BS 3059 : Part 2 : 1990

British Standard

Steel boiler and superheater tubes

Part 2. Specification for carbon, alloy and austenitic stainless steel tubes with specified elevated temperature properties

Tubes pour chaudières et surchauffeurs en acier
Partie 2. Tubes en acier au carbone, allié et inoxydable à propriétés spécifiées aux températures élevées — Spécifications

Rohre für Kessel und Uberhitzer aus Stahl
Teil 2. Rohre aus warmfestem unlegiertem, legiertem oder austenitischem Stahl

British Standards Institution

Foreword

This Part of BS 3059 has been prepared under the direction of the Iron and Steel Standards Policy Committee and supersedes BS 3059 : Part 2 : 1978, which is withdrawn.

As with the previous edition this standard is published in two Parts to assist users of the standard in selecting tubes for particular duties. Part 1 is 'Specification for low tensile carbon steel tubes without specified elevated temperature properties' and Part 2 is 'Specification for carbon, alloy and austenitic stainless steel tubes with specified elevated temperature properties'.

The main technical differences between this edition and the previous edition are that changes have been made to the specified ladle analysis to take into account current steel-making practice, and an additional grade, 316S52 steel with a specified boron content has been included. The estimated average stress rupture values have been amended for both grades of steel 316.

This Part of BS 3059 is aligned as far as possible with corresponding material requirements and test procedures now agreed for incorporation in documents by the International Organization for Standardization (ISO).

The designations of steel tubes in this specification and their nearest equivalent designations in ISO 2604 : Parts II and III are given in appendix A for information.

Most of the dimensions for tubes and also the tube tolerances are taken from ISO 1129 but the range of dimensions in this standard is wider than that in ISO 1129.

The specified elevated temperature yield or proof stress values are those derived by the procedure described in BS 3920. Additionally, provision is made for the application of the related procedure for verifying that a product consistently meets specified levels of elevated temperature values. Average stress rupture values are shown in appendix B. Typical physical properties of the steels are given in appendix C for information only.

It is recommended that the results of elevated temperature tests together with information on the product thickness, the room temperature tensile properties, heat treatment details and the chemical composition of the material, should be sent to Secretariat of ISM/73/-/1, British Standards Institution, 3 York Street, Manchester M2 2AT, UK so that, for future revisions of this standard, minimum elevated temperature proof stress values can be derived from a continuously updated data bank.

The steels covered by this Part of BS 3059 are generally regarded as being weldable. However, care should be taken and welding should be carried out in accordance with the requirements of the appropriate British Standards for welding.

The appropriate British Standard for the design and construction of boilers should be consulted for requirements relating to the application and permissible design stresses for products made in accordance with this Part of BS 3059.

Purchasers ordering to this Part of BS 3059 are advised to specify in their purchasing contract that the supplier operates a quality system in compliance with BS 5750 : Part 2 to assure themselves that products claimed to comply with BS 3059 : Part 2 consistently achieve the required level of quality.

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

For the purposes of this Part of BS 3059, no difference is intended in the meaning between 'pipe' and 'tube' though idiomatic use prefers sometimes the one and sometimes the other.

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

Contents

Specification

1 Scope

This Part of BS 3059 specifies requirements for plain end, seamless and welded, carbon and alloy steel tubes and for cold finished seamless austenitic steel tubes, not exceeding 127 mm outside diameter and not exceeding 12.5 mm thickness for use in boilers and superheaters.

Tubes manufactured in accordance with this Part of BS 3059 have specified room temperature properties and specified proof stress values at elevated temperatures.

In addition to the definitive requirements, this Part of BS 3059 requires the items detailed in **2.1** to be documented. It also requires options selected by the purchaser from those detailed in **2.2** to be documented. For compliance with this Part of BS 3059 both the definitive requirements and the documented items have to be satisfied.

This Part of BS 3059 provides for two categories of room temperature test procedure, designated category 1 and category 2 (see clause **11**).

NOTE 1. The preferred outside diameters and thicknesses appropriate to this standard are given in appendix D and masses per unit length are included in this appendix for information.

NOTE 2. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Information to be supplied by the purchaser and options to be documented

2.1 Information to be supplied by the purchaser

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

(a) the designation of the tubes, i.e. the number of this Part of BS 3059, the method of manufacture of the tube and the tolerance class where applicable, the grade of steel and the category of test specified (see clause **3**). e.g. BS 3059 : Part 2 : ERW 1 620-460 : Cat 1;

(b) the tube outside diameter and thickness (see appendix B) for seamless tubes class 2, electric resistance welded tubes, and cold finished seamless tubes, or the outside or inside diameter and thickness for seamless tubes class 1 and cold finished electrical resistance welded tubes (see **10.2**);

(c) the tube length, if exact (see **2.2**(e) and **10.3**);

(d) the quantity in metres or number of lengths.

2.2 Options to be documented

A number of options are permitted by this Part of BS 3059 as listed below, and the purchaser shall identify the options required. Both the definitive requirements specified throughout this Part of BS 3059 and the following documented items shall be satisfied before a claim of compliance with this Part of BS 3059 can be made and verified. In the event that the purchaser does not indicate his requirements at the time of enquiry and order the manufacturer shall select the options where appropriate.

(a) The steelmaking process (see **4.1**).

(b) Whether a product analysis is required (see **6.2** and **15**(1)).

(c) Whether selected chemical elements additional to those specified are to be reported (see **6.3** and **15**(3)).

(d) The final supply condition of the tubes (see clause **7**).

(e) Whether lengths other than random lengths are required (see **10.3**).

(f) Whether the method of leak tightness test to be carried out on test category 2 tubes is the hydraulic test or the eddy current test (see **12.4** and **15**(5)).

(g) Whether the hydraulic test, if specified, is to be carried out at a pressure in excess of 140 bar* and the pressure required (see **13.4** and **15**(5)).

(h) Whether additional non-destructive testing is required (see **13.7**).

(i) Whether verification of elevated temperature proof stress values is required (see **13.8**).

(j) Whether verification of elevated temperature proof stress values by testing is required and the temperature selected from table 6 at which this is to be carried out (see **13.8.2**).

(k) Whether the tubes are to be supplied uncoated or with the manufacturer's normal mill coating (see clause **16**).

(l) Whether marking requirements in accordance with BS 5383 are required (see **17.1** and **17.4**).

3 Designation

The tubes shall be designated by the number and Part of this British Standard, i.e. BS 3059 : Part 2, from table 1 by the reference which indicates the method of manufacture (see clause **5**), the tolerance class (see **10.2**) and, from table 2, by a number which indicates the type of steel.

Table 1. Method of manufacture of tube, tolerance class and reference

Method of manufacture and tolerance class*	Reference
Seamless, class 1	S1
Seamless, class 2	S2
Electric resistance welded, class 1	ERW 1
Electric resistance welded, class 2	ERW 2
Cold finished electric resistance welded	CEW
Cold finished seamless (applicable only to austenitic stainless steel types)	CFS

*Tolerance class is not applicable to CEW and CFS.

*1 bar = 10^5 N/m^2 = 100 kPa.

Table 2. Steel type and type number

Steel type	Type number
Carbon and carbon manganese steels	
Carbon	360
Carbon manganese	440
Ferritic alloy steels	
0.3 % molybdenum	243
1 % chromium 0.5 % molybdenum	620-460
2.25 % chromium 1 % molybdenum (normalized and tempered)	622-490*
9 % chromium 1 % molybdenum (annealed)	629-470*
9 % chromium 1 % molybdenum (normalized and tempered)	629-590*
9 % chromium 1 % molybdenum, vanadium, niobium, nitrogen	91
12 % chromium 1 % molybdenum, vanadium	762*
*Austenitic stainless steels**	
18 % chromium 10 % nickel	304S51
18 % chromium 12 % nickel, molybdenum	316S51
18 % chromium 12 % nickel, molybdenum, boron	316S52
18 % chromium 12 % nickel, titanium (solution treated at 950 °C to 1070 °C)	321S51 (1010)†
18 % chromium 12 % nickel, titanium (solution treated at 1070 °C to 1140 °C)	321S51 (1105)†
18 % chromium 12 % nickel, niobium	347S51
15 % chromium 10 % nickel 6 % manganese, niobium, vanadium	215S15

*Only seamless tubes are available in these alloys.
†The mean of the permissible solution treatment temperature range is given.
The lower solution treatment temperature range results in higher yield strength values and the higher solution treatment temperature range gives higher stress rupture values.

Example. BS 3059 : Part 2 : CEW 620-460 : Cat 1 denotes cold finished electric resistance welded tube made from steel 620-460 tested to category 1.

NOTE. The designations for tubes in this Part of BS 3059 and their nearest equivalent designations in BS 3059 : Part 2 : 1978 and in ISO 2604 : Parts II and III are listed in appendix A for information.

4 Manufacture of the steel

4.1 Steelmaking process

The steel shall be produced by an electric process or one of the basic oxygen processes at the option of the manufacturer unless otherwise specified by the purchaser (see 2.2(a)).

4.2 Deoxidation

All steels shall be fully-killed

5 Manufacture of the product

The tubes shall be manufactured by one of the following processes.

(a) *Seamless.* The tubes shall be manufactured by a seamless process.

Carbon and ferritic alloy seamless tubes shall be hot or cold finished (see note 1). Austenitic stainless steel seamless tubes shall be cold finished (see note 1).

(b) *Electric resistance welded* (see note 2). The tubes shall be manufactured from hot or cold, flat-rolled strip longitudinally welded continuously by the passage of an electric current across the abutting edges or along the edges prior to the closure under welding pressure without the addition of filler metal. The tubes shall be as welded, hot finished or cold finished (see note 1). The finished tubes shall not include welds used for joining lengths of the hot or cold, flat-rolled strip prior to tube forming.

For tubes of both test categories ultrasonic or other suitable non-destructive testing method shall be used for the continuous examination of the weld area (see note 3).

NOTE 1. The terms 'as welded', 'hot finished' and 'cold finished' apply to the condition of the tubes before they are heat treated, if required, in accordance with clause 7.

NOTE 2. Electric resistance welded tubes cover those produced by both high and low frequency techniques using either direct contact or induction.

NOTE 3. For welded tubes, ultrasonic or other suitable non-destructive testing is used for the purpose of quality control during the process of manufacture by a method and at a place chosen by the manufacturer.

6 Chemical analysis

6.1 Ladle analysis

6.1.1 The steel shall show on ladle analysis the composition given in table 3, appropriate to the steel type specified.

6.1.2 For steel types 360 and 440 the steelmaker shall report the following additional elements to enable a carbon equivalent value to be calculated: chromium, nickel, molybdenum, vanadium and copper.

6.2 Product analysis

If a product analysis for acceptance purposes is required by the purchaser this shall be stated in the enquiry and order (see 2.2(b)).

When an analysis on the product is carried out, the permitted deviations given in table 4 shall apply to the specified ladle analysis in table 3.

The number of samples to be taken shall be one per cast. The samples shall be taken either from the test pieces used for the verification of the mechanical properties or from the whole thickness of the tube at the same location as for the mechanical test samples.

