



Pressure equipment—Boilers



This Australian Standard® was prepared by Committee ME-001, Pressure Equipment. It was approved on behalf of the Council of Standards Australia on 18 April 2016. This Standard was published on 18 May 2016.

The following are represented on Committee ME-001:

- Australasian Corrosion Association
 - Australasian Institute of Engineer Surveyors
 - Australian Aluminium Council
 - Australian Chamber of Commerce and Industry
 - Australian Industry Group
 - Australian Institute for the Certification of Inspection Personnel
 - Australian Institute of Energy
 - Australian Institute of Petroleum
 - Bureau of Steel Manufacturers of Australia
 - Department of Justice and Attorney General, Qld
 - Energy Networks Association
 - Engineers Australia
 - Insurance Council of Australia
 - Materials Australia
 - National Association of Testing Authorities Australia
 - SafeWork NSW
 - Welding Technology Institute of Australia
 - WorkSafe Division, Department of Commerce, WA
 - WorkSafe Victoria
-

This Standard was issued in draft form for comment as DR AS 1228:2015.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

Keeping Standards up-to-date

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting www.standards.org.au

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at mail@standards.org.au, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

Australian Standard[®]

Pressure equipment—Boilers

Originated as part of AS CB1—1932.
Previous edition AS 1228—2006.
Seventh edition AS 1228:2016.

COPYRIGHT

© Standards Australia Limited

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968.

Published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia

ISBN 978 1 76035 483 1

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME-001, Pressure Equipment, to supersede AS 1228—2006. After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian, rather than an Australian/New Zealand Standard.

The objective of this revision is to bring the Standard into line with the developments taking place worldwide.

Table 2.1, Materials, includes references to EN material standards. The design strength values for these materials may be derived from the appropriate EN material properties, in conjunction with the principles as set out in Appendix D of this Standard. A number of British (BS) material standards have been withdrawn in favour of the EN standards; however, reference to the BS standards has been retained in Table 2.1 and Table 2.2.1 at this time, in recognition that material stocks may still be available.

The design strength values in Table 2.2.1 have generally been revised and updated to fall in line with the latest editions of the AS (e.g. AS 1548), BS and ASME material specifications and standards, which were available at the time of this Standard being published. Time-dependent design strength values in the table have been *italicized*, to assist in determining the calculation pressure for components designed in this range.

Users of this Standard are reminded that it has no legal authority in its own right, but may acquire legal standing in one or more of the following circumstances:

- (a) Adoption by a government or other authority having jurisdiction.
- (b) Adoption by a purchaser as the required standard of construction when placing a contract.
- (c) Adoption where a manufacturer states that a boiler is in accordance with this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

Statements expressed in mandatory terms in notes to figures and tables are deemed to be requirements of this Standard.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	5
1.2 REFERENCED DOCUMENTS.....	5
1.3 DEFINITIONS.....	5
1.4 DESIGNATION	12
1.5 VALVES, GAUGES, FITTINGS AND BOILER INSTALLATION	12
1.6 RATING	12
1.7 INFORMATION TO BE SUPPLIED BY THE PURCHASER.....	12
SECTION 2 MATERIALS AND DESIGN STRENGTHS	
2.1 MATERIALS.....	13
2.2 MAXIMUM DESIGN STRENGTH	14
2.3 DESIGN LIFETIME	52
SECTION 3 DESIGN	
3.1 DESIGN CRITERIA.....	53
3.2 CYLINDRICAL SHELLS, DRUMS AND HEADERS SUBJECT TO INTERNAL PRESSURE.....	54
3.3 DISHED ENDS SUBJECT TO INTERNAL PRESSURE	77
3.4 RECTANGULAR SECTION HEADERS.....	86
3.5 HEADER ENDS	89
3.6 PRESSURE PARTS OF IRREGULAR SHAPE	94
3.7 TUBES AND INTEGRAL PIPES.....	94
3.8 STRUCTURAL ATTACHMENTS TO TUBES	98
3.9 INSPECTION OPENINGS.....	102
3.10 STAYS, STIFFENERS AND SUPPORTED SURFACES FOR FIRE-TUBE AND MISCELLANEOUS BOILERS	112
3.11 TUBES AND TUBE PLATE FOR FIRE-TUBE AND MISCELLANEOUS BOILERS.....	146
3.12 FURNACES, REVERSAL CHAMBERS AND FIREBOXES OF CYLINDRICAL FORM SUBJECT TO EXTERNAL PRESSURE.....	150
3.13 BOILER SETTINGS	163
3.14 CONNECTIONS AND BRANCHES	163
3.15 SUPPORTING STRUCTURES	189
SECTION 4 MANUFACTURE AND WORKMANSHIP	
4.1 PRESSURE PARTS	190
4.2 WELDING.....	198
SECTION 5 INSPECTION AND TESTING	
5.1 GENERAL.....	199
5.2 NON-DESTRUCTIVE EXAMINATION	199
5.3 TEST PLATES	199
5.4 HYDROSTATIC TESTS	199
SECTION 6 DOCUMENTATION AND MARKING	
6.1 DRAWINGS, DOCUMENTS, AND DATA SHEETS	201
6.2 CERTIFICATES.....	201
6.3 MARKING	201

SECTION 7 MISCELLANEOUS BOILERS AND COIL-TYPE FORCED CIRCULATION BOILERS

7.1	MISCELLANEOUS BOILERS	202
7.2	CAST IRON BOILERS	203
7.3	MINIATURE BOILERS.....	204
7.4	COIL-TYPE FORCED CIRCULATION BOILERS.....	205
7.5	ORGANIC FLUID HEATERS AND VAPORIZERS	206
7.6	HEAT RECOVERY STEAM GENERATORS (HRSG).....	206

APPENDICES

A	LIST OF REFERENCED DOCUMENTS.....	207
B	EXAMPLE OF PRINCIPAL INTEGRAL WATER-TUBE BOILER PIPING COVERED BY THIS STANDARD	212
C	INFORMATION TO BE SUPPLIED BY THE PURCHASER.....	213
D	DERIVATION OF MATERIAL DESIGN STRENGTH	215
E	CALCULATION OF TUBEPLATE TEMPERATURES.....	218
F	ANALYTICAL DESIGN METHOD FOR REINFORCEMENT OF OPENINGS ALTERNATIVE TO THE DESIGN METHOD SHOWN IN CLAUSE 3.2.10	234
G	EXAMPLE OF MANUFACTURER'S REPORT	254
H	GUIDANCE FOR DESIGN OF SADDLE SUPPORTS FOR FIRETUBE BOILERS.....	257
I	BLOWDOWN TANK AND VESSEL DESIGN CONDITIONS	260
J	COMPETENCIES OF BODIES AND PERSONNEL FOR BOILER CONSTRUCTION AND USE	264
K	LOCOMOTIVE, TRACTION ENGINE AND HERITAGE BOILERS	267
L	EXAMPLE OF THE DESIGN OF A BOILER DRUM	272
M	CONFORMANCE TO DESIGN AND CONSTRUCTION CRITERIA.....	280

STANDARDS AUSTRALIA

Australian Standard

Pressure equipment—Boilers

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out requirements for materials, design, manufacture, inspection and testing of boilers as defined in AS/NZS 1200.

NOTE: The Scope of this Standard covers requirements for cast iron in addition to welded boilers inclusive of vapour-generating and hot fluid units subject to internal vapour or liquid pressure. Other forms of design and manufacture should be by agreement between the parties concerned.

It also applies to all pressure parts containing fluid up to and including the valves separating the pressure parts from—

- (a) steam piping to and from other equipment;
- (b) water piping to and from other equipment;
- (c) drain piping;
- (d) the surrounding atmosphere, except that for safety valves, their vent piping to the atmosphere is also covered; and
- (e) for equipment such as reheaters which may not incorporate valves at their supply and return connection points, the Standard applies to the equipment included between the inlet to the inlet header and the outlet from the outlet header of such equipment (see Appendix B).

This Standard also provides guidance on locomotive and other heritage boilers, and on the design of blowdown vessels.

Requirements for boiler safety, water and firing management systems are specified in AS 2593.

1.2 REFERENCED DOCUMENTS

A list with titles of the documents referred to in this Standard is given in Appendix A.

1.3 DEFINITIONS

For the purposes of this Standard the definitions given in AS 4942 and those given in this Clause apply. For calculations, AS ISO 1000, the international system of units, has been applied.

1.3.1 Actual thickness

The actual thickness of the material used in the pressure part, which may be taken as the nominal thickness minus any applicable manufacturing tolerances.

1.3.2 Calculation pressure

Except as specified in Item (b) below, the calculation pressure for all pressure parts is as given in Item (a):

- (a) The design pressure increased, where applicable, to take into account the pressure differential and hydrostatic head corresponding to the most severe conditions of operation.

- (b) For boiler pressure components where the design strength is derived from time-dependent values S_R (see Clauses 2.2.2 and 2.2.3), the calculation pressure is the lowest set pressure of any superheater or reheater safety valve mounted on the steam outlet, increased to take account of the pressure drop corresponding to the most severe conditions of operation.

1.3.3 Design lifetime

The lifetime specified by agreement between the manufacturer and the purchaser for each boiler component operating in the creep (high temperature) range and used in determining material design strength; it is expressed in hours service at specified conditions.

NOTE: The design lifetime relates only to the creep performance of the relevant component and is not necessarily related to the life of the boiler.

1.3.4 Design pressure

The maximum allowable operating pressure for—

- (a) natural or assisted circulation boilers, at the top of the steam or water drum;
- (b) once-through forced circulation boilers, at the final superheater outlet, except where an intervening shut-off valve is fitted; and
- (c) steam reheaters, independently fired superheaters, and economizer separated from the boiler by a shut-off valve, at the final outlet of the particular equipment.

1.3.5 Design strength

The maximum allowable stress for use in the formulas for calculation of pressure parts.

1.3.6 Design temperature

The metal temperature at the coincidental calculation pressure used to select the design strength and to determine the dimensions of the boiler component under consideration.

NOTE: Consideration should be given to operating conditions which could result in a higher metal temperature occurring at a lower operating pressure. The selected components should be verified for their integrity at such conditions, calculated on the basis of the most adverse pressure and temperature conditions.

1.3.7 Drum

A cylindrical pressure part having a diameter sufficiently large to admit personnel by design intent, for which purpose an access opening or branch is provided.

NOTE: A drum may have the function of a header, or additionally or alternatively other functions, such as to separate steam from water or to act as a reservoir for boiler water.

1.3.8 Economizer

A heat exchanger designed to use the products of combustion to heat boiler feedwater and is normally located between the boiler feedwater pumps and the boiler.

1.3.9 Electrode boiler

A boiler in which the water or other liquid is heated by the passage of an alternating current through the liquid.

1.3.10 Element boiler

A boiler in which the water or other liquid is heated by an electrical element.

1.3.11 Fire-tube boiler

A boiler in which the fluid to be heated is contained in a vessel which may be directly heated and/or contain tubes in which combustion takes place or through which products of combustion flow. Typical examples of fire-tube boilers are shown in Figures 1.3(A) to 1.3(E).

1.3.12 Forced or assisted circulation boiler

A boiler in which mechanical pumping is used either entirely or partly to promote the circulation of fluid.

1.3.13 Header

A pressure part whose principal purpose is to collect fluid from, or distribute fluid to, arrays of tubes directly connected to it.

1.3.14 Heat recovery steam generator (HRSG)

A boiler that has as its principal source of thermal energy a hot gas stream having high-ramp rates and temperatures such as the exhaust of a gas turbine. It may include supplementary firing.

1.3.15 Heritage boiler

A boiler manufactured before 1952 and is used for a historical purpose or activity, including an activity that is ancillary to a historical activity.

1.3.16 Integral piping

A tubular pressure part that is not a tube, drum or header.

NOTES:

- 1 The term 'piping' implies that there is no design intent to effect heat transfer through the wall of the pressure part.
- 2 The term 'integral' implies that the pressure part is connected directly to other pressure parts without any intervening valve.
- 3 The term 'integral piping', subject to Note 2, includes those parts of piping that carry a flow of steam or water during normal operation, those that carry intermittent flow, e.g. drain piping, and those in which no flow occurs, e.g. instrument piping. The principal integral piping covered by this Standard is shown diagrammatically in Appendix B.
- 4 The terms 'piping' and 'tube' are used freely in Australian Standards for materials, and certain Standards state that they are synonymous. The use of 'piping' or 'tube' in any Standard for material does not pre-empt the definitions given in Clauses 1.3.16 and 1.3.23, and likewise material defined as piping or tube may be used for any duty defined, if appropriate. The selective reference to Australian Standard materials, British Standard materials and ASTM Standard materials in this Standard is intended for guidance based on general usage of those Standards.

1.3.17 Miniature boilers

A steam boiler with maximum size and pressure limited (see Clause 7.3).

1.3.18 Miscellaneous boilers

Boilers which are not classified as fire-tube or water-tube boilers.

NOTE: Some types of fire-tube and miscellaneous boilers have an obvious shell and are also referred to commercially as 'shell boilers'.

1.3.19 Natural circulation boiler

A water-tube boiler in which fluid circulation is a result of the thermo-siphonic head produced by heating.

1.3.20 Nominal thickness

The nominal thickness of material selected as commercially available and to which specified manufacturing tolerances are applicable.

