

*Incorporating
Amendments Nos. 1, 2,
3, 4, 5 and 6*

*Incorporating
Corrigendum No. 1 to
Enquiry Case 5500/106*

Specification for Unfired fusion welded pressure vessels

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- British Compressed Air Society
- British Compressed Gases Association
- British Gas plc
- British Refrigeration Association
- Department of Trade and Industry (Mechanical Engineering Division (ME))
- Electricity Association
- Energy Industries Council
- Engineering Equipment and Materials Users' Association
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- LP Gas Association
- Lloyd's Register of Shipping
- Power Generation Contractors Association (PGCA (BEAMA Ltd.))
- Process Plant Association
- Safety Assessment Federation Ltd.
- Society of British Gas Industries
- The Welding Institute

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- AEA Technology
- Association of Consulting Engineers
- BEAMA Ltd.
- British Cryogenics Council
- British Iron and Steel Producers' Association
- GAMBICA (BEAMA Ltd.)
- Institute of Refrigeration
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- Institution of Mechanical Engineers
- Institution of Plant Engineers
- Ministry of Defence
- Transmission and Distribution Association (BEAMA Ltd.)
- Tubes Investments Limited
- University of Liverpool
- Welding Manufacturers' Association (BEAMA Ltd.)

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Foreword

This British Standard has been prepared by Technical Committee PVE/1. It is a new edition of the 1994 version and incorporates all technical changes up to and including Amendment No. 4 (September 1996) associated with that version.

This edition has been published, for the first time, using an electronic process which has made it necessary to amend certain aspects of the table and figure numbering. The table and figure numbers are now derived from the number of the main clause in which they are cited, not from subclause or sub-subclause numbers. This will reduce the opportunity for error in future updating.

Despite the various amendments that have been made to this standard since it was first published in 1976, some of the requirements can still be traced back to the proposals in ISO/DIS 2694 *Pressure vessels* drafted by Technical Committee 11 of the International Organization for Standardization (ISO) which were taken into account in preparing the original edition.

BS 5500, which covers pressure vessels manufactured from carbon, ferritic alloy, austenitic steels, aluminium and nickel replaced the following standards:

- | | |
|---------|--|
| | <i>Fusion welded pressure vessels for general purposes</i> |
| BS 1500 | Part 1 <i>Carbon and low alloy steels</i> |
| | Part 3 <i>Aluminium</i> |
| | <i>Fusion welded pressure vessels for use in the chemical, petroleum and allied industries</i> |
| BS 1515 | Part 1 <i>Carbon and ferritic alloy steels</i> |
| | Part 2 <i>Austenitic stainless steel</i> |

Previous editions have stated the intention of integrating into one British Standard the requirements for design, manufacture, testing and inspection of fusion welded pressure vessels. It is intended to keep under review the question of publishing appropriate supplements covering other types of pressure vessels.

If there is sufficient demand from industry, the standard will be extended to cover other non-ferrous materials.

The requirements of this standard vary considerably depending upon the thickness and type of material to be used. When this combination is such as will permit satisfactory fabrication by relatively straightforward processes, spot non-destructive testing is permitted without any penalty in design thickness; in certain cases visual inspection only is permitted with an appropriate penalty on design thickness.

The strengths that may be assumed for design purposes of materials covered by current British Standards, as well as some materials to withdrawn standards which are still available, are individually specified (see table 2.3-1).

Design strengths in the creep range are given for a range of design lifetimes that may be extended, on expiry, on the basis of periodic 'fitness-for-continued-service reviews' based on inspection and consideration of actual load-temperature history. This approach recognizes the limitations inherent in any simple design method for vessels operating in the creep range and also provides a flexible basis that may be used in cases where the design strength values which have been derived from ISO data, are significantly different from those used with success in the past. Specific requirements for these reviews are not given in this standard.

Recommendations covering aspects requiring further consideration in particular cases are given in the annexes. The British Standards Institution will be pleased to receive constructive proposals based on experience or research that may lead to improvements in these annexes.

Reference is made in the text to a number of standards which have been withdrawn. Such standards are identified in the list of references (see page III). Consideration is currently being given to whether replacement standards are available or are being developed, for example, in the European programme and to the implications for BS 5500 of such replacement standards. When a decision is made about any replacement standards, these will be identified by the issue of an amendment.

As with the previous editions, it is intended to keep this standard up to date by the issue from time to time of replacement pages, or additional pages where necessary. Each replacement or added page will carry an issue number (with the effective date) indicating its relationship to the original standard, the pages of which are marked 'Issue 1'.

For example

Issue 1 will indicate an original page or one that has been added to the original standard and has not been amended since insertion;

Issue 2 will indicate a first amendment of either an original page or an added page;

Issue 3 will indicate a second amendment of either an original page or an added page.

Side-lining on replacement pages will indicate that changes of technical or reference significance have been made at that point.

It should be noted that the effective date of amendments to this edition will usually be later than the publication date to allow users time to amend their own working procedures and documentation. The issue date on each page reflects the effective date not the publication date.

The following figures are reproduced by courtesy of the American Welding Research Council.

Figure G.32 was originally published as figure 2 on page 21 of WRC Bulletin 90 September 1963

Figure G.33 was originally published as figure 3 on page 21 of WRC Bulletin 90 September 1963

Figure G.34 was originally published as figure 7 on page 24 of WRC Bulletin 90 September 1963

Figure G.35 was originally published as figure 8 on page 24 of WRC Bulletin 90 September 1963

Figure G.36 was originally published as figure 9 on page 25 of WRC Bulletin 90 September 1963

Figure G.37 was originally published as figure 10 on page 25 of WRC Bulletin 90 September 1963

Figure G.38 was originally published as figure 11 on page 26 of WRC Bulletin 90 September 1963

Figure G.39 was originally published as figure 12 on page 26 of WRC Bulletin 90 September 1963

Figures G.40 to G.47 are reproduced by courtesy of the *International Journal of Solids and Structures*, 1967.

This standard may be referred to by the UK Health and Safety Executive (HSE) when giving guidance.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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

Section 1. General

1.1 Scope

1.1.1 This British Standard specifies requirements for the design, construction, inspection, testing and verification of compliance of unfired fusion welded pressure vessels. The materials of construction are specified in section 2. The term 'pressure vessel' as used in this standard includes branches up to the point of connection to the connecting piping by bolting, screwing or welding, and supports, brackets or other attachments directly welded to the pressure containing shell. The term 'unfired' excludes vessels that are subject to direct generated heat or flame impingement from a fired process. It does not exclude vessels subject to electrical heating or heated process streams.

1.1.2 In addition to the definitive requirements this standard also requires the items detailed in 1.5 to be documented. For compliance with this standard, both the definitive requirements and the documented items have to be satisfied.

1.1.3 This standard applies only to pressure vessels manufactured under the survey of a competent engineering inspecting authority or organization. The intent of this requirement is regarded as satisfied where inspection is carried out by competent personnel of a separate engineering inspection department maintained by the purchaser of the vessel. An inspection department maintained by the manufacturer does not satisfy this requirement except:

- a) that specific responsibilities may be delegated at the discretion of the inspecting authority or organization; or
- b) in the case of vessels for the manufacturer's own use and not for resale.

This standard applies only to vessels made by manufacturers who can satisfy the inspecting authority or organization that they are competent and suitably equipped to fulfil the appropriate requirements of this standard.

The requirements for testing and inspecting serially manufactured pressure vessels are given in annex V. In all other respects the appropriate requirements in the specification apply.

Glass lined steel vessels require special design considerations subject to the limits imposed by the method of construction which should have the agreement of the inspecting authority.

1.1.4 This standard does not cover the following.

- a) Storage tanks designed for the storage of liquids at near atmospheric pressures, i.e. where the pressure additional to that due to the hydrostatic head does not exceed 140 mbar¹⁾ above or 6 mbar below atmospheric pressure in accordance with such standards as BS 799, BS 2594, BS 2654, BS 7777.

b) Low pressure, above ground storage tanks which have a single vertical axis of revolution designed for the storage of liquids at a pressure not exceeding 1 bar¹⁾.

c) Vessels in which the stresses calculated in accordance with the equations given in section 3 are less than 10 % of the design stress permitted by section 3.

d) Multilayered, autofrettaged, prestressed vessels or other special designs of vessels which may be appropriate for very high pressures.

e) Transport vessels, i.e. vessels used for transport of contents under pressure.

f) Vessels for specific applications which are covered by standards listed in the *BSI Catalogue*.

NOTE. The titles of the publications referred to in this standard are listed on the last page.

1.1.5 This standard does not address the nature or consequences of a fire in the vicinity of a pressure vessel. Any consideration of the effect of a fire hazard in the design of a pressure vessel would have to be under the direction of the plant owner or his responsible agent such as the plant architect/engineer, with analysis of the consequences of a fire adjacent to a pressure vessel being undertaken in accordance with a comprehensive specification of the fire conditions, impingement parameters, analytical methods and assessment criteria.

1.1.6 The standard addresses materials in various ways:

- a) The main text gives requirements for steels.
- b) Certain other materials are covered by supplements which identify either where the main text is applicable or where specific requirements of the supplement apply.

1.2 Interpretation

If any ambiguity be found or doubt arise as to the meaning or effect of any part of this standard or as to whether anything ought to be done or omitted to be done in order that this standard should be complied with in full, the question shall be referred to the Pressure Vessels Technical Committee (PVE/1) of the British Standards Institution, whose interpretation of the requirements of this standard upon the matter at issue shall be given free of charge and shall be final and conclusive. Parties adopting this standard for the purposes of any contract shall be deemed to adopt this provision unless they expressly exclude it or else import an arbitration provision in terms extending to interpretation of this standard. However, this provision is limited to questions of interpretation and does not confer upon the committee any power, duty or authority to adjudicate upon the contractual rights or duties of any person under a contract except in so far as they may necessarily be affected by the interpretation arrived at by the committee.