In cases of dispute, the methods of chemical analysis shall be in accordance with British Standard Handbook No. 19 or BS 6200 : Part 3, as appropriate.

Table 3. Chemical composition and mechanical properties at room temperature

Steel type	Type no.	Chemical composition (ladle analysis) (see notes 1 to 3)															Mechanical properties at room temperature (see note 5)							
		C		Si		Mn		P	S	Cr		Mo		Ni		Others (see notes 3, 4 and 6)	R_e	R_m (see note 7)		A	Flattening test constant C	Drift expanding test increase in D d/D ratio		
		min.	max.	min.	max.	min.	max.	max.	max.	min.	max.	min.	max.	min.	max.		min.	min.	max.	min.		≤0.6	>0.6 ≤0.8	>0.8
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	N/mm²	N/mm²	N/mm²	%		%	%	%
Carbon	360	–	0.17	0.10	0.35	0.40	0.60	0.035	0.035	–	–	–	–	–	–	–	235	360	500	24	0.10	12	15	19
Carbon manganese	440	0.12	0.18	0.10	0.35	0.90	1.20	0.035	0.035	–	–	–	–	–	–	–	245	440	580	21	0.07	10	12	17
0.3 % molybdenum	243	0.12	0.20	0.10	0.35	0.40	0.80	0.035	0.035	–	–	0.25	0.35	–	–	Al_{met} 0.012 max.	275	480	630	22	0.07	8	10	15
1 % chromium 0.5 % molybdenum	620-460	0.10	0.15	0.10	0.35	0.40	0.70	0.030	0.030	0.70	1.10	0.45	0.65	–	–	Al_{met} 0.020 max.	180	460	610	22	0.07	8	10	15
2.25 % chromium 1 % molybdenum (normalized and tempered)	622-490	0.08	0.15	–	0.50	0.40	0.70	0.030	0.030	2.00	2.50	0.90	1.20	–	–	Al_{met} 0.020 max.	275	490	640	20	0.07	8	10	15
9 % chromium 1 % molybdenum (annealed)	629-470	–	0.15	0.25	1.00	0.30	0.60	0.030	0.030	8.00	10.00	0.90	1.10	–	–	Al_{met} 0.020 max.	185	470	620	20	0.07	8	10	15
9 % chromium 1 % molybdenum (normalized and tempered)	629-590																400	590	740	18	0.07	8	10	15
9 % chromium 1 % molybdenum, vanadium, niobium, nitrogen	91	0.08	0.12	0.20	0.50	0.30	0.60	0.020	0.020	8.00	9.50	0.85	1.05	–	0.40	Nb 0.06 to 0.10 V 0.18 to 0.25 Al_{met} 0.030 max. N 0.030 to 0.070	450	630	830	18				
12 % chromium 1 % molybdenum, vanadium	762	0.17	0.23	–	0.50	–	1.00	0.030	0.030	10.00	12.50	0.80	1.20	0.3	0.8	Vanadium 0.25 min. 0.35 max.	470	720	870	15	0.06	6	8	12
18 % chromium 10 % nickel	304S51	0.04	0.10	–	1.00	–	2.00	0.040	0.030	17.0	19.0	–	–	8.0	11.0	–	230	490	690	35	0.09	9	15	17
18 % chromium 12 % nickel, molybdenum	316S51	0.04	0.10	–	1.00	–	2.00	0.040	0.030	16.5	18.5	2.00	2.50	10.5	13.5	–	240	510	710	35	0.09	9	15	17
18 % chromium 12 % nickel, molybdenum, boron	316S52	0.04	0.10	–	1.00	–	2.00	0.040	0.030	16.5	18.5	2.00	2.50	10.5	13.5	Boron 0.0015 min. 0.006 max.	240	510	710	35	0.09	9	15	17
18 % chromium 12 % nickel, titanium (solution treated at 950 °C to 1070 °C)	321S51 (1010)	0.04	0.10	–	1.00	–	2.00	0.040	0.030	17.0	19.0	–	–	9.0	12.00	Titanium 5 × C min. 0.80 max.	235	510	710	35	0.09	9	15	17
18 % chromium 12 % nickel, titanium (solution treated at 1070 °C to 1140 °C)	321S51 (1105)																190	490	690	35	0.09	9	15	17
18 % chromium 12 % nickel, niobium	347S51	0.04	0.10	–	1.00	–	2.00	0.040	0.030	17.0	19.0	–	–	9.0	13.0	Niobium 10 × C min. 1.2 max.	240	510	710	35	0.09	9	15	17
15 % chromium 10 % nickel 6 % manganese, niobium, vanadium	215S15	0.06	0.15	0.20	1.00	5.50	7.00	0.040	0.030	14.0	16.0	0.80	1.20	9.0	11.0	Vanadium 0.15 to 0.40 Niobium 0.75 to 1.25 Boron 0.003 to 0.009	270	540	740	35	0.09	9	15	17

NOTE 1. Elements not quoted in the table shall not be intentionally added without the agreement of the purchaser other than for the purpose of finishing the heat. Elements added for the purpose of finishing the heat shall be reported. All reasonable precautions shall be taken to prevent the addition of such elements from scrap or other materials used in the manufacture.

NOTE 2. For permissible deviations on product analysis, see table 4.

NOTE 3. Where a maximum metallic aluminium content Al_{met} of 0.020 % or 0.012 % is specified, determination of the total aluminium content provided it does not exceed the specified value is deemed to meet this requirement. In cases of dispute the metallic aluminium content is determined.

NOTE 4. For steel types 243, 620-460, 622-490, 629-470 and 629-590 the content of the following residual incidental elements shall not be greater than : nickel 0.30 % max.
copper 0.25 % max.
tin 0.03 % max.
This applies also to steel type number 91 with the exception of nickel content.

NOTE 5. R_e is the yield strength. For acceptance purposes for carbon and ferritic alloy steels either the upper yield strength R_{eH} or the 0.5 % proof stress (total elongation) $R_{t0.5}$ may be used: for austenitic stainless steels the 1 % proof stress (non-proportional elongation) $R_{p1.0}$ or the 1 % proof stress (total elongation) $R_{t1.0}$ is used (see 13.1).

d is the inside diameter;

D is the outside diameter;

R_m is the tensile strength;

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

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

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

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

NOTE 6. For steel type number 91 a maximum copper content of 0.25 % and a maximum tin content of 0.03 % may be requested by the purchaser in order to facilitate subsequent operations of forming.

NOTE 7. For steel type number 91, a maximum tensile strength of 780 N/mm² may be requested by the purchaser.

Table 4. Permitted deviations of the product analysis from the specified ladle analysis

Steel	Element	Range in which the specified ladle analysis fails		Permitted deviations from the specified limits	
				Greater than maximum	Less than minimum
		%		%	%
360, 440	Carbon	⩽ 0.25		0.03*	0.03*
	Silicon	⩽ 0.50		0.05*	0.05*
	Manganese	⩽ 2.0		0.10*	0.10*
	Sulphur	⩽ 0.050		0.005	–
	Phosphorus	⩽ 0.050		0.005	–
243, 620-460, 622-490, 629-470 629-590 and 91	Carbon	⩽ 0.25		0.03*	0.03*
	Silicon	⩽ 1.0		0.05*	0.05*
	Manganese	⩽ 2.0		0.10*	0.10*
	Sulphur	⩽ 0.050		0.005	–
	Phosphorus	⩽ 0.050		0.005	–
	Chromium	⩽10.0		0.10*	0.10*
	Molybdenum	⩽ 0.35		0.04*	0.04*
		> 0.35	⩽ 1.5	0.05*	0.05*
	Nickel	≤5.0		0.07	0.07
	Niobium	≤0.20		0.005	0.005
	Vanadium	≤0.35		0.03	0.03
	Aluminium	≤0.045		0.005	0.005
	Nitrogen	≤0.070		0.010	0.010
	Copper	≤0.25		0.05	0.05
762, 304S51, 316S51, 316S52 321S51(1010), 321S51(1105), 347S51 and 215S15	Carbon	> 0.03	⩽ 0.25	0.01*	0.01*
	Silicon	⩽ 1.0		0.05*	0.05*
	Manganese	> 0.70	⩽ 1.0	0.04*	0.04*
		> 1.0	⩽ 2.0	0.05*	0.05*
		> 2.0	⩽ 7.0	0.10*	0.10*
	Sulphur	⩽ 0.030		0.003	–
		> 0.030	⩽ 0.040	0.004	–
	Phosphorus	⩽ 0.030		0.003	–
		> 0.030	⩽ 0.040	0.004	–
	Chromium	>10.0	⩽15.0	0.15*	0.15*
		>15.0	⩽20.0	0.20*	0.20
	Molybdenum	> 1.0	⩽ 2.0	0.05*	0.05*
		> 2.0	⩽ 3.0	0.08*	0.08*
	Nickel	>5.0	⩽ 10.0	0.10*	0.10*
		>10.0	⩽20.0	0.15*	0.15*
	Titanium and niobium	All ranges		0.05*	0.05*
	Vanadium	⩽ 0.04		0.03*	0.03*

*The deviations apply either above the specified maximum or below the specified minimum but both deviations shall not be applied to different samples from the same cast.

6.3 Content of elements

If required by the purchaser (see **2.2**(c)), the content of elements selected by the purchaser, in addition to those specified in table 3 and in **6.1.2** for steel types 360 and 440 shall be reported.

7 Final supply condition

The tubes shall be supplied in the final supply condition as given in table 5 unless otherwise specified by the purchaser (see note 1). For seamless hot finished tubes in steels 360 and 440, unless otherwise specified by the purchaser on the enquiry and order (see **2.2**(d)), the manufacturer shall have the option of supplying in either of the final supply conditions given in table 5.

Heat treatment temperatures shall be selected from within the temperature ranges specified in table 5 and shall refer to the metal temperature (see note 2).

NOTE 1. In the event that the tubes are required for subsequent manipulation, the purchaser may request delivery of the tubes in a condition other than the final supply condition given in table 5. In this case the purchaser should be informed of the heat treatment necessary to give the required properties (see clause 8).

NOTE 2. The supplier should demonstrate if required that the appropriate heat treatment cycle has been achieved.

8 Mechanical properties

8.1 Mechanical properties at room temperature

The mechanical properties at room temperature* to be obtained on test pieces selected, prepared and tested in accordance with clauses **12** and **13** shall be as specified in table 3.

NOTE. If heat treatments different from, or additional to, the normal reference heat treatment (which may have an adverse effect on the mechanical properties) are to be carried out after the delivery of the tubes, the purchaser may request, at the time of the enquiry and order, additional mechanical tests on samples that have been given heat treatments different from, or additional to, those given in table 3. The heat treatment of the samples, and the mechanical properties to be obtained from tests on them should be agreed between the purchaser and the manufacturer at the time of the enquiry and order.

8.2 Elevated temperature minimum proof stress values

The elevated temperature minimum proof stress values shall be as specified in table 6 and table 7 when sampled as described in **12.6** and tested or verified as described in **13.8**.