1.3.21 Once-through boiler

One in which the feed pump is used to force the flow of water and steam through the tubes, and where there is no fixed position of the final evaporation point.

1.3.22 Organic fluid heater and vaporizer

A boiler in which an organic fluid is vaporized or heated above its atmospheric boiling point. It excludes pressure equipment, such as fired heaters and heat exchangers, which are covered by other Standards.

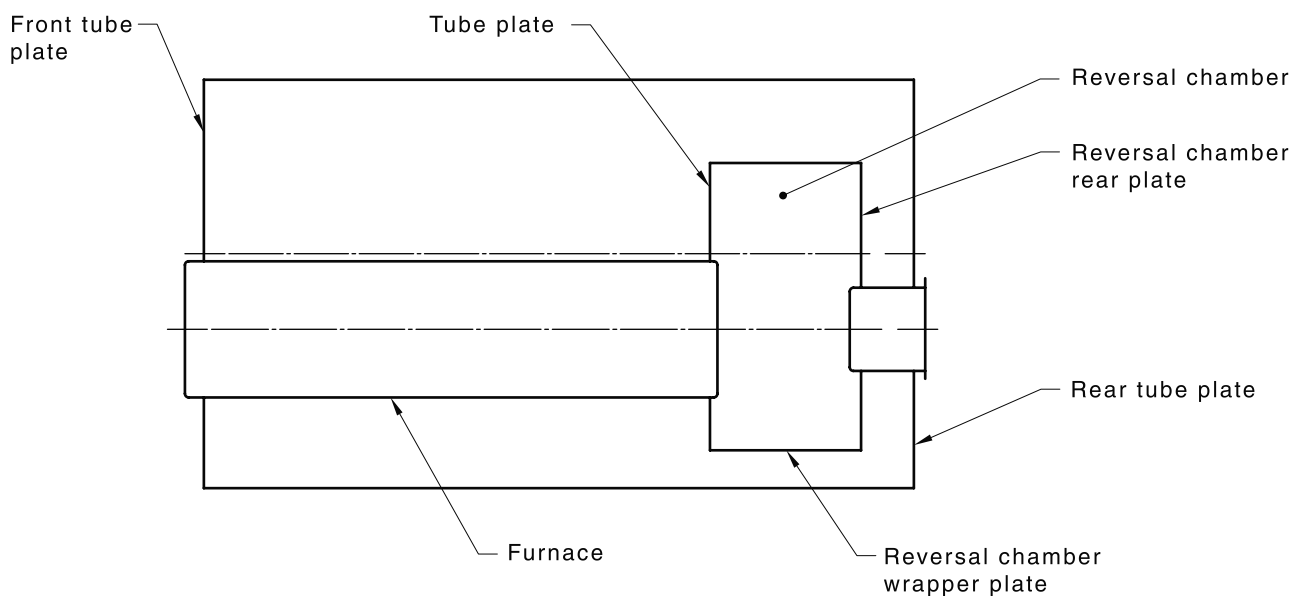
1.3.23 Tube

A tubular pressure part that is either exposed over much of its length to hot gases for purposes of heat transfer, or is directly butt welded to such a tubular pressure part.

NOTE: This definition also includes a stub on a drum or header.

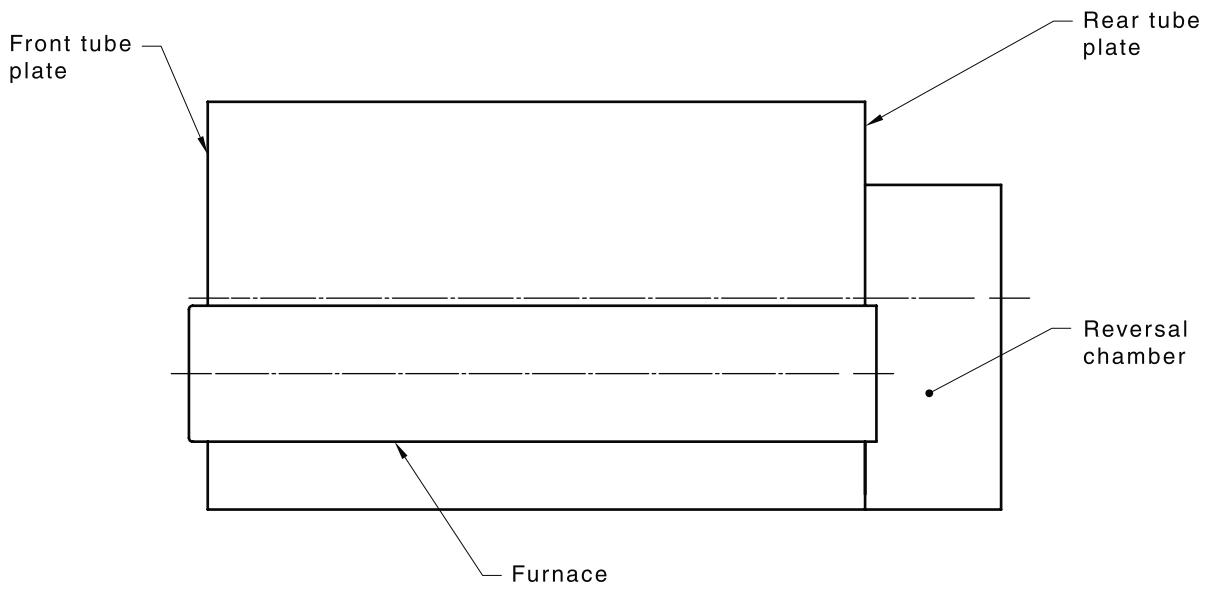
1.3.24 Water-tube boiler

A boiler in which the heat transfer takes place through the wall of tubes inside which the fluid to be heated flows or circulates.



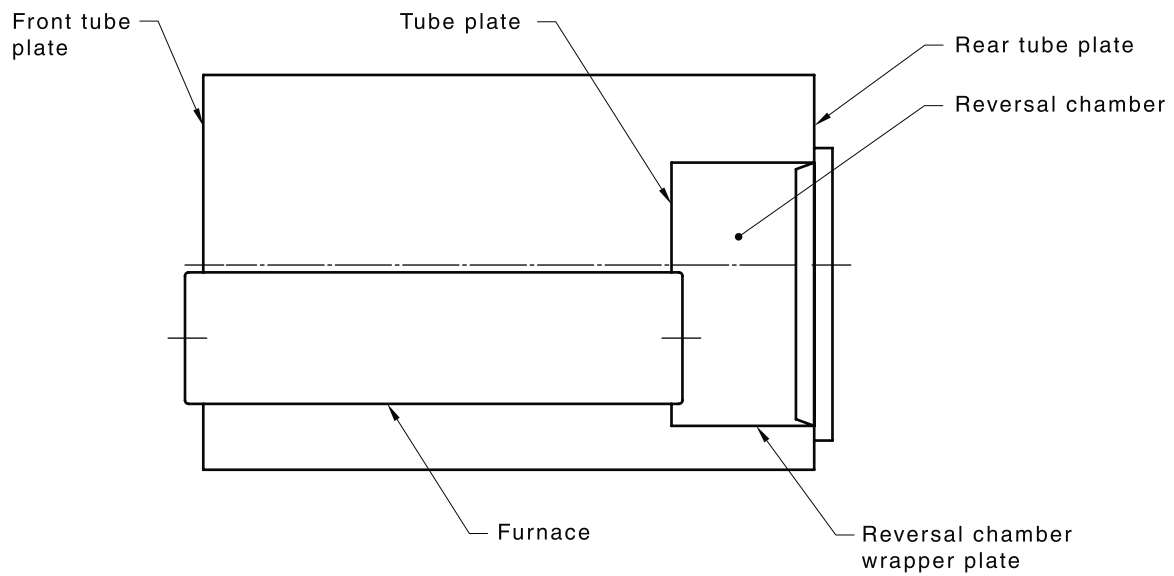
NOTE: The radiant heating surface consists of the furnace, the wrapper plate and the reversal chamber rear plate.

FIGURE 1.3(A) WET BACK BOILER



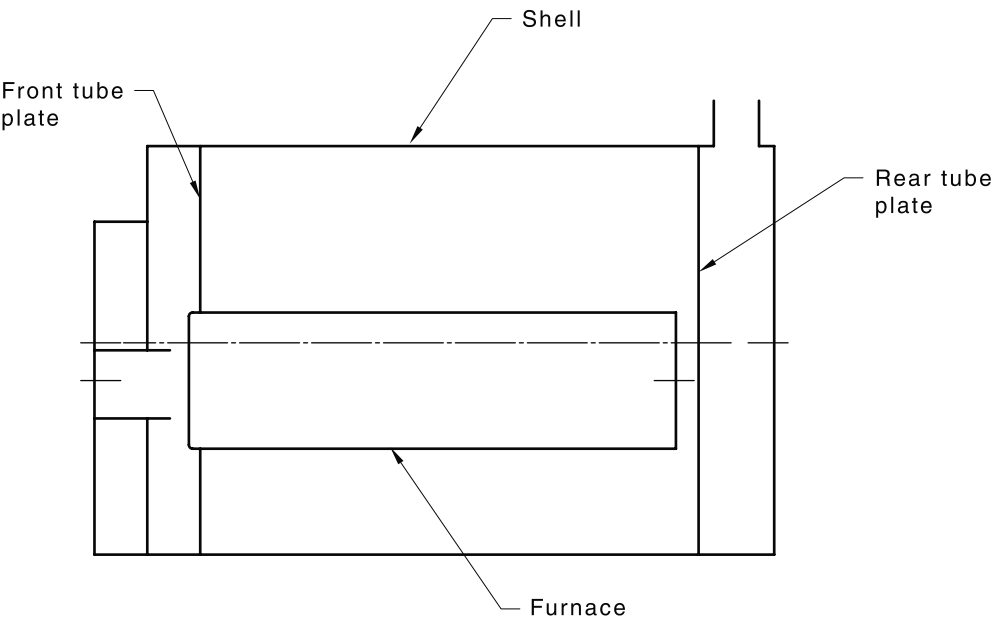
NOTE: The radiant heating surface consists of the furnace.

FIGURE 1.3(B) DRY BACK BOILER



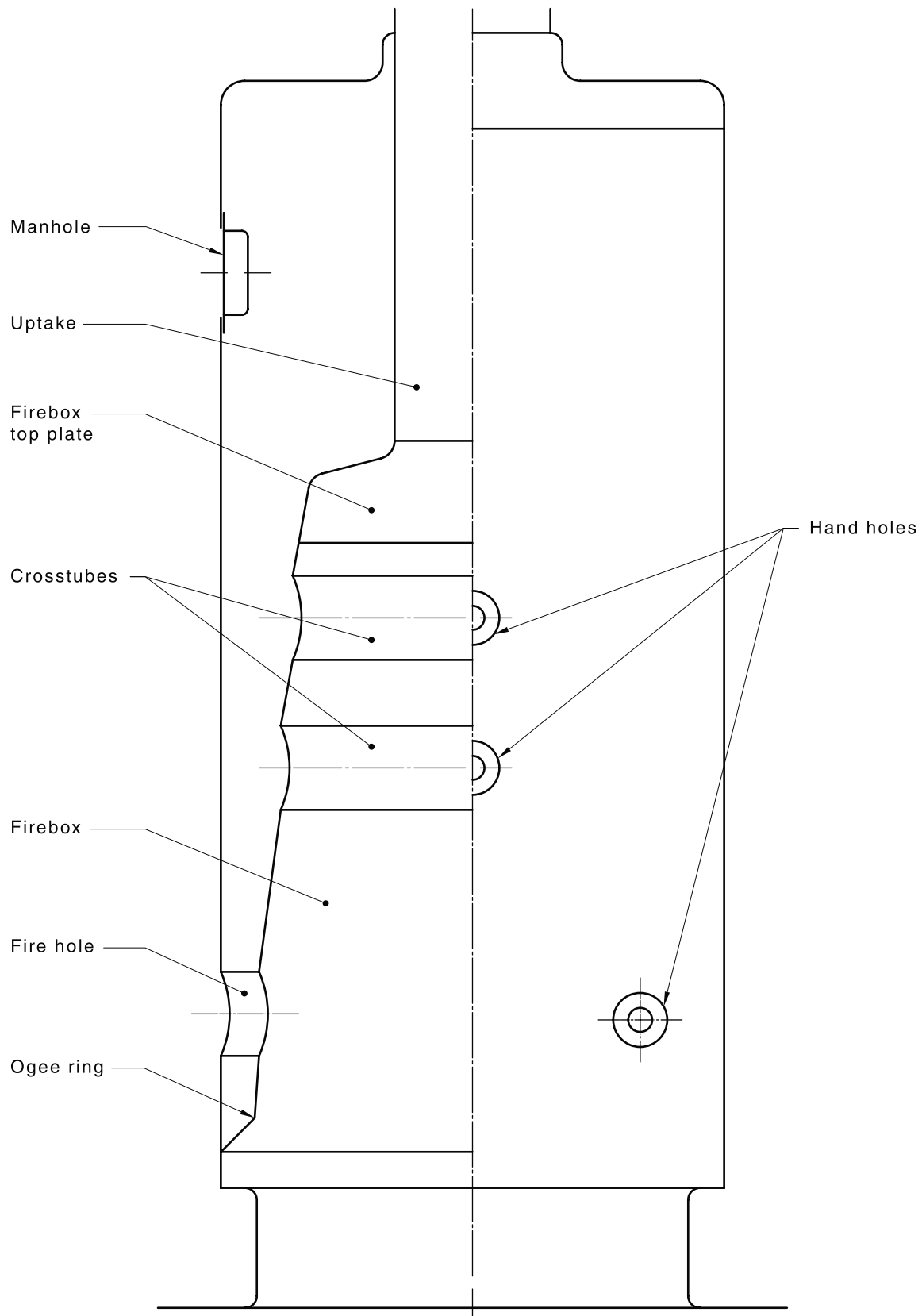
NOTE: The radiant heating surface consists of the furnace and the wrapper plate.