¹⁾ 1 mbar = 10² N/m² = 100 Pa.

1 bar = 10⁵ N/m² = 0.1 N/mm² = 100 kPa.

Findings or rulings of the committee upon all enquiries, including matters of interpretation, which are of sufficient importance that both enquiries and replies be made public as soon as possible will be published in an enquiry reply form for inclusion in the BS 5500 ring binder as Enquiry Cases. Their availability will be notified in *BSI News*.

After taking into account any public comment thereon, Enquiry Cases may be incorporated, as appropriate, into the standard as amendments which will form part of the next convenient annual updating.

1.3 Definitions

For the purposes of this British Standard the following definitions apply.

1.3.1 Purchaser

The organization or individual who buys the finished pressure vessel for its own use or as an agent for the owner.

1.3.2 Manufacturer

The organization that designs, constructs and tests the pressure vessel in accordance with the purchaser's order. The design function may be carried out by the purchaser or his agent, independently from the organization that constructs and tests the vessel (see 1.4.2).

1.3.3 Inspecting Authority

The body or organization that verifies that the vessel has been designed, constructed and tested in accordance with this standard.

1.3.4 Regulating Authority

The authority in the country of installation that is legally charged with the enforcement of the requirements of the law and regulations of that country relating to pressure vessels.

1.4 Responsibilities

1.4.1 Responsibilities of the purchaser

The purchaser shall be responsible for furnishing the manufacturer and the Inspecting Authority with the information required by 1.5.1.

Where the Inspecting Authority is nominated by the purchaser, the purchaser shall be responsible for ensuring that any information which the manufacturer is required to supply, as specified in this standard, is made available to the Inspecting Authority.

Where necessary, it shall be the responsibility of the purchaser to ensure that the Inspecting Authority is acceptable to the Regulating Authority.

Where the purchaser elects to perform the design function for the vessel, the purchaser shall be responsible for maintaining a complete design dossier for the vessel (see 1.5.1) and for ensuring that all the information contained in it, or agreed modifications to it, comply with this standard; the purchaser shall also be responsible for the accuracy of all design calculations for the vessel.

1.4.2 Responsibilities of the manufacturer

The manufacturer shall be responsible for the completeness and accuracy of all design calculations and for compliance with all applicable requirements of this standard for the whole vessel. During fabrication, unexpected factors may arise which justify deviations from the specified requirements but which do not affect the safety as intended by this standard. Such deviations shall be submitted to the purchaser for approval and shall be recorded in accordance with 1.5.2.2e.

Where the Inspecting Authority is not nominated by the purchaser, the manufacturer shall appoint an Inspecting Authority. The manufacturer shall be responsible for ensuring that the Inspecting Authority is provided with any information the manufacturer is required to supply, as specified in this standard.

The organization which discharges the manufacturer's responsibilities for construction and testing shall assume overall responsibility for compliance with this standard during all related activities including part manufacture and subsequent fabrication to completion at works and/or site. It shall satisfy the Inspecting Authority, as necessary, under the general provisions of 1.1 that it is competent to ensure by appropriate control or surveillance of such activities, whether carried out by itself or by subcontractors, that all the relevant requirements of this standard are met.

Examinations carried out by the Inspecting Authority do not absolve the manufacturer from his responsibility for compliance with the applicable requirements of this standard.

Where the purchaser elects to perform the design function for the vessel, the manufacturer shall be responsible for ensuring that all the design information he requires to construct and test the vessel is provided by the purchaser and for ensuring that all construction and testing is carried out in compliance with this standard. The manufacturer shall also be responsible for the accuracy of any information he provides to enable the purchaser to fulfil the design function.

1.4.3 Responsibilities of the Inspecting Authority

The Inspecting Authority shall be responsible for verifying:

- a) that all parts of the vessel have been designed in accordance with the requirements of this standard as are applicable for the conditions specified by the purchaser according to **1.5.1**;
- b) that the vessel has been constructed and tested in accordance with this standard and any additional requirements in respect of purchaser options covered by this standard (see table 1.5-1).

1.4.4 Certificate of Compliance

On completion of the vessel the manufacturer shall issue Form X to certify that the vessel has been designed, constructed and tested in every respect in accordance with this standard and with any additional requirements in respect of purchaser's options covered by this standard. Form X shall be countersigned by the Inspecting Authority as required.

Where some of the activities covered by this standard are performed under the surveillance of a second Inspecting Authority, each Inspecting Authority shall attach a statement to Form X, countersigned as required thereon, confirming which part of the total works has been carried out under its surveillance.

The countersigned Certificate and its attachments (if any) shall be furnished to the purchaser with a copy of the Regulating Authority if required.

Where the purchaser or his appointed design consultant/contractor elects to perform the design function for the vessel, the purchaser or his appointed design consultant/contractor shall complete the section of Form X which certifies that the design of the vessel complies with this standard.

NOTE. Form X may be reproduced as hard copy or by electronic means provided that such reproductions are fair copies of the original. All copies should state 'Reproduced from BS 5500' with a reference to the current issue.

Form X Certificate of Compliance

Vessel description

Type
Approx. overall dimensions
Approved drawing number(s).....
.....
.....
.....
.....

Year of manufacture..... Relevant BS 5500 edition including Amd. No(s).....
Purchaser..... Purchaser's serial no.

Manufacture

Name of manufacturer.....
Manufacturer's serial number..... (see note 1)
Name of Design Organization (if not above manufacturer)
Name of Inspecting Authority

Design

Design conditions of principal components (see notes 2 and 3)	Design pressure bar	Design temp. °C	Construction category	Corrosion allowance mm
.....				
.....				
.....				
.....				
.....				

Other factors affecting design (e.g. weight, nature of contents, environment)
(see notes 3 and 4)
.....
.....
.....
.....
.....

Post-weld heat treatment

Component	Temperature °C	Holding time h
.....		
.....		
.....		
.....		
.....		
.....		
.....		

Pressure test

Location (see note 5)	Test pressure bar	Test medium and temperature	Date
.....			
.....			
.....			
.....			

Form X (*continued*)**Certificate of Compliance (design)**

We hereby certify that the design of this vessel complies with BS 5500

Date:

For manufacturer (see note 6):

Position:

Name of company:

We hereby confirm that we have checked the design of the above vessel and that this complies with BS 5500.

Date:

For Inspecting Authority:

Position:

Name of company:

Certificate of Compliance (construction and testing)

We hereby certify that this vessel has been constructed and tested in compliance with BS 5500.

Date:

For manufacturer:

Position:

Name of company:

We hereby confirm that the construction and testing of the above vessel has been carried out under our surveillance and that to the best of our knowledge and belief all aspects of this work comply with BS 5500.

Date:

For Inspecting Authority:

Position:

Name of company:

We hereby confirm that the construction and testing of the above vessel has been carried out under our surveillance and that to the best of our knowledge and belief all aspects of this work comply with BS 5500.

NOTE 1. The suffix 'XX' is to be added to the serial number of each vessel for which any deviations or concessions have been authorized (see 1.5.2.2e).

NOTE 2. The design conditions associated with the operational duties specified by the purchaser should be given.

If a purchaser wishes to change the operational duty of a vessel, revised design conditions, consistent with the vessel scantlings, will be established separately, as appropriate.

NOTE 3. Where the design covers operation below 0 °C the various combinations of temperature, pressure and calculated membrane stresses considered in determining the design minimum temperature (see annex D) should be stated.

NOTE 4. Where appropriate, cross reference to drawings or specifications will suffice.

NOTE 5. Where a vessel is tested in a different orientation to that in which it will normally operate, this should be stated.

NOTE 6. This part of the Certificate to be signed by the purchaser in cases where the purchaser elects to perform the design function (see 1.4.4).

1.5 Information and requirements to be agreed and to be documented

1.5.1 Information to be supplied by the purchaser

The following information shall be supplied by the purchaser and shall be fully documented.

Both the definitive requirements specified throughout the standard and the documented items shall be satisfied before a claim of compliance with the standard can be made and verified.

- a) The normal working conditions of the required vessel, together with details of any transient cyclic and/or adverse conditions in which the vessel is required to operate and any special requirements for in-service inspection.
- b) Any requirements relating to the various options covered by this standard (see table 1.5-1).
- c) Any special statutory or other regulations with which the finished vessel is required to comply.
- d) The name of the Inspecting Authority to be commissioned by the purchaser.
- e) The name of the Regulating Authority (if any).
- f) The requirement to obtain copies for record purposes of any documents other than those listed in 1.5.2.2a to g (see table 1.5-1). (To facilitate the identification of such documents, a check list of optional documents is given in annex S.)

Where the purchaser elects to perform the design function for the vessel, the purchaser shall supply any additional design information required by the manufacturer in accordance with 1.4.2. The design dossier maintained by the purchaser in accordance with 1.4.1 shall cover all the information (whether supplied by the purchaser or by the manufacturer) which the manufacturer would otherwise be required by 4.1.1 to submit before commencing manufacture.

1.5.2 Information to be supplied by the manufacturer

The information in 1.5.2.1 and 1.5.2.2 shall be supplied by the manufacturer and shall be fully documented.

Both the definitive requirements specified throughout the standard and the documented items shall be satisfied before a claim of compliance with the standard can be made and verified.

1.5.2.1 Before commencement of manufacture

The manufacturer shall submit the information specified in 4.1.1 for approval before commencement of manufacture. In submitting this information, the manufacturer shall identify, in an appropriate manner, any features of the proposed design and/or in the proposed manufacturing, inspection or test procedures which by the terms of this standard require to be approved by the purchaser.

NOTE. Table 1.5-1 lists and classifies such features. The features should be identified in an appropriate document such as purchase order, approved drawing or an approved working procedure (e.g. weld preparation procedure, heat treatment procedure, welding procedure etc.).

