S31†	192	180	172	164	158	152	148	144	140	138	135	130	124
321S51-490	149	139	131	125	118	114	110	107	105	104	102	100	97
321S51-510	192	180	172	164	158	152	148	144	140	138	135	130	124
316S11†	177	161	149	139	133	127	123	119	115	112	110	107	105
316S13†	177	161	149	139	133	127	123	119	115	112	110	107	105
316S31†	189	172	159	150	143	137	133	129	125	121	119	116	113
316S33†	189	172	159	150	143	137	133	129	125	121	119	116	113
316S51†	189	172	159	150	143	137	133	129	125	121	119	116	113
316S61	238	208	192	180	172	166	161	157	152	149	144	142	138
316S63	238	208	192	180	172	166	161	157	152	149	144	142	138

*Minimum 1 % proof stress values at elevated temperatures for steel grade 310S31 and 320S33 are not available.
†Stress-rupture values (appendix J), which may influence design considerations above 550 °C, are not available for these grades of steel.
‡ Values for steel 304S61 based on 304 smoothed lower 95 % confidence lines.

Appendix F. Procedure for verification of elevated temperature proof stress values

As an alternative to verification of individual casts by testing at elevated temperatures, the manufacturer may verify that his product consistently meets the minimum elevated temperature proof stress values specified for the relevant type of steel by adopting the procedure described in BS 3920 : Part 1.

The basis of the procedure is that the manufacturer compares appropriate data relating to his product with the confidence lines that have been determined from the analysis of a large body of data and that have been used to derive the minima specified in this standard.

An example of lower confidence lines (for steel grade 224) is shown in figure 1. To achieve the appropriate degree of accuracy however it is necessary to construct the confidence lines on a larger scale. To enable this to be done, the coordinates of two suitably spaced points on each temperature line are given for various grades of steel in tables 11 to 24.

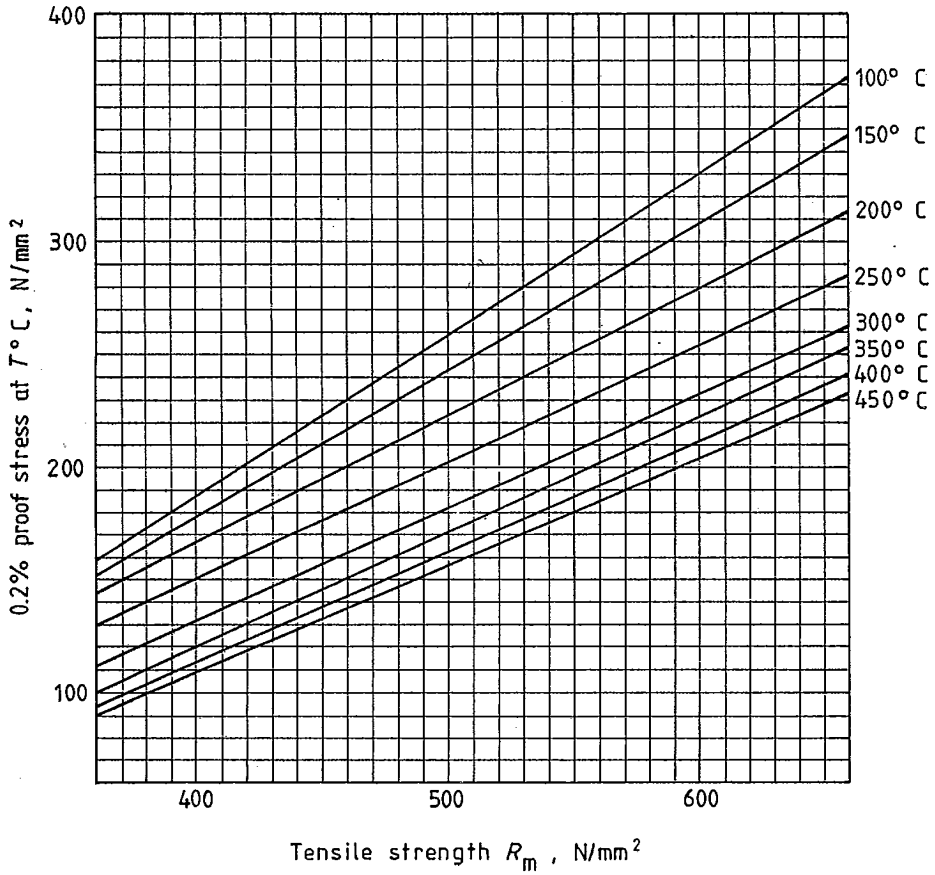

Figure 1. Example of lower confidence lines (for steel grade 224)

Table 11. Parameters for lower confidence lines: steel grades 221-410, 221-430, 221-460, 221-490, 221-510, 221-530 and 221-550: up to and including 100 mm thick

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	400 N/mm²	600 N/mm²
°C	N/mm²	N/mm²
100	168	287
150	164	283
200	158	271
250	146	254
300	129	235
350	122	224
400	119	214
450	118	205

Table 12. Parameters for lower confidence lines: steel grades 221-410, 221-430, 221-460, 221-490 and 221-550: greater than 100 mm thick

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	400 N/mm²	600 N/mm²
°C	N/mm²	N/mm²
100	156	266
150	153	263
200	150	253
250	141	244
300	129	234
350	122	223
400	119	214
450	117	207

Table 13. Parameters for lower confidence lines: steel grades 223-410, 223-430, 223-460, 223-490 and 223-550: up to and including 100 mm thick

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	400 N/mm²	600 N/mm²
°C	N/mm²	N/mm²
100	180	431
150	176	393
200	169	349
250	156	323
300	134	306
350	124	291
400	116	275
450	111	265

Table 14. Parameters for lower confidence lines: steel grade 164-490, and steel grades 224-410, 224-430, 224-460, 224-490 and 224-510: up to and including 100 mm thick

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	400 N/mm²	600 N/mm²
°C	N/mm²	N/mm²
100	186	330
150	178	308
200	165	279
250	150	255
300	132	232
350	121	223
400	114	212
450	110	206

Table 15. Parameters for lower confidence lines: steel grades 620-440, 620-540 and grade 621-460

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	460 N/mm²	600 N/mm²
°C	N/mm²	N/mm²
100	233	364
150	216	356
200	205	356
250	187	345
300	175	334
350	161	326
400	153	311
450	150	299
500	144	282
550	140	257
600	139	255