FIGURE 1.3(C) SEMI-WET BACK BOILER



NOTE: The radiant heating surface consists of the furnace.

FIGURE 1.3(D) REVERSE FIRED BOILER



NOTE: The radiant heating surface consists of the firebox and crosstubes.

FIGURE 1.3(E) VERTICAL BOILER

1.4 DESIGNATION

The following designation shall be used to identify boilers built to this Standard:

AS 1228-A

where

AS 1228 = number of this Standard

A = the identity of the class of boiler as set out in Table 1.4

NOTE: See Clause 7.3.2 for the designation of miniature boilers.

TABLE 1.4
CLASSIFICATION OF BOILERS

Requirement	Class 3	Class 2	Class 1
Design pressure (kPa)	≤250 fire-tube and miscellaneous boilers	≤750 fire-tube and miscellaneous boilers	>750 fire-tube, miscellaneous and all water-tube boilers
P (kPa) × internal diameter (mm) × 10 ⁻³	≤300	≤900	Exceeding class 2 requirements
Welding efficiency <i>η</i>	0.65	(a) 0.85 radiography (b) 0.75 no radiography	1.0
Post weld heat treatment	Not required	AS 4458	
Mechanical tests production		AS/NZS 3992	
Non-destructive testing		AS 4037	
Hydrostatic tests	AS 4037		

1.5 VALVES, GAUGES, FITTINGS AND BOILER INSTALLATION

Any boiler covered by this Standard shall be complete with all necessary valves, gauges and fittings. All such valves, gauges and fittings shall be in accordance with AS 2593 and AS 1271, and shall enable each boiler to be shut off from all piping connecting with other equipment, such as water supply, steam, and drain piping.

The boiler installation shall be in accordance with AS 3892.

1.6 RATING

The rating of any boiler shall be defined in terms of the designed maximum energy output in watts.

The rating of an electrode boiler shall be taken as the manufacturer's kilowatt rating at the voltage and conductivity for which the boiler was designed and at which the boiler is intended to operate.

1.7 INFORMATION TO BE SUPPLIED BY THE PURCHASER

NOTE: The purchaser should supply the manufacturer with the information set out in Appendix C.

SECTION 2 MATERIALS AND DESIGN STRENGTHS

2.1 MATERIALS

2.1.1 General

The materials used in the construction of pressure parts of boilers shall comply with the appropriate specifications or requirements listed in Table 2.1 or Clauses 2.1.5, 2.1.6 and 2.1.7 and shall be identified in accordance with Clause 2.1.2.

2.1.2 Material identification

Material identification shall comply with AS 4458.

2.1.3 Welding materials

Welding materials shall comply with AS/NZS 3992.

2.1.4 Prohibition of use of certain materials

Cast iron and copper bearing non-ferrous alloys shall not be used in the construction of pressure parts, except for valves and fittings within the limits specified in AS 2593 and Section 7 of this Standard.

2.1.5 Alternative material specifications

Subject to agreement between the purchaser and the manufacturer, materials other than those listed in Table 2.1 may be used provided that such materials meet the full requirements of the relevant Australian, British, European or ASTM (as appropriated by ASME) Standard, in regard to relevant material properties. (See Clause 2.2.1 for the determination of design strength.)

2.1.6 Use of structural or similar quality steels

Structural or similar quality steel plates, sheets, tubes, bars and sections not listed in Table 2.1 may be used for pressure parts of boilers, provided that the following conditions are fulfilled:

- (a) The specified minimum tensile strength of the steel is not greater than 460 MPa.
- (b) The ladle analysis does not exceed the following:

Carbon.....	0.25%.
Phosphorus	0.040%.
Sulfur	0.040%.
Carbon + $\frac{\text{Manganese}}{6}$	0.45%.
- (c) Test certificates (or equivalent) identifying the steel to a national Standard are provided and the steel is suitably marked or labelled.
- (d) The steel is not greater than—
 - (i) 40 mm thick for plates;
 - (ii) 60 mm diameter for round bars; or
 - (iii) 16 mm thick for tubes, sections and machined sockets and bosses.

- (e) The design strength for calculation purposes is determined in accordance with Appendix D, for material without specified elevated temperature values, and multiplied by a factor of 0.92.
- (f) The design temperature is not greater than 250°C.
- (g) The pressure part is not used for applications with high risk of lamellar tearing or hydrogen blistering.
- (h) All weld preparations and openings in plates, and all ends of tubes, bars and sections are visually examined and any evidence of lamination may render the material unacceptable.
- (i) Welded tubes comply with a specification which requires hydrostatic testing of the tube.
- (j) Sections, which have been manufactured by a cold-forming process, are unacceptable.

2.1.7 Specifically tested materials

The use of steel outside the limits of Clause 2.1.5, or other materials, is permitted for pressure parts of boilers provided that—

- (a) the material is shown by special tests to be equally suitable for the particular application as a similar material listed in Table 2.1; and
- (b) approval is given by the parties concerned.

These special tests may include chemical analysis, mechanical tests or non-destructive examination.

2.2 MAXIMUM DESIGN STRENGTH

2.2.1 General

The material design strength (f) (see Table 2.2.1) used in all equations for the calculation of pressure parts shall be in accordance with Table 2.2.1 for the relevant grade of material, design temperature, and, where applicable, the specified design lifetime.

NOTE: Where the materials used have properties proved by a test to be higher than those given in the relevant material specification, the use of those higher properties to determine the design strength of value f , at the design temperature by reference to Appendix D may be permitted subject to agreement between the manufacturer and the parties concerned.

Where a material is not listed in Table 2.2.1, its design strengths shall be determined in accordance with Appendix D or for ASTM materials (as appropriated by ASME), in accordance with ASME BPV-1.

In addition, the requirements of Clauses 2.2.2 to 2.2.6 shall apply as appropriate.

2.2.2 Carbon and carbon-manganese steels

The design strengths for carbon and carbon-manganese steels specified in Table 2.2.1 are intended for general use with the steels listed (see Notes).

NOTES:

- 1 Where carbon or carbon-manganese material is heat treated as part of an assembled component, acceptance tests are not generally required as any reduction in properties due to postweld heat treatment is compensated by the overall benefit obtained by stress relief of the component. This Note is not applicable to TMCP material, refer to steel manufacturer for steel properties after heat treatment.
- 2 Where acceptance tests on materials heat treated as part of an assembled component subject to standard or non-standard heat treatments are required by the purchaser, such tests are to be specified in a supplementary specification, together with agreed acceptance criteria.

In designs where deformation is critical, testing of material after heat treatment is recommended, or the manufacturer shall ensure by carrying out appropriate procedural tests, that the specified minimum mechanical properties are retained.

TABLE 2.1
MATERIALS

Material type	Material form	Reference Standard	Grades
C, C-Mn	Plate	AS 1548 AS/NZS 3678 BS 1501: Part 1 ASTM A515 ASTM A516 EN 10028-2 EN 10028-3	PT, 5 and 7 250, 300 and 350 (See Note) 151, 161, 164, 223, 224 60, 65, 70 60, 65, 70 P235GH, P265GH, P295GH, P355GH P275N, P355N, P275NH, P355NH, P460NH
		AS/NZS 3679.1 BS 1502 EN 10273	250, 300 and 350 (See Note) 151, 161, 211, 221, 224 P235GH, P250GH, P265GH, P295GH, P355GH, P275NH, P355NH, P460NH, P355QH, P460QH, P500QN, P690QH
	Forgings	BS 1503 EN 10222-2 EN 10222-4 ASTM A105	221, 223, 224 P245GH, P280GH, P305GH P285NH, P355NH, P420NH, P285QH, P355QH, P420QH
	Castings	AS 2074 BS 1504 ASTM A216	C7A-1, C7A-2 161-430A,E, 480A,E, 540A WCA, WCB, WCC
	Tubes	BS 3059: Part 1 BS 3059: Part 2 BS 3601 BS 3602: Parts 1 and 2 EN 10216-1 EN 10216-2 EN 10216-3 EN 10217-1 EN 10217-2 EN 10217-3	320 360, 440 320, 360, 430 360, 410, 430, 460, 500 Nb P195TR2, P235TR2, P265TR2 P195GH, P235GH, P265GH P275NL1, P275NL2, P355NH, P460N P195TR2, P235TR2, P265TR2 P195GH, P235GH, P265GH P275NL1, P275NL2, P355NH, P460N
		ASTM A53	B
		ASTM A106	B
		API 5L	B
C-½ Mo	Plate	BS 1501: Part1 EN 10028-2	240 16Mo3
	Forgings	BS 1503 EN 10222-2	245 16Mo3
	Castings	AS 2074 BS 1504 ASTM A217	L5A-2 245E WC1
	Tubes	BS 3059: Part 2 EN 10216-2 EN 10217-2	243 16Mo3 16Mo3

(continued)

TABLE 2.1 (continued)

Material type	Material form	Reference Standard	Grades
1¼ Ni Cu Mo Nb	Tubes	BS 3604: Part 1	591
1 Cr-½ Mo	Plate	BS 1501: Part 2 EN 10028-3	620 13CrMo4-5
	Forgings	EN 10222-1	620
	Tubes	BS 3604: Part 1 BS 3059: Part 2 EN 10216-2	620–440 620–460 13CrMo4-5
1¼ Cr-½ Mo	Plate	BS 1501: Part 2	621
	Forgings	BS 1503	621
	Castings	AS 2074 BS 1504 ASTM A217	L5B 621A WC6
	Tubes	BS 3604: Part 1 EN 10216-2	621–420 10CrMo5-5
Mn-Cr-Mo-V Ni-Cr-Mo-V	Plate	BS 1501: Part 2	271, 281
	Forgings	BS 1503	271
½ Cr-½ Mo-¼ V	Forgings	BS 1503 EN 10222-2	660 14MoV6-3
	Castings	AS 2074 BS 1504	L5H 660A
	Tubes	BS 3604 EN 10216-2	660–460 14MoV6-3
2¼ Cr-1 Mo	Plate	BS 1501: Part 2 EN 10028-2	622 10CrMo9-10, 11CrMo9-10
	Forgings	BS 1503 EN 10222-2	622 11CrMo9-10
	Castings	AS 2074 BS 1504 ASTM A217	L5C 622E WC9
	Tubes	BS 3604: Part 1 BS 3059: Part 2 EN 10216-2	622–490 622–490 10CrMo9-10, 11CrMo9-10
5 Cr-½ Mo	Plate	ASTM A387	5 C1
	Forgings	BS 1503 EN 10222-2 ASTM A182 ASTM A336	625 X16CrMo5-1 F5, F5a F5, F5A
	Castings	AS 2074 ASTM A217	L5E C5
	Tubes	BS 3604: Part 1 EN 10216-2 ASTM A213 ASTM A335	625 X11CrMo5+1, X11CrMo5+NT1, X11CrMo5+NT2 T5 P5, P5b, P5c

(continued)

TABLE 2.1 (continued)

Material type	Material form	Reference Standard	Grades
9 Cr-1 Mo	Forgings	ASTM A182	F9
	Castings	BS 1504 ASTM A217	629A C12
	Tubes	BS 3604: Part 1 BS 3059: Part 2 EN 10216-2 ASTM A213 ASTM A335	629–590 629–590 X11CrMo9–1+I, X11CrMo9–1+NT T9 P9
9 Cr Mo-V Nb-N	Plate	ASTM A387	91
	Forgings	BS 1503 ASTM A182	91 F91
	Tubes	BS 3059: Part 2 BS 3604: Part 1 EN 10216-2 ASTM A213 ASTM A335	91 91 X10CrMoVNb9–1 T91 P91
12 Cr-1 Mo-V	Forgings	BS 1503	762-690
	Tubes	BS 3604: Part 1 BS 3059: Part 2 EN 10216-2	762 762 X20CrMoV11-1
18 Cr-10 Ni	Plate	BS 1501: Part 3 EN 10028-7 ASTM A240	304S31, 304S11, 304S51 X5CrNi18-10, X2CrNi19-11, X6CrNi18-10 304, 304H
	Forgings	BS 1503 EN 10222-5 ASTM A182	304S11, 304S31, 304S51 X5CrNi18-10, X2CrNi18-9, X6CrNi18-10 F304, F304H
	Castings	BS 1504 ASTM A351	304C15A CF8
	Tubes	BS 3059: Part 2 BS 3605: Parts 1 and 2 EN 10216-5 EN 10217-7 ASTM A213 ASTM A312	304S51 304S31, 304S11, 304S51 X5CrNi18-10, X2CrNi18-9, X2CrNi19-11, X6CrNi18-10 X2CrNi18-9, X2CrNi19-11, X5CrNi18-10 TP304, TP304H TP304, TP304H
18 Cr-12 Ni-2 Mo	Plate	BS 1501: Part 3 EN 10028-7 ASTM A240	316S31, S33, 316S11, S13, 316S51, S53 X5CrNiMo17-12-2, X2CrNiMo17-12-2 316, 316H
	Forgings	BS 1503 EN 10222-5 ASTM A182	316S31, S33, 316S11, S13, 316S51 X5CrNiMo17-12-2, X2CrNiMo17-12-2 F316, F316H
	Castings	BS 1504 ASTM A351	316C71 CF8M