1.5.2.2 On completion of construction

The manufacturer shall supply to the purchaser for record purposes a copy of the following documentation, as finally approved, for each vessel or batch of vessels.

- a) A fully dimensioned drawing of the vessel, as built, together with any relevant supporting information as specified in 4.1.1 and which is not covered by items b to g.
- b) A list of materials (including welding consumables) used in the construction of the vessel with details of any special heat treatments carried out by the material supplier.
- c) The welding procedures used during vessel manufacture (see 5.2.2).
- d) The procedures used for radiography, ultrasonic inspection and/or crack detection of welds (see 5.6.6.1 to 5.6.6.4).
- e) Records of any specific deviations from the requirements of this standard (see table 1.5-1). The manufacturer shall add the suffix 'XX' to the serial number of any vessel for which a specific deviation has been approved.
- f) A Certificate of Compliance (Form X) for each vessel (see 1.4.4).
- g) A facsimile of the vessel nameplate (see 5.8.9).

NOTE. The duration for which a manufacturer will retain all records he is required to generate during the manufacture of a vessel is influenced by a number of factors which are outside the scope of this standard.

Table 1.5-1 Purchaser options and features requiring approval by the purchaser
(see 1.5.1, 1.5.2)

Purchaser option or feature requiring approval by purchaser	Classification (see 1.5.2.e)
Requirements for additional records; documentation additional to that specified in 1.5.2 (1.5.1)	Purchaser option
Any special requirements governing the selection, heat treatment or testing of materials (2.1.1, 2.3.2.8, 3.4.2, 5.6.2)	Purchaser option
Use of castings and appropriate inspection procedure (2.1.2)	Variation
Use of materials other than those covered by listed British Standards (2.1.2.3)	Variation
Design strength values for materials qualified by notes b, 1 d, f, 8, 17 to tables 2.3-1 to 2.3-12	Basic requirements
Use of increased design stresses for certain alloy steels as per note 6 to tables 2.3-1 to 2.3-12	Purchaser option/variation
Use of steels with carbon content greater than 0.25 % (2.3.2)	Variation
Heat treatment of non-BS materials (2.3.2)	Basic requirement
Use of design methods other than detailed in section 3 (3.2.2, 3.5.4, 3.8.1, 3.9)	Variation
Any relaxation of the design pressure for protected vacuum vessels (3.2.3)	Purchaser option/variation
The design lifetime for high temperature applications (3.2.4)	Basic requirement
The service lifetime for applications where fatigue strength is a potential life-limiting factor (3.2.4)	Basic requirement
The provisions for corrosion (3.3)	Basic requirement
Contained media giving rise to stress corrosion cracking and whether associated post-weld heat treatment is required (3.3.1)	Basic requirement
The construction category for vessel or component parts (3.4.1)	Basic requirement
Properties of alloy steels used for design purposes when post-weld heat treatment exceeds time and temperature limits given in table 4.4-1 (3.4.2)	Basic requirement
Design of nozzles and openings not covered in 3.5.4.2 (3.5.4.1)	Variation
Design of reinforcing pads outside criteria (3.5.4.5.1)	Variation
Use of bolt stresses in excess of values given in table 3.8-1 (3.8.1)	Variation
Use of plate material for flanged hubs (3.8.1)	Variation
Special requirements for leak tightness of flanges (3.8.1)	Purchaser option
Design of tubesheets outside limits specified in 3.9	Variation
Design of tubesheets with simultaneous shell and tubesheet-pressures (3.9.4.3.4)	Variation
Commencement of manufacture before approval of all information specified in 4.1.1	Variation
Any modifications to information supplied in accordance with 4.1.1	Formal revision of original documentation
Relaxation of amount of dressing on thermally cut edges of ferritic alloy steel and aluminium (4.2.1 and 4.2.1 of the Aluminium Supplement)	Variation
Supplementary non-destructive testing of cut edges and rectification of defects (4.2.1)	Purchaser option/variation
Procedures for forming and inspection of shell sections and plates (4.2.2 and 4.2.2 of the Aluminium Supplement)	Basic requirement

Table 1.5-1 Purchaser options and features requiring approval by the purchaser (see 1.5.1, 1.5.2) <i>(continued)</i>	
Purchaser option or feature requiring approval by purchaser	Classification (see 1.5.2.2e)
Assembly tolerances for thicknesses > 200 mm (4.2.3)	Basic requirement
Departures from specified tolerances on circumference of ends, circumference, straightness and circularity of shells (4.2.4)	Variation
Supplementary structural tolerance requirements (4.2.5)	Purchaser option
Commencement of production welding prior to approval of welding procedures, welders, welding operators (4.3.1); or assembly of category 3 components (4.3.1)	Variation
Use of welding consumables other than those used in the welding procedure test (4.3.2 and 4.3.2 of the Aluminium Supplement)	Variation
Consumables used in the welding of 9 % Ni steel (4.3.2)	Basic requirement
Preparation of aluminium plate edges (4.3.3 of the Aluminium Supplement)	Variation
Use of attachments of different nominal composition to shell (4.3.5)	Variation
Use of backing strips for welds (4.3.6 and 4.3.6 of the Aluminium Supplement)	Variation
Thinning of welds by dressing or grinding to less than thickness shown on drawings (4.3.7)	Specific deviation
Use of single layer welds for attachment of branch pipes in aluminium vessels (see 4.3.7 of aluminium supplement)	Variation
Approval of welding procedure (preheat requirements) (4.4.1)	Variation
Modified post-weld heat treatment procedures (4.4.3, 4.4.4, 4.4.5)	Variation
Welding carried out after final post-weld heat treatment (4.4.3)	Specific deviation
Post-weld heat treatment of aluminium (4.4.3 of the Aluminium Supplement)	Basic requirement
Requirements for special finish (4.5)	Purchaser option
Criteria for welding procedure tests (all weld tensile) (5.2.5)	Basic requirement
Welder to retake whole or part of approval test (5.3.3)	Purchaser option
Production test plate requirements (5.4 and 5.4 of the Aluminium Supplement)	Purchaser option
Production control testing of 9 % Ni (5.4.2)	Basic requirement
Reduction in width of standard production test plates for aluminium (5.4.2 of the Aluminium Supplement)	Variation
Details of procedure, welder and production control testing of aluminium (5.5 of the Aluminium Supplement)	Purchaser option
Necessity of micro-examination of welds in aluminium (5.5)	Purchaser option
Comprehensive schedule covering non-destructive testing requirements (5.6.1)	Purchaser option
Acceptance standards for defects revealed by non-destructive testing in parent material (5.6.2 and 5.6.2 of the Aluminium Supplement)	Basic requirement
Non-destructive testing techniques for examination of authorized repairs to parent materials (5.6.2)	Basic requirement
Any relaxation in requirements for ultrasonic/radiographic non-destructive testing of welds, other than full penetration butt welds, in category 1 components (5.6.4 and 5.6.4 of the Aluminium Supplement)	Variation

Table 1.5-1 Purchaser options and features requiring approval by the purchaser
(see 1.5.1, 1.5.2) *(continued)*

Purchaser option or feature requiring approval by purchaser	Classification (see 1.5.2.2e)
Use of magnetic particle or penetrant methods for examination of Type A welds in category 1 components and categories 1 and 2 in case of aluminium vessels (5.6.4 and 5.6.4 of the Aluminium Supplement)	Purchaser option/variation
Grouping of nozzles and branches for examination of internal flaws (5.6.4)	Basic requirement
Use of magnetic particle or penetrant methods for examination of category 3 components (5.6.4)	Purchaser option/variation
Repair of aluminium welds (5.6.4 of the Aluminium Supplement)	Basic requirement
Choice of non-destructive testing technique (5.6.5, 5.6.6)	Basic requirement
Method used to provide reference points for accurate location of non-destructive testing reports (5.6.6 and 5.6.6 of the Aluminium Supplement)	Basic requirement
Acceptance criteria for non-main construction weld (5.7.1 and 5.7.1 of the Aluminium Supplement)	Basic requirement
Weld defect acceptance criteria different to those in table 5.7-1	Purchaser option/concession
Acceptance of specific welds with defects in excess of levels specified in table 5.7-1	Specific deviation
Repair of welds (5.7.3)	Basic requirement
Options permitted in pressure tests specified in 5.8 and 5.8 of the Aluminium Supplement	Basic requirement
Agreement to waive repeat test on vessel repaired after pressure test (5.8.2)	Specific deviation

1.6 Thicknesses

Thicknesses are referred to in several ways in this standard in accordance with the following definitions.