NOTE. The values are not normally subject to verification except for steel type number 91.

Table 5. Steel type number and tube manufacturing process, final supply condition and temperature of heat treatment

Steel type number and tube manufacturing process	Final supply condition	Temperature of heat treatment
		°C
360, 440 (seamless hot finished)	Hot finished	—
	Normalized	880 to 940
360, 440 (seamless cold finished)	Normalized	880 to 940
360, 440 (welded, hot finished)	Hot finished	—
360, 440 (as welded, welded hot finished, welded cold finished)	Normalized	880 to 940
243 (all manufacturing conditions see clause 5)	Normalized	900 to 960
620-460 (all manufacturing conditions see clause 5)	Normalized	900 to 960
622-490 (seamless see clause 5)	Normalized and tempered	Normalizing: 900 to 960 Tempering: 680 to 750
629-470 (seamless see clause 5)	Annealed	850 to 950
629-590 (seamless see clause 5)	Normalized and tempered	Normalizing: 900 to 1000 Tempering : 700 to 800
91 (seamless, see clause 5)	Normalized and tempered	Normalizing: 1040 to 1090 Tempering: 730 to 790 Tempering : 700 to 800
762 (seamless see clause 5)	Normalized and tempered	Normalizing: 1020 to 1070 Tempering: 730 to 780
304S51 (seamless see clause 5)	Solution treated	950 to 1100
316S51 (seamless see clause 5)	Solution treated	1000 to 1100
316S52 (seamless see clause 5)	Solution treated	1000 to 1100
321S51 (1010) (seamless see clause 5)	Solution treated	950 to 1070
321S51 (1105) (seamless see clause 5)	Solution treated	1070 1140
[illegible] mless see clause 5)	Solut on treated	1000 to 1100
[illegible] 5)	Solut[illegible]ed	1050 to 1150

Table 6. Minimum proof stress values ($R_{p0.2}$) for carbon manganese and ferritic alloy steels at elevated temperatures (see note)

Steel type	Type no.	Final supply condition	$R_{p0.2}$ min. at a temperature (°C) of:							
			250	300	350	400	450	500	550	600
			N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
Carbon	360	Hot finished and normalized	150	132	120	112	108	–	–	–
Carbon manganese	440	Hot finished and normalized	195	173	158	150	140	–	–	–
0.3% molybdenum	243	Normalized	221	192	180	176	172	166	–	–
1 % chromium 0.5 % molybdenum	620–460	Normalized	–	–	187	180	174	169	166	–
2.25 % chromium 1 % molybdenum	622–490	Normalized and tempered	–	–	224	218	204	190	168	–
9 % chromium 1 % molybdenum	629–470	Annealed	–	–	121	117	115	112	–	–
	629–590	Normalized and tempered	–	–	322	316	311	290	235	–
9 % chromium 1 % molybdenum, vanadium, niobium, nitrogen	91	Normalized and tempered	–	351	344	331	311	286	250	207
12 % chromium 1 % molybdenum, vanadium	762	Normalized and tempered	–	–	345	337	324	296	–	–

NOTE. All values are based on tests carried out in accordance with BS 3688 : Part 1 at the specified strain rate of 0.001/min to 0.003/min.

[AMD 8707]

Table 7. Minimum proof stress values ($R_{p1.0}$) for austenitic stainless steels at elevated temperatures (see note)

Steel type	Type no.	Final supply condition	$R_{p1.0}$ min. at a temperature (°C) of:								
			250	300	350	400	450	500	550	600	650
			N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
18 % chromium, 10 % nickel	304S51	Solution treated	139	132	125	120	117	115	112	109	104
18 % chromium, 12 % nickel molybdenum	316S51 316S52	Solution treated	150	143	137	133	129	125	121	119	116
18 % chromium, 12 % nickel titanium	321S51 (1010)	Solution treated 950 °C to 1070 °C	164	158	152	148	144	140	138	135	130
	321S51 (1105)	Solution treated 1070 °C to 1140 °C	125	118	114	110	107	105	104	102	100
18 % chromium, 12 % nickel niobium	347S51	Solution treated	172	166	162	159	157	155	153	151	–
15 % chromium, 10 % nickel, 6 % manganese, niobium, vanadium	215S15	Solution treated	190	187	184	182	179	178	175	170	165

NOTE. All values are based on tests carried out in accordance with BS 3688 : Part 1 at the specified strain rate of 0.001/min. to 0.003/min.

8.3 Stress rupture properties

The stress rupture properties shall not be subject to verification.

NOTE. For tubes complying with this Part of BS 3059 the estimated average stress rupture values are shown in appendix D and can be used for design purposes.

8.4 Flattening test properties

8.4.1 When tested in accordance with **13.2** the ring shall withstand being flattened without showing any cracks or flaws in the metal, except as specified in **8.4.2**, until the distance between platens, *H*, is equal to or less than the value calculated using the constant specified.

8.4.2 The test pieces are normally tested without preparation of the cut edges and, in this condition, cracks originating at the edges of the test piece which are less than 6 mm long and which do not penetrate through the wall shall be deemed not to affect compliance with this Part of BS 3059.

8.5 Drift expanding test properties

When tested in accordance with clauses **12** and **13** no cracks shall appear in the test piece.

9 Visual inspection and appearance

9.1 The tubes shall be clean and free from such defects as can be established by visual inspection in accordance with this Part of BS 3059 (see clause **11**).

9.2 Visual inspection shall be carried out on the external and internal surfaces. In the case of the internal surface, the tube shall be viewed from each end.

NOTE 1. Visual inspection should be carried out in suitable lighting, i.e. an illuminance of 500lux or greater.

NOTE 2. It is recognized that the ability to visually examine the inner surface from the tube ends is limited in the case of small diameter tubes.

9.3 The tubes shall have a finish and surface condition which permits surface imperfections or marks requiring dressing to be identified.

NOTE. Any special requirements for surface condition should be agreed between the purchaser and manufacturer at the time of enquiry and order.

9.4 It shall be permissible to dress by grinding or machining surface marks and imperfections such as scabs, seams, tears, laps, slivers or gouges provided that the thickness of the tube after dressing does not fall below the nominal thickness by more than the tolerance specified in this Part of BS 3059.

9.5 Surface imperfections which encroach on the minimum wall thickness shall be considered defects and shall be deemed not to comply with this Part of BS 3059.

9.6 All dressed areas shall blend smoothly into the contour of the tube.

9.7 The tubes shall not deviate from straightness by more than 1 in 600 at the centre of the tube length.

9.8 The ends shall be cut nominally square with the axis of the tube and shall be free from excessive burrs.

9.9 Any non-ferrous metals or their compounds coming into contact with the tubes during manufacture shall not be deposited so as to be harmful during subsequent fabrication and operation.

10 Tolerances

10.1 General

The maximum tolerances on the dimensions of the tubes shall be as specified in **10.2** and **10.3**.

NOTE. Seamless tubes, class 1 and cold finished electric resistance welded tubes are produced to outside diameter and thickness or inside diameter and thickness dimensions. Seamless tubes, class 2, electric resistance welded tubes and cold finished seamless tubes are produced to outside diameter and thickness dimensions.

10.2 Diameter, thickness and size of weld upset

The tolerances on outside diameter or inside diameter shall include ovality and those on thickness shall include eccentricity.

(a) *Seamless class 1 (S1)*

The outside or inside diameter and the thickness shall be subject to the following tolerances:

outside diameter or inside diameter: ± 0.5 % with a minimum tolerance of ± 0.10 mm;

thickness: ± 7.5 %.

(b) *Seamless class 2 (S2)*

The outside diameter and the thickness shall be subject to the following tolerances:

outside diameter: ± 0.75 % with a minimum tolerance of ± 0.30 mm;

thickness: ± 10.0 %.

(c) *Electric resistance welded class 1 (ERW 1)*

The outside diameter and the thickness shall be subject to the following tolerances:

outside diameter: ± 0.5 % with a minimum tolerance of ± 0.10 mm;

thickness: ± 7.5 % (excluding the weld area).

The minimum thickness in the weld area shall be not less than that permitted in the body of the tube.

The external weld upset (flash) shall be removed completely, i.e. flush with the outside surface of the tube. Where practicable the internal weld upset shall be trimmed throughout the length of the tube so that its maximum height shall not exceed 0.25 mm.

(d) *Electric resistance welded class 2 (ERW 2)*

The outside diameter and the thickness shall be subject to the following tolerances:

outside diameter: ± 0.75 % with a minimum of ± 0.30 mm;

thickness: ± 10 % (excluding the weld area).

The minimum thickness in the weld area shall be not less than that permitted in the body of the tube.

The external weld upset (flash) shall be removed completely, i.e. flush with the outside surface of the tube. Where practicable the internal weld upset shall be trimmed throughout the length of the tube so that its maximum height shall not exceed 0.25 mm.

(e) *Cold finished electric resistance welded (CEW)*

The outside or inside diameter and the thickness shall be subject to the following tolerances:

outside diameter or inside diameter: ± 0.5 % with a minimum tolerance of ± 0.10 mm;

thickness: ± 7.5 %.

(f) *Cold finished seamless (CFS) (austenitic steels)*

The outside diameter and the thickness shall be subject to the following tolerances:

outside diameter: ± 0.5 % with a minimum tolerance of ± 0.15 mm;

thickness: up to and including 3.25 mm thick: ± 10 %;
over 3.25 mm thick: ± 7.5 %.

10.3 Length

Unless otherwise specified by the purchaser (see 2.2(e)) tubes shall be supplied as random lengths.

NOTE. The actual range of the random lengths may be the subject of agreement between the manufacturer and the purchaser.

Where the length is specified as 'exact length' or 'cut length', the permissible deviation shall be +3, −0 mm for lengths up to and including 6 m. For every 3 m increase in length above 6 m, the plus tolerance shall be increased by 1.5 mm with a maximum of 12.0 mm.

11 Tests

The tubes shall be subjected to the tests specified in table 8 appropriate to the test category.

The elevated temperature properties (see 8.2 and 8.3) shall apply to tubes of both test category 1 and test category 2.

12 Number, selection and preparation of samples and test pieces

12.1 Selection of 'batches' for testing purposes

For tubes not heat treated, a batch shall consist only of tubes of the same diameter and thickness, and of the same steel cast. For tubes that are heat treated, a batch shall consist only of tubes of the same diameter and thickness and of the same steel cast subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch-type furnace. If the number of tubes to be tested as determined by 12.2 includes a fraction the number shall be rounded up to the next whole number.

12.2 Mechanical tests at room temperature*

12.2.1 For test category 1 the number of tubes on which mechanical tests at room temperature are to be performed shall be 2 % of the tubes from each batch.

12.2.2 For test category 2 the number of tubes on which mechanical tests at room temperature are to be performed shall be 1 % of the tubes from each batch.

12.2.3 Test samples shall be cut from the tube in the final supply condition (see clause 7). If the tubes are to be delivered in a condition different from the specified final supply condition, the test sample shall be in the appropriate final supply condition given in table 5.