Table 16. Parameters for lower confidence lines: steel grade 660-460

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	460 N/mm²	560 N/mm²
°C	N/mm²	N/mm²
100	262	333
150	258	326
200	249	315
250	219	299
300	202	286
350	193	276
400	185	270
450	179	264
500	177	258
550	177	248
600	151	198

Table 17. Parameters for lower confidence lines: steel grades 622-490, 622-560 and 622-650

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	440 N/mm²	700 N/mm²
°C	N/mm²	N/mm²
100	164	479
150	158	465
200	151	459
250	140	452
300	137	444
350	134	425
400	130	415
450	118	397
500	110	370
550	100	319
600	88	269

Table 18. Parameters for lower confidence lines: steel grades 625-520 and 625-590

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	540 N/mm²	700 N/mm²
°C	N/mm²	N/mm²
100	336	492
150	326	478
200	318	471
250	314	464
300	314	456
350	308	440
400	298	420
450	278	387
500	250	344

Table 19. Parameters for lower confidence lines: steel grades 410S21, 420S29, 403S17 and 405S17

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	430 N/mm²	730 N/mm²
°C	N/mm²	N/mm²
100	138	453
150	122	440
200	115	431
250	109	419
300	108	413
350	104	396
400	100	379
450	90	344
500	81	301
550	71	227
600	58	146

Table 20. Parameters for lower confidence lines: steel grade 762-690

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	580 N/mm²	900 N/mm²
°C	N/mm²	N/mm²
100	265	589
150	245	571
200	233	555
250	220	541
300	202	538
350	196	523
400	194	497
450	184	469
500	174	419
550	163	347
600	144	220

Table 21. Parameters for lower confidence lines: steel grades 304S11, 304S31 and 304S51

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	220 N/mm²	350 N/mm²
°C	N/mm²	N/mm²
100	158	248
150	139	228
200	126	217
250	118	207
300	112	199
350	106	190
400	101	184
450	99	180
500	96	177
550	94	173
600	91	168
650	89	155
700	88	138

Table 22. Parameters for lower confidence lines: steel grades 347S31 and 347S51

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	250 N/mm²	350 N/mm²
°C	N/mm²	N/mm²
100	196	285
150	184	271
200	172	263
250	164	254
300	158	248
350	153	242
400	150	238
450	149	232
500	148	228
550	146	221
600	145	212

Table 23. Parameters for lower confidence lines: steel grades 321S31, 321S51-490 and 321S51-510

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	200 N/mm²	350 N/mm²
°C	N/mm²	N/mm²
100	140	281
150	130	265
200	123	256
250	116	247
300	110	240
350	105	233
400	103	227
450	99	220
500	97	215
550	96	211
600	95	204
650	93	194
700	91	180

Table 24. Parameters for lower confidence lines: steel grades 316S11, 316S13, 316S31, 316S33 and 316S51

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	220 N/mm²	350 N/mm²
°C	N/mm²	N/mm²
100	157	263
150	143	241
200	131	224
250	121	215
300	115	207
350	110	200
400	105	194
450	102	190
500	98	184
550	96	180
600	94	177
650	91	173
700	90	168

Appendix G. Stress rupture values for carbon-manganese steels excluding grade 221-550

Grade	Rupture time	Estimated average stress for rupture (see note 1) at a temperature of:														
		380 °C	390 °C	400 °C	410 °C	420 °C	430 °C	440 °C	450 °C	460 °C	470 °C	480 °C	490 °C	500 °C	510 °C	520 °C
	h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
See note 2	10 000	291	266	243	221	200	180	161	143	126	110	96	84	74	65	58
	30 000	262	237	214	192	171	151	132	115	99	86	74	65	57	50	—
	50 000	248	223	200	177	156	136	118	102	87	75	65	57	50	—	—
	100 000	227	203	179	157	136	117	100	85	73	63	55	(47)	—	—	—
	150 000	215	190	167	144	124	105	89	76	65	56	(49)	—	—	—	—
	200 000	206*	181*	157*	135*	115*	97*	82*	70*	60*	52*	—	—	—	—	—
	250 000	199*	174*	150*	128*	108*	91*	77*	66*	56*	(48)*	—	—	—	—	—

NOTE 1. Values obtained by extrapolation. Asterisks and parentheses indicate where values have been obtained by either 'extended time' or 'extended stress' extrapolation respectively.
The confidence that can be placed upon such values is related to the extent of extrapolation, and for the purposes of this standard, extrapolation exceeding approximately three times the above minimum duration are described as 'extended time extrapolations' and marked with an asterisk in the table.
Values may also be obtained by extending the parametric master curves to stresses beyond those at which casts have been tested. Such values may also be obtained by 'extended stress extrapolation' are enclosed in parentheses. They are subject to greater uncertainty than other values.

NOTE 2. The values given in the table are applicable to all the steels given in table 1 with the exception of steel grade 221-550, for which stress-rupture values are not available.

Appendix H. Stress-rupture values for low alloy, ferritic stainless and martensitic stainless steels