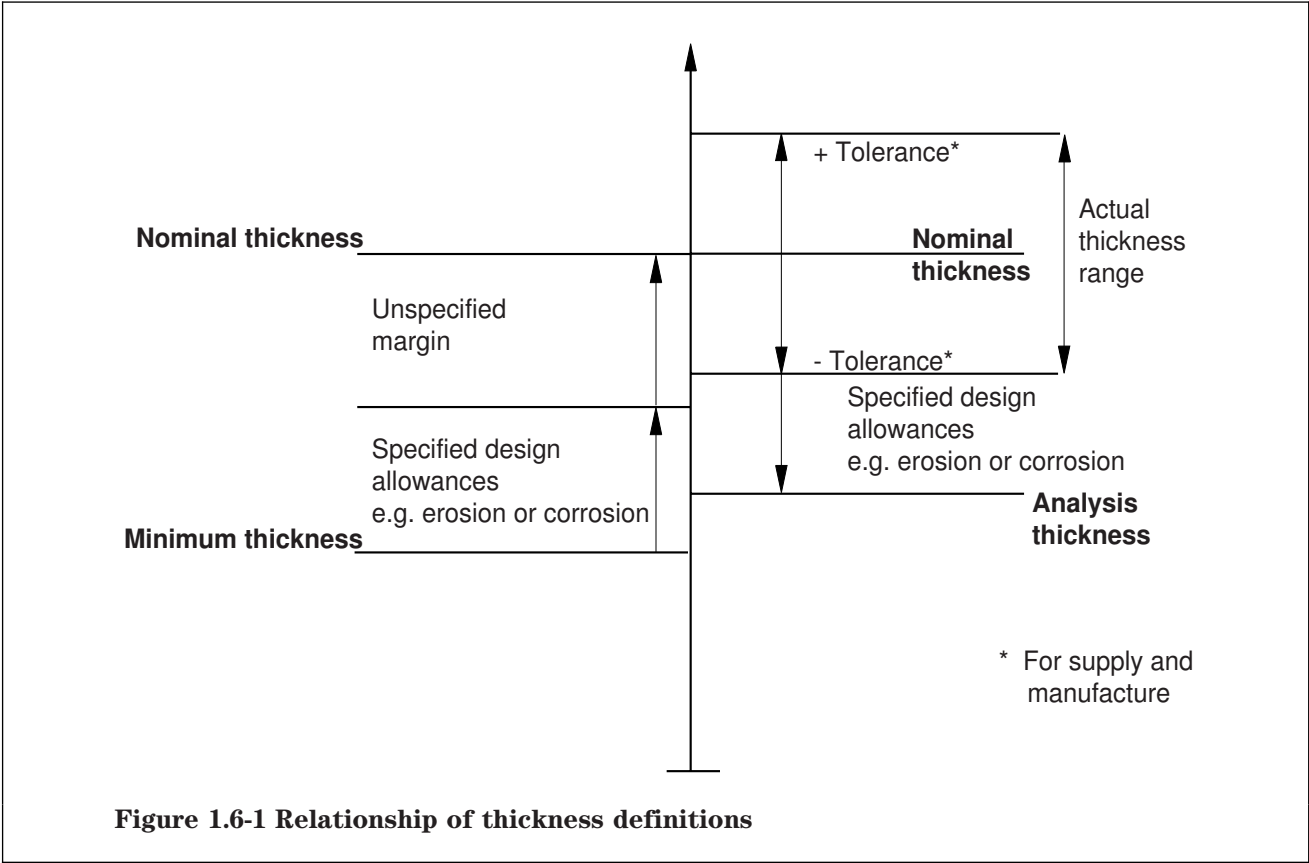
- a) Minimum thickness; the thickness calculated in section 3 and some design annexes, to satisfy the relevant design requirement.
- b) Nominal thickness; the thickness as specified on the construction drawing which includes all allowances and tolerances.
- c) Analysis thickness; the thickness used in design calculations and assessments, which equals the nominal thickness less corrosion allowances and less any other allowances and tolerances.

The nominal thickness, less any negative tolerance permitted by the specification to which the material is ordered, shall not be less than the minimum thickness plus any allowances specified for corrosion, erosion etc.

The relationships between the defined thicknesses are shown in Figure 1.6-1. This figure indicates:

- a) on the left hand side, that the thickness calculated from the rules is increased by the amount of the specified allowances (for effects such as corrosion) and possibly by an unspecified margin (in consideration, for example, of materials availability);
- b) on the right hand side, that the nominal thickness should be reduced by any negative supply (i.e. negative plate thickness) tolerance and any manufacturing (i.e. dishing) allowances as well as by the specified design allowances, to arrive at the analysis thickness.

NOTE. Following the replacement of BS 1501 by BS EN 10028, it should be noted that plate conforming to this latter specification is normally supplied in accordance with BS EN 10029 class B which permits a negative tolerance of 0.3 mm for all nominal thicknesses. However, the purchaser may specify a zero negative tolerance.



Section 2. Materials

2.1 Selection of materials

2.1.1 General

2.1.1.1 The selection of the materials of construction for pressure containing parts and their integral attachments shall take into account the suitability of the material with regard to fabrication²⁾ and to the conditions under which they will eventually operate.

2.1.1.2 Any special limits, for example with respect to composition, heat treatment, or non-destructive testing, which the manufacturer or the purchaser is permitted to specify in relation to the particular end use of material, shall be the subject of agreement between the purchaser and the manufacturer at the time of enquiry and order (see table 1.5-1).

2.1.1.3 For the ease of reference throughout this standard, ferritic materials, with the exception of the following, have been grouped into 'M' bands as summarized in table 2.1-1

- 1½Ni;
- martensitic stainless steel;
- ferritic stainless steel;
- austenitic stainless steel;
- clad material;
- duplex austenitic-ferritic stainless steel;
- quenched and tempered fine grain steel.

Table 2.1-1 Material banding	
Band	Type
M0	Carbon and carbon manganese steel
M1	
M2	Carbon molybdenum steel
M4	Low alloy manganese chromium molybdenum vanadium steel
M5	3½Ni
M6	9Ni
M7	1 to 1½Cr ½Mo
M8	½Cr½Mo¼V
M9	2¼Cr1Mo
M10	5Cr½Mo
M11	9Cr1Mo
M12	12Cr1Mo1V

2.1.2 Materials for pressure parts

2.1.2.1 All the materials used in the manufacture of pressure parts shall either:

- a) comply with the appropriate British Standard referred to in the design strength tables of this standard, except as otherwise permitted by this section; or
 - b) be agreed between the purchaser and the manufacturer (see table 1.5-1) provided that:
 - i) they comply with **2.3.2** and are covered by a written specification:
 - i) at least as comprehensive as the British Standards listed in the design strength tables of this standard for the nearest equivalent material; and
 - ii) as a minimum specifying the manufacturing process, compositional limits for all constituents, deoxidation practice, heat treatment and appropriate mechanical properties for acceptance and other purposes;
 - 2) the nominal design strength of materials for time independent stresses shall be derived in accordance with the principles of **K.3**. The nominal design strength of materials for time dependent stresses shall be derived in accordance with the principles of **K.4**.
- Consideration of whether time dependent stresses are applicable shall be given when the design temperature exceeds the values given in table 2.1-2.
- 3) the details of the procedure used for determination of the nominal design strength used are agreed between the purchaser and the manufacturer and are recorded.
 - 4) An equivalent 'M' band for the material is chosen and agreed between manufacturer, inspection authority and purchaser. This 'M' banding shall be used to assist in the selection of manufacturing and inspection requirements of sections 4 and 5 (see **2.1.1.3**).

²⁾See annex G of BS 5135 : 1984 for general guidance on the susceptibility of materials to lamellar tearing during fabrication.

Table 2.1-2 Temperature above which time dependent properties shall be considered

M band	Material type	Temperature °C
M0 & M1	Carbon and carbon manganese steel	400
M2	Carbon molybdenum steel	
M5	3½Ni	
M6	9Ni	
M4	Low alloy Mn, Cr, Mo, V	470
M7	1Cr ½Mo	
M8	½Cr½Mo¼V	490
M12	12Cr 1Mo V	
M9	2¼Cr 1Mo where $R_e \leq 350 \text{ N/mm}^2$	460
M10	5Cr ½Mo	
M11	9Cr 1Mo	
M9	2¼Cr 1Mo where $R_e > 350 \text{ N/mm}^2$	350
	Stainless steels	
	Type 321 and Type 347	540
	Type 304 and Type 316	560

NOTE. Where the vessel is subject to fatigue, C.1.3 limits the applicability of annex C up to 350 °C for ferritic steels and 430 °C for austenitic stainless steels.

2.1.2.2 Welding material shall comply with sections 4 and 5.

2.1.2.3 The use of castings for pressure parts shall be subject to agreement between the purchaser and the manufacturer (see table 1.5-1). An appropriate 'quality specification' for such castings shall be agreed between the manufacturer and the material supplier at the time of enquiry, specifying the standards of inspection to be applied and of acceptance for defects. As a minimum, all accessible fillets and changes of section, etc., shall be subject to magnetic particle or penetrant inspection.

2.1.2.4 Bolts and nuts shall comply with the material specifications listed in tables 3 and 4 of BS 4882 : 1973 or table 3 of BS 1473 : 1972.

2.1.3 Materials for non-pressure parts

Materials for supporting lugs, skirts, baffles and similar non-pressure parts welded to vessels shall be of established identity and shall be compatible with the material to which they are attached.

2.2 Materials for low temperature applications

2.2.1 Special consideration shall be given to the selection of materials for vessels designed to operate below 0 °C or, where it is considered by the purchaser or manufacturer that there would otherwise be undue risk of brittle fracture in pressure testing a vessel at the temperature of the available test fluid.

2.2.2 Table 2.2-1 specifies bolting material suitable for use at low temperature and the minimum design temperature for each material.

2.2.3 The impact requirements for ferritic steels in band M0 to M4 inclusive used for vessels designed to operate below 0 °C shall be in accordance with annex D.

Annex D shall also be used as specified in 5.8.2.4 when it is agreed by the purchaser and manufacturer to carry out the final pressure test of a vessel at a temperature higher than that of the available test fluid.

2.2.4 Requirements for the use of ferritic steels in bands M5 (3½ % Ni) and M7 to M10 inclusive, used for such vessels, shall be agreed between the purchaser and manufacturer.

2.2.5 The impact requirements for ferritic steels in band M6 (9 % Ni) used for vessels designed to operate below 0 °C shall be in accordance with the British Standards listed in table 2.3-1 for M6 steels.

2.2.6 Austenitic stainless steels (including the high nitrogen and warm worked varieties) are not susceptible to low stress brittle fracture and no special requirements are necessary for their use at temperatures down to -196 °C.

2.2.7 Aluminium and aluminium alloys are not susceptible to low stress brittle fracture and no special requirements are necessary for their use at temperatures down to -196 °C.