(continued)

TABLE 2.1 (continued)

Material type	Material form	Reference Standard	Grades
	Tubes	BS 3059: Part 2 BS 3605 EN 10216-5 EN 10217-7 ASTM A213 ASTM A312	316S51, 316S52 316S31, 33, 316S11, 13, 316S51, 52 X2CrNiMo17-12-2, X5CrNiMo17-12-2 X3CrNiMo17-13-3, X6CrNiNb17-13-2 X2CrNiMo17-12-2, X5CrNiMo17-12-2, X2CrNiMo17-12-3, X3CrNiMo17-13-3 TP304, TP304H TP316, TP316H
18 Cr-10 Ni-Ti	Plate	BS 1501: Part 3 EN 10028-7 ASTM A240	321S31, 321S51 X6CrNiTi18-10 321, 321H
	Forgings	BS 1503 EN 10222-5 ASTM A182	321S31, 321S51 X6CrNiTi18-10 F321, F321H
	Tubes	BS 3059: Part 2 BS 3605: Parts 1 and 2 EN 10216-5 EN 10217-7 ASTM A213 ASTM A312	321S51 (1010), 321S51(1105) 321S51 (1010), 321S51 (1105) X6CrNiTi18-10, X7CrNiTi18-10 X6CrNiTi18-10 TP321, TP321H TP321, TP321H
18 Cr-10 Ni-Nb	Plate	BS 1501: Part 3 EN 10028-7 ASTM A240	347S31, 347S51 X6CrNiNb18-10, X8CrNiTi16-13 347, 347H
	Forgings	BS 1503 EN 10222-5 ASTM A182	347S31, 347S51 X6CrNiNb18-10, X7CrNiNb18-10 F347, F347H
	Castings	BS 1504	347C17A
	Tubes	BS 3059: Part 2 BS 3605: Parts 1 and 2 EN 10216-5 EN 10217-7 ASTM A213 ASTM A312	347S51 347S31, 347S51 X6CrNiNb18-10, X7CrNiNb18-10 X6CrNiNb18-10 TP347, TP347H TP347, TP347H
15 Cr-10 Ni-6 Mo-Nb-V	Tubes	BS 3059: Part 2 BS 3605: Parts 1 and 2	215S15 215S15

NOTES:

- AS/NZS 3678 and AS/NZS 3679.1 can be used for pressure parts subject to the thickness and temperature limitations within Clause 2.1.6.
- Some British Standards (BS) may have been superseded by EN standards and the associated material grades may no longer be current. These materials have been retained in recognition that material stocks may still be available.

TABLE 2.2.1
DESIGN STRENGTH VALUES

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
			MPa	mm			100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630
C, C-Mn	Plate	AS 1548	PT430	>3 ≤16		INDEF	159	159	155	142	131	121	113	111	110	109	108	107	105	104	103	102	102													
				>16 ≤40			159	157	145	133	122	113	106	104	103	102	101	100	99	98	97	96	96													
				>40 ≤80			159	152	139	128	117	109	102	100	99	98	97	96	95	94	93	92	92													
				>80 ≤150			159	141	129	119	109	101	95	93	92	91	90	89	88	87	86	86	86													
			PT460	>3 ≤16		INDEF	170	170	157	144	133	123	115	113	112	111	110	109	108	107	106	105	104													
				>16 ≤40			170	166	152	139	128	119	111	109	108	107	106	105	104	103	102	101	100													
				>40 ≤80			167	155	142	130	119	111	104	102	100	99	98	97	95	93	93	92	91													
				>80 ≤150			161	149	137	125	115	107	100	98	97	96	95	94	93	92	91	90	90													
			PT490	>8 ≤16		INDEF	181	181	181	170	157	145	136	134	132	130	129	128	126	125	124	123	123													
				>16 ≤40			181	181	175	161	148	137	129	127	125	124	122	121	120	119	118	117	117													
				>40 ≤80			181	181	170	156	144	133	125	123	121	120	118	117	116	115	114	113	113													
				>80 ≤150			181	179	165	151	140	129	121	119	117	116	115	115	114	113	112	111	111													
			7-460R, N, T	All	23	INDEF				124	110	105		98	86	73	61	52	45	38	32															
							100 000							98	96	84	71	60	52	44	37															
							150 000							98	89	75	63	54	46	38	30															
							200 000							98	82	69	58	49	42	34																
							250 000							93	78	65	55	46	38																	
			7-460RH, NH, TH	All	23	INDEF				132	117	112	105	101	86	73	61	52	45	38	32															
							100 000							104	99	84	71	60	52	44	37															
							150 000							104	89	75	63	54	46	38	30															
							200 000							98	82	69	58	49	42	34																
							250 000							93	78	65	55	46	38																	

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																															
							Temperature, °C																															
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
			5-490N	All	23	INDEF				150	138	130	110	97	82	69	59	49	43	36	31																	
						100 000							123	112	95	80	68	57	49	42	35																	
						150 000							117	101	85	72	60	52	44	37	29																	
						200 000																																
						250 000																																
			5-490NH, AH	All	23	INDEF				160	147	139	110	97	82	69	59	49	43	36	31																	
						100 000							127	112	95	80	68	57	49	42	35																	
						150 000							117	101	85	72	60	52	44	37	29																	
						200 000																																
						250 000																																
			7-490R, N, T	All	23	INDEF				133	120	114	108	105	91	78	67	57	49	42	37																	
						100 000							107	105	90	77	65	56	48	42																		
						150 000							107	95	81	68	58	50	43	38																		
						200 000							104	88	75	63	54	46	40	34																		
						250 000							98	83	70	59	51	43	37	32																		
		7-490RH, NH, TH, AH	All	23	INDEF				141	128	121	115	105	91	78	67	57	49	42	37																		
					100 000							114	105	90	77	65	56	48	42																			
					150 000							111	95	81	68	58	50	43	38																			
					200 000							104	88	75	63	54	46	40	34																			
					250 000							98	83	70	59	51	43	37	32																			
		ASTM A515	60 (415)	All	21, 22, 23	INDEF	134	130	126	121	115	108	88	83	78	72	67	62	55	48	42	37	31	24	27	20	16	13										
			65 (450)	All	21, 22, 23	INDEF	146	142	138	132	125	118	95	88	82	76	69	63	56	48	42	37	31	24	27	20	16	13										
			70 (485)	All	21, 22, 23	INDEF	159	154	150	144	136	128	101	94	87	80	73	67	60	54	47	40	33	28	23	19	16	13										
		ASTM A516	60 (415)	All	21, 22, 23	INDEF	134	130	126	121	114	108	88	83	78	72	67	62	55	48	42	37	31	24	27	20	16	13										
			65 (450)	All	21, 22, 23	INDEF	146	142	138	132	125	118	95	88	82	76	69	63	56	48	42	37	31	24	27	20	16	13										
			70 (485)	All	21, 22, 23	INDEF	159	154	150	144	136	128	101	94	87	80	73	67	60	54	47	40	33	28	23	19	16	13										

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
			MPa	mm	100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
		AS/NZS 3678	250	All	10, 11	INDEF	125	112	106	99	138	129																								
			300	All	10, 11	INDEF	146	139	126	116	109	105																								
			350	All	10, 11	INDEF	153	153	145	134	125	118																								
			400	All	10, 11	INDEF	164	164	164	150	138	129																								
		BS 1501-1	151-430A, B 161-430A, B	>3 ≤16	11	INDEF	128	128	128	128	107	102	94	85	76	68	60	52	45	38	31															
				>16 ≤40	7, 11	100 000	121	121	121	121			99	98	88	79	69	60	52	44	36															
				>40 ≤63		150 000	119	119	119	119			99	93	83	74	65	56	48	40	32															
				>63 ≤100		200 000	115	115	115	115			99	90	80	71	62	53	45	37	28															
				>100 ≤150		250 000	110	110	110	110			97	87	78	68	59	51	42	35	26															
			164-400A	All	11	INDEF	111	111	111	111	98	91	86	85	76	68	60	52	45	38	31															
						100 000								85	84	79	69	60	52	44	36															
						150 000								93	83	74	65	56	48	40	32															
						200 000								89	80	71	62	53	45	37	28															
						250 000								87	78	68	59	51	42	35	26															
			164-400B	All	11	INDEF	121	121	121	121	108	101	95	85	76	68	60	52	45	38	31															
						100 000								94	88	79	69	60	52	44	36															
						150 000								93	83	74	65	56	48	40	32															
						200 000								90	80	71	62	53	45	37	28															
						250 000								87	78	68	59	51	42	35	26															
			223-460A	All	11	INDEF	143	143	143	143	130	124	115	105	91	78	67	57	49	42	37															
						100 000								115	114	105	90	77	65	56	48	42														
						150 000								115	111	95	81	68	58	50	43	39														
						200 000								115	104	88	75	63	54	46	40	34														
						250 000								115	98	83	70	59	51	43	37	32														

* End of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630
			223-460B	All	11	INDEF	158	158	158	158	139	131	124	110	91	78	67	57	49	42	37															
						100 000							124	121	105	90	77	65	56	48	42															
						150 000							124	111	95	81	68	58	50	43	38															
						200 000							121	104	88	75	63	54	46	40	34															
						250 000							115	98	83	70	59	51	43	37	32															
			223-490A	All	11	INDEF	158	158	158	158	139	131	119	105	91	78	67	57	49	42	37															
						100 000							124	121	105	90	77	65	56	48	42															
						150 000							124	111	95	81	68	68	50	43	38															
						200 000							121	104	88	75	63	63	46	40	34															
						250 000							115	98	83	70	59	59	43	37	32															
			223-490B	All	11	INDEF	168	168	168	168	147	137	119	105	91	78	67	57	49	42	37															
						100 000							132	121	105	90	77	65	56	48	42															
						150 000							128	111	95	81	68	58	50	43	38															
						200 000							121	104	88	75	63	54	46	40	34															
						250 000							115	98	83	70	59	51	43	37	32															
			224-430A	All	11	INDEF	121	121	121	121	108	101	95	94	89	78	67	57	49	42	37															
						100 000									93	90	77	65	56	48	42															
						150 000									93	81	68	58	50	43	38															
						200 000									88	75	63	54	46	40	34															
						250 000									83	70	59	51	43	37	32															
			224-430B -460A	All	11	INDEF	132	132	132	132	117	111	105	104	89	78	67	57	49	42	37															
						100 000									104	103	90	77	65	56	48	42														
						150 000									104	95	81	68	58	50	43	38														
						200 000									104	88	75	63	54	46	40	34														
						250 000									98	83	70	59	51	43	37	32														

AWA Document

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630
AWA Do			224-490A, B -460B	All	11	INDEF	142	142	142	142	128	121	115	105	91	78	67	57	49	42	37															
						100 000							115	114	105	90	77	65	56	48	42															
						150 000							115	111	95	81	68	58	50	43	38															
						200 000							115	104	88	75	63	54	46	40	34															
						250 000							115	98	83	70	59	51	43	37	32															
	Sections and bars	BS 1502	151-430 161-430 >16 ≤40 (25 ≤63) >40 ≤63 (63 ≤100) >63 ≤100 (100 ≤160)	>3 ≤16 (≤25)	7, 11, 17	INDEF	128	128	128	128	107	102	94	85	76	68	60	52	45	38	31	24														
						100 000	121	121	121	121			99	98	88	79	69	60	52	44	36	28														
						150 000	119	119	119	119			99	93	83	74	65	56	48	40	32	22														
						200 000	115	115	115	115			99	90	80	71	62	53	45	37	28	18														
						250 000							97	87	78	68	59	51	42	35	26															
			211-430 221-430 >16 ≤40 (25 ≤63) >40 ≤63 (63 ≤100) >63 ≤100 (100 ≤160)	>3 ≤16 (≤25)	7, 11, 17	INDEF	128	128	128	128	107	102	99	98	89	78	67	57	49	42	37	31	28													
						100 000	121	121	121	121					97	90	77	65	56	48	42	36	32													
						150 000	119	119	119	119					95	81	68	58	50	43	38	32	26													
						200 000	115	115	115	115					88	75	63	54	46	40	34	28														
						250 000									83	70	59	51	43	37	31	25														
			224-430	All	11	INDEF	121	121	121	121	108	101	95	94	89	78	67	57	49	42	37															
						100 000									93	90	77	65	56	48	42	36	32													
						150 000									93	81	68	58	50	43	38	32	26													
						200 000									88	75	63	54	46	40	34	28														
						250 000									83	70	59	51	43	37	32	25														