Grade (see note 2)	Rupture time	Estimated average stress for rupture (see note 1) at a temperature of:																												
		400 °C	410 °C	420 °C	430 °C	440 °C	450 °C	460 °C	470 °C	480 °C	490 °C	500 °C	510 °C	520 °C	530 °C	540 °C	550 °C	560 °C	570 °C	580 °C	590 °C	600 °C	610 °C	620 °C	630 °C	640 °C	650 °C	660 °C	670 °C	680 °C
	h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
243-430	10 000	–	–	–	–	–	298	273	247	222	196	171	147	125	102	82	64	–	–	–	–	–	–	–	–	–	–	–	–	–
	30 000	–	–	–	–	–	273	244	216	187	159	134	113	93	76	61	49	–	–	–	–		–	–	–	–	–	–	–	–
	50 000	–	–	–	–	–	260	229	200	172	144	119	99	80	66	53	(42)	–	–	–	–	–	–	–	–	–	–	–	–	–
	100 000	–	–	–	–	–	239*	208*	178*	148	123	101	81	66	53*	(42)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	150 000	–	–	–	–	–	226*	197*	168*	139*	114*	91*	74*	60*	48*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	200 000	–	–	–	–	–	217*	188*	159*	130*	105*	84*	69*	55*	45*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	250 000	–	–	–	–	–	210*	180*	151*	124*	100*	80*	65*	52*	(42)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
620-440, 620-540 and 621-460	10 000	–	–	–	–	–	373	343	315	287	261	235	210	185	160	136	112	88	69	55	46	39	35	31	29	–	–	–	–	–
	30 000	–	–	–	–	–	333	305	277	250	224	198	172	147	122	97	76	59	48	41	36	32	29	–	–	–	–	–	–	–
	50 000	–	–	–	–	–	315	287	259	232	206	180	154	129	104	80	62	50	42	37	33	30	27*	–	–	–	–	–	–	–
	100 000	–	–	–	–	–	290	262	235	208	181	155	129	103	80	62	49	42	36	32	29	–	–	–	–	–	–	–	–	–
	150 000	–	–	–	–	–	276	247	220	193	167	140	114	89	68*	53*	44	38	33	30	27	–	–	–	–	–	–	–	–	–
	200 000	–	–	–	–	–	265*	237*	210*	183*	156*	129*	103*	79*	61*	49*	41	36*	32*	29*	–	–	–	–	–	–	–	–	–	–
	250 000	–	–	–	–	–	257*	229*	202*	175*	148*	121*	95*	72*	56*	46*	39	34*	31*	28*	–	–	–	–	–	–	–	–	–	–
660-460	10 000	–	–	–	–	–	380	353	328	304	280	257	234	212	190	170	151	133	118	104	92	81	–	–	–	–	–	–	–	–
	30 000	–	–	–	–	–	352	326	300	276	251	227	204	182	161	142	125	109	96	84	71	–	–	–	–	–	–	–	–	–
	50 000	–	–	–	–	–	339	313	287	262	237	213	190	168	147	129	113	99	87	74	–	–	–	–	–	–	–	–	–	–
	100 000	–	–	–	–	–	321	294	268	242	217	193	170	149	130	113	99	86	73	–	–	–	–	–	–	–	–	–	–	–
	150 000	–	–	–	–	–	309	282	256	230	205	181	158	138	120	104	90	77	61	–	–	–	–	–	–	–	–	–	–	–
	200 000	–	–	–	–	–	301*	274*	247	221	196	172	150	130	113	98	85	71	–	–	–	–	–	–	–	–	–	–	–	–
	250 000	–	–	–	–	–	295*	267*	240*	214*	189*	160*	144*	125*	108*	93*	80*	65*	–	–	–	–	–	–	–	–	–	–	–	–
271-560	10 000	454*	445*	432*	415	394	371	346	321	294	265	234	205	177	150	125	102	83	69	–	–	–	–	–	–	–	–	–	–	–
	30 000	435*	425*	411*	392	371	346	316	284	252	219	189	157	137	106	85	68	52	42	–	–	–	–	–	–	–	–	–	–	–
	50 000	425*	416*	401*	381	358	330	296	263	230	198	168	136	116	89	70	55	–	–	–	–	–	–	–	–	–	–	–	–	–
	100 000	417*	405*	388*	367	341	309	272	235	201	168	139	113	90	70	53	39	–	–	–	–	–	–	–	–	–	–	–	–	–
	150 000	407*	394*	377*	355*	328*	296*	258*	219*	183*	152*	124*	99*	75*	58*	42*	30*	–	–	–	–	–	–	–	–	–	–	–	–	–
	200 000	399*	385*	368*	346*	318*	287*	249*	208*	171*	141*	113*	88*	66*	50*	34*	23*	–	–	–	–	–	–	–	–	–	–	–	–	–
	250 000	391*	377*	360*	337*	303*	273*	240*	199*	161*	132*	105*	80*	58*	42*	27*	16*	–	–	–	–	–	–	–	–	–	–	–	–	–
622-490, 622-560 and 622-650	10 000	–	–	–	–	–	–	–	271	244	220	199	180	162	146	131	118	105	92	82	72	63	53	–	–	–	–	–	–	–
	30 000	–	–	–	–	–	–	–	242	217	194	174	156	139	124	110	96	84	73	63	52	–	–	–	–	–	–	–	–	–
	50 000	–	–	–	–	–	–	–	229	204	182	162	144	128	113	99	86	74	64	53	–	–	–	–	–	–	–	–	–	–
	100 000	–	–	–	–	–	–	–	210	186	165	145	128	112	98	84	72	61	49	–	–	–	–	–	–	–	–	–	–	–
	150 000	–	–	–	–	–	–	–	199	175	155	136	119	103	89*	76*	64	52	–	–	–	–	–	–	–	–	–	–	–	–
	200 000	–	–	–	–	–	–	–	191	168	147	129	112	97	82*	70*	58*	44*	–	–	–	–	–	–	–	–	–	–	–	–
	250 000	–	–	–	–	–	–	–	184*	162*	141*	123*	107*	91*	78*	65*	53*	–	–	–	–	–	–	–	–	–	–	–	–	–
625-520 (see note 3) and 625-590	10 000	–	–	–	–	–	–	–	226	220	190	164	145	129	114	100	88	77	68	60	53	46	40	(36)	–	–	–	–	–	–
	30 000	–	–	–	–	–	–	273*	221*	187	160	140	123	107	92	80	70	61	52	45	39	(35)	–	–	–	–	–	–	–	–
	50 000	–	–	–	–	–	–	247*	204*	172*	148*	129*	112*	96*	82*	71*	62*	53*	45*	39*	–	–	–	–	–	–	–	–	–	–
	100 000	–	–	–	–	–	276*	218*	181*	153*	132*	113*	96*	81*	70*	59*	50*	43*	(37)*	–	–	–	–	–	–	–	–	–	–	–
	150 000	–	–	–	–	–	252*	202*	167*	142*	122*	103*	86*	73*	62*	52*	44*	(38)*	–	–	–	–	–	–	–	–	–	–	–	–
	200 000	–	–	–	–	–	237*	192*	158*	135*	114*	96*	80*	68*	57*	47*	40*	(36)*	–	–	–	–	–	–	–	–	–	–	–	–
	250 000	–	–	–	–	–	226*	183*	152*	129*	108*	90*	75*	64*	53*	44*	(37)*	–	–	–	–	–	–	–	–	–	–	–	–	–
762-690	10 000	–	–	–	–	–	–	–	–	350	319	290	264	240	217	196	176	157	139	123	107	93	81	71	62	54	48	42	37	33
	30 000	–	–	–	–	–	–	–	–	324	293	265	240	216	194	173	153	135	117	102	88	75	65	57	50	44	38	33	29	–
	50 000	–	–	–	–	–	–	–	–	311	281	254	228	205	183	162	142	124	107	92	79	68	59	51	45	39	34	29	–	–
	100 000	–	–	–	–	–	–	–	–	294	265	237	212	189	167	146	127	109	93	80	68	59	51	44	38	33	28	–	–	–
	150 000	–	–	–	–	–	–	–	–	284*	255*	228*	203*	179*	157	137	118	101	86	73	62	54	46	40	35*	30*	–	–	–	–
	200 000	–	–	–	–	–	–	–	–	277*	247*	221*	196*	172*	151*	130*	112*	95*	80*	68*	58*	50*	44*	38*	32*	–	–	–	–	–
	250 000	–	–	–	–	–	–	–	–	271*	242*	215*	190*	167*	145*	125*	107*	90*	76*	65*	56*	48*	41*	36*	30*	–	–	–	–	–