Table 2.2-1 Bolting materials for low-temperature

Material/bolting specification	Material specification	Bolting grade	Application	Impact requirements ¹⁾	Minimum design temperature °C
Carbon steel bolting in accordance with BS 1768, BS 1769, BS EN 20898-1 or BS EN 20898-2	BS 3111 grade 0/3 BS 3111 grade 1/3 BS 3111 grade 10/2 BS 970 grade 070M20 BS 970 grade 080M40	B or 4.8 P or 6.8 P or 6.8 B or 4.8 P or 6.8	Nuts and bolts	Not required for BS 1769. At room temperature for BS 1768 and BS EN 2089	−30
Low alloy steel bolting in accordance with BS 1768 or BS EN 20898-1 or BS EN 20898-2	BS 1506 grade 630 BS 970 grade 135M44 BS 970 grade 708M40	6.8/8.8 S or 8.8 S or 8.8	Nuts and bolts	At room temperature	−50
Low alloy steel bolting in accordance with BS 4882	BS 1506 grade 162	2H/2HM	Nuts	Not required ²⁾	−50
	BS 1506 grade 253	4/4M		At −100 °C	−100
	BS 1506 grade 253	L/4	Nuts and bolts	At room temperature	−50
	BS 1506 grade 630	B7/B7M			
	BS 1506 grade 631	B7A			
	BS 1506 grade 670	B16			
	BS 1506 grade 681	B16A	Nuts and bolts	At −100 °C	−100
	BS 1506 grade 671	B16B			
9 % nickel steel bolting in accordance with BS 4882	BS 1506 grade 630	L7/L7M	Nuts and bolts	At −100 °C	−100
	BS 1506 grade 509-650 BS 1506 grade 509-690	L9 L9A	Nuts and bolts	At −196 °C	−196
Austenitic stainless steel bolting in accordance with BS 4882	BS 1506 grade 304-S31, S51, S61, S71	B8+	Nuts and bolts	Not required ²⁾	−196
	BS 1506 grade 316-S31, S33, S51, S53, S61, S63, S65, S67	B8M+			
	BS 1506 grade 321-S31, S51	B8T+			
	BS 1506 grade 304-S31, S61, S71	L8+		At −196 °C	−250
	BS 1506 grade 316-S31, S33, S61, S63, S65, S67	L8M+			
	BS 1506 grade 321-S31	L8T			
	BS 1506 grade 347-S31	L8C			
Precipitation hardening alloys in accordance with BS 4882	BS 1506 grade 286-S31 BS 3076 grade NA20	L17B+ L80A	Nuts and bolts	At −196 °C	−196

¹⁾Impact energy values shall be as material/bolting specification at the temperature indicated.

²⁾‘Not required’ indicates that the material may be used, without impact testing, down to the minimum design temperature given in column 6.

2.3 Carbon, carbon manganese and alloy steels

2.3.1 Materials covered by British Standards

2.3.1.1 Permissible materials complying with appropriate British Standards shall be as given in table 2.3-1³⁾.

Hot testing to confirm the properties of material supplied shall not be required for materials listed in table 2.3-1.

Additionally, it is permissible to use materials complying with British Standards listed in table 2.3-13 for the construction of only category 3 components provided the qualifying requirements indicated in table 2.3-13 are satisfied.

Non-destructive testing requirements shall be as specified in 5.6.2.

Where relevant, the restrictions in 2.3.2.2 shall apply.

2.3.1.2 Nominal design strength values for materials complying with appropriate British Standards shall be as given in tables 2.3-2 to 2.3-13.

These values are for design purposes as specified in the relevant sections of this standard only and shall not be used as a basis for acceptance or rejection of material.

NOTE.1. Their derivation is described in annex K.

NOTE 2. Values between those given in the various columns of the table may be linearly interpolated.

Table 2.3-1 Design strength values: index of steels

	Standard	Table number
Steel plates	BS 1501 : Part 1	2.3-2
	BS 1501 : Part 2	2.3-3
	BS 1501 : Part 3	2.3-4
Steel sections and bars	BS 1502	2.3-5
Steel forgings	BS 1503	2.3-6
Steel castings	BS 1504	2.3-7
Steel pipes and tubes	BS 3059 : Parts 1 and 2	2.3-8
	BS 3601, BS 3602 : Parts 1 and 2	2.3-9
	BS 3603	2.3-9
	BS 3604 : Parts 1 and 2	2.3-10
	BS 3605 : Parts 1 and 2	2.3-11
	BS 3606	2.3-12

2.3.2 Materials not covered by British Standards

2.3.2.1 Other materials as specified in 2.1.2.1b shall comply with the general requirements of 2.3.2.2 to 2.3.2.11.

2.3.2.2 The maximum allowable phosphorus and sulfur content shall not exceed 0.05 % each in the ladle analysis.

For ferritic steels intended for welding, the upper limit of the carbon range (in the ladle analysis) should not normally exceed 0.25 %, but in the cases of such steels with a carbon content higher than 0.25 % intended for welding, they shall only be used subject to special agreement on welding procedures between the purchaser, the manufacturer and the Inspecting Authority (see table 1.5-1).

2.3.2.3 The deoxidation practice shall be appropriate to the type of steel ordered particularly where it influences the level of elevated or low temperature properties. It is permissible to use semi-killed steel in accordance with this standard for plates, seamless and welded tubes in carbon and carbon manganese steels with an upper limit of the specified tensile strength range of 640 N/mm² and with a thickness not exceeding 100 mm. Rimming steel shall only be used for welded tubes in carbon and carbon manganese steel types with an upper limit of the specified tensile strength range of 490 N/mm² under service temperature conditions between 0 °C and 380 °C.

2.3.2.4 Mechanical properties at room temperature shall be specified for acceptance tests in accordance with BS EN 10002-1⁴⁾ covering R_m , R_e (see annex K) and minimum elongation at fracture.

The specified minimum percentage elongation at fracture referred to a gauge length of $5.65 \sqrt{S_0}$ ⁵⁾ shall be appropriate to the type of steel with a lower limit of 16 % for plates, 15 % for castings and 14 % for tubes and forgings, unless the use of the steel is subject to special agreement (see 2.1.1.2).

The rate of testing and methods of acceptance testing shall generally be consistent with appropriate British Standards for similar product forms.

2.3.2.5 For materials that will be used above 50 °C, a yield point or proof stress properties shall be specified by the manufacturer for acceptance tests in accordance with BS EN 10002-5⁴⁾.

2.3.2.6 Stress rupture properties shall be specified for materials which will be used in the creep range. These shall be determined in accordance with the procedure laid down in ISO 6303⁴⁾. The manufacturer of the vessel shall be assured that the product supplied is

³⁾In certain applications higher design strengths than those specified in tables 2.3-4 to 2.3-12 for common grades of stainless steel are permitted (see annex P).

⁴⁾Acceptance of properties obtained by other recognized test methods (e.g. other national standards) shall be subject to agreement between the purchaser, manufacturer and inspection authority.

⁵⁾ S_0 is the original cross-sectional area of the gauge length of the tensile test specimen.

capable of complying with the specified properties by a statement that the manufacturing processes have remained equivalent to those for the steel for which the test results were obtained.

2.3.2.7 Charpy V-notch impact test properties at appropriate temperatures shall, where necessary, comply with **2.2.3** to **2.2.5**.

2.3.2.8 Materials shall be supplied in a heat treated condition appropriate to the nearest equivalent British Standard unless otherwise agreed between the purchaser, the manufacturer and the material supplier (see table 1.5-1).

NOTE 1. Plates for hot forming may be supplied in any suitable condition as agreed between the manufacturer and the material supplier.

NOTE 2. Normalized properties of non-BS materials may be achieved by the rolling process where this is agreed between the purchaser, manufacturer and material supplier. The properties of the normalized rolled plates should be demonstrated to be similar to the nearest equivalent BS normalized material.

2.3.2.9 Carbon and carbon manganese steel plates for cold forming shall be supplied in the normalized condition except when their thickness is less than 25 mm, when it is permissible to supply plates as-rolled if guaranteed elevated temperature properties are not required.

Low alloy steel plates for cold forming shall be supplied in the normalized and tempered condition except that, where metallurgically suitable and where post-weld heat treatment will suffice as the tempering treatment, plates supplied in the normalized condition shall be permitted.

2.3.2.10 It is permissible to use electric resistance welded or induction welded tubes in the as-welded condition provided the specified upper limit of tensile strength does not exceed 540 N/mm² and they are not intended for service below a temperature of 0 °C.

2.3.2.11 The heat treatment condition to which the specified properties relate shall be clearly stated in the material specifications. These properties can be affected by reheating during fabrication and, where necessary (see **3.4.2** or **4.4**), the manufacturer shall discuss the application and proposed heating or reheating of the steel with the material supplier. However, the test plates shall be supplied and tested in a condition corresponding to the material specification specifically requested by the manufacturer. The heat treatment to be given to the test pieces and the acceptance properties shall be agreed between the manufacturer and the material supplier at the time of order.