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630
Forgings			224-490	All	11	INDEF	142	142	142	142	128	121	115	105	91	78	67	57	49	42	37															
						100 000								114	105	90	77	65	56	48	42	36	32													
						150 000								111	95	81	68	58	50	43	37	32	26													
						200 000								104	88	75	63	54	46	40	34	28														
						250 000								98	83	70	59	51	43	37	31	25														
		AS/NZS 3679.1	250	—	9, 10	INDEF	114	114	114	114																										
		AS/NZS 3679.1	350	—	9, 10	INDEF	138	138	138	138																										
		BS 1503	221-430	≤100 >100	6, 7, 11	INDEF	119	119	119	119	107	102	99	99	89	78	67	57	49	42	37															
						100 000	115	115	115	115				99	98	90	77	65	56	48	42															
	150 000												99	95	81	68	58	50	43	38																
	200 000												99	88	75	63	54	46	40	34																
	250 000												98	83	70	59	51	43	37	32																
	221-460		≤100 >100	6, 7, 11	INDEF	129	129	129	129	117	112	108	104	91	78	67	57	49	42	37																
		100 000			125	125	125	125				108	105	90	77	65	56	48	42																	
		150 000										108	95	81	68	58	50	43	38																	
200 000											104	88	75	63	54	46	40	34																		
250 000											98	83	70	59	51	43	37	32																		
221-490	≤100 >100	6, 7, 11	INDEF	140	140	140	140	128	122	118	105	91	78	67	57	49	42	37																		
			100 000	135	135	135	135			118	118	105	90	77	65	56	48	42																		
			150 000							118	111	95	81	68	58	50	43	38																		
			200 000							118	104	88	75	63	54	46	40	34																		
			250 000							115	98	83	70	59	51	43	37	32																		

(continued)

* See end of this Table for Notes

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630
			221-510	≤100	6, 11	INDEF	147	147	147	147	135	129	119	105	91	78	67	57	49	42	37															
						100 000							124	121	105	90	77	65	56	48	42															
						150 000							124	111	95	81	68	58	50	43	38															
						200 000							121	104	88	75	63	54	46	40	34															
						250 000							115	98	83	70	59	51	43	37	32															
			223-430	≤100 >100	6, 7, 11	INDEF	128	128	128	128	114	107	100	99	89	78	67	57	49	42	37															
						100 000	123	123	123	123					98	90	77	65	56	48	42															
						150 000									95	81	68	58	50	43	38															
						200 000									88	75	63	54	46	40	34															
						250 000									83	70	59	51	43	37	32															
			223-460	≤100 >100	6, 7, 11	INDEF	140	140	140	140	127	119	111	104	91	78	67	57	49	42	37															
						100 000	135	135	135	135					110	105	90	77	65	56	48	42														
						150 000									110	95	81	68	58	50	43	38														
						200 000									104	88	75	63	54	46	40	34														
						250 000									98	83	70	59	51	43	37	32														
			223-490	≤100 >100	6, 7, 11	INDEF	152	152	152	152	139	131	119	105	91	78	67	57	49	42	37															
						100 000	146	146	146	146					123	121	105	90	77	65	56	48	42													
						150 000									123	111	95	81	68	58	50	43	38													
						200 000									121	104	88	75	63	54	46	40	34													
						250 000									115	98	83	70	59	51	43	37	32													
			223-510	≤100	6, 11	INDEF	159	159	159	159	147	138	119	105	91	78	67	57	49	42	37															
						100 000									131	121	105	90	77	65	56	48	42													
						150 000									128	111	95	81	68	58	50	43	38													
						200 000									121	104	88	75	63	54	46	40	34													
						250 000									115	98	83	70	59	51	43	37	32													

* At end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																															
							Temperature, °C																															
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
AV Document 8			224-430	≤100 >100	6, 7, 11	INDEF	121	121	121	121	108	101	96	95	89	78	67	57	49	42	37																	
						100 000	117	117	117	117					95	90	77	65	56	48	42																	
						150 000									95	81	68	58	50	43	38																	
						200 000									88	75	63	54	46	40	34																	
						250 000									83	70	59	51	43	37	32																	
			224-460	≤100 >100	6, 7, 11	INDEF	132	132	132	132	118	111	105	105	104	78	67	57	49	42	37																	
						100 000	127	127	127	127				105	104	90	77	65	56	48	42																	
						150 000								105	95	81	68	58	50	43	38																	
						200 000								104	88	75	63	54	46	40	34																	
						250 000								98	83	70	59	51	43	37	32																	
			224-490	≤100 >100	6, 7, 11	INDEF	142	142	142	142	128	121	115	105	91	78	67	57	49	42	37																	
						100 000	137	137	137	137			115	115	105	90	77	65	56	48	42																	
						150 000							115	111	95	81	68	58	50	43	38																	
						200 000							115	104	88	75	63	54	46	40	34																	
						250 000							115	98	83	70	59	51	43	37	32																	
			224-510	≤100	6, 11	INDEF	149	149	149	149	135	128	119	105	91	78	67	57	49	42	37																	
						100 000							122	121	105	90	77	65	56	48	42																	
						150 000							122	111	95	81	68	58	50	43	38																	
						200 000							121	104	88	75	63	54	46	40	34																	
						250 000							115	98	83	70	59	51	43	37	32																	
			ASTM A105		All	14	INDEF	136	136	136	136	129	121	101	94	87	81	74	67	61	54	48																
	Castings	AS 2074	C7A-1	All	2	INDEF	98	98	98	98	93	89	86	84	83	74	62	53	45	38	30																	
						100 000									83	79	71	60	51	44	37																	
						150 000									83	75	63	54	46	38	30																	
						200 000									82	69	58	49	42	34																		
						250 000									78	65	54	46	38																			

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
			MPa	mm	100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
			C7A-1E	All	2	INDEF	104	104	104	104	99	95	92	91	89	74	63	53	45	38	30															
						100 000										91	84	71	60	51	44	37														
						150 000										89	75	63	54	46	38	30														
						200 000										82	69	58	49	42	34															
						250 000								88	78	65	54	46	38																	
			C7A-2	All	2	INDEF	113	113	113	113	108	103	100	98	89	74	63	53	45	38	30															
						100 000									99	99	84	71	60	51	44	37														
						150 000									99	89	75	63	54	46	38	30														
						200 000									92	82	69	58	49	42	34															
						250 000							99	88	78	65	54	46	38																	
			C7A-2E	All	2	INDEF	120	120	120	120	115	109	107	98	89	74	63	53	45	38	30															
						100 000									106	99	84	71	60	51	44	37														
	150 000												100	89	75	63	54	46	38	30																
	200 000											103	92	82	69	58	49	42	34																	
	250 000										99	88	78	65	54	46	38																			
Tubes	BS 3059-1	320 HFS, CFS ERW, CEW	All	11			86	86	86	86	77	71	68																							
	BS 3601	320, ERW	All	11			95	95	95	95	86	79	75																							
BS 3059-2	360 S1, S2 ERW, CEW	All	11	INDEF	111	111	111	111	97	87	79	78	77	66	60	52	45	38	31																	
					100 000										76	69	60	52	44	36																
					150 000										74	65	56	48	40	32																
					200 000										71	62	53	45	37	28																
					250 000											68	59	51	42	35	26															

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
			MPa	mm	100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
		BS 3601	430 ERW	All	11		115	115	115	115	103	95	89																							
		BS 3602-2	430 LAW	All	5, 11		120	120	120	120	109	101																								
			490 LAW	All	5		143	143	143	143	131	121																								
		BS 3602-1	430 HFS, CFS ERW, CEW		11	INDEF	120	120	120	120	109	101	95	82	76	68	60	52	45	38	31															
						100 000									95	88	79	69	60	52	44	36														
						150 000									93	83	74	65	56	48	40	32														
						200 000									90	80	71	62	53	45	37	28														
						250 000									87	78	68	59	51	42	35	26														
		BS 3059-2	440 S1, S2 ERW, CEW	All	11	INDEF	134	134	134	134	119	106	101	101	87	78	67	56	48	42	36															
						100 000									101	100	90	77	65	56	48	42														
						150 000									101	95	81	68	58	50	43	38														
						200 000									101	88	75	63	54	46	40	34														
						250 000									98	83	70	59	51	43	37	32														
		ASTM A53 ASTM A106 API 5L	S/B, E/B B B (seamless, ERW)	All	14, 18	INDEF	147	143	138	132	125	118	89	84	78	73	68	62	56	49	42															
		BS 3602-1	500-Nb HFS, CFS	All	11	INDEF	163	163	163	163	148	135	119	105	91	78	67	56	48	42	36															
						100 000									125	121	105	90	77	65	56	48	42													
						150 000									125	111	95	81	68	58	50	43	38													
						200 000									121	104	88	75	63	54	46	40	34													
						250 000									115	98	83	70	59	51	43	37	32													

* See end of this Table for Notes

(continued)



TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
			MPa	mm	100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
C-1/2 Mo	Castings	AS 2074	L5A-2	≤32	2	INDEF	131	131	131	131	113	106	104					103	101	99	98	82	68	54	45	36	28									
			L5A-2E	≥32	2	INDEF	140	140	140	140	121	113	111					110	109	106	98	82	68	54	45	36	28									
						100 000														106	94	78	62	52	41	32										
						150 000														106	87	70	57	46	37	30										
						200 000														100	81	65	53	42	34	28										
						250 000														95	77	62	50	40	32	25										
	Tubes	BS 3059-2	243 S1, S2 ERW, CEW	All	11	INDEF	149	149	149	149	128	120	117					115		113	99	82	68	54	45	36	28									
						100 000														112	94	78	62	52	41	32										
						150 000														107	87	70	57	46	37	30										
						200 000														100	81	65	53	42	34	28										
1 1/4 Ni-Cu-Mo-Nb	Tubes	BS 3604-1	591 HFS, CFS	All	11, 13	INDEF	226	226	226	226	226	226																								

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																														
							Temperature, °C																														
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	
1 Cr-1/2 Mo	Plate	BS 1501-2	620-A	≤75	11		154	154	154	154	143	134	132					129		127																	
				≤100			136	136	136	136	121	113	110					108		106																	
				≤150			125	125	125	125	108	99	96					94			92																
			620-B	≤75	11	INDEF	165	165	165	165	152	143	141					137			128	113	97	81	66	54	45	36	29	23							
							100 000																135	134	112	93	76	62	52	42	33	27					
							150 000																135	124	102	83	67	55	44	35	29	24					
			200 000																	135	114	94	76	61	49	40	32	26	22								
				250 000																	131	107	88	70	57	45	37	30	25	20							
				620-B	>75 ≤100	11	INDEF	145	145	145	145	129	121	117					115			113	112	97	81	66	54	45	36	29	23						
			100 000																				113	112	111	93	76	62	52	42	33	27					
			150 000																					112	102	83	67	55	44	35	29	14					
			200 000																		112	94	76	61	49	40	32	26	22								
	250 000																		107	88	70	57	45	37	30	25	20										
	620-B	>100 ≤150		11	INDEF	133	133	133	133	115	105	103					100				98	97	81	66	54	45	36	29	23								
			100 000																		98	97	93	76	62	52	42	33	27								
			150 000																			97	83	67	55	44	35	29	24								
	200 000																		94	76	61	49	40	32	26	22											
		250 000																	88	70	57	45	37	30	25	20											
Forgings		BS 1503	620-440	All	6, 11	INDEF	131	131	131	131	123	113	108					105				101	97	81	66	54	45	36	29	23							
	100 000																					101	101	93	76	62	52	42	33	27							
	150 000																						101	101	83	67	55	44	35	29	24						
	200 000																						101	94	76	61	49	40	32	26	22						
	250 000																						101	88	70	57	45	37	30	25	20						

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630
			620-540	≤200	6, 11	INDEF	200	200	200	200	196	189	186					182	181	157	140	118	105	81	66	54	45	36	29	23						
						100 000														181	180	162	136	112	93	76	62	52	42	33	27					
						150 000														181	174	149	124	102	83	67	55	44	35	29	24					
						200 000														181	162	138	114	94	76	61	49	40	32	26	22					
						250 000														179	155	131	107	88	70	57	45	37	30	25	20					
	Tubes	BS 3604-1	620-440 HFS, CFS ERW, CEW	All	11	INDEF	157	157	157	157	128	121	116					112			112	111	97	81	66	54	45	36	29	23						
						100 000																111	111	93	76	62	52	42	33	27						
						150 000																111	102	83	67	55	44	35	29	24						
						200 000																111	94	76	61	49	40	32	26	22						
						250 000																107	88	70	57	45	37	30	25	20						
		BS 3059-2	620-460 S1, S2 ERW, CEW	All	11	INDEF	129	129	129	129	129	129	120					116			114	113	97	81	66	54	45	36	29	23						
						100 000																113	112	93	76	62	52	42	33	27						
						150 000																113	102	83	67	55	44	35	29	24						
						200 000																113	94	76	61	49	40	32	26	22						
						250 000																107	88	70	57	45	37	30	25	20						
1 1/4 Cr- 1/2 Mo	Plate	BS 1501-2	621-A	≤76	11		175	175	175	175	166	159	157					153	152																	
				>76 ≤100			166	166	166	166	156	149	146					143		141																
				>100 ≤150			160	160	160	160	149	142	139					136		134																
		621-B	≤76	11	INDEF	187	187	187	187	177	170	167					163	162	161	139	118	97	81	66	54	45	36	29	23							
					100 000															161	160	136	112	93	76	62	52	42	33	27						
					150 000															161	149	124	102	83	67	55	44	35	29	24						
					200 000															161	138	114	94	76	61	49	40	32	26	22						
					250 000															155	131	107	88	70	57	45	37	30	25	20						