NOTE 1. Values obtained by extrapolation. Asterisks and parentheses indicate where values have been obtained by either 'extended time' or 'extended stress' extrapolation respectively. The confidence that can be placed upon such values is related to the extent of such extrapolation, and for the purposes of this standard, extrapolations exceeding approximately three times the above minimum duration are described as 'extended time extrapolations' and marked with an asterisk in the table. Values may also be obtained by extending the parametric master curves to stresses beyond those at which casts have been tested. Such values obtained by 'extended stress extrapolation' are enclosed in parentheses. Extrapolated values are subject to greater uncertainty than other values.

NOTE 2. Stress-rupture values for steel grades 410S21, 420S29, 403S17 and 405S17 are not available.

NOTE 3. The values given for steel grade 625-520 are not applicable if the tempering temperature exceeds 750 °C.

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Appendix J. Stress-rupture values for austenitic stainless steels

J.1 Steel grades 304S51, 347S510, 321S51-490, 321S51-510, 316S51, 316S61 and 316 S 63

Grade (see note 2)	Rupture time	Estimated average stress for rupture (see note 1) at a temperature of:												
		530 °C	540 °C	550 °C	560 °C	570 °C	580 °C	590 °C	600 °C	610 °C	620 °C	630 °C	640 °C	650 °C
	h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
304S51	10 000	—	—	186	174	163	153	144	134	126	117	109	102	94
	30 000	—	—	165	154	144	135	126	117	109	101	94	87	80
	50 000	—	—	155	145	136	126	118	110	102	94	87	80	73
	100 000	—	—	143	133	124	116	107	99	92	85	78	71	65
	150 000	—	—	136*	127*	118*	109	101	94	86	79	72*	66*	60*
	200 000	—	—	131*	122*	113*	105*	97*	90*	82*	75*	69*	63*	57*
	250 000	—	—	127*	118*	110*	102*	94*	86*	79*	72*	66*	60*	55*
347S51	10 000	—	258	236	218	202	187	174	162	151	140	131	121	113
	30 000	—	214*	197*	182*	169*	157	145	135	125	116	107	98	90
	50 000	—	196*	181*	167*	155*	144	133	123	114	105	96	87	78
	100 000	—	174*	161*	148*	137*	127*	117*	107*	98*	89*	80*	71*	58*
	150 000	—	162*	149*	138*	127*	117*	108*	98*	89*	80*	70*	57*	—
	200 000	—	154*	142*	131*	120*	110*	101*	92*	82*	72*	61*	—	—
	250 000	—	147*	136*	125*	115*	105*	96*	86*	77*	66*	—	—	—
321S51-490	10 000	—	237	223	210	196	182	169	156	143	130	119	108	98
	30 000	—	212	198	183	169	155	141	128	116	105	95	86	79
	50 000	—	201	186	171	157	142	129	117	105	95	86	78	72
	100 000	—	185	170	155	140	127	114	102	92	83	76	69	64
	150 000	—	176	160	146	131	118	106	95	86	78	71	65	60
	200 000	—	170*	154*	139*	125*	112*	100*	90*	81*	74*	67	62	57
	250 000	—	165*	149*	134*	120*	108*	97*	87*	78*	71*	65*	60*	55*
321S51-510	10 000	—	222	206	192	178	165	152	140	129	118	108	98	88
	30 000	—	189	174	161	148	136	125	114	103	93	84	75	67
	50 000	—	174*	160*	147*	135*	124	112	102	92	82	73	65	57
	100 000	—	154*	142*	129*	118*	107*	96*	86*	77*	68*	60*	53*	46*
	150 000	—	143*	131*	119*	108*	97*	87*	78*	69*	61*	53*	46*	40*
	200 000	—	136*	123*	112*	101*	91*	81*	72*	63*	55*	48*	42*	36*
	250 000	—	130*	118*	107*	96*	86*	76*	67*	59*	51*	45*	39*	34*
316S51	10 000	—	247	233	220	206	193	180	167	155	142	130	119	108
	30 000	—	222	208	195	181	168	155	143	131	119	107	97	87
	50 000	—	210	197	183	170	157	144	132	120	108	97	87	78
	100 000	—	194*	181*	167*	154*	141	128	116	105	94	84	75	67
	150 000	—	185*	172*	158*	145*	132	120	108	97	86	77*	69*	61*
	200 000	—	178*	164*	151*	138*	125	113	102	91	81	72*	65*	58*
	250 000	—	173*	159*	146*	133*	120*	108*	97*	87*	77*	69*	61*	55*
316S61 and 316S63	10 000	349	329	311	294	278	262	247	233	218	204	189	175	159
	30 000	325	306	289	272	256	241	226	211	196	180	164	146	127
	50 000	315*	297*	279*	263*	247*	231	216	200	185	169	151	132	—
	100 000	302*	284*	267*	250*	234*	218*	202*	186*	170*	152*	132	—	—
	150 000	295*	277*	259*	243*	227*	211*	194*	178*	160*	141*	(120)*	—	—
	200 000	289*	271*	254*	238*	221*	205*	189*	172*	154*	133*	—	—	—
	250 000	285*	268*	250*	234*	217*	201*	184*	167*	148*	127*	—	—	—

J.2 Steel grade 310 S 31

Grade (see note 2)	Rupture time	Estimated average stress for rupture (see note 1) at a temperature of:												
		600 °C	610 °C	620 °C	630 °C	640 °C	650 °C	660 °C	670 °C	680 °C	690 °C	700 °C	710 °C	720 °C
	h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
310S31	10 000	137	120	105	92	81	72	64	57	51	47	42	39	35
	30 000	113	98	85	75	66	58	52	46	42	38	34	31	29
	50 000	104*	90*	78*	68*	60*	53*	47*	42*	38	35	32	29	26
	100 000	92*	79*	69*	60*	53*	47*	42*	38*	34*	31*	28*	26*	23.5*
	150 000	86*	74*	64*	56*	50*	44*	39*	35*	32*	29*	26*	24*	22*
	200 000	82*	71*	61*	54*	47*	42*	38*	34*	31*	28*	25*	23*	21*
	250 000	79*	68*	59*	52*	46*	41*	36*	33*	29*	27*	24*	22*	20*