Table 2.3-2 Design strength values (N/mm²)

Table 2.2-2 Design strength values (N/mm ²) Plates																							
Grade, type and method of manufacture	R _m N/mm ²	R _e N/mm ²	BS 5500 band	Thickness mm	Values of f for design temperatures (°C) not exceeding																Design lifetime h	Notes	
					50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470			480
Carbon steel (rimmed) to BS 1501 : Part 1																							
141, 360A	360	205	M 0	3 to 16*	137	126	115	112	100	86	79												9, 16, 18
		195		19*	130	122	113	108															
Carbon steel (semi-killed with aluminium) to BS 1501 : Part 1																							
154, 360A	360	205	M 1	3 to 9.5	137	126	115	112	100	86	79												9
154, 400A	400	235	M 1	3 to 9.5	156	144	133	130	116	97	91												
154, 430A	430	250	M 1	3 to 9.5	167	157	148	143	128	107	102												
Carbon steel (semi-killed or fully-killed) to BS 1501 : Part 1																							
151, 161, 360 (A and B)	360	205	M 1	3 to 16*	137	126	115	112	100	86	81	78	77	76	69	60	52	44	36	100 000	9, 16		
		195		40*	130	119	113	108	96													150 000	
		185		63*	123	114	105	101	95													200 000	
		175		100*	117	108	99	96	91													250 000	
		170		150*	113	105	96	93	88														
151, 161, 400 (A and B)	400	225	M 1	3 to 16*	150	141	133	130	117	97	92	89	88	87	79	69	60	52	44	36	100 000	9, 16	
		215		40*	143	135	128	123	110												150 000		
		205		63*	137	129	121	117	108												200 000		
		200		100*	133	123	113	111	105												250 000		
		195		150*	130	119	110	108	102														
151, 161, 430 (A and B)	430	250	M 1	3 to 16*	167	157	148	143	128	107	102	99	98	88	79	69	60	52	44	36	100 000	9, 16	
		240		40*	160	150	140	135	121												150 000		
		230		63*	153	143	133	128	119												200 000		
		220		100*	147	135	124	121	115												250 000		
		210		150*	140	129	118	115	110														

Table 2.3-2 Design strength values (N/mm²) (continued)**Plates**

Grade, type and method of manufacture	R_m	R_e	BS 5500 band	Thickness mm	Values of f for design temperatures (°C) not exceeding																		Design lifetime h	Notes		
	N/mm ²	N/mm ²			50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470	480					
Carbon steel (fully-killed aluminium treated) to BS 1501 : Part 1																										
164, 360A	360	255	M 1	3 to 16*	153	138	124	110	97	86	79		73	73	72	71	69	60	52	44	36	100 000	9, 16			
		235			40*	153	137	122								109	71	65	56	48	40	32		150 000		
		220			63*	147	130	115								106	71	62	53	45	37	28		200 000		
		202			100*	135	122	110								104	68	59	51	42	35	26		250 000		
		180			150*	120	112	105								102										
164, 360B	360	255	M 1	3 to 16*	153	145	137	122	107	95	87		83	82	81	79	69	60	52	44	36	100 000	9, 16			
		235			40*	153	143	134								121	81	74	65	56	48	40		32	150 000	
		220			63*	147	137	127								117	80	71	62	53	45	37		28	200 000	
		202			100*	135	129	122								115	78	68	59	51	42	35		26	250 000	
		180			150*	120	118	117								112										
164, 400A	400	275	M 1	3 to 16*	170	155	140	125	111	98	91		86	85	84	79	69	60	52	44	36	100 000	9, 16			
		265			40*	170	154	138								125	83	74	65	56	48	40		32	150 000	
		245			63*	163	147	131								122	80	71	62	53	45	37		28	200 000	
		225			100*	150	138	126								120	78	68	59	51	42	35		26	250 000	
		201			150*	134	127	121								117										
164, 400B	400	275	M 1	3 to 16*	170	161	153	137	121	108	101		95	94	88	79	69	60	52	44	36	100 000	9, 16			
		265			40*	170	160	149								135	93	83	74	65	56	48		40	32	150 000
		245			63*	163	152	144								133	90	80	71	62	53	45		37	28	200 000
		225			100*	150	143	138								130	87	78	68	59	51	42		35	26	250 000
		201			150*	134	132	132								128										
Carbon manganese steel (fully-killed niobium treated) to BS 1501 : Part 1																										
223, 460A	460	340	M 1	3 to 16*	195	182	169	155	143	130	124	117	115	114	105	90	77	65	56	48	42	100 000	9, 16			
		330			40*	195									182	115	111	95	81	68	58	50		43	38	150 000
		320			63*	195									182	115	104	88	75	63	54	46		40	34	200 000
		294			100*	195									182	115	98	83	70	59	51	43		37	32	250 000
		262			150*	175									172											

Table 2.3-2 Design strength values (N/mm²) (continued)

Plates																									
Grade, type and method of manufacture	R_m	R_e	BS 5500 band	Thickness	Values of f for design temperatures (°C) not exceeding																			Design lifetime	Notes
	N/mm ²	N/mm ²			mm	50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470	480	h		
Carbon manganese steel (fully-killed niobium treated) to BS 1501 : Part 1																									
223, 460B	460	340	M 1	3 to 16*	195	187	179	173	158	139	131	125	124	121	105	90	77	65	56	48	42	100 000	9, 16		
		330			195	187	179						124	111	95	81	68	58	50	43	38	150 000			
		320			195	187	179						121	104	88	75	63	54	46	40	34	200 000			
		294			195	187	179						115	98	83	70	59	51	43	37	32	250 000			
		262			175	175	175																		
223, 490A	490	355	M 1	3 to 16*	208	193	179	173	158	139	131	125	124	121	105	90	77	65	56	48	42	100 000	9, 16		
		345			208	193	179						124	111	95	81	68	58	50	43	38	150 000			
		340			208	193	179						121	104	88	75	63	54	45	40	34	200 000			
		313			208	193	179						115	98	83	70	59	51	43	37	32	250 000			
		279			186	180	175																		
223, 490B	490	355	M 1	3 to 16*	208	198	189	184	168	147	137	133	132	121	105	90	77	65	56	48	42	100 000	9, 16		
		345			208	198	189						128	111	95	81	68	58	50	43	38	150 000			
		340			208	198	189						121	104	88	75	63	54	46	40	34	200 000			
		313			208	198	189						115	98	83	70	59	51	43	37	32	250 000			
		279			186	186	186																		
Carbon manganese steel (fully-killed aluminium treated) to BS 1501 : Part 1																									
224, 400A	400	275	M 1	3 to 16*	170	155	140	125	111	98	91	86	85	84	83	77	65	56	48	42	100 000	9, 16			
		265			170	154	138	125						84	81	68	58	50	43	38	150 000				
		245			163	147	131	122						84	75	63	54	46	40	34	200 000				
		225			150	138	126	120						83	70	59	51	43	37	32	250 000				
		201			134	127	121	117																	
224, 400B	400	275	M 1	3 to 16*	170	161	153	137	121	108	101	95	94	93	90	77	65	56	48	42	100 000	9, 16			
		265			170	161	149	135						93	81	68	58	50	43	38	150 000				
		245			163	154	144	133						88	75	63	54	46	40	34	200 000				
		225			150	144	138	130						83	70	59	51	43	37	32	250 000				
		201			134	133	132	128																	

Table 2.3-2 Design strength values (N/mm²) (*continued*)**Plates**

Grade, type and method of manufacture	R_m	R_e	BS 5500 band	Thickness mm	Values of f for design temperatures (°C) not exceeding																		Design lifetime h	Notes		
	N/mm ²	N/mm ²			50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470	480					
Carbon manganese steel (fully-killed aluminium treated) to BS 1501 : Part 1																										
224, 430A	430	305	M 1	3 to 16*	183	168	153	137	121	108	101	95	94	93	90	77	65	56	48	42	100 000	9, 16				
		285			40*	183	166	149							135	93	81	68	58	50	43		38	150 000		
		275			63*	183	164	144							133	88	75	63	54	46	40		34	200 000		
		253			100*	168	153	138							130	83	70	59	51	43	37		32	250 000		
		225			150*	150	141	132							128											
224, 430B	430	305	M 1	3 to 16*	183	174	165	149	132	117	111	105	104	103	90	77	65	56	48	42	100 000	9, 16				
		285			40*	183	172	161						147	104	95	81	68	58	50	43		38	150 000		
		275			63*	183	170	157						145	104	88	75	63	54	46	40		34	200 000		
		253			100*	168	160	151						142	98	83	70	59	51	43	37		32	250 000		
		225			150*	150	148	144						139												
224, 460A	460	325	M 1	3 to 16*	196	180	165	149	132	117	111	105	104	103	90	77	65	56	48	42	100 000	9, 16				
		315			40*	196	178	161						147	104	95	81	68	58	50	43		38	150 000		
		305			63*	196	176	157						145	104	88	75	63	54	46	40		34	200 000		
		281			100*	187	169	151						142	98	83	70	59	51	43	37		32	250 000		
		250			150*	167	155	144						139												
224, 460B	460	325	M 1	3 to 16*	196	186	177	160	142	128	121	116	115	114	105	90	77	65	56	48	42	100 000	9, 16			
		315			40*	196	184	173							158	115	111	95	81	68	58	50		43	38	150 000
		305			63*	196	183	171							156	115	104	88	75	63	54	46		40	34	200 000
		281			100*	187	176	164							153	115	98	83	70	59	51	43		37	32	250 000
		250			150*	167	162	157							150											
224, 490 (A and B)	490	325	M 1	3 to 16*	208	192	177	160	142	128	121	116	115	114	105	90	77	65	56	48	42	100 000	9, 16			
		315			40*	208	190	173							158	115	111	95	81	68	58	50		43	38	150 000
		305			63*	204	187	171							156	115	104	88	75	63	54	46		40	34	200 000
		281			100*	187	176	164							153	115	98	83	70	59	51	43		37	32	250 000
		250			150*	167	162	157							150											

Table 2.3-2 Design strength values (N/mm²) (continued)

Plates																										
Grade, type and method of manufacture	R_m	R_e	BS 5500 band	Thickness mm	Values of f for design temperatures (°C) not exceeding																			Design lifetime h	Notes	
	N/mm ²	N/mm ²			50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470	480					
Carbon manganese steel (fully-killed niobium and aluminium treated) to BS 1501 : Part 1																										
225, 460A	460	340	M 1	3 to 16*	196	175	154	142	131	119	111	105	104	104	103	90	77	65	56	48	42	100 000	9, 16			
		330			196	175								104	95	81	68	58	50	43	38	150 000				
		320			196	175								104	88	75	63	54	46	40	34	200 000				
		294			196	175								98	83	70	59	51	43	37	32	250 000				
		262			175	165																				
225, 460B	460	340	M 1	3 to 16*	196	180	164	151	140	127	119	112	111	111	105	90	77	65	56	48	42	100 000	9, 16			
		330			196	180								111	95	81	68	58	50	43	38	150 000				
		320			196	180								104	88	75	63	54	46	40	34	200 000				
		294			196	180								98	83	70	59	51	43	37	32	250 000				
		262			175	170																				
225, 490A	490	355	M 1	3 to 16*	208	193	173	158	139	131	125	124	121	105	90	77	65	56	48	42	100 000	9, 16				
		345			208	193							124	111	95	81	68	58	50	43	38		150 000			
		340			208	193							121	104	88	75	63	54	46	40	34		200 000			
		313			208	193							115	98	83	70	59	51	43	37	32		250 000			
		279			186	180							175													
225, 490B	490	355	M 1	3 to 16*	208	198	184	168	147	137	133	132	121	105	90	77	65	56	48	42	100 000	9, 16				
		345			208	198							128	111	95	81	68	58	50	43	38		150 000			
		340			208	198							121	104	88	75	63	54	46	40	34		200 000			
		313			208	198							115	98	83	70	59	51	43	37	32		250 000			
		279			186	186							186													