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																														
							Temperature, °C																														
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	
AISI 304 Document 8			621-B	>76 ≤100	11	INDEF	177	177	177	177	167	159	156					152		150	139	118	97	81	66	54	45	36	29	23							
						100 000																150	149	136	112	93	76	62	52	42	33	27					
						150 000																	150	149	124	102	83	67	55	44	35	29	24				
						200 000																	150	138	114	94	76	61	49	40	32	26	22				
						250 000																	150	131	107	88	70	57	45	37	30	25	20				
			621-B	>100 ≤150	11	INDEF	171	171	171	171	159	151	148					145		142	139	118	97	81	66	54	45	36	29	23							
						100 000																142	136	112	93	76	62	52	42	33	27						
						150 000																142	124	102	83	67	55	44	35	29	24						
						200 000																138	114	94	76	61	49	40	32	26	22						
						250 000																131	107	88	70	57	45	37	30	25	20						
	Forgings	BS 1503	621-460	All	6, 11	INDEF	145	145	145	145	137	127	122					117			115	113	97	81	66	54	45	36	29	23							
						100 000																114	112	93	76	62	52	42	33	27							
						150 000																114	102	83	67	55	44	35	29	24							
						200 000																114	94	76	61	49	40	32	26	22							
						250 000																107	88	70	57	45	37	30	25	20							
	Castings	AS 2074	L5B	All	2	INDEF	136	136	136	136	128	119	114					110			108	106	97	81	66	54	44	35	29	23							
	Tubes	BS 3604-1	621 HFS, CFS ERW, CEW	All	11	INDEF	145	145	145	145	116	110	105					101			100	100	96	81	66	54	45	36	29	23							
						100 000																	100	93	76	62	52	42	33	27							
						150 000																	100	83	67	55	44	35	29	24							
						200 000																	94	76	61	49	40	32	26	22							
						250 000																	88	70	57	45	37	30	25	20							
Mn-Cr-Mo-V	Plate	BS 1501-2	271	≤25	11	INDEF	237	237	237	237	237	234					232	230	205	181	157	134	112	93	75	60	47	36	26								
						100 000																231	231	209	181	155	129	107	87	69	54	41	30				
						150 000																	229	202	173	145	118	95	76	60	44	32	23				
						200 000																	221	192	160	132	108	87	68	51	38	26	18				
						250 000																	216	188	157	129	105	83	65	48	35	23	14				

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																														
							Temperature, °C																														
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	
		BS 1501-2	271	>25 ≤76	11	INDEF	226	226	226	226	226	226	221				219	205	181	157	134	112	93	75	60	47	36	26									
						100 000												219	209	181	155	129	107	87	69	54	41	30									
						150 000												219	202	173	145	118	95	76	60	44	32	23									
						200 000												219	192	160	132	108	87	68	51	38	26	18									
						250 000												216	188	157	129	105	83	65	48	35	23	14									
		BS 1501-2	271	>76 ≤150	11	INDEF	219	219	219	219	207	201	195					193	181	157	134	112	93	75	60	47	36	26									
						100 000												193	190	181	155	129	107	87	69	54	41	30									
						150 000												190	173	145	118	95	76	60	44	32	23										
						200 000												190	160	132	108	87	68	51	38	26	18										
						250 000												188	157	129	105	83	65	48	35	23	14										
	Forgings	BS 1503	271	All	6, 11	INDEF	208	208	208	208	204	199	192					188	181	157	134	112	93	75	60	47	36	26									
						100 000												188	186	181	155	129	107	87	69	54	41	30									
						150 000													173	145	118	95	76	60	44	32	23										
						200 000													160	132	108	87	68	51	38	26	18										
						250 000													157	129	105	83	65	48	35	23	14										
Ni-Cr-Mo-V	Plate	BS 1501-2	281	≤25	11	INDEF	237	237	237	237	237	237	234	226	211	196	181	163	146	126	107	89	74	60	48	38	29	21									
						100 000								233	233	226	209	188	168	145	124	103	85	69	55	44	33	24									
						150 000								233	232	218	202	182	158	135	112	93	77	62	47	35	26										
						200 000								233	226	213	196	177	152	128	105	87	69	55	40	31	22										
						250 000								232	222	207	191	172	147	123	98	82	65	50	35	27											
			281	>25 ≤76	11	INDEF	226	226	226	226	226	226	221	221	217	199	181	163	146	126	107	89	74	60	48	38	29	21									
						100 000												220	209	188	168	145	124	103	85	69	55	44	33	24							
						150 000												218	202	182	158	135	112	93	77	62	47	35	26								
						200 000												213	196	177	152	128	105	87	69	55	40	31	22								
						250 000												207	191	172	147	123	98	82	65	50	35	27									

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630
			281	>76 ≤150	11	INDEF 100 000 150 000 200 000 250 000	219	219	219	219	207	201	195			193	181	163	146	126	107	89	74	60	48	38	29	21								
																																			</	

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																														
							Temperature, °C																														
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	
AWA Document 3			622-515B	>100 ≤150	11	INDEF	165	165	165	165	161	157	153					143	141	124	114	102	91	82	71	62	53	46	39	34	30						
						100 000													143	141	139	131	118	105	94	82	72	61	53	45	39	34					
						150 000														141	135	122	108	97	85	73	63	56	48	42	36	31					
						200 000														141	130	117	104	92	79	68	59	52	45	38	33	28					
						250 000														139	126	113	100	87	75	65	57	49	42	36	32	27					
			622-690A	≤50	3, 8, 11		256	256	256	256	256	256	256																								
			622-690B	≤50	3, 8, 11	INDEF	256	256	256	256	256	256	250	238	226	215	204	147	136	124	114	102	91	82	71	62	53	46	39	34	30						
						100 000							256	256	256	248	235	170	157	143	131	118	105	94	82	72	61	53	45	39	34						
						150 000								256	251	238	225	161	148	135	122	108	97	85	73	63	56	48	42	36	31						
						200 000								256	247	234	221	156	143	130	117	104	92	79	68	59	52	45	38	33	28						
						250 000								255	242	229	216	152	139	126	113	100	87	75	65	57	49	42	36	32	27						
	Forgings	BS 1503	622-490	All	3, 6, 8, 11	INDEF	157	157	157	157	153	149	145	143	141	139	138	137	135	124	114	102	91	82	71	62	53	46	39	34	30						
						100 000														132	131	118	105	94	82	72	61	53	45	39	34						
						150 000															132	122	108	97	85	73	63	56	48	42	36	31					
						200 000															130	117	104	92	79	68	59	52	45	38	33	28					
						250 000															126	113	100	87	75	65	57	49	42	36	32	27					
		622-560	All	3, 6, 8, 11	INDEF	207	207	207	207	207	201	197	187	175	168	157	147	136	124	114	102	91	82	71	62	53	46	39	34	30							
						100 000								196	195	194	183	170	157	143	131	118	105	94	82	72	61	53	45	39	34						
						150 000									195	186	173	161	148	135	122	108	97	85	73	63	56	48	42	36	31						
						200 000									195	182	169	156	143	130	117	104	92	79	68	59	52	45	38	33	28						
						250 000									190	178	165	152	139	126	113	100	87	75	65	57	49	42	36	32	27						
Castings	AS 2074	L5C	All	2, 3	INDEF	185	185	185	185	181	175	170			164	161	147	133	119	104	93	82	74	66	56	53	46	39	34	30							
					100 000														163	162	153	137	120	107	95	85	76	65	61	53	45	39	34				
					150 000														163	161	144	129	112	98	88	77	68	63	56	48	41	36	31				
					200 000														163	156	139	124	107	94	83	71	63	59	52	45	38	33	28				
					250 000														163	152	135	119	103	91	79	68	60	57	49	42	36	32	27				

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																													
							Temperature, °C																													
			MPa	mm	100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
			L5C-E	All	2, 3	INDEF	197	197	197	197	193	187	181			175	161	147	133	119	104	93	82	74	66	56	53	46	39	34	30					
						100 000											174	170	153	137	120	107	95	85	76	65	61	53	45	39	34					
						150 000											174	161	144	129	112	98	88	77	68	63	56	48	41	36	31					
						200 000											172	156	139	124	107	94	83	71	63	59	52	45	38	33	28					
						250 000											170	152	135	119	103	91	79	68	60	57	49	42	36	32	27					
	Tubes	BS 3059-2	622-490	All	3, 8, 11	INDEF	157	157	157	157	153	149	145	143	141	139	138	137	135	124	113	102	91	82	71	62	53	46	39	34	30	25	23			
			S1, S2			100 000												135	133	131	118	105	94	82	72	61	53	45	39	34	29	26				
			150 000																133	122	108	97	85	73	63	56	48	42	36	31	27	23				
		BS 3604-1	622	All	3, 8, 11	200 000													130	117	104	91	79	68	59	52	45	38	33	28	25	22				
			HFS, CFS			250 000													126	113	100	87	75	65	57	49	42	36	32	27	23	20				
5 Cr-1/2 Mo	Plate	ASTM A387	5 CL 1	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	91	84	77	70	62	55	50	44	39	35	31	28	24	21	18			
	Forgings	ASTM A182	F5	All	14	INDEF	132	132	132	132	131	128	121	120	118	115	108	102	94	86	77	70	62	55	50	44	39	35	31	28	24	21	18			
			F5a	All		INDEF	170	170	170	170	168	164	156	147	138	128	116	104	94	86	77	70	62	55	50	44	39	35	31	28	24	21	18			
		ASTM A336	F5	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	91	84	77	70	62	55	50	44	39	35	31	28	24	21	18			
			F5A	All		INDEF	151	151	151	151	150	146	139	136	134	128	116	104	94	86	77	70	62	55	50	44	39	35	31	28	24	21	18			
	Castings	AS 2074	L5E	All	2		230	230	230	230	230	230	230	230	230	228	224	220																		
			L5E-E	All	2		230	230	230	230	230	230	230	230	230	230	230	230	230																	
	Tubes	ASTM A213	T5, T5b, T5c	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	91	84	77	70	62	55	50	44	39	35	31	28	24	21	18			
		ASTM A335	P5, P5b, P5c	All	14																															

See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																																					
							Temperature, °C																																					
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630								
9 Cr-1 Mo	Forgings	ASTM A182	F9	All	14	INDEF	161	161	161	161	159	155	147	145	143	141	139	136	131	123	115	103	89	76	67	58	50	44	38	33	28	24	21											
	Castings	ASTM A217	C12	All	2	INDEF	170	170	170	170	168	164	156	154	152	150	147	145	137	127	116	103	89	76	67	58	50	44	38	33	28	24	21											
	Tubes	BS 3059-2 S1, S2 BS 3604-1 HFS, CFS	629-590 S1, S2 629-590 HFS, CFS	All	11	INDEF	219	219	219	219	217	215	211	210	209	208	208	188	169	153	138	125	112	100	89	79	69	60	50	41	33	27	23											
						100 000															207	195	176	159	144	129	115	103	91	80	68	58	48	38	31	26								
						150 000																207	188	169	152	137	123	110	97	85	74	62	52	42	34	28	23							
						200 000																204	183	165	148	132	118	105	93	81	69	58	48	38	31	25	22							
						250 000																199	179	161	144	129	115	102	89	78	66	55	45	35	28	24	21							
	ASTM A213 ASTM A335	T9 P9	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20												
					Temperature, °C																																							
					100	150	200	250	300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660											
9 Cr-Mo-V	Tubes	ASTM A213 ASTM A335	T91 P91	All	14	INDEF	166	166	166	166	164	161	153	141	138	135	132	129	126	123	119	115	111	102	94	85	77	69	62	55	49	42	36	29										
9 Cr-Mo-V-Nb-N	Tubes	BS 3604-1 BS 3059-2	91 HFS, CFS 91 S1, S2	All	11	INDEF	233	233	233	233	233	229	221	207	204	201	190	177	165	153	141	129	119	108	97	88	79	70	62	55	49	43	38	33	28									
						100 000																																						
						150 000																																						
						200 000																																						
						250 000																																						
	ASTM A213 ASTM A335	T91 P91	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20												
					Temperature, °C																																							
					100	150	200	250	300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660											
					9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2	All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29			
					ASTM A213 ASTM A335	T91 P91	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20								
Temperature, °C																																												
100	150	200	250	300					350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2	All					11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
ASTM A213 ASTM A335	T91 P91	All	14	INDEF					113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20									
				Temperature, °C																																								
				100	150	200	250	300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
				9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2	All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
				ASTM A213 ASTM A335	T91 P91	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20									
Temperature, °C																																												
100	150	200	250					300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2					All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
ASTM A213 ASTM A335	T91 P91	All	14					INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20									
				Temperature, °C																																								
				100	150	200	250	300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
				9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2	All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
				ASTM A213 ASTM A335	T91 P91	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20									
Temperature, °C																																												
100	150	200	250					300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2					All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
ASTM A213 ASTM A335	T91 P91	All	14					INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20									
				Temperature, °C																																								
				100	150	200	250	300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
				9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2	All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
				ASTM A213 ASTM A335	T91 P91	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20									
Temperature, °C																																												
100	150	200	250					300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2					All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
ASTM A213 ASTM A335	T91 P91	All	14					INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20									
				Temperature, °C																																								
				100	150	200	250	300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
				9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2	All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
				ASTM A213 ASTM A335	T91 P91	All	14	INDEF	113	113	113	113	112	109	104	103	101	99	98	96	94	92	90	85	79	73	65	57	50	44	38	33	28	24	20									
Temperature, °C																																												
100	150	200	250					300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660												
9 Cr-Mo-V	Tubes	BS 3059-2	762 S1, S2					All	11	INDEF	241	241	241	241	234	230	225						215	200	192	183	174	166	150	134	120	106	93	81	69	59	50	42	35	29				
ASTM A213 ASTM A335	T91 P91	All	14					INDEF	113	113	113	113	112	109	104	103	101	99	98	96</																								