Notes to J.1 and J.2

NOTE 1. Values obtained by extrapolation. Asterisks and parentheses indicate where values have been obtained by either 'extended 'extended stress' extrapolation respectively. The confidence that can be placed upon such values is related to the extent of extrapola for the purposes of this standard, extrapolations exceeding approximately three times the above minimum duration are describe 'extended time extrapolations' and marked with an asterisk in the table. Values may also be obtained by extending the parametri

660 °C	670 °C	680 °C	690 °C	700 °C	710 °C	720 °C	730 °C	740 °C	750 °C	760 °C	770 °C
N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
87	81	74	68	63	56	53	49	45	42	39	37
73	67	62	56	52	48	44	41	39	37	—	—
67	62	56	52	48	44	41	39	36	—	—	—
59	54	50*	46*	43*	40*	37*	—	—	—	—	—
55*	51*	47*	43*	40*	38*	—	—	—	—	—	—
52*	48*	44*	41*	39*	36*	—	—	—	—	—	—
50*	46*	43*	40*	38*	—	—	—	—	—	—	—
104	96	88	80	71	61	—	—	—	—	—	—
81	72	62	—	—	—	—	—	—	—	—	—
69	56	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
90	82	75	70	65	60	56	—	—	—	—	—
72	67	61	57	53	50	(47)	—	—	—	—	—
66	61	56	53	49	(46)	(44)	—	—	—	—	—
59	54	51	48	(45)	—	—	—	—	—	—	—
55	51	48	(45)	—	—	—	—	—	—	—	—
53	49	(46)*	(43)*	—	—	—	—	—	—	—	—
51*	48*	(45)*	—	—	—	—	—	—	—	—	—
79	71	63	56	49	43	38	—	—	—	—	—
59	52	45	39	35	30	(27)	—	—	—	—	—
50	44	38*	34*	29*	(26)*	—	—	—	—	—	—
40*	35*	31*	(27)*	—	—	—	—	—	—	—	—
35*	31*	(27)*	—	—	—	—	—	—	—	—	—
32*	(28)*	—	—	—	—	—	—	—	—	—	—
30*	(26)*	—	—	—	—	—	—	—	—	—	—
97	87	78	70	63	57	52	47	—	—	—	—
78	69	62	56	51	46	(42)	—	—	—	—	—
70	62	56	51	46	(42)	—	—	—	—	—	—
60	54	49*	(44)*	—	—	—	—	—	—	—	—
55*	50*	(45)*	—	—	—	—	—	—	—	—	—
52*	47*	(43)*	—	—	—	—	—	—	—	—	—
50*	(45)*	—	—	—	—	—	—	—	—	—	—
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730 °C	740 °C	750 °C	760 °C	770 °C	780 °C	790 °C	800 °C	810 °C	820 °C	830 °C	840 °C	850 °C	860 °C	870 °C	880 °C	890 °C	900 °C	910 °C
N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
32	30	28	26	24	22	21	19.5	18	17	16	15	14	13	12	11.5	10.5	10	9.5
27	24.5	22.5	21	19.5	18	17	15.5	14.5	13.5	12.5	12	11	10	9.5	(9)	—	—	—
14.5*	22.5*	21*	19*	18*	16.5*	15.5*	14*	13*	12*	11.5*	10.5*	10*	(9)	—	—	—	—	—
12*	20*	18.5*	17*	15.5*	14.5*	13.5*	12.5*	11.5*	10.5*	10*	(9)*	—	—	—	—	—	—	—
10*	18.5*	17*	16*	14.5*	13.5*	12.5*	11.5*	10.5*	10*	(9)*	—	—	—	—	—	—	—	—
9.5*	18*	16.5*	15*	14*	13*	12*	11*	10*	9.5*	—	—	—	—	—	—	—	—	—
8.5*	17*	16*	14.5*	13.5*	12.5*	11.5*	10.5*	9.5*	(9)*	—	—	—	—	—	—	—	—	—

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curves to stresses beyond those at which casts have been tested. Such values obtained by 'extended stress extrapolation' are enclosed in parentheses. Extrapolated values are subject to greater uncertainty than other values.

NOTE 2. Stress-rupture values are not available for the following austenitic stainless steels:
304S11, 304S31, 347S31, 321S31, 316S11, 316S13, 316S31, 316S33 and 320S33.

Appendix K. Equivalent designations of steels in BS 1503 and ISO 2604/1-1975

The following table lists the designations for steels in this edition of this standard and gives their nearest equivalents in the 1980 and 1969 edition of BS 1503 and their nearest equivalents in ISO 2604/1-1975.

NOTE. The designations are indicated as the nearest equivalents; the equivalent steels are not necessarily identical.

BS 1503: 1989	BS 1503: 1980	BS 1503: 1969	ISO 2604/1 — 1975
Grade	Reference number	Designation	Designation
164-490	164-490	—	F18
221-410	221-410	161 Grade 26	F8
221-430	221-430	161 Grade 28	—
221-460	221-460	—	F12
221-490	221-490	161 Grade 32 and 221 Grade 32	F17
221-510	221-510	—	F17Q
221-530	221-530	221 Grade 34	F22Q
221-550	221-550	—	F23Q
223-410	223-410	—	—
223-430	223-430	223 Grade 28	—
223-460	223-460	—	—
223-490	223-490	223 Grade 32	—
223-510	223-510	—	—
224-410	224-410	—	F9
224-430	224-430	224 Grade 28	—
224-460	224-460	—	F13
224-490	224-490	224 Grade 32	F18
224-510	224-510	—	F18Q
225-490	—	—	—
243-430	—	—	—
←	245-420	—	F28
620-440	620-440	620	F32
620-540	620-540	—	F32Q
621-460	621-460	621	—
660-460	660-460	660	F33
271-560	271-560	271	—
622-490	622-490	—	F34
622-560	622-560	622	F34Q
622-650	622-650	—	—
—	—	623 Grade 38	F35
—	—	623 Grade 47	F36
625-520	625-520	—	—
625-590	625-590	625	F37
762-690	—	—	—
503-490	503-490	503	F44
509-690	509-690	509	F45
318S13	—	—	—
410S21	410S21	410S21	—
420S29	420S29	420S29	—
403S17	403S17	403S17	—
405S17	405S17	405S17	—
304S11	304S11	304S30	F46
304S31	304S31	304S40	F47
304S51	304S51	304S50	F48
304S61	—	—	—
316S11	316S11	316S30	F59
316S13	316S13	316S31	F59
316S31	316S31	316S40	F62
316S33	316S33	316S41	F62
316S51	316S51	316S50	F64
316S61	—	—	—
316S63	—	—	—
320S33	320S33	320S40	F68
347S31	347S31	347S40	F50
347S51	347S51	347S50	F51
321S31	321S31	321S40	F53
321S51-490 and 321S51-510	321S51-490 and 321S51-510	321S50	F54A and F54B
310S31	310S31	—	F68