From the test samples from each tube selected for testing, one test piece shall be prepared for each of the mechanical tests specified in clause 11.

12.2.4 For the tensile test (see 13.1), the dimensions of the test piece shall comply with the appropriate requirements of BS 18.

For welded tubes the tensile test piece shall not include the weld unless the tube is tested in full section.

12.2.5 For the flattening test, a ring not less than 40 mm in length shall be taken from one end of each selected tube.

12.2.6 For the drift expanding test, a ring equal in length to 1.5 times the outside diameter of the tube, but not less than 50 mm long, shall be taken from one end of each selected tube.

Table 8. Tests for test category 1 and test category 2

Test category 1	Test category 2
Visual inspection (see clause 9 and 12.3) Tensile test (see 8.1, 12.2.4 and 13.1) Flattening test (see 8.4, 12.2.5 and 13.2) Drift expanding test (see 8.5, 12.2.6 and 13.3) Ultrasonic test (see 12.5 and 13.6)	Visual inspection (see clause 9 and 12.3) Tensile test (see 8.1, 12.2.4 and 13.1) Flattening test (see 8.4, 12.2.5 and 13.2) Drift expanding test (see 8.5, 12.2.6 and 13.3) Leak tightness test (see 12.4)

*In cases of dispute room temperature is to be taken as 20 ± 5 °C.

12.3 Visual inspection

Every tube shall be inspected visually (see clause 9).

12.4 Leak tightness

All test category 2 tubes shall be subjected to a leak tightness test. This shall be either a hydraulic test in accordance with 13.4 or an eddy current test in accordance with 13.5, at the option of the manufacturer unless otherwise specified by the purchaser (see 2.2(f)).

NOTE 1. The hydraulic leak tightness test is capable of detecting defects of a size and disposition permitting the test fluid to leak through the tube wall. It may not detect through-wall defects that are tight or defects extending an appreciable depth into the tube wall without complete penetration. The test specified in 13.4 should not be regarded as a test of strength since the maximum pressure specified will develop only limited stress in the wall of tubes having low diameter to thickness ratio.

NOTE 2. Both the hydraulic test and the eddy current test may leave a short length at each end of the tube incompletely tested. If requested at the time of enquiry and order, the length affected should be determined by the manufacturer and reported to the purchaser. Furthermore, if requested at the time of enquiry and order, the manufacturer may either cut off the untested lengths or test them by an agreed alternative procedure.

12.5 Ultrasonic testing

All tubes to test category 1 shall be tested ultrasonically (see 13.6).

NOTE. Ultrasonic testing may leave a short length at each end of the tube incompletely tested. If specified at the time of the enquiry and order, the length affected should be determined by the manufacturer and reported to the purchaser. Furthermore, if specified at the time of the enquiry and order, the manufacturer may either cut off the untested lengths or test them by an agreed alternative procedure.

12.6 Elevated temperature proof stress testing

If elevated temperature proof stress testing is carried out (see 13.8), one test shall be made on each cast using a test piece taken at a position adjacent to the test pieces used for the tensile test at room temperature. If tubes of more than one thickness are to be supplied from one cast, the test piece shall be taken from a tube with the nominally thickest dimension.

NOTE. Cast separation is required for all tubes when acceptance tests for verification of the elevated temperature values are required.

13 Test methods

13.1 Tensile test

The tensile test shall be carried out in accordance with BS 18.

The tensile strength R_m, the yield strength R_e and the elongation A shall be determined.

For the yield strength for carbon and ferritic alloy steels either the upper yield stress R_{eH} or the 0.5 % proof stress (total elongation) $R_{t0.5}$ shall be determined.

For austenitic stainless steels either the 1.0 % proof stress (non-proportional elongation) $R_{p1.0}$ or the 1.0 % proof stress (total elongation) $R_{t1.0}$ shall be determined.

The percentage elongation shall be reported with reference to a gauge length of $L_o = 5.65\sqrt{S_o}$, where S_o is the original cross-sectional area of the gauge length. If other gauge lengths are used, the corresponding percentage elongation on $5.65\sqrt{S_o}$ shall be obtained by reference to BS 3894 : Part 1 for carbon and ferritic alloy steels or BS 3894 : Part 2 for austenitic steels. In cases of dispute, a gauge length of $5.65\sqrt{S_o}$ shall be used.

13.2 Flattening test

The test piece shall be flattened at room temperature* between parallel flat platens until the distance between the platens H (in mm), measured under load, is not greater than the value given by the equation:

$$H = \frac{(1 + C)\,a}{C + \frac{a}{D}} \qquad (1)$$

where

a is the specified tube thickness (in mm);

D is the specified tube outside diameter (in mm);

C is the flattening test constant (see table 3).

For electric resistance welded including induction welded tubes the weld shall be positioned at 90 ° to the direction of flattening.

13.3 Drift expanding test

The test piece shall be expanded by a tapered mandrel having an included angle of 45 ° or 60 ° (at the option of the manufacturer) and the outside diameter shall be increased by not less than the amount specified in table 3.

13.4 Hydraulic test

For test category 2 tubes which are hydraulically tested for verification of leak tightness (see 12.4), the test pressure P (in bar) shall be calculated from the equation:

$$P = \frac{20Sa}{D} \qquad (2)$$

where

D is the specified tube outside diameter (in mm);

a is the specified tube thickness (in mm);

S is a stress (in N/mm^2), which shall be taken as 80 % of the specified minimum yield strength at room temperature for carbon and ferritic alloy steels, and 70 % of the minimum yield strength at room temperature for austenitic stainless steels.

The test shall be carried out at the pressure P or at 140 bar, whichever is lower, but when 140 bar is lower than P, the purchaser has the option (see 2.2(g)) to specify that the test shall be carried out at a pressure higher than 140 bar, but not greater than the value P determined from equation (2).

The test pressure shall be maintained sufficiently long for any leakage to be observed. Any tube failing to withstand the hydraulic pressure test shall be deemed not to comply with this Part of BS 3059.

*In cases of dispute room temperature is taken as 20 ± 5 °C.

13.5 Eddy current test

For test category 2 tubes that are eddy current tested for verification of leak tightness (see **12.4**) the eddy current test and the assessment of results shall be carried out in accordance with appendix E.

13.6 Ultrasonic testing

For test category 1 tubes, ultrasonic testing for longitudinal imperfections and assessment of results shall be carried out in accordance with appendix F.

13.7 Additional non-destructive testing

The purchaser has the option to specify additional non-destructive tests. The additional methods of test and the basis of acceptance shall be as stated on the enquiry and order (see **2.2**(h)).

13.8 Elevated temperature proof stress tests or verification procedure

13.8.1 If the purchaser requires verification of elevated temperature proof stress values, this shall be carried out in accordance with **13.8.2** or **13.8.3** (see **2.2**(i)). The method of verification shall be at the option of the manufacturer unless the purchaser specifies verification in accordance with **13.8.2** in the enquiry and order (see **2.2**(j)).

13.8.2 When the purchaser requires verification of elevated temperature proof stress values by testing, the tests shall be carried out in accordance with BS 3688 : Part 1 at a temperature selected by the purchaser from table 6 or table 7 and specified at the time of enquiry and order (see **2.2**(h)).

NOTE. The specified strain rate in BS 3688 . Part 1 is 0.001/min. to 0.003/min.

13.8.3 For verification of elevated temperature proof stress values without testing, the values shall be verified by the procedure given in BS 3920 (see appendix G).

14 Retests

Should a tube selected for testing fail in any of the tests specified in **13.1, 13.2, 13.3** or **13.8** the tube and the batch of tubes it represents shall be deemed not to comply with this Part of BS 3059 unless:

(a) two further tests of the same kind as produced the failure are made from the same tube, and both of these further tests prove satisfactory; or

(b) the first tube tested is rejected and all the tests specified in **13.1, 13.2, 13.3** and **13.8** are carried out on two further tubes from the batch and all these tests are satisfactory; or

(c) if either of the further tests required by (a) or (b) proves unsatisfactory, the tubes represented are suitably heat treated or re-heat treated and samples are selected and tested in accordance with all the tests specified in **13.1, 13.2, 13.3** and **13.8** and all these tests are satisfactory.

15 Test certificate

A manufacturer's test certificate shall be supplied giving the following information:

(a) the designation (see clause **3**);

(b) the ladle analysis for elements specified in table 3 for each cast used;

(c) the mechanical test results for each batch tested;

(d) the purchaser's order number or other appropriate mark (see **17.2**(c));

(e) the steelmaking process used (see **4.1**).

The test certificate shall also give the following information where appropriate for options selected by the purchaser (see **2.2**):

(1) the product analysis (see **6.2**);

(2) the final supply condition (see clause **7**);

(3) the content of selected elements in addition to those specified in table 3 and **6.1.2** (see **6.3**);

(4) the elevated temperature test results (see **13.8.2**) or statement of verification of values (see **13.8.3**);

(5) for category 2 tubes the method of verification of leak tightness, either by eddy current or hydraulic test and, in the latter case, the pressure applied (see **13.4**);

(6) the results of additional non-destructive testing (see **13.7**).

16 Protective coating

The tubes shall be supplied either uncoated or with the manufacturer's normal mill coating at the option of the purchaser (see **2.2**(k)).

NOTE. If the purchaser requires additional measures for protection during delivery or storage then this should be the subject of agreement between the purchaser and the manufacturer.

17 Marking

17.1 Before despatch from the manufacturer's works, the tubes shall be marked in accordance with **17.2** or, if specified by the purchaser in the enquiry and order (see **2.2**(l)), in accordance with **17.4**.

17.2 Except as provided for tubes that are bundled, each tube shall be legibly marked at one end, commencing not more than 300 mm from the end, by stencilling or other indelible marking.

The marking shall consist of the following in the sequence indicated:

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

(b) the designation as given in clause **3**, e.g. BS 3059 : Part 2 : CEW 620-460: Cat 1*;

(c) the purchaser's order number or other appropriate mark to identify it with the test certificate.

*Marking BS 3059 : Part 2 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

For tubes that are bundled the information given in (a), (b) and (c) shall be either stamped on one or more metal or other durable tags, or printed on banding clips or straps, which shall be securely attached to each bundle.

Not more than one steel grade shall be included in any one bundle.

NOTE. If traceability of cast identity is required this should be the subject of an agreement between the manufacturer and the purchaser at the time of the enquiry and order.

17.3 The quality of the paint or ink applied shall be such that it shall have a life of at least one year in unheated storage under cover.

The dried film shall contain not more than 0.025 % (*m/m*) of any of the following metals:

lead, tin, copper, zinc.

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

17.4 If specified by the purchaser in the enquiry and order (see **2.2**(l)) each tube shall be marked in accordance with BS 5383 and shall include the information specified in **17.2** (a), (b) and (c).

NOTE. Colour coding is an optional requirement in BS 5383 and if required should be specified by the purchaser in the enquiry and order.