End of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																															
							Temperature, °C																															
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
18 Cr-10- Ni	Plate	BS 3604-1	762 HFS, CFS	All	11	INDEF	240	240	240	240	232	227	217					206	200	192	183	174	166	150	134	120	108	93	81	69	60	50	42	35	29			
						100 000															191	187	173	155	138	122	107	93	80	68	58	48	40	33				
						150 000																	184	168	152	135	115	98	85	72	62	52	44	37	30			
						200 000																	180	164	146	128	110	94	80	68	58	49	41	34	28			
						250 000																	176	160	142	124	105	90	77	65	55	46	38	32	25			
			Temperature, °C																																			
			100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	520	540	550	560	580	600	620	640	650	660	680	700	720						
		ASTM A240	304S51	≤100	11	INDEF	103	103	103	103	98	93	89					87					85			83	82	76	66	56	48	43	39	33	29	24		
						100 000																				82	82	76	65	55	50	45	38	33	28			
						150 000																					82	72	61	51	46	42	36	31				
	200 000																									81	69	58	48	44	40	34	30					
	250 000																									78	66	55	46	42	38	33	29					
	ASTM A240	304H	All	14, 15	INDEF	122	122	122	122	116	111	107				105		103			101		99	98	96	92	88	76	64	54	46	42	38	32	27	22		
304					All	14, 15	INDEF	122	122	122	122	116	111	107				105		103			101		99	98	96											
								Temperature, °C																														
								100	150	200	250	300	350	400	410	420	430	440	450	500	520	540	550	560	570	580	590	600	610	620	630	640	650	660	680	700	720	
Forgings	BS 1503	304S51	All	11	INDEF	103	103	103	103	98	93	89					87	85			83		82	76	71	66		56		48	43	39	33	29	24			
					100 000																				82	81	76		65		55	50	45	38	33	28		
					150 000																					82	78	72		61		51	46	42	36	31		
					200 000																					81	75	69		58		48	44	40	34	30		
					250 000																					78	72	66		55		46	42	38	33	29		
	ASTM A182	F304H	≤127	14, 15	INDEF	122	122	122	122	116	111	107				105		103	99	98	96	92	88	83	76	70	64	59	54	50	46	42	38	32	27	22		
					F304	≤127	14, 15	INDEF	122	122	122	122	116	111	107				105		103	99	98	96														
									Temperature, °C																													
									100	150	200	250	300	350	400	410	420	430	440	450	500	520	540	550	560	570	580	590	600	610	620	630	640	650	660	680	700	720

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																														
							Temperature, °C																														
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	
18 Cr-12- Ni-2 Mo	Castings	BS 1504	304C15A	All	2, 11, 13	INDEF	108	108	108	108	104	101	99					95	92	82	70	65	59		49		41		33		27	23	20	16			
						100 000														90	81	75	68		57		47		38		31	27	23	18			
						150 000														90	76	68	62		52		42		33		26	23	20	15			
						200 000														85	72	65	58		48		38		31		24	21	18				
						250 000														82	68	61	56		45		36		28		22	19	17				
	Tubes	BS 3059-2	304S51 CFS	All	11	INDEF	101	101	101	101	97	94	91					88	86			83		82	76	71	66	62	56	52	48	43	39	33	29	24	
						100 000																				82	81	76	71	65	60	55	50	45	38	33	38
		BS 3605	HFS, CFS, HFM	All		150 000																		82	78	72	66	61	55	51	46	42	36	31			
						200 000																			81	75	69	63	58	53	48	44	40	34	30		
						250 000																			78	72	66	61	55	51	46	42	38	33	29		
		ASTM A312	TP304 Smls	All	14, 15	INDEF	122	122	122	122	116	111	107					105		99	98	96															
						ASTM A213	TP304H Smls	All	14, 15	INDEF	122	122	122	122	116	111	107					105		99	98	96	92	88	83	76	70	64	59	54	50	46	42
		Temperature, °C																																			
		100 150 200 250 300 350 400 410 420 430 440 450 460 470 480 490 500 520 540 550 560 580 600 620 640 650 660 680 700 720																																			
	18 Cr-12- Ni-2 Mo	Plate	BS 1501-3	316S51, S53	≤100	11	INDEF	111	111	111	111	106	101	99					96					93			90		89	78	64	51	46	40	31	25	20
100 000																												89	88	74	58	53	46	35	28	23	
150 000																													85	66	52	46	41	32	25	19	
200 000																													79	62	48	43	38	29	22	18	
250 000																													75	58	45	40	35	27	22	18	
ASTM A240		316H	All	14, 15	INDEF	127	127	127	127	119	113	111					109					106			105		97	81	68	56	51	46	37	30	24		
		316	All	14, 15	INDEF	127	127	127	127	119	113	111					109					106		106													
Forgings		BS 1503	316S51	All	11	INDEF	111	111	111	111	106	101	99					96					93		90		89	88	78	64	51	46	40	31	25	20	
						100 000																						89	88	88	74	58	53	46	35	28	23
						150 000																							88	85	66	52	46	41	32	25	19
	200 000																											88	79	62	48	43	38	29	22	18	
	250 000																											85	75	58	45	40	35	27	22	18	

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																															
							Temperature, °C																															
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
Do not use for design		ASTM A182	F316H F316	≤127	14, 15 14, 15	INDEF	127	127	127	127	119	113	111					109					106	106	105		97	90	81	68	56	51	46	37	30	24		
						INDEF	127	127	127	127	119	113	111					109					106	106														
						Temperature, °C																																
						100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	540	550	560	580	590	600	620	640	650	660	680	700	720			
						122	122	122	122	116	110	106					102					96		93	87	79		64	51	40	36	31	25	20				
						100 000																			92	91		74	58	46	41	35	28	23				
		150 000																					85		66	52	41	36	32	25	19							
		200 000																					79		62	48	38	33	29	22	18							
		250 000																					75		58	45	35	31	27	22	18							
		Temperature, °C																																				
		100	150	200	250	300	350	400	410	420	430	440	450	460	500	520	540	550	560	580	590	600	610	620	630	640	650	660	680	700	720							
		Tubes	BS 3059-2	316S51, S52 CFS	All	3, 11	INDEF	111	111	111	111	106	102	98					96		93			90		89	86	78	71	64	57	51	46	40	31	25		
	100 000																									88	88	82	74	66	58	53	46	35	28			
	150 000																									88	85	75	66	58	52	46	41	32	25			
	200 000																									88	79	70	62	55	48	43	38	29	22			
	250 000																									85	75	66	58	52	45	40	35	27	22			
	Temperature, °C																																					
	100						150	200	250	300	350	400	410	420	430	440	450	460	500	520	540	550	560	580	590	600	610	620	630	640	650	660	680	700	720			
	111						111	111	111	106	102	98					96		93			90		89	86	78	71	64	57	51	46	40	31	25				
	100 000																				89	88	88	82	74	66	58	53	46	35	28	23						
	150 000																					85	75	66	58	52	46	41	32	25	19							
	200 000																					79	70	62	55	48	43	38	29	22	18							
	250 000																					75	66	58	52	45	40	35	27	22	18							
	Temperature, °C																																					
	100		150	200	250	300	350	400	410	420	430	440	450	460	500	520	540	550	560	580	590	600	610	620	630	640	650	660	680	700	720							
	127		127	127	127	119	113	111					109		106		106	105	105	97	90	81	75	68	62	56	51	46	37	30	24							
	ASTM A231		TP316 Smls	All	14, 15	INDEF	127	127	127	127	119	113	111					109		106		106																

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																														
							Temperature, °C																														
			MPa	mm	100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630			
18Cr-10 Ni-Ti	Plate	BS 1501-3	321S31	≤100	11	INDEF	121	121	121	121	117	113	110					107		104	103	97	90	83	76		62		49		36	32	27				
						100 000																103	102	102	86		71		57		42	36	31				
						150 000																103	101	93	78		64		49		36	32	27				
						200 000																103	97	89	74		58		45		33	28	25				
						250 000																100	93	85	71		55		42		31	26	22				
			321S51	≤100	11	INDEF	104	104	104	104	99	96	93					90		87				127	125	83		71		59		48	42	38	29	23	
						100 000																86	86	85		82		68		55	49	44	34	26			
						150 000																		85		76		62		50	44	38	29				
						200 000																		85		72		58		46	41	35	27				
						250 000																		84		68		55		44	38	33	25				
				Temperature, °C																																	
				100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	500	520	540	550	560	580	590	600	620	640	650	660	680	700	720				
				129	129	129	129	127	122	119					116			114			111	101	91	76	68	59	48	41	37	34	28	23	19				
				129	129	129	129	127	122	119					116			114			111			76	68	59	48	41	37	34	28	23					
Forgings	BS 1503	321S51-490	All	11	INDEF	93	93	93	93	87	84	81					79				78			76		76	76	71	59	48	43	38	30	23			
					100 000																						76	76	68	55	49	44	34	26			
					150 000																							76	62	50	44	38	29				
					200 000																							76	72	58	46	41	35	27			
					250 000																							76	68	55	44	38	33	25			

See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade MPa	Size mm	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																															
							Temperature, °C																															
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
Tubes			321S51-510	All	11	INDEF	121	121	121	121	117	113	110					107	104	103	103	95	88		75		62		49		36	32	27					
						100 000															103	102	102		86		71		57		42	36	31					
						150 000																103	101	93		78		64		49		36	32	27				
						200 000																103	97	89		74		58		45		33	28	25				
						250 000																100	93	85		71		55		42		31	26	22				
		ASTM A182	F321H F321	≤127	14, 15, 16 14, 15, 16	INDEF	129	129	129	129	127	122	119					116			111	101	91	84	76	68	59	54	48	44	41	37	34	28	23	19		
						INDEF	129	129	129	129	127	122	119					116			111																	
		BS 3059-2	321S51 (1010) CFS	All	11	INDEF	121	121	121	121	117	112	110					107	104		102	95	88	82	75	68	62	55	48	42	36	32						
						100 000																102	101	95	86	78	71	63	57	49	42	36						
						150 000																	101	93	86	78	72	64	56	49	42	36	32					
						200 000																	97	89	82	74	66	58	52	45	38	33	28					
						250 000																	93	85	78	71	62	55	48	42	35	31	26					
			321S51 (1105) CFS	All	11	INDEF	93	93	93	93	87	84	82					79	76				77			75	71	65	59	52	48	42	38	29				
						100 000																			75	75	75	68	60	55	49	44	34					
						150 000																			75	68	62	56	50	44	38	29						
						200 000																			72	65	58	52	46	41	35	27						
						250 000																			68	62	55	49	44	38	33	25						
		BS 3605	321S51 (1010) HFS, CFS HFM	All	11	INDEF	121	121	121	121	117	112	110					107	104		102	95	88		75		62		49	42	36	31	27					
						100 000																102	102	101		86		71		57	49	42	36	31				
						150 000																	102	101	93		78		64		49	42	36	32	27			
						200 000																	102	97	89		74		58		45	38	33	28	25			
						250 000																		100	93	85		71		55		42	35	31	26	22		

* See end of this Table for Notes

(continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																															
							Temperature, °C																															
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
			321S51 (1105) HFS, CFS HFM	All	11	INDEF	93	93	93	93	87	84	82					79	76						76		71	65	59	52	48	42	38	29	23			
			100 000																				76		75		68	60	55	49	44	34	26					
			150 000																						75		62	56	50	44	38	29						
			200 000																					76	75	72		58	52	46	41	35	27					
			250 000																					76	75	68		55	49	44	38	33	25					
		ASTM A312	TP321H Smls	All	14, 15, 16	INDEF	129	129	129	129	127	122	119					116			110	101	91	84	76	68	59	54	48	44	41	37	34	28	23	19		
		ASTM A213	TP321 Smls			INDEF	129	129	129	129	127	122	119					116			110																	
18 Cr-10 Ni-Nb	Plate	BS 1501-3	347S51	≤100	11	INDEF	127	127	127	127	123	120	118					116	115			113	101		86		71		57		46	41	36	27	20			
						100 000																		113	113		99		82		66		53	47	41	31	23	
						150 000																		113	112		93		75		61		48	42	37	28	22	
						200 000																		113	106		88		72		58		45	39	34	25	19	
						250 000																		112	102		85		68		55		42	37	32	24	19	
	Forgings	ASTM A240	347H 347	All	14, 15, 16 14, 15, 16	INDEF	119	119	119	119	117	116	116					116	115		113		112	111	106	101	91	82	73	67	60	54	49	39	32	26		
							119	119	119	119	117	116	116					116	115		110																	
		BS 1503	347S51	All	11	INDEF	127	127	127	127	123	120	118					116	115			113	101		86		71		57		46	41	36	27	20			
						100 000																		113	113		99		82		66		53	47	41	31	23	
						150 000																		113	112		93		75		62		48	42	37	28	22	
						200 000																		113	106		88		72		58		45	39	34	25	19	
						250 000																		112	102		85		68		55		42	37	32	24	19	
	ASTM A182	F347H F347	≤127		INDEF	119	119	119	119	117	116	116					116	115		113		112	111	106	101	91	82	73	67	60	54	49	39	32	26			
					INDEF	119	119	119	119	117	116	116					116	115		110																		