Appendix L. Equivalent diameter and ruling section of forgings

L.1 Equivalent diameter

L.1.1 The equivalent diameter of any forging (or part of a forging) is the diameter of a long bar (effectively of infinite length) of uniform circular cross section, the axis of which will cool at a rate equivalent to that at the slowest cooling position in the forging (or that part of the forging) at the time of heat treatment.

L.1.2 For a long round bar the equivalent diameter is the same as the actual diameter. For other shapes, or short round bars, the equivalent diameter may be calculated according to BS 5046.

L.1.3 The calculation of the equivalent diameter of simple tubular forgings, rings, etc. is described in BS 5046. In certain cases the effect of axial boring is very complex, and where the bore is small, the equivalent diameter should be taken as being that of the unbored forging, and test properties appropriate to an unbored forging of similar external dimensions would normally apply. If the bore is large and is present at the heat treatment stage, the equivalent diameter may have to be estimated.

L.2 Ruling section

The ruling section is normally considered to be the equivalent diameter of the portion of the forging that is most important in relation to mechanical properties. In cases where the primary interest is related to the mechanical properties of a faster cooling portion, rather than the slowest cooling portion, the equivalent diameter of the former may be agreed as the ruling section for test purposes.

L.3 Limiting ruling section

For any given composition of steel, the limiting ruling section is the largest diameter in which certain specified mechanical properties can be expected after a specified heat treatment.

Appendix M. Request for room and elevated temperature information

M.1 General

For future revisions of this standard, and international standards, room and elevated temperature information is invited from users of this standard, as detailed below. This should be sent to the Secretariat of ISM/73/-/1, British Standards Institution, 3 York Street, Manchester M2 2AT.

It is emphasized that available information should be sent even if all details below are not completed.

M.2 Manufacturing details

Cast No.

Code No.

Steelmaker

Testing laboratory

Steelmaking process
(Include any secondary refining and/or re-melting processes used)

Deoxidation practice

Concast/Ingot size

Concast/Ingot mass

Product form

Product dimensions
(Outside diameter and thickness for tube)

Product process route.

M.3 Chemical composition

(a) State whether information provided in cast or product composition.

(b) Detailed chemical composition data to include (where known):

C, Si, Mn, P, S, Cr, Mo, Ni, Al, As, B, Bi, Co, Cu, N, Nb, Pb, Sb, Sn, Ti, V, W, Zr.

M.4 Heat treatment of test sample or piece

(a) Pretreatments	Indicate if treatments are works or laboratory treatments
(b) Austenitizing treatment (Solution treatment)	
Actual temperature	
Time at temperature	
Cooling medium	
Cooling rate and temperature range over which measured if control cooled.	
(c) Tempering treatment	Indicate if treatments are works or laboratory treatments
Actual temperature	
Time at temperature	
Cooling medium	
Cooling rate and temperature range over which measured if control cooled.	
(d) Any subsequent treatments (e.g. post weld heat treatment(s))	

M.5 Test results

(a) Laboratory accreditation

(b) Test piece location
(e.g. transverse

(c) Test piece size

(d) Strain rate used in tensile test(s)

(e) Room and elevated temperature tensile properties
(To include $R_{p0.2}/R_{p1.0}/R_m$ /A/Z where determined)
(State stress units)

(f) Elevated temperature stress rupture/creep data
(To include temperature stress, duration, A Z)
(Please state whether test is completed or unbroken at duration stated)
(Time to specific creep strain(s),
e.g. 0.05, 0.1, 0.2, 0.5, 1 %)

(g) Testing atmosphere

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Publications referred to

BS 18	Method for tensile testing of metals (including aerospace materials)
BS 131	Methods for notched bar tests Part 2 The Charpy V-notch impact test on metals
BS 1501*	Steels for pressure purposes. Plates, sheet and strip Part 1 Specification for carbon and carbon-manganese steels Part 2 Specification for alloy steels Part 3 Specification for corrosion- and heat-resisting steel
BS 1502*	Specification for steels for fired and unfired pressure vessels: sections and bars
BS 1504*	Specification for steel castings for pressure purposes
BS 1506*	Steel bar and billets for bolting material for pressure purposes
BS 3601*	Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes
BS 3602*	Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties
BS 3603*	Specification for steel pipes and tubes for pressure purposes: carbon and alloy steel with specified low temperature properties
BS 3604*	Specification for steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties
BS 3605*	Specification for seamless and welded austenic stainless steel pipes and tubes for pressure purposes
BS 3688	Methods for mechanical testing of metals at elevated temperatures Part 1 Tensile testing
BS 3894	Method for converting elongation values for steel Part 1 Carbon and low alloy steels Part 2 Method of conversion for application to austenitic steels
BS 3920	Derivation and verification of elevated temperature properties for steel products for pressure purposes Part 1 Method for deriving the minimum elevated temperature yield or proof stress properties when data on a minimum of 50 casts are available
BS 4124	Methods for ultrasonic detection of imperfections in steel forgings
BS 5046	Method for the estimation of equivalent diameters in the heat treatment of steel
BS 5750*	Quality systems Part 2 Specification for production and installation
BS 5903	Method for determination of resistance to intergranular corrosion of austenitic stainless steels: Copper sulphate-sulphuric acid method (Moneypenny Strauss test)
BS 6072	Method for magnetic particle flaw detection
BS 6200	Sampling and analysis of iron, steel and other ferrous metals
BS 6443	Method for penetrant flaw detection
BS Handbook 19.	Methods for the sampling and analysis of iron, steel and other ferrous metals
ISO 2604	Steel products for pressure purposes — Quality requirements Part 1 Forgings
Stahl-Eisen Werkstoffblatt 400 : 1986†	

*Referred to in the foreword only.
†Available from BSI Sales Department, Linford Wood, Milton Keynes, MK14 6LE.