Appendices

Appendix A. Designations of steel tubes in BS 3059 : Part 2 :1990 and the nearest equivalent designations in BS 3059 : Part 2 : 1978 and ISO 2604 : Parts II and III

Table 9 lists the designations for tubes in this Part of BS 3059 and the nearest equivalent in the previous edition as well as in ISO 2604 : Parts II and III.

NOTE. The designations are indicated as nearest equivalents and are not necessarily identical.

Table 9. Designations of steel tubes in BS 3059 : Part 2 : 1990 and the nearest equivalent designations in BS 3059 : Part 2 : 1978 and ISO 2604 : Parts II and III

BS 3059 : Part 2 : 1990		BS 3059 : Part 2 : 1978	ISO 2604 : Parts II and III
Designation	Colour code in accordance with BS 5383	Designation	Designation
S1 360 Cat 1	White	S1 360 Cat 1	TS 5 Cat V (cold finished)
S2 360 Cat 1		S2 360 Cat 1	TS 5 Cat V
ERW 1 360 Cat 1 ERW 2 360 Cat 1		ERW 360 Cat 1	TW 5 Cat V
CEW 360 Cat 1		CEW 360 Cat 1	TS 5 Cat V (cold finished)
S1 360 Cat 2		S1 360 Cat 2	TS 5 Cat III (cold finished)
S2 360 Cat 2		S2 360 Cat 2	TS 5 Cat III
ERW 1 360 Cat 2 ERW 2 360 Cat 2		ERW 360 Cat 2	TW 5 Cat III
CEW 360 Cat 2		CEW 360 Cat 2	TW 5 Cat III (cold finished)
S1 440 Cat 1	Yellow	S1 440 Cat 1	—
S2 440 Cat 1		S2 440 Cat 1	—
ERW 1 440 Cat 1 ERW 2 440 Cat 1		ERW 440 Cat 1	—
CEW 440 Cat 1		CEW 440 Cat 1	—
S1 440 Cat 2		S1 440 Cat 2	—
S2 440 Cat 2		S2 440 Cat 2	—
ERW 1 440 Cat 2 ERW 2 440 Cat 2		ERW 440 Cat 2	—
CEW 440 Cat 2		CEW 440 Cat 2	
S1 243 Cat 1	Plum	S1 243 Cat 1	TS 26 Cat V (cold finished)
S2 243 Cat 1		S2 243 Cat 1	TS 26 Cat V
ERW 1 243 Cat 1 ERW 2 243 Cat 1		ERW 243 Cat 1	TW 26 Cat V
CEW 243 Cat 1		CEW 243 Cat 1	TW 26 Cat V (cold finished)
S1 243 Cat 2		S1 243 Cat 2	TS 26 Cat III (cold finished)
S2 243 Cat 2		S2 243 Cat 2	TS 26 Cat III
ERW 1 243 Cat 2 ERW 2 243 Cat 2		ERW 243 Cat 2	TW 26 Cat III
CEW 243 Cat 2		CEW 243 Cat 2	TW 26 Cat III (cold finished)
S1 620-460 Cat 1	Red	S1 620 Cat 1	TS 32 Cat V (cold finished)
S2 620-460 Cat 1		S2 620 Cat 1	TS 32 Cat V
ERW 1 620-460 Cat 1 ERW 2 620-460 Cat 1		ERW 620 Cat 1	TW 32 Cat V
CEW 620-460 Cat 1		CEW 620 Cat 1	TW 32 Cat V (cold finished)
S1 620-460 Cat 2		S1 620 Cat 2	TS 32 Cat III (cold finished)
S2 620-460 Cat 2		S2 620 Cat 2	TS 32 Cat III
ERW 1 620-460 Cat 2 ERW 2 620-460 Cat 2		ERW 620 Cat 2	TW 32 Cat III
CEW 620-460 Cat 2		CEW 620 Cat 2	TW 32 Cat III (cold finished)

Table 9 *(concluded)*

BS 3059 : Part 2 : 1990		BS 3059 : Part 2 : 1978	ISO 2604 : Parts II and III
Designation	**Colour code in accordance with BS 5383**	**Designation**	**Designation**
S1 622-490 Cat 1	Light blue	S1 622-490 Cat 1	TS34* Cat V (cold finished)
S2 622-490 Cat 1		S2 622-490 Cat 1	TS34* Cat V
S1 622-490 Cat 2		S1 622-490 Cat 2	TS34* Cat III (cold finished)
S2 622-490 Cat 2		S2 622-490 Cat 2	TS34* Cat III
S1 629-470 (or 629-590) Cat 1	Olive	S1 629-470 (or 629-590) Cat 1	TS38* Cat V (cold finished)
S2 629-470 (or 629-590) Cat 1		S2 629-470 (or 629-590) Cat 1	TS38* Cat V
S1 629-470 (or 629-590) Cat 2		S1 629-470 (or 629-590) Cat 2	TS38* Cat III (cold finished)
S2 629-470 (or 629-590) Cat 2		S1 629-470 (or 629-590) Cat 2	TS38* Cat III
S1 762 Cat 1	Orange	S1 762 Cat 1	TS40 Cat V (cold finished)
S2 762 Cat 1		S2 762 Cat 1	TS40 Cat V
S1 762 Cat 2		S1 762 Cat 2	TS40 Cat III (cold finished)
S2 762 Cat 2		S2 762 Cat 2	TS40 Cat III
CFS 304S51 Cat 1	Light blue	CFS 304S59 Cat 1	TS48 Cat V (cold finished)
CFS 304S51 Cat 2		CFS 304S59 Cat 2	TS48 Cat III (cold finished)
CFS 316S51 Cat 1	Light green	CFS 316S59 Cat 1	TS63 Cat V (cold finished)
CFS 316S51 Cat 2		CFS 316S59 Cat 2	TS63 Cat III (cold finished)
CFS 316S52 Cat 1	Light green	–	–
CFS 316S52 Cat 2		–	–
CFS 321S51 Cat 1	Yellow	CFS 321S59 Cat 1	TS54 Cat V (cold finished)
CFS 321S51 Cat 2		CFS 321S59 Cat 2	TS54 Cat III (cold finished)
CFS 347S51 Cat 1		CFS 347S59 Cat 1	TS56 Cat V (cold finished)
CFS 347S51 Cat 2		CFS 347S59 Cat 2	TS56 Cat III (cold finished)
CFS 215S15 Cat 1	–	CFS 1250 Cat 1	–
CFS 215S15 Cat 2		CFS 1250 Cat 2	–

*Annealed or normalized and tempered.

NOTE. Steel type number 91 is not included as it does not fall within any of the groups in the table, and is not yet referenced in ISO 2604 or BS 5383.

Appendix B. Estimated average stress rupture values

Estimated average stress rupture values are shown in tables 10 and 11 for design purposes.

Table 10. Estimated average stress rupture values for carbon and ferritic alloy steels

NOTE. Notes to this table are located at the end of table 11.