Table 2.3-3 Design strength values (N/mm ²)																										
Plates																										
Grade, type and method of manufacture	R _m N/mm ²	R _e N/mm ²	BS 5500 band	Thickness mm	Values of f for design temperature (°C) not exceeding																	Design lifetime h	Notes			
					50	100	150	200	250	300	350	400	450	480	490	500	510	520	530	540	550			560	570	580
Low alloy steel to BS 1501 : Part 2																										
243A 0.3Mo	440	275	M 2	≤ 16*	183	164	145	136	125	104	96	93											1d, 16			
	440	270		40*	180	163																				
	440	260		60*	173	159																				
	430	240		100*	160	151	141	133	121	100	91	88														
243B 0.3Mo	440	275	M 2	≤ 16*	183	169	155	145	133	111	102	99											1d, 16			
	440	270		40*	180	167																				
	440	260		60*	173	164																				
	430	240		100*	160	155	151	141	129	107	97	93														
660A CrMoV	460	310		≤ 100	196	184	173	167	151	141	135	131	127	126											100 000 150 000 200 000 250 000	
660B CrMoV	460	310		≤ 100	196	190	184	178	161	150	144	139	135	134	133	131	115	100	87	76	66	56				
															133	122	106	92	80	69	59	47				
															132	115	100	87	75	65	55	50				
503	450	275	M 5	≤ 30	183																		13,16			
3½N	450	265	50*	175																						
510	690	590	M 6	≤ 50	295																		13			
510N	690	525																								
9Ni																										
828 NiCrMo	640	550		≤ 100																		1/13				

Table 2.3-3 Design strength values (N/mm²) (continued)

Plates						Values of <i>f</i> for design temperature (°C) not exceeding																									Design lifetime	Notes	
Grade, type and method of manufacture	<i>R</i> _m N/mm ²	<i>R</i> _e N/mm ²	BS 5500 band	Thickness mm																										h			
Low alloy steel to BS 1501 : Part 2																																	
271 MnCrMoV	640	500	M 4	≤ 25*	272	271	271	265	259	249	242	234						231	209	181	155	129	107	87	69	54	41	30	100 000	16			
																				229	202	173	145	118	95	76	60	44	32		23	150 000	
																					221	192	160	132	108	87	68	51	38		26	18	200 000
																					216	188	157	129	105	83	65	48	35		23	14	250 000
	610	460	75*	260	259	259	253	248	236	229	221							219	209	181	155	129	107	87	69	54	41	30	100 000	16			
																				219	202	173	145	118	95	76	60	44	32		23	150 000	
																				219	192	160	132	108	87	68	51	38	26		18	200 000	
																				216	188	157	129	105	83	65	48	35	23		14	250 000	
	590	430	150*	251	242	233	227	221	207	201	195							193	190	181	155	129	107	87	69	54	41	30	100 000	16			
																				190	173	145	118	95	76	60	44	32	23		150 000		
																				190	160	132	108	87	68	51	38	26	18		200 000		
																				188	157	129	105	83	65	48	35	23	14		250 000		
281 NiCrMoV	640	500	≤ 25*	272	271	271	265	259	249	242	234	233	233	226	209	188	168	145	124	103	85	69	55	44	33	24	100 000	16					
																															150 000		
																															200 000		
																															250 000		
	610	460	75*	260	259	259	253	248	236	229	221			220	209	188	168	145	124	103	85	69	55	44	33	24	100 000	16					
																															150 000		
																															200 000		
																															250 000		
	590	430	150*	251	242	233	227	221	207	201	195			193	188	168	145	124	103	85	69	55	44	33	24	100 000	16						
																															150 000		
																															200 000		
																															250 000		

Table 2.3-3 Design strength values (N/mm²) (continued)**Plates**

Grade, type and method of manufacture	R_m	R_e	BS 5500 band	Thickness mm	Values of f for design temperature (°C) not exceeding																				Design lifetime h	Notes		
	N/mm ²	N/mm ²			50	100	150	200	250	300	350	400	450	460	470	480	490	500	510	520	530	540	550	560			570	
Low alloy steel to BS 1501 : Part 2																												
620A 1Cr½Mo	480	340	M 7	≤ 75*	204	186	169	161	154	143	134	132	129		127												16	
	450	280		100*	187	168	150	144	136	121	113	110	108			106												
	430	255		150*	170	154	138	131	125	108	99	96	94				92											
620B 1Cr½Mo	480	340	M 7	≤ 75*	204	192	180	172	165	152	143	141	137		136	135	134	112	93	76	62	52	42	33	27	100 000	16	
																	135	124	102	83	67	55	44	35	29	24		150 000
																	135	114	94	76	61	49	40	32	26	22		200 000
																	131	107	88	70	57	45	37	30	25	20		250 000

Table 2.3-3 Design strength values (N/mm ²) (continued)																																		
Plates																																		
Grade, type and method of manufacture	<i>R_m</i>	<i>R_e</i>	BS 5500 band	Thickness	Values of <i>f</i> for design temperature (°C) not exceeding																												Design lifetime	Notes
	N/mm ²	N/mm ²		mm	50	100	150	200	250	300	340	350	360	400	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	h				
Low alloy steel to BS 1501 : Part 2																																		
622-515A	515	310	M 9	≤ 100*	207	192	177	172	166	163		158		153	146																	16		
2¼Cr1Mo	500	285		150*	190	178	166	161	155	151		147		143	132																			
622-515B	515	310	M 9	≤ 100*	207	198	189	183	177	173		168		163	156	154	152	143	131	118	105	94	82	72	61	53	45	39	34	100 000	2, 16			
2¼Cr1Mo																154	148	135	122	108	97	85	73	63	56	48	42	36	31	150 000				
																154	143	130	117	104	92	79	68	59	52	45	38	33	28	200 000				
																152	139	126	113	100	87	75	65	57	49	42	36	32	27	250 000				
	500	285		150*	190	183	177	171	165	161		157		153		143	141	139	131	118	105	94	82	72	61	52	45	39	34	100 000				
																	141	135	122	108	97	85	73	63	56	48	42	36	31	150 000				
																	141	130	117	104	92	79	68	59	52	45	38	33	28	200 000				
																	139	126	113	100	87	75	65	57	49	42	36	32	27	250 000				
622-690A	690	555	M 9	≤ 50	294	294	294	294	294	292	284																							
2¼Cr1Mo																																		
622-690B	690	555	M 9	≤ 50	294	294	294	294	294	294	294	294	287	235		170	157	143	131	118	105	94	82	72	61	53	45	39	34	100 000	2			
2¼Cr1Mo																														150 000				
													290	277	225	161	148	135	122	108	97	85	73	63	56	48	42	36	31	200 000				
													286	273	221	156	143	130	117	104	92	79	68	59	52	45	38	33	28	250 000				
													281	268	216	152	139	126	113	100	87	75	65	57	49	42	36	32	27	250 000				

Plates

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Table 2.3-4 Design strength values (N/mm ²) (continued)																																		
Grade, type and method of manufacture	R _m	R _e	BS 5500 band	Thickness mm	Values of <i>f</i> for design temperature (°C) not exceeding																											Design lifetime h	Notes	
	N/mm ²	N/mm ²			50	100	150	200	250	300	350	400	450	500	520	540	550	560	580	600	620	640	650	660	680	700	720	740	750					
High alloy steel to BS 1501 : Part 3																																		
316-S11, S13	490	225		Up to 100	150	134	119	110	103	99	94	91	88																					
316-S31, S33	510	240		Up to 100	160	143	127	118	111	106	101	99	96	93			90	89	89	74	58	46	41	35	28	23					100 000	20		
																			85	66	52	41	36	32	25	19					150 000			
																			79	62	48	38	33	29	22	18					200 000			
																			75	58	45	35	31	27	22	18					250 000			
316-S51, S53	510	240		Up to 100	160	143	127	118	111	106	101	99	96	93			90		89	88	74	58	53	46	35	28	23					100 000	6	
																			85	66	52	46	41	32	25	19					150 000			
																			79	62	48	43	38	29	22	18					200 000			
																			75	58	45	40	35	27	22	18					250 000			
316-S61, S63	580	315		Up to 100	210	180	154	142	133	127	123	119	116	113			110				107											1d		
320-S31	510	245		Up to 100	163	147	130	121	114	109	104	101																						
309-S16	510	240		Up to 100	160	142	124	114	108	103	98	93	91	90			87																	
310-S16	510	240		Up to 100	160	142	124	114	108	103	98	93	91	90			87															1d		
318-S13	680	450		Up to 20	289	249	209 194 184 178																											
	680	480		80	289	249																												
	640	480		100	272	241																												
904-S13	520	255		Up to 100																												1f		