BS 1503 : 1989

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Iron and Steel Standards Policy Committee (ISM/-) to Technical Committee ISM/73, upon which the following bodies were represented:

Associated Offices Technical Committee
BEAMA Ltd.
British Forging Industry Association
British Gas plc
British Steel Industry
Electricity Supply Industry in England and Wales
Engineering Equipment and Material Users' Association
Process Plant Association
Water Tube Boiler Group (Power Plant Contractors' Association)
Welding Institute

Amendments issued since publication

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AMD 6739

Amendment No. 1
published and effective from 30 September 1991
to BS 1503 : 1989

Specification for steel forgings for pressure purposes

Revised text

AMD 6739
September 1991

Table 1. Chemical composition, mechanical properties at room temperature and heat treatment of carbon-manganese steels

For steel grade 223-430, in column headed **'Treatment'**, in line 2, delete 'N+T'.

For steel grade 224-490, in column headed **'Treatment'**, in line 2, delete 'N+T or' and substitute 'or Q+T'.

AMD 6739
September 1991

Clause B.8.1.1

In line 8, delete 'BS 231 : Part 2' and substitute 'BS 131 : Part 2'.

AMD 6739
September 1991

Appendix D. Minimum lower yield stress (R_{eL}) or minimum 0.2 % proof stress ($R_{p0.2}$) values at elevated temperatures for low alloy, ferritic stainless, martenistic stainless, and duplex stainless steels

In the appendix title, delete 'martenistic' and substitute 'martensitic'.

In the table, for steel grade 271-560, in column headed **'450 ° C'** delete '289' and substitute '282'.

AMD 6739
September 1991

Appendix E. Minimum 1 % proof stress $R_{p1.0}$ values at elevated temperatures for austenitic stainless steels

In the table, after the entry for steel grade 304S51, insert the following new entry.

304S61‡	230	201	182	172	163	156	149	144	140	136	131	128	124

At the end of the footnotes, insert the following new footnote.

'‡ Values for steel 304S61 based on 304 smoothed lower 95 % confidence lines.'

AMD 6739
September 1991

Appendix H. Stress rupture values for low alloy, ferritic stainless and martensitic stainless steels

Delete the existing appendix and substitute the attached new appendix which incorporates data for steel grade 660-460.

AMD 6739
September 1991

Appendix K. Equivalent designations of steels in BS 1503 and ISO 2604/1-1975

In the table, after the entry for steel grade 164-490, insert the following new entry.

'| 221-410 | 221-410 | 161 Grade 26 | F8 |'

For steel grade 221-530, in column headed **'Reference number'**, delete '212-530' and substitute '221-530'.

For steel grade 381S13, in column headed **'Grade'**, delete '381S13' and substitute '318S13'.

For steel grade 316S51, in column headed **'BS 1503 : 1969 Designation'**, delete '317S50' and substitute '316S50' and in column headed **'ISO 2604/1—1975 Designation'**, delete '—' and substitute 'F64'.

For steel grade 320S33, in column headed **'ISO 2604/1—1975 Designation'**, delete 'F66' and substitute 'F68'.

For steel grade 320S31, in column headed **'Grade'**, delete '320S31' and substitute '310S31'.

Appendix H. Stress-rupture values for low alloy, ferritic stainless and martensitic stainless steels

Grade (see note 2)	Rupture time	Estimated average stress for rupture (see note 1) at a temperature of:														
		400 °C	410 °C	420 °C	430 °C	440 °C	450 °C	460 °C	470 °C	480 °C	490 °C	500 °C	510 °C	520 °C	530 °C	540 °C
	h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
243-430	10 000	–	–	–	–	–	298	273	247	222	196	171	147	125	102	82
	30 000	–	–	–	–	–	273	244	216	187	159	134	113	93	76	61
	50 000	–	–	–	–	–	260	229	200	172	144	119	99	80	66	53
	100 000	–	–	–	–	–	239*	208*	178*	148	123	101	81	66	53*	(42)*
	150 000	–	–	–	–	–	226*	197*	168*	139*	114*	91*	74*	60*	48*	–
	200 000	–	–	–	–	–	217*	188*	159*	130*	105*	84*	69*	55*	45*	–
	250 000	–	–	–	–	–	210*	180*	151*	124*	100*	80*	65*	52*	(42)*	–
620-440, 620-540 and 621-460	10 000	–	–	–	–	–	373	343	315	287	261	235	210	185	160	136
	30 000	–	–	–	–	–	333	305	277	250	224	198	172	147	122	97
	50 000	–	–	–	–	–	315	287	259	232	206	180	154	129	104	80
	100 000	–	–	–	–	–	290	262	235	208	181	155	129	103	80	62
	150 000	–	–	–	–	–	276	247	220	193	167	140	114	89	68*	53*
	200 000	–	–	–	–	–	265*	237*	210*	183*	156*	129*	103*	79*	61*	49*
	250 000	–	–	–	–	–	257*	229*	202*	175*	148*	121*	95*	72*	56*	46*
660-460	10 000	–	–	–	–	–	380	353	328	304	280	257	234	212	190	170
	30 000	–	–	–	–	–	352	326	300	276	251	227	204	182	161	142
	50 000	–	–	–	–	–	339	313	287	262	237	213	190	168	147	129
	100 000	–	–	–	–	–	321	294	268	242	217	193	170	149	130	113
	150 000	–	–	–	–	–	309	282	256	230	205	181	158	138	120	104
	200 000	–	–	–	–	–	301*	274*	247	221	196	172	150	130	113	98
	250 000	–	–	–	–	–	295*	267*	240*	214*	189*	160*	144*	125*	108*	93*
271-560	10 000	454*	445*	432*	415	394	371	346	321	294	265	234	205	177	150	125
	30 000	435*	425*	411*	392	371	346	316	284	252	219	189	157	137	106	85
	50 000	425*	416*	401*	381	358	330	296	263	230	198	168	136	116	89	70
	100 000	417*	405*	388*	367	341	309	272	235	201	168	139	113	90	70	53
	150 000	407*	394*	377*	355*	328*	296*	258*	219*	183*	152*	124*	99*	75*	58*	42*
	200 000	399*	385*	368*	346*	318*	287*	249*	208*	171*	141*	113*	88*	66*	50*	34*
	250 000	391*	377*	360*	337*	303*	273*	240*	199*	161*	132*	105*	80*	58*	42*	27*
622-490, 622-560 and 622-650	10 000	–	–	–	–	–	–	–	271	244	220	199	180	162	146	131
	30 000	–	–	–	–	–	–	–	242	217	194	174	156	139	124	110
	50 000	–	–	–	–	–	–	–	229	204	182	162	144	128	113	99
	100 000	–	–	–	–	–	–	–	210	186	165	145	128	112	98	84
	150 000	–	–	–	–	–	–	–	199	175	155	136	119	103	89*	76*
	200 000	–	–	–	–	–	–	–	191	168	147	129	112	97	82*	70*
	250 000	–	–	–	–	–	–	–	184*	162*	141*	123*	107*	91*	78*	65*
625-520 (see note 3) and 625-590	10 000	–	–	–	–	–	–	–	226	220	190	164	145	129	114	100
	30 000	–	–	–	–	–	–	273*	221*	187	160	140	123	107	92	80
	50 000	–	–	–	–	–	–	247*	204*	172*	148*	129*	112*	96*	82*	71*
	100 000	–	–	–	–	–	276*	218*	181*	153*	132*	113*	96*	81*	70*	59*
	150 000	–	–	–	–	–	252*	202*	167*	142*	122*	103*	86*	73*	62*	52*
	200 000	–	–	–	–	–	237*	192*	158*	135*	114*	96*	80*	68*	57*	47*
	250 000	–	–	–	–	–	226*	183*	152*	129*	108*	90*	75*	64*	53*	44*
762-690	10 000	–	–	–	–	–	–	–	–	350	319	290	264	240	217	196
	30 000	–	–	–	–	–	–	–	–	324	293	265	240	216	194	173
	50 000	–	–	–	–	–	–	–	–	311	281	254	228	205	183	162
	100 000	–	–	–	–	–	–	–	–	294	265	237	212	189	167	146
	150 000	–	–	–	–	–	–	–	–	284*	255*	228*	203*	179*	157	137
	200 000	–	–	–	–	–	–	–	–	277*	247*	221*	196*	172*	151*	130*
	250 000	–	–	–	–	–	–	–	–	271*	242*	215*	190*	167*	145*	125*