Steel	Reference	Rupture time	Estimated average stress for rupture (see note to table 11) at a temperature (in °C) of:																													
			380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680
		h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
Carbon	360	10 000	213	197	181	166	151	138	125	112	100	89	78	67	57	47	(37)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		30 000	192	176	161	147	133	120	107	95	84	73	63	52	42	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		50 000	183	167	152	138	125	112	100	88	77	66	56*	46*	(35)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		100 000	171*	155*	141*	127*	114*	102*	90*	78*	67*	57*	47*	(36)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		150 000	164*	149*	134*	121*	108*	96*	84*	73*	62*	52*	41*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		200 000	159*	144*	130*	118*	104*	92*	80*	69*	58*	48*	(37)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		250 000	155*	140*	126*	113*	101*	89*	77*	66*	55*	45*	(34)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Carbon manganese	440	10 000	281	266	243	221	200	180	161	143	126	110	96	84	74	65	58	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		30 000	262	237	214	192	171	151	132	115	99	86	74	65	57	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		50 000	248	223	200	177	156	136	118	102	87	75	65	57	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		100 000	227	203	179	157	136	117	100	85	73	63	55	(47)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		150 000	215	190	167	144	124	105	89	76	65	56	(49)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		200 000	206*	181*	157*	135*	115*	97*	82*	70*	60*	52*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		250 000	199*	174*	150*	128*	108*	91*	77*	66*	56*	(48)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.3 % molybdenum	243	10 000	–	–	–	–	–	–	–	298	273	247	222	196	171	147	125	102	82	64	–	–	–	–	–	–	–	–	–	–	–	–	–
		30 000	–	–	–	–	–	–	–	273	244	218	187	159	134	113	93	76	61	49	–	–	–	–	–	–	–	–	–	–	–	–	–
		50 000	–	–	–	–	–	–	–	260	229	200	172	144	119	98	80	66	53	(42)	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		100 000	–	–	–	–	–	–	–	239*	208*	178*	148	123	101	81	66	53*	(42)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		150 000	–	–	–	–	–	–	–	226*	197*	168*	139*	114*	91*	74*	60*	48*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		200 000	–	–	–	–	–	–	–	217*	188*	159*	130*	105*	84*	69*	55*	45*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		250 000	–	–	–	–	–	–	–	210*	180*	151*	124*	100*	80*	65*	52*	(42)*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1 % chromium 0.5 % molybdenum	620-460	10 000	–	–	–	–	–	–	–	406	368	332	297	264	232	202	174	148	126	105	88	73	61	52	44	38	33	–	–	–	–	–	–
		30 000	–	–	–	–	–	–	–	372	333	296	260	227	195	166	139	116	96	79	65	54	45	38	33	–	–	–	–	–	–	–	–	–
		50 000	–	–	–	–	–	–	–	357	318	280	244	210	178	150	125	103	84	69	57	47	40	34	–	–	–	–	–	–	–	–	–	–
		100 000	–	–	–	–	–	–	–	337	297	259	223	189	158	131	107	87	70	57*	47*	40*	34*	–	–	–	–	–	–	–	–	–	–	–
		150 000	–	–	–	–	–	–	–	325	285	246	210	177	147	120*	97*	79*	64*	52*	43*	36*	31*	–	–	–	–	–	–	–	–	–	–	–
		200 000	–	–	–	–	–	–	–	317*	276*	238*	202*	169*	139*	113*	91*	73*	59*	48*	40*	34*	–	–	–	–	–	–	–	–	–	–	–	–
		250 000	–	–	–	–	–	–	–	311*	270*	231*	196*	163*	133*	108*	87*	69*	56*	46*	38*	32*	–	–	–	–	–	–	–	–	–	–	–	–
2.25 % chromium 1 % molybdenum (normalized and tempered)	622-490	10 000	–	–	–	–	–	–	–	–	–	271	244	220	199	180	162	146	131	118	105	92	82	72	63	53	–	–	–	–	–	–	–
		30 000	–	–	–	–	–	–	–	–	–	242	217	194	174	156	139	124	110	96	84	73	63	52	–	–	–	–	–	–	–	–	–	–
		50 000	–	–	–	–	–	–	–	–	–	229	204	182	162	144	128	113	99	86	74	64	53	–	–	–	–	–	–	–	–	–	–	–
		100 000	–	–	–	–	–	–	–	–	–	210	186	165	145	128	112	98	84	72	61	49	–	–	–	–	–	–	–	–	–	–	–	–
		150 000	–	–	–	–	–	–	–	–	–	199	175	155	136	119	103	89*	76*	64	52	–	–	–	–	–	–	–	–	–	–	–	–	–
		200 000	–	–	–	–	–	–	–	–	–	191	168	147	129	112	97	82*	70*	58*	44*	–	–	–	–	–	–	–	–	–	–	–	–	–
		250 000	–	–	–	–	–	–	–	–	–	184*	162*	141*	123*	107*	91*	78*	65*	53*	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9 % chromium 1 % molybdenum (annealed)	629-470	10 000	–	–	–	–	–	–	–	278	250	226	200	182	163	146	129	114	101	89	79	71	63	57	52	47	43	39	36	–	–	–	–
		30 000	–	–	–	–	–	–	–	250	228	204	182	161	143	126	110	97	85	75	67	60	54	48	43	39	35	–	–	–	–	–	–	–
		50 000	–	–	–	–	–	–	–	245*	218*	194*	172*	151*	133*	116*	102*	89	78	69	61	55	49*	44*	40*	35*	(31)*	–	–	–	–	–	–	–
		100 000	–	–	–	–	–	–	–	229*	203*	179*	157*	138*	120*	104*	90*	79*	69*	61*	55*	49*	44*	39*	(34)*	–	–	–	–	–	–	–	–	–
		150 000	–	–	–	–	–	–	–	220*	194*	171*	148*	130*	112*	97*	84*	73*	64*	57*	51*	45*	40*	36*	(31)*	–	–	–	–	–	–	–	–	–
		200 000	–	–	–	–	–	–	–	214*	188*	164*	143*	124*	107*	92*	80*	70*	61*	54*	48*	43*	38*	–	–	–	–	–	–	–	–	–	–	–
		250 000	–	–	–	–	–	–	–	209*	183*	160*	138*	119*	103*	88*	77*	67*	59*	52*	46*	41*	36*	–	–	–	–	–	–	–	–	–	–	–
9 % chromium 1 % molybdenum (normalized and tempered)	629-590	10 000	–	–	–	–	–	–	(404)	364	329	298	270	245	222	202	183	165	149	133	119	104	91	78	66	55	46	38	33	29	26	(24)	–	–
		30 000	–	–	–	–	–	(418)	373	335	302	273	248	222	201	181	163	146	130	114	100	86	73	60	50	41	35	30	27	(24)	(22)	–	–	–
		50 000	–	–	–	–	–	(402)	359	322	290	261	235	212	191	171	153	136	120	103	91	77	64	53	43	36	31	27	25	(23)	–	–	–	–
		100 000	–	–	–	–	–	(381)	340	304	273	245	220	198	177	158	140	124	108	93	78	65	53	43	36	31*	27*	(24)*	(22)*	–	–	–	–	–
		150 000	–	–	–	–	–	369*	329*	294	263	236	211	189	168	150	133	118	100	85	71	58	47	39	33	28*	25*	(23)*	–	–	–	–	–	–
		200 000	–	–	–	–	–	360*	321*	286	256	229	205	183	163	144	127	111	95	80	66*	53*	43*	36*	31*	27*	(24)*	–	–	–	–	–	–	–
		250 000	–	–	–	–	–	354*	315*	281*	251*	224*	200*	179*	159*	140*	123*	108*	91*	78*	62*	50*	41*	34*	29*	26*	(23)*	–	–	–	–	–	–	–
12 % chromium 1 % molybdenum vanadium	762	10 000	–	–	–	–	–	–	–	–	–	–	350	319	290	264	240	217	196	176	157	139	123	107	93	81	71	62	54	48	42	37	33
		30 000	–	–	–	–	–	–	–	–	–	–	324	293	265	240	216	194	173	153	135	117	102	88	76	65	57	50	44	38	33	29	–	–
		50 000	–	–	–	–	–	–	–	–	–	–	311	281	254	228	205	183	162	142	124	107	92	79	68	59	51	45	39	34	29	–	–	–
		100 000	–	–	–	–	–	–	–	–	–	–	294	265	237	212	189	167	146	127	109	93	80	68	59	51	44	38	33	28	–	–	–	–
		150 000	–	–	–	–	–	–	–	–	–	–	284*	255*	228*	203*	178*	157	137	118	101	86	73	62	54	46	40	35*	30*	–	–	–	–	–
		200 000	–	–	–	–	–	–	–	–	–	–	277*	247*	221*	196*	172*	151*	130*	112*	95*	80*	68*	58*	50*	44*	38*	32*	–	–	–	–	–	–
		250 000	–	–	–	–	–	–	–	–	–	–	271*	242*	215*	190*	167*	145*	125*	107*	90*	76*	65*	56*	48*	41*	36*	30*	–	–	–	–	–	–

Table 10a Estimated average stress rupture values for steel 91

NOTE. Notes to this table are located at the end of table 11.

Steel	Reference	Rupture time	Estimated average stress for rupture at a temperature in °C of:																		
			490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690
		h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
9% chromium	91	10 000	302	283	265	248	230	214	197	182	166	151	137	124	111	99	89	79	71	63	55	48	41
1 % molybdenum		30 000	284	266	248	231	213	197	181	165	150	135	122	109	97	87	77	68	60	53	46	37	—
vanadium		50 000	276	258	240	223	205	189	173	157	142	128	115	102	91	81	72	64	56	49	41	—	—
niobium																							
nitrogen		100 000	265	247	229	212	194	178	162	146	132	118	105	94	83	74	65*	57*	50*	42*	—	—	—
		150 000	259	240	222	205	188	171	155	140	126	112	100	89	78	69	61*	54*	46*	37*	—	—	—
		200 000	254*	236*	218*	200*	183*	167*	151*	136*	121*	108*	96*	85*	75*	67*	58*	51*	43*	—	—	—	—
		250 000	250*	232*	214*	197*	180*	163*	147*	132*	118*	105*	93*	83*	73*	64*	56*	49*	41*	—	—	—	—

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Table 11. Estimated average stress rupture values for austenitic steels

Steel	Reference	Rupture time	Estimated average stress for rupture (see note) at a temperature (in °C) of:																								
			540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720	730	740	750	760	770	780	790
		h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
18 % chromium 10 % nickel	304S51	10 000	–	186	174	163	153	144	134	126	117	109	102	94	87	81	74	68	63	56	53	49	46	42	39	37	–	–
		30 000	–	165	154	144	135	126	117	109	101	94	87	80	73	67	62	56	52	48	44	41	39	37	–	–	–	–
		50 000	–	155	145	136	126	118	110	102	94	87	80	73	67	62	56	52	48	44	41	38	36	–	–	–	–	–
		100 000	–	143	133	124	115	107	99	92	85	78	71	65	59	54	50*	46*	43*	40*	37*	–	–	–	–	–	–	–
		150 000	–	136*	127*	118*	109	101	94	86	79	72*	66*	60*	55*	51*	47*	43*	40*	38*	–	–	–	–	–	–	–	–
		200 000	–	131*	122*	113*	105*	97*	90*	82*	75*	69*	63*	57*	52*	48*	44*	41*	39*	36*	–	–	–	–	–	–	–	–
		250 000	–	127*	118*	110*	102*	94*	86*	79*	72*	66*	60*	55*	50*	46*	43*	40*	38*	–	–	–	–	–	–	–	–	–
18 % chromium 12 % nickel niobium	316S61	10 000	247	233	220	206	193	180	167	155	142	130	119	108	97	87	78	70	63	57	52	47	–	–	–	–	–	–
		30 000	222	208	195	181	168	155	143	131	119	107	97	87	78	69	62	56	51	46	(42)	–	–	–	–	–	–	–
		50 000	210	197	183	170	157	144	132	120	108	97	87	78	70	62	56	51	46	(42)	–	–	–	–	–	–	–	–
		100 000	194*	181*	167*	154*	141	128	116	105	94	84	75	67	60	54	49*	(44)*	–	–	–	–	–	–	–	–	–	–
		150 000	185*	172*	158*	145*	132	120	108	97	86	77*	69*	61*	55*	50*	(45)*	–	–	–	–	–	–	–	–	–	–	–
		200 000	178*	164*	151*	138*	125	113	102	91	81	72*	65*	58*	52*	47*	(43)*	–	–	–	–	–	–	–	–	–	–	–
		250 000	173*	159*	146*	133*	120*	108*	97*	87*	77*	69*	61*	55*	50*	(45)*	–	–	–	–	–	–	–	–	–	–	–	–
18 % chromium 12 % nickel molybdenum boron	316S52	10 000	268	251	236	222	208	195	183	171	159	147	136	124	112	101	90	80	71	65	60	56	–	–	–	–	–	–
		30 000	238	225	211	197	184	172	160	148	136	124	112	100	89	79	71	64	59	(55)	(52)	–	–	–	–	–	–	–
		50 000	227	213	199	186	173	161	149	137	125	113	101	90	79	71	64	59	(55)	(52)	–	–	–	–	–	–	–	–
		100 000	211*	197*	184*	171*	159	146	134	122	110	98	88	76	69	63	57	(54)*	(51)	–	–	–	–	–	–	–	–	–
		150 000	201*	188*	175*	162*	150	138	125	113	101	89	79	70	64	59	64	(51)*	-	–	–	–	–	–	–	–	–	–
		200 000	195*	181*	169*	156*	144	131	119	106	94	83	74	66	61	57	(53)*	-	–	–	–	–	–	–	–	–	–	–
		250 000	190*	176*	164*	151*	139*	126*	114*	101*	90*	79*	71*	64*	59*	(55)*	(51)*	-	–	–	–	–	–	–	–	–	–	–
18 % chromium 12 % nickel titanium (solution treated at 950 °C to 1070 °C)	321S51 (H10)	10 000	222	206	192	178	165	152	140	129	118	108	98	88	79	71	63	56	49	43	38	–	–	–	–	–	–	–
		30 000	189	174	161	148	136	125	114	103	93	84	75	67	59	52	45	39	35	30	(27)	–	–	–	–	–	–	–
		50 000	174*	160*	147*	135*	124	112	102	92	82	73	65	57	50	44	38*	34*	29*	(26)*	–	–	–	–	–	–	–	–
		100 000	164*	142*	129*	118*	107*	96*	88*	77*	68*	60*	53*	46*	40*	35*	31*	(27)*	–	–	–	–	–	–	–	–	–	–
		150 000	143*	131*	119*	108*	97*	87*	78*	69*	61*	53*	46*	40*	35*	31*	(27)*	–	–	–	–	–	–	–	–	–	–	–
		200 000	136*	123*	112*	101*	91*	81*	72*	63*	55*	48*	42*	36*	32*	(28)*	–	–	–	–	–	–	–	–	–	–	–	–
		250 000	130*	118*	107*	98*	86*	76*	67*	59*	51*	45*	39*	34*	30*	(26)*	–	–	–	–	–	–	–	–	–	–	–	–
18 % chromium 12 % nickel titanium (solution treated at 1070 °C to 1140 °C)	321S51 (H105)	10 000	237	223	210	196	182	169	156	143	130	119	108	98	90	82	75	70	65	60	56	–	–	–	–	–	–	–
		30 000	212	198	183	169	155	141	128	116	105	95	86	79	72	67	61	57	53	50	(47)	–	–	–	–	–	–	–
		50 000	201	186	171	157	142	128	117	105	95	86	78	72	66	61	56	53	49	(48)	(44)	–	–	–	–	–	–	–
		100 000	185	170	156	140	127	114	102	92	83	76	69	64	59	54	51	48	(45)	–	–	–	–	–	–	–	–	–
		150 000	176	160	146	131	118	106	95	86	78	71	66	60	55	51	48	(45)	–	–	–	–	–	–	–	–	–	–
		200 000	170*	154*	139*	125*	112*	100*	90*	81*	74*	67	62	57	53	49	(46)*	(43)*	–	–	–	–	–	–	–	–	–	–
		250 000	165*	149*	134*	120*	108*	97*	87*	78*	71*	65*	60*	55*	51*	48*	(45)*	–	–	–	–	–	–	–	–	–	–	–
18 % chromium 12 % nickel niobium	347S51	10 000	258	235	218	202	187	174	162	151	140	131	121	113	104	96	88	80	71	61	–	–	–	–	–	–	–	–
		30 000	214*	197*	182*	169*	157	145	135	125	118	107	98	90	81	72	62	–	–	–	–	–	–	–	–	–	–	–
		50 000	196*	181*	167*	155*	144	133	123	114	105	96	87	78	69	58	–	–	–	–	–	–	–	–	–	–	–	–
		100 000	174*	161*	148*	137*	127*	117*	107*	98*	88*	80*	71*	58*	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		150 000	162*	149*	138*	127*	117*	108*	98*	89*	80*	70*	57*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		200 000	154*	142*	131*	120*	110*	101*	92*	82*	72*	61*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		250 000	147*	138*	125*	115*	105*	96*	86*	77*	66*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15 % chromium 10 % nickel 6 % manganese niobium vanadium	215S15	10 000	–	–	–	–	–	–	241	231	221	210	198	184	167	147	124	102	86	75	67	61	55	51	46	42	38	34
		30 000	–	–	–	–	–	–	223	211	200	185	168	148	124	102	86	75	67	60	55	50	46	41	37	32	–	–
		50 000	–	–	–	–	–	–	213	201	187	170	151	127	104	87	76	67	61	55	50	46*	41*	37*	32*	–	–	–
		100 000	–	–	–	–	–	–	199	186	167	147	122	100	84	74	66	59	54	49	45	40*	36*	30*	–	–	–	–
		150 000	–	–	–	–	–	–	190	174	154	130	108	88	78	68	61	55	50	46	41	37*	32*	–	–	–	–	–
		200 000	–	–	–	–	–	–	183	165	143	118	97	82	72	64	58	52	48	43	39	35*	–	–	–	–	–	–
		250 000	–	–	–	–	–	–	177	158	134	109*	90*	78*	68*	62*	56*	51*	46*	42*	37*	32*	–	–	–	–	–	–