Table 2.3-5 Design strength values (N/mm²)**Sections and bars**

Grade, type and method of manufacture	R_m	R_e	BS 5500 band	Thickness mm	Diameter mm	Values of f for design temperature (°C) not exceeding																Design lifetime h	Notes	
	N/mm ²	N/mm ²				50	100	150	200	250	300	350	400	410	420	430	440	450	460	470	480			
Carbon steel (semi-or silicon-killed) to BS 1502																								
151, 161	430	250	M 0	Up to 16*	Up to 25*	167	157	148	143	128	107	102	99	98	88	79	69	60	52	44	36	100 000	16, 19	
		240		Up to 40*	Up to 50*	160	150	140	135	121			99	93	83	74	65	56	48	40	32	150 000		
		230		Up to 63*	Up to 100*	153	143	133	128	119			99	90	80	71	62	53	45	37	28	200 000		
		220		Up to 100*	Up to 160*	147	135	124	121	115			97	87	78	68	59	51	42	35	26	250 000		
Carbon manganese steel (semi-or silicon-killed) to BS 1502																								
211, 221	430	250	M 1	Up to 16*	Up to 25*	167	157	148	143	128	107	102	99	98	97	90	77	65	56	48	42	100 000	16	
		240		Up to 40*	Up to 50*	160	150	140	135	121			95	81	68	58	50	43	38	150 000				
		230		Up to 63*	Up to 100*	153	143	133	128	119			88	75	63	54	46	40	34	200 000				
		220		Up to 100*	Up to 160*	147	135	124	121	115			83	70	59	51	43	37	32	250 000				
Carbon manganese steel (silicon-killed, aluminium treated) to BS 1502																								
224, 430	430	275	M 1	Up to 16*	Up to 25*	183	168	153	137	121	108	101	95	94	93	90	77	65	56	48	42	100 000	16	
		265		Up to 40*	Up to 50*	176	163	149	136						93	81	68	58	50	43	38	150 000		
		245		Up to 63*	Up to 100*	163	154	144	133						88	75	63	54	46	40	34	200 000		
		240		Up to 100*	Up to 160*	160	151	141	131						83	70	59	51	43	37	32	250 000		
224, 490	490	325	M 1	Up to 16*	Up to 25*	208	193	177	160	142	128	121	115	114	105	90	77	65	56	48	42	100 000	16	
		315		Up to 40*	Up to 50*	208	191	173	158						111	95	81	68	58	50	43	38		150 000
		305		Up to 63*	Up to 100*	203	187	171	156						104	88	75	63	54	46	40	34		200 000
		300		Up to 100*	Up to 160*	200	184	168	152						98	83	70	59	51	43	37	32		250 000

Table 2.3-5 Design strength values (N/mm²) (continued)

Sections and bars

Grade, type and method of manufacture	R_m	R_e	BS 5500 band	Thickness	Values of f for design temperature (°C) not exceeding																												Design lifetime	Notes	
	N/mm ²	N/mm ²			mm	50	100	150	200	250	300	350	400	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	h						
Low alloy steel to BS 1502																																			
271-560 MnCrMoV	560	370	M 4	≤ 160	238	229	220	215	208	204	199	192		188	186	181	155	129	107	87	69	54	41	30					100 000	15, 19					
																																150 000			
																																200 000			
																																250 000			
620-440 1Cr½Mo	440	265	M 7	≤ 160	177	163	153	147	139	123	113	109		107				105	104	93	76	62	52	42	33	27		100 000	15						
																															150 000				
																																200 000			
																																250 000			
620-470 1Cr½Mo	470	300	M 7	≤ 160	200	187	173	166	159	144	136	133		130			128	127	112	93	76	62	52	42	33	27		100 000	15						
																															150 000				
																																200 000			
																																250 000			
620-540 1Cr½Mo	540	375	M 7	≤ 160	230	224	219	210	202	196	189	186		182	181	180	162	136	112	93	76	62	52	42	33	27		100 000	15						
																															150 000				
																																200 000			
																																250 000			
622-490 2¼Cr1Mo	490	275	M 9	≤ 160	183	176	169	163	157	153	149	145		137	135	132	131	118	105	94	82	72	61	53	45	39	34		100 000	6,15					
																															150 000				
																																200 000			
																																250 000			
625-590 5Cr½Mo	590	450	M 10	≤ 160																															
625-640 5Cr½Mo	640	500		≤ 160																															
629-590 9Cr1Mo	590	400		≤ 160	251	241	232	223	220	217	215	211	208	207	195	176	159	144	129	115	103	91	80	68	58	48	38		100 000						
																															150 000				
																																200 000			
																																250 000			
509-650 5Cr1Mo	650	490		≤ 75	277																														
509-690 5Cr1Mo	690	580	M 5	≤ 100	294																														

Table 2.3-5 Design strength values (N/mm²) (continued)**Sections and bars**

Grade, type and method of manufacture	R_m	R_e	BS 5500 band	Ruling section mm	Values of f for design temperature (°C) not exceeding																										Design lifetime h	Notes
	N/mm ²	N/mm ²			50	100	150	200	250	300	350	400	450	500	520	540	550	560	580	600	620	640	650	660	680	700	720	740	750			
Austenitic stainless steel to BS 1502																																
304-S11	480	215		160	143	127	111	101	95	90	86	81	80																			
304-S31	490	230		160	153	136	119	109	103	98	93	89	87																			
304-S51	490	230		160	153	136	119	109	103	98	93	89	87	85		83		82	76	65	55	50	45	38	33	28				100 000		
																		82	72	61	51	46	42	36	31					150 000		
																		81	69	58	48	44	40	34	30					200 000		
																		78	66	55	46	42	38	33	29					250 000		
304-S61	550	305		160	203	174	149	135	127	121	116	110	107	104																		
304-S71	550	305		160	203	174	149	135	127	121	116	110	107	104																		
316-S11, S13	490	225		160	150	134	119	110	103	99	94	91	88																			
316-S31, S33	510	240		160	160	143	127	118	111	106	101	99	96																			
316-S51, S53	510	240		160	160	143	127	118	111	106	101	99	96	93		90		89	88	74	58	53	46	35	28	23				100 000	6	
																			85	66	42	46	41	32	25	19					150 000	
																			79	62	48	43	38	29	22	18					200 000	
																			75	58	45	40	35	27	22	18					250 000	
316-S61, S63-S65, S67	580	315		160	210	180	154	142	133	127	123	119	116	113																		
321-S31	510	235		160	157	145	133	127	121	117	113	110	107																			
321-S51	490	190		160	127	115	103	97	93	87	84	81	79	78		77		76	76	68	55	49	44	34	26					100 000		
(490)																			76	62	50	44	38	29							150 000	
																			72	58	46	41	35	27							200 000	
																			68	55	44	38	33	25							250 000	
321-S51	510	235		160	157	145	133	127	121	117	113	110	107	104		103	102	102	86	71	57	42	36	31						100 000		
(510)																			103	97	89	74	58	45	36	32	27				150 000	
																			103	97	89	74	58	45	33	28	25				200 000	
																			100	93	85	71	55	42	31	26	22				250 000	
347-S31	510	240		160	160	151	142	135	127	123	120	118	116																			
347-S51	510	240		160	160	151	142	135	127	123	120	118	116	115		114	113	113	99	82	66	53	47	41	31	23				100 000		
																			113	112	93	75	61	48	42	37	28	22			150 000	
																			113	106	88	72	58	45	39	34	25	19			200 000	
																			112	102	85	68	55	42	37	32	24	19			250 000	

Table 2.3-6 Design strength values (N/mm ²)																								
Forgings (see special note 1b)																								
Grade, type and method of manufacture	<i>R_m</i>	<i>R_e</i>	BS 5500 band	Ruling section mm (see note d)	Values of <i>f</i> for design temperatures (°C) not exceeding																	Design lifetime	Notes	
	N/mm ²	N/mm ²			50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470	480			
	h																							
Carbon manganese steels to BS 1503																								
164-490	490	305	M 1	≤ 100*	203	187	171	156	142	128	121		115	114	105	90	77	65	56	48	42	100 000	15, 16, 19	
		150*		187	173	159	145	137	111						95	81	68	58	50	43	38	150 000		
									104						88	75	63	54	46	40	34	200 000		
									98						83	70	59	51	43	37	32	250 000		
221-410	410	215	M 1	≤ 100	143	134	125	121	112	100	95		92		92	90	77	65	56	48	42	100 000	15, 19	
		> 100		137	126	116	113	108	92						81	68	58	50	43	38	150 000			
									88						75	63	54	46	40	34	200 000			
									83						70	59	51	43	37	32	250 000			
221-430	430	225	M 1	≤ 100	150	141	133	129	119	107	102		99	99	98	90	77	65	56	48	42	100 000	15, 19	
		> 100		143	133	124	121	115	99						95	81	68	58	50	43	38	150 000		
									99						88	75	63	54	46	40	34	200 000		
									98						83	70	59	41	43	37	32	250 000		
221-460	460	245	M 1	≤ 100	163	154	145	140	129	117	112		108	108	105	90	77	65	56	48	42	100 000	15, 19	
		> 100		157	146	135	131	125	108						95	81	68	58	50	43	38	150 000		
									104						88	75	63	54	46	40	34	200 000		
									98						83	70	59	51	43	37	32	250 000		
221-490	490	265	M 1	≤ 100	177	167	157	151	140	128	122	119	118	118	105	90	77	65	56	48	42	100 000	15, 19	
		> 100		170	158	146	141	135	118						111	95	81	68	58	50	43	38		150 000
									118						104	88	75	63	54	46	40	34		200 000
									115						98	83	70	59	51	43	37	32		250 000
221-510	510	285	M 1	100	190	177	165	159	147	135	129	125	124	121	105	90	77	65	56	48	42	100 000	15, 19	
									124						111	95	81	68	58	50	43	38		150 000
									121						104	88	75	63	54	46	40	34		200 000
									115						98	83	70	59	51	43	37	32		250 000
221-530	530	295	M 1	100	197	185	173	167	155	141	136												14, 15, 19	
221-550	550	305	M 1	100	203	192	181	175	162	149	142												14, 15, 19	