NOTE 1. Values obtained by extrapolation. Asterisks and parentheses indicate where values have been obtained by either 'extended time' or 'extended stress' extrapolation respectively. The confidence that can be placed upon such values is related to the extent of such extrapolation, and for the purposes of this standard, extrapolations exceeding approximately three times the above minimum duration are described as 'extended time extrapolations' and marked with an asterisk in the table. Values may also be obtained by extending th
'extended str
NOTE 2. Stre
NOTE 3. The

	550 °C	560 °C	570 °C	580 °C	590 °C	600 °C	610 °C	620 °C	630 °C	640 °C	650 °C	660 °C	670 °C	680 °C
	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
	64	—	—	—	—	—	—	—	—	—	—	—	—	—
	49	—	—	—	—		—	—	—	—	—	—	—	—
	(42)	—	—	—	—	—	—	—	—	—	—	—	—	—
*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	112	88	69	55	46	39	35	31	29	—	—	—	—	—
	76	59	48	41	36	32	29	—	—	—	—	—	—	—
	62	50	42	37	33	30	27*	—	—	—	—	—	—	—
	49	42	36	32	29	—	—	—	—	—	—	—	—	—
	44	38	33	30	27	—	—	—	—	—	—	—	—	—
	41	36*	32*	29*	—	—	—	—	—	—	—	—	—	—
	39	34*	31*	28*	—	—	—	—	—	—	—	—	—	—
	151	133	118	104	92	81	—	—	—	—	—	—	—	—
	125	109	96	84	71	—	—	—	—	—	—	—	—	—
	113	99	87	74	—	—	—	—	—	—	—	—	—	—
	99	86	73	—	—	—	—	—	—	—	—	—	—	—
	90	77	61	—	—	—	—	—	—	—	—	—	—	—
	85	71	—	—	—	—	—	—	—	—	—	—	—	—
	80*	65*	—	—	—	—	—	—	—	—	—	—	—	—
	102	83	69	—	—	—	—	—	—	—	—	—	—	—
	68	52	42	—	—	—	—	—	—	—	—	—	—	—
	55	—	—	—	—	—	—	—	—	—	—	—	—	—
	39	—	—	—	—	—	—	—	—	—	—	—	—	—
	30*	—	—	—	—	—	—	—	—	—	—	—	—	—
	23*	—	—	—	—	—	—	—	—	—	—	—	—	—
	16*	—	—	—	—	—	—	—	—	—	—	—	—	—
	118	105	92	82	72	63	53	—	—	—	—	—	—	—
	96	84	73	63	52	—	—	—	—	—	—	—	—	—
	86	74	64	53	—	—	—	—	—	—	—	—	—	—
	72	61	49	—	—	—	—	—	—	—	—	—	—	—
*	64	52	—	—	—	—	—	—	—	—	—	—	—	—
*	58*	44*	—	—	—	—	—	—	—	—	—	—	—	—
*	53*	—	—	—	—	—	—	—	—	—	—	—	—	—
	88	77	68	60	53	46	40	(36)	—	—	—	—	—	—
	70	61	52	45	39	(35)	—	—	—	—	—	—	—	—
*	62*	53*	45*	39*	—	—	—	—	—	—	—	—	—	—
*	50*	43*	(37)*	—	—	—	—	—	—	—	—	—	—	—
*	44*	(38)*	—	—	—	—	—	—	—	—	—	—	—	—
*	40*	(36)*	—	—	—	—	—	—	—	—	—	—	—	—
*	(37)*	—	—	—	—	—	—	—	—	—	—	—	—	—
	176	157	139	123	107	93	81	71	62	54	48	42	37	33
	153	135	117	102	88	75	65	57	50	44	38	33	29	—
	142	124	107	92	79	68	59	51	45	39	34	29	—	—
	127	109	93	80	68	59	51	44	38	33	28	—	—	—
	118	101	86	73	62	54	46	40	35*	30*	—	—	—	—
*	112*	95*	80*	68*	58*	50*	44*	38*	32*	—	—	—	—	—
*	107*	90*	76*	65*	56*	48*	41*	36*	30*	—	—	—	—	—

the parametric master curves to stresses beyond those at which casts have been tested. Such values obtained by stress extrapolation' are enclosed in parentheses. Extrapolated values are subject to greater uncertainty than other values.
tress-rupture values for steel grades 410S21, 420S29, 403S17 and 405S17 are not available.
he values given for steel grade 625-520 are not applicable if the tempering temperature exceeds 750 °C.

[AMD 6739]