NOTE. Values obtained by extrapolation

Asterisks and parentheses indicate that values have been obtained by either extended time or extended stress extrapolation respectively. Where asterisks and parentheses are used together this indicates that values have been obtained using both extrapolations.

Experience suggests that reliable extrapolations may be made covering a range of ± 25 °C about each test temperature on the basis of a series of tests from at least five casts of steel, the longest test of each series exceeding a certain minimum duration. The confidence which can be placed upon such properties will be related to the extent of extrapolation and for the purposes of this standard extrapolations exceeding approximately three times the above minimum duration are described as extended time extrapolations and marked with an asterisk in the foregoing tables.

Values may also be obtained by extending the parametric master curves to stresses beyond those at which casts have been tested. Such values obtained by extended stress extrapolation are enclosed in parentheses. They are subject to greater uncertainty than other values.

Appendix C. Physical properties of steels

Tables 12 to 15 have been compiled on the basis of data obtained from a number of sources. The properties are believed to be typical for the various steels and are given for information only.

Table 12. Physical properties of steel type number 360 and 440

Temperature	Physical property					
	Density	Modulus of elasticity	Coefficient of thermal expansion from 20 °C to temperature	Electrical resistivity	Specific heat capacity from 20 °C to temperature	Thermal conductivity
°C	kg/dm^3	kN/mm^2	$K^{-1} \times 10^{-6}$	μΩ·m	J/(kg·K)	W/(m·K)
20	7.85	212	—	0.210	—	54.7
100	—	206	11.9	0.248	468	53.8
200	—	198	12.6	0.310	492	50.5
300	—	191	13.1	0.394	516	47.0
400	—	183	13.7	0.496	541	43.5
500	—	174	14.1	0.610	566	40.0
600	—	165	14.4	0.756	594	36.5

Table 13. Physical properties of steel type number 243, 620-460 and 622-490

Temperature	Physical property									
	Density	Modulus of elasticity	Coefficient of thermal expansion from 20 °C to temperature	Electrical resistivity			Specific heat capacity from 20 °C to temperature	Thermal conductivity		
				243	620-460	622-490		243	620-460	622-490
°C	kg/dm^3	kN/mm^2	$K^{-1} \times 10^{-6}$	μΩ·m	μΩ·m	μΩ·m	J/(kg·K)	W/(m·K)	W/(m·K)	W/(m·K)
20	7.85	212	—	0.210	0.240	0.300	—	49.3	44.6	37.0
100	—	206	11.9	0.248	0.280	0.340	468	48.3	43.7	37.4
200	—	198	12.6	0.310	0.350	0.410	492	46.2	42.2	37.2
300	—	191	13.1	0.394	0.430	0.497	516	43.7	40.1	36.5
400	—	183	13.7	0.496	0.524	0.590	541	41.0	38.0	35.0
500	—	174	14.1	0.610	0.632	0.690	566	38.3	35.8	33.2
600	—	165	14.4	0.756	0.770	0.810	594	35.3	33.5	31.0

Table 14. Physical properties of steel type number 629-470, 629-590 and 762

Temperature	Physical property							
	Density	Modulus of elasticity	Coefficient of thermal expansion from 20 °C to temperature	Electrical resistivity		Specific heat capacity from 20 °C to temperature	Thermal conductivity	
				629-470 629-590	762		629-470 629-590	762
°C	kg/dm^3	kN/mm^2	$K^{-1} \times 10^{-6}$	μΩ·m	μΩ·m	J/(kg·K)	W/(m·K)	W/(m·K)
20	7.73	214	–	0.520	0.622	–	28.1	23.3
100	–	211	10.7	0.571	0.680	475	28.3	23.6
200	–	205	11.2	0.648	0.749	494	28.0	24.3
300	–	197	11.6	0.727	0.817	516	28.0	25.5
400	–	188	11.9	0.810	0.885	593	28.0	25.7
500	–	178	12.2	0.895	0.995	570	27.8	26.0
600	–	165	12.5	0.980	1.021	612	27.0	26.5

Table 15. Physical properties of steel type number 304S51, 316S51, 316S52, 321S51 (1010), 321S51 (1105), 347S51 and 215S15

Temperature	Physical property						
	Density	Modulus of elasticity	Coefficient of thermal expansion from 20 °C to temperature	Electrical resistivity	Specific heat capacity from 20 °C to temperature	Thermal conductivity	
						304S51 316S51 316S52 321S51 347S51	215S15
°C	kg/dm^3	kN/mm^2	$K^{-1} \times 10^{-6}$	μΩ·m	J/(kg·K)	W/(m·K)	W/(m·K)
20	7.97	200	–	0.730	–	14.3	12.5
100	–	193	15.9	0.790	490	15.5	14.0
200	–	185	16.6	0.870	510	17.0	15.5
300	–	176	17.2	0.930	522	18.4	17.0
400	–	168	17.7	0.990	533	20.0	18.6
500	–	159	18.3	1.044	544	21.5	20.1
600	–	151	18.7	1.090	553	23.0	21.7
700	–	142	19.1	1.125	560	24.5	23.0
800	–	134	19.3	1.146	563	26.0	24.2

Appendix D. Preferred outside diameters and thicknesses for tubes appropriate to this Part of BS 3059 and masses per unit length

The preferred outside diameters and thicknesses for tubes appropriate to this Part of BS 3059 and masses per unit length are given in tables 16 and 17.

Table 16. Preferred outside diameters and thicknesses for carbon, carbon manganese and ferritic alloy steel boiler and superheater tubes appropriate to this Part of BS 3059 and masses per unit length

Outside diameter	Conventional mass per unit length for a tube thickness (in mm) of:																
	2.0	2.3	2.6	2.9	3.2	3.6	4.0	4.5	5.0	5.6	6.3	7.1	8.0	8.8	10.0	11.0	12.5
mm	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m
25.4	1.15	1.31	1.46	1.61	1.75	1.94	2.11	2.32	2.52	2.73	2.97	—	—	—	—	—	—
26.9	1.23	1.40	1.56	1.72	1.87	2.07	2.26	2.49	2.70	2.94	3.20	—	—	—	—	—	—
31.8	1.47	1.67	1.87	2.07	2.26	2.50	2.74	3.03	3.30	3.62	3.96	4.32	4.70	—	—	—	—
33.7	1.56	1.78	1.99	2.20	2.41	2.67	2.93	3.24	3.54	3.88	4.26	4.66	5.07	5.40	—	—	—
38	1.78	2.02	2.27	2.51	2.75	3.05	3.35	3.72	4.07	4.47	4.93	5.41	5.92	6.34	—	—	—
42.4	—	2.27	2.55	2.82	3.09	3.44	3.79	4.21	4.61	5.08	5.61	6.18	6.79	7.29	—	—	—
44.5	—	2.39	2.69	2.98	3.26	3.63	4.00	4.44	4.87	5.37	5.94	6.55	7.20	7.75	8.51	—	—
48.3	—	2.61	2.93	3.25	3.56	3.97	4.37	4.86	5.34	5.90	6.53	7.21	7.95	8.57	9.45	—	—
51	—	2.76	3.10	3.44	3.77	4.21	4.64	5.16	5.67	6.27	6.94	7.69	8.48	9.16	10.1	—	—
57	—	—	3.49	3.87	4.25	4.74	5.23	5.83	6.41	7.10	7.88	8.74	9.67	10.5	11.6	12.5	—
60.3	—	—	3.70	4.11	4.51	5.03	5.55	6.19	6.82	7.55	8.39	9.32	10.3	11.2	12.4	13.4	—
63.5	—	—	3.90	4.33	4.76	5.32	5.87	6.55	7.21	8.00	8.89	9.88	10.9	11.9	13.2	14.2	—
70	—	—	4.32	4.80	5.27	5.90	6.51	7.27	8.01	8.89	9.90	11.0	12.2	13.3	14.8	16.0	—
76.1	—	—	—	5.24	5.75	6.44	7.11	7.95	8.77	9.74	10.8	12.1	13.4	14.6	16.3	17.7	19.6
82.5	—	—	—	—	6.26	7.00	7.74	8.66	9.56	10.6	11.8	13.2	14.7	16.0	17.9	19.4	21.6
88.9	—	—	—	—	6.76	7.57	8.38	9.37	10.3	11.5	12.8	14.3	16.0	17.4	19.5	21.1	23.6
101.6	—	—	—	—	—	8.70	9.63	10.8	11.9	13.3	14.8	16.5	18.5	20.1	22.6	24.6	27.5
114.3	—	—	—	—	—	—	10.9	12.2	13.5	15.0	16.8	18.8	21.0	22.9	25.7	28.0	31.4
127	—	—	—	—	—	—	—	13.6	15.0	16.8	18.8	21.0	23.5	25.7	28.9	31.5	35.3

NOTE. For alloy steel types 629-470, 629-590 and 762 the above mass values multiplied by a factor of 0.985 apply.