* See end of this Table for Notes (continued)

TABLE 2.2.1 (continued)

Steel type	Form	Standard No.	Grade	Size	Note*	Design lifetime h	Maximum allowable design strength, MPa (Notes 1, 4 and 7)*																															
							Temperature, °C																															
							100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630		
15 Cr-10 Ni-6 Mn- Fe-V	Castings	BS 1504	347C17A	All	2, 11, 13	INDEF	132	132	132	132	128	126	122					119	116	114	103	94	86		71		57		46		36	30	27	19				
						100 000															113	109	99		82		66		53		41	35	31	22				
						150 000																112	102	93		75		61		48		37	32	28	22			
						200 000																106	98	88		72		58		45		34	29	25	19			
						250 000																102	94	85		68		55		42		32	28	24	19			
	Tubes	BS 3059-2	347S51	All	11	INDEF	135	135	135	135	130	124	122					119	119		117	112	103	94	86	79	71	64	57	51	46	41	36	27	20			
						100 000															117	116	109	99	91	82	74	66	59	53	47	41	31	23				
						150 000															117	112	102	93	84	75	68	61	55	48	42	37	28	22				
						200 000															116	106	98	88	79	72	64	58	51	45	39	34	25	19				
						250 000															112	102	94	85	76	68	61	55	48	42	37	32	24	19				
		BS 3605	347S51 HFS, CFS HFM	All	11	INDEF	135	135	135	135	130	124	122					119	118		117	112	103		86		71		57	51	46	41	36	27	20			
						100 000															117	116		99		82		66	59	53	47	41	31	23				
						150 000															117	112		93		75		61	54	48	42	37	28	22				
						200 000															116	106		88		72		58	51	45	39	34	25	19				
						250 000															112	102		85		68		55	48	42	37	32	24	19				
		ASTM A312	TP347H Smls	All	14, 15, 16	INDEF	119	119	119	119	117	116	116					116	115		113		112	111	106	101	91	82	73	67	60	54	49	39	32	36		
						100 000															116	115		110														
						150 000															116	115		110														
						200 000															116	115		110														
						250 000															116	115		110														
ASTM A313	TP347 Smls	All	14, 15, 16	INDEF	119	119	119	119	117	116	116					116	115		110																			
				100 000															116	115		110																
				150 000																116	115		110															
				200 000																116	115		110															
				250 000																116	115		110															
Tubes	BS 3059 Part 2 BS 3605	215S15 CFS 215S15 HFS, CFS HFM	All		INDEF	141	141	141	141	138	136	135					133	132			130					126		124	111	93	75	62	45	35				
					100 000																							124	123	107	87	71	52	40				
					150 000																								124	114	93	75	62	46	35			
					200 000																									124	104	83	67	56	42	32		
					250 000																										118	96	76	62	52	40	—	

NOTES TO TABLE 2.2.1:

1 *General Notes:*

- (a) Table 2.2.1 gives the maximum allowable design strength (f) of various materials for the design temperatures stated at the head of each column. Time-dependent values (shown in *italics*) are given for a non-defined (INDEF) design lifetime and for design lifetimes of 100 000 h, 150 000 h, 200 000 h and 250 000 h. Values at intermediate temperatures and intermediate times shall be obtained by linear interpolation; values obtained by linear interpolation involving only one time-dependent value may be regarded as time-dependent. Unless otherwise indicated, design strength values have been determined in accordance with Appendix D.

Where the material specification makes provision for the material to be supplied with elevated temperature properties (hot tested or verified), design strength values are given for each condition, e.g. for AS 1548 plates where the letter 'H' in the grade designation indicates hot tested material, for BS 1501 plates where the letter 'A' indicates non-hot tested material and the letter 'B' indicates hot tested material, for AS 2074 castings and BS 1503 forgings where the letter 'E' indicates hot tested material.

- (b) The design temperature as defined in Clause 2.2.5 should not exceed the upper temperature for which a value of f is given except where Note 1(c) applies. Where extrapolation of the values given is required, this shall be the subject of agreement between the parties concerned.
- (c) If required for stress analysis purposes, the transition from linear elastic to linear plastic behaviour for all materials except austenitic steels may be assumed to occur at a stress of $1.5 f$ unless f is time-dependent. For austenitic steels, the corresponding stress may be taken as $1.35 f$.
- (d) Overall thickness limits are as defined in the relevant material specification. For forgings, the term 'ruling section' shall be interpreted in accordance with BS 5046.
- (e) For values between the thicknesses stated, design strengths shall be obtained by linear interpolation.
- 2 An appropriate casting quality factor, as specified in Clause 2.2.4 shall be applied to these values.
- 3 Time-dependent values may be increased by up to 10%, subject to continued fitness for service reviews (see Clause 2.3) being instituted at two-thirds of the design lifetime indicated, provided the resulting value does not exceed the lowest time-independent stress value.
- 4 Time-dependent values should be reduced by 10%, unless continued fitness for service reviews (see Clause 2.3) are instituted at two-thirds of design lifetime indicated.
- 5 Use of submerged arc welded tube is conditional on its being subjected to the same non-destructive examination requirements as those laid down for longitudinal seams in drums.
- 6 Materials may be supplied in the quenched and tempered condition, in which case properties will be particularly susceptible to degradation as a result of subsequent fabrication processes.
- 7 Values to the left of '(' are associated with material size (not design lifetime).
- 8 At temperatures at or above 580°C the effect of scaling becomes significant and due allowance should be made for this.
- 9 Thickness to satisfy requirements of Clause 2.1.6, see also Clause 2.1.7.
- 10 The AS/NZS 3678 grades/thickness are produced by thermo-mechanical controlled process (TMCP). Plates produced by this process may experience reduction in properties after hot forming/normalizing. The fabricator should check for suitability of the plates for such applications with the manufacturer before ordering the material. In the case of hot forming/normalizing applications, mechanical properties of the plates may need to be verified by tests once specimen subjected to simulated heat treatment equivalent to that to which the vessel is subjected.
- 11 Some British Standards covering these materials may have been withdrawn in favour of the EN series Standards. These materials are regarded as obsolescent, but their use may be continued using the design strength values given in Table 2.2.1. The design strength values for the EN materials have not been listed in Table 2.2.1; however, their values may be calculated in accordance with Appendix D, using properties obtained from the EN Standards.
- 12 Time-dependent design stress values apply only if the minimum carbon content equals or exceeds 0.04%.
- 13 The use of steel BS 3604-1 Grade 591 shall be limited to applications at design temperatures not exceeding 400°C.
- 14 For general notes, recommendations, conditions, and limitations on the use of ASME materials, reference should be made to ASME BPV-II-D, Notes to Table 1A.

- 15 Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed 66.67% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.
- 16 For temperatures above 540°C, these stress values may be used only if the material is heat treated by heating to a minimum temperature of 1090°C, and quenching in water or rapidly cooling by other means.
- 17 Sizes in parenthesis apply to sections and flat bars.
- 18 The design strength values for the welded pipes (A53 E/B, API-5L ERW) have a weld joint factor of 1.0. These values may be used for boiler construction, providing the following requirements are met:
 - (a) The pipe is used for pressure parts enclosed within the boiler casing enclosure.
 - (b) The maximum outside diameter shall not exceed 89 mm.
 - (c) The weld seam of each pipe shall be subject to an angle beam ultrasonic inspection meeting the requirements of ASME BPV-II-A SA-450.
 - (d) A complete volumetric inspection of the entire length of each pipe shall be performed to meet the requirements of ASME BPV-II-A SA-450.
 - (e) Each pipe shall be hydrostatically tested to meet the requirements of ASME BPV-II-A SA-450.
 - (f) Material test reports to be provided.
- 19 Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite.
- 20 Stress values at temperatures of 450°C and above are permissible but, except for tubular products 75 mm OD or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.
- 21 Allowable stresses for temperatures of 370°C and above are values obtained from time-dependent properties. *Italic font indicates these values.*
- 22 Allowable stresses for temperatures of 400°C and above are values obtained from time-dependent properties. *Italic font indicates these values.*
- 23 The design strength values for these superseded material specifications are included as a guide and reference only.

2.2.3 Alloy steels

The design strengths for alloy steels given in Table 2.2.1 shall be used.

NOTES:

- 1 Where non-standard materials or heat treatment parameters are to be used, the appropriate design strength and heat treatment period and temperatures are subject to prior agreement between the parties concerned.
- 2 Where acceptance tests on material heat treated as part of an assembled component are required, these are to be specified in a supplementary specification, together with the agreed acceptance criteria.

2.2.4 Cast steels

For cast steels the design strength (f) shall be taken as 80% of the value specified in Table 2.2.1 except for high class castings subjected to the inspection procedure specified in AS 4037, where f may be taken as 90% of the value specified in Table 2.2.1.

2.2.5 Design temperature for water-tube boilers

2.2.5.1 General

The design temperature (T) used to evaluate the design strength (f) shall be determined in accordance with Clauses 2.2.5.2 to 2.2.5.7 inclusive, as appropriate.

2.2.5.2 Shells, drums, headers and similar pressure parts

For drums, headers and similar pressure parts the design temperature shall be determined as follows:

- (a) For pressure parts not heated by hot gases and those parts adequately protected by insulation from hot gases, T shall be equal to the maximum temperature of the internal fluid.
NOTE: A covering of refractory or insulating material that may be liable to become dislodged is not considered adequate protection.
- (b) For pressure parts heated by hot gases, T shall be the mean wall temperature determined by the manufacturer, but shall not be taken as less than 25°C in excess of the maximum temperature of the internal fluid.

Drums and headers of thickness greater than 30 mm shall not be exposed to combustion gases having an expected temperature in excess of 650°C unless they are efficiently cooled by closely arranged tubes.

In determining the maximum temperature of superheated steam, the following factors shall be taken into account:

- (i) Increased heat input into the tube bank under consideration, increase in steam inlet temperature resulting from deviation in the performance of preceding heating surfaces and deviation from ideal combustion conditions.
- (ii) Inequalities in gas temperature and flow occurring in any cross-section of the gas path.

For expected steam temperatures not in excess of 425°C in the part under consideration, an addition of 15°C shall be deemed to cover these factors; for higher steam temperatures only in exceptionally favourable circumstances would a smaller addition than 15°C be acceptable.

2.2.5.3 *Boiler tubes*

For boiler tubes, T shall be taken as—

- (a) for tubes mainly subject to convection heat, not less than 25°C in excess of the saturated steam temperature at the calculation pressure; and
- (b) for tubes mainly subject to radiant heat, not less than 50°C in excess of the saturated steam temperature at the calculation pressure.

2.2.5.4 *Superheater and reheater tubes*

For superheater and reheater tubes, T shall be taken as—

- (a) for tubes mainly subject to convection heat, not less than 35°C in excess of the steam temperature expected in the part being considered; and
- (b) for tubes mainly subject to radiant heat, not less than 50°C in excess of the steam temperature expected in the part being considered.

For superheater and reheater tubes subject to the direct radiant heat from the combustion chamber, or for expected steam temperatures in excess of 425°C in the part under consideration, the calculation of T shall take account of the following factors:

- (i) Variation in the steam flow from the mean value in individual tubes of a tube bank produced by entry and exit conditions and by manufacturing tolerances on thickness and diameter.
- (ii) Increased heat input into the tube bank under consideration, increase in steam inlet temperature resulting from deviation in the performance of preceding heating surfaces and deviation from ideal combustion conditions.
- (iii) Inequalities in gas temperature and flow occurring in any cross-section of the gas path.

2.2.5.5 *Economizer tubes*

For economizer tubes, T shall be taken as not less than 25°C in excess of the working temperature of the internal fluid or not less than the saturation temperature corresponding to the design pressure of the boiler, whichever is greater.

2.2.5.6 *Integral pipes*

For integral pipes, T shall be taken as the maximum temperature of the fluid inside the pipe.

For piping between interstages of superheaters and reheaters and/or attemperators, the factor for imbalance in steam conditions and margins outlined in Clause 2.2.5.2(i) and (ii) shall be taken into account.

2.2.5.7 *Parts beyond the final superheater header*

For parts beyond the final superheater or reheater header(s) where by suitable design arrangements factors such as inequalities in gas temperature and flow occurring in any cross-section of the gas path cannot have any sustained effect on the steam temperature, T shall be the rated steam temperature at the superheater or reheater outlet, provided that in service—

- (a) the temperature on the average during any one year of operation does not exceed the design temperature; and