Table 17. Preferred outside diameters and thicknesses for austenitic stainless steel boiler and superheater tubes appropriate to this Part of BS 3059 and masses per unit length.

Outside diameter	Conventional mass per unit length for a tube thickness (in mm) of:															
	2.0	2.3	2.6	2.9	3.2	3.6	4.0	4.5	5.0	5.6	6.3	7.1	8.0	8.8	10.0	11.0
mm	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m	kg/m
25.4	1.17	1.33	1.48	1.63	1.78	1.97	2.14	2.35	2.56	2.77	3.01	–	–	–	–	–
26.9	1.25	1.42	1.58	1.75	1.90	2.10	2.29	2.53	2.74	2.98	3.25	–	–	–	–	–
30	1.40	1.59	1.79	1.97	2.14	2.38	2.60	2.87	3.13	3.42	3.74	–	–	–	–	–
31.8	1.49	1.70	1.90	2.10	2.29	2.54	2.78	3.08	3.35	3.67	4.02	4.38	4.77	–	–	–
32	1.50	1.71	1.92	2.11	2.30	2.56	2.80	3.10	3.38	3.70	4.05	4.43	4.81	–	–	–
33.7	1.58	1.81	2.02	2.23	2.45	2.71	2.97	3.29	3.59	3.94	4.32	4.73	5.15	5.48	–	–
35	1.65	1.88	2.11	2.33	2.55	2.83	3.11	3.43	3.76	4.12	4.53	4.96	5.41	5.78	–	–
38	1.81	2.05	2.30	2.55	2.79	3.10	3.40	3.78	4.13	4.54	5.00	5.49	6.01	6.44	–	–
40	–	2.17	2.44	2.69	2.94	3.28	3.60	4.00	4.38	4.82	5.32	5.85	6.40	6.87	–	–
42.4	–	2.30	2.59	2.86	3.14	3.49	3.85	4.27	4.68	5.16	5.69	6.27	6.89	7.40	–	–
44.5	–	2.43	2.73	3.02	3.31	3.68	4.06	4.51	4.94	5.45	6.03	6.65	7.31	7.87	8.64	–
48.3	–	2.65	2.97	3.30	3.61	4.03	4.44	4.93	5.42	5.99	6.33	7.32	8.07	8.70	9.59	–
51	–	2.80	3.15	3.49	3.83	4.27	4.71	5.24	5.76	6.36	7.04	7.81	8.61	9.30	10.3	–
54	–	–	3.35	3.70	4.07	4.54	5.00	5.57	6.13	6.78	7.52	8.33	9.22	9.96	11.1	–
57	–	–	3.54	3.93	4.31	4.81	5.31	5.92	6.51	7.21	8.00	8.87	9.82	10.7	11.8	12.7
60.3	–	–	3.76	4.17	4.58	5.11	5.63	6.28	6.92	7.66	8.52	9.46	10.5	11.4	12.6	13.6
63.5	–	–	3.96	4.39	4.83	5.40	5.96	6.65	7.32	8.12	9.02	10.0	11.1	12.1	13.4	14.4
70	–	–	4.38	4.87	5.35	5.99	6.61	7.38	8.13	9.02	10.0	11.2	12.4	13.5	15.0	16.2
76.1	–	–	–	5.32	5.84	6.54	7.22	8.07	8.90	9.89	11.0	12.3	13.6	14.8	16.5	18.0
88.9	–	–	–	–	6.86	7.68	8.51	9.51	10.5	11.7	13.0	14.5	16.2	17.7	19.8	21.4
101.6	–	–	–	–	–	8.83	9.77	11.0	12.1	13.5	15.0	16.7	18.8	20.4	22.9	25.0
114.3	–	–	–	–	–	–	11.1	12.4	13.7	15.2	17.1	19.1	21.3	23.2	26.1	28.4

Appendix E. Eddy current testing of tubes for verification of leak tightness

E.1 General

The tubes shall be tested in accordance with BS 3889 : Part 2A, with the options of BS 3889 : Part 2A as specified in E.2 and E.3 and with the modification to BS 3889 : Part 2A as specified in E.4.

E.2 Test procedure

The tubes shall be tested for verification of leak tightness using a concentric coil or a rotating tube/rotating coil eddy current technique as described for methods A and B of BS 3889 : Part 2A.

E.3 Reference standards

The equipment shall be calibrated using reference standards prepared in accordance with **5.2.4**(a) for method A and **5.2.4**(b) for method B of BS 3889 : Part 2A : 1986. The dimensions of the reference hole (method A) and the reference notch (method B) shall be as specified in tables 18 and 19 of this Part of BS 3059.

E.4 Assessment of results

The results of the test shall be assessed in accordance with clause 7 of BS 3889 : Part 2A : 1986, except that 7.3(b) shall be replaced by the following.

'Explore the suspect area of the tube by dressing. If the tube thickness within the dressed area remains within the thickness tolerance either:

(1) retest the tube using the selected eddy current method in accordance with this appendix and if no signals are obtained that give a trigger/alarm condition the tube shall be deemed to have passed the test; or

(2) subject the suspect area to magnetic particle inspection in accordance with BS 6072 to ensure that dressing has resulted in complete removal of the imperfection; the tube shall then be deemed to have passed the test.

If the tube thickness within the dressed area does not remain within the thickness tolerance or if on retesting using the eddy current test method signals are obtained that give a trigger/alarm condition, either:

(i) cut off the suspect area, the remaining length being deemed to have passed the test; or

(ii the tube shall be deemed not to have passed the test.'

Table 18. Drill diameter sizes for method A

Outside diameter of tube	Drill diameter
mm	mm
⩽ 25	1.20
> 25 ⩽ 45	1.70
> 45 ⩽ 65	2.20
> 65 ⩽100	2.70
>100 ⩽127	3.20

Table 19. Notch dimensions for method B

Depth	12½ % of the specified tube thickness
Minimum depth	0.6 mm
Maximum depth	1.5 mm
Tolerance on depth	± 15 % of notch depth
Width	Not greater than the notch depth with a minimum of 0.5 mm
Length	A convenient length selected by the manufacturer for calibration and checking purposes

Appendix F. Ultrasonic testing of tubes for the detection of longitudinal imperfections

F.1 General

The tube shall be tested as specified in F.2 and F.3 and with the modification to clause 9 of BS 3889 : Part 1 : 1983 as specified in F.4.

F.2 Test procedure

The tube shall be tested for the detection of imperfections that are oriented predominantly longitudinally to the major axis of the tube in accordance with method A of BS 3889 : Part 1. Scanning shall be carried out in both directions of beam travel in accordance with figure 1(a) of BS 3889 : Part 1 : 1983.

F.3 Reference standards

The equipment shall be calibrated using longitudinal reference notches parallel to the major axis of the tube, in accordance with 7.1, 7.2.1, 7.2.2 and 7.2.5 of BS 3889 : Part 1 : 1983. The dimensions of the reference notches shall be as given in table 20.

Table 20. Reference notch dimensions and tolerances

Depth	5 % of specified tube thickness
Minimum depth	0.3 mm
Maximum depth	1.5 mm
Tolerance on depth	± 15 % of notch depth or ± 0.05 mm whichever is the larger
Maximum width	1.5 mm
Length	A convenient length selected by the manufacturer for calibration and checking purposes

F.4 Assessment of results

F.4.1 Any tube that does not produce signals giving a trigger/alarm condition shall be deemed to have passed the test.

F.4.2 Any tube that produces signals giving a trigger/alarm condition shall be designated 'suspect' or, at the manufacturer's option, shall be retested on the same automatic equipment as used in the original test.

F.4.3 If upon retesting no signal giving a trigger/alarm condition is obtained, the tube shall be deemed to have passed the test. Tubes giving a trigger/alarm condition upon retesting shall be designated 'suspect'.

F.4.4 For 'suspect' tubes, one or more of the following actions specified in items (a) to (e) shall be taken, or item (f) shall apply.

(a) The manufacturer shall show to the satisfaction of the purchaser that the trigger/alarm condition arises from a combination of minor imperfections, individually not serious enough to cause a trigger/alarm condition, and the tube shall then be deemed to have passed the test.

(b) For inside surface imperfections, the 'suspect' area shall be explored by dressing, using an acceptable method and, after checking that the remaining thickness is within tolerance, the suspect area shall be retested by an ultrasonic shear wave method using equipment with the same ultrasonic parameters and calibrated to give the same test sensitivity as used in the original ultrasonic test. If no signals are obtained that give a a trigger/alarm condition, the tube shall be deemed to have passed the test.

(c) For outside surface imperfections, the 'suspect' area shall be explored by dressing, using an acceptable method, and after checking that the remaining thickness is within tolerance, the 'suspect' area shall be retested non-destructively using the magnetic particle inspection method in accordance with BS 6072, until it can be shown that the imperfection has been completely removed.

The 'suspect' area shall then be retested by an ultrasonic shear wave method using equipment with the same ultrasonic parameters and calibrated to give the same test sensitivity as used in the original ultrasonic test. If no signals are obtained that give a trigger/alarm condition, the tube shall be deemed to have passed the test.

(d) The full circumference of the surface of the tube shall be dressed using an acceptable method, either completely or locally along its length to include the 'suspect' area and, after checking that the thickness is within tolerance, the tube shall be retested on the same automatic equipment as that used in the original test. If no signals are obtained that give a trigger/alarm condition, the tube shall be deemed to have passed the test.

(e) The 'suspect' area shall be cropped off, the remaining length being deemed to have passed the test.

(f) The tube shall be deemed not to have passed the test.

Appendix G. Procedure for verification of elevated temperature values

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

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

Information required for the construction of the lower confidence lines which are necessary for the application of the procedure are given in tables 21 to 33.

An example of confidence lines for steel type 762 is shown in figure 1. To achieve the appropriate degree of accuracy however it is necessary to construct the confidence lines on a larger scale. To enable this to be done the co-ordinates of two suitably spaced points on the lines, appropriate to the various grades of steel at each temperature, are given in tables 21 to 33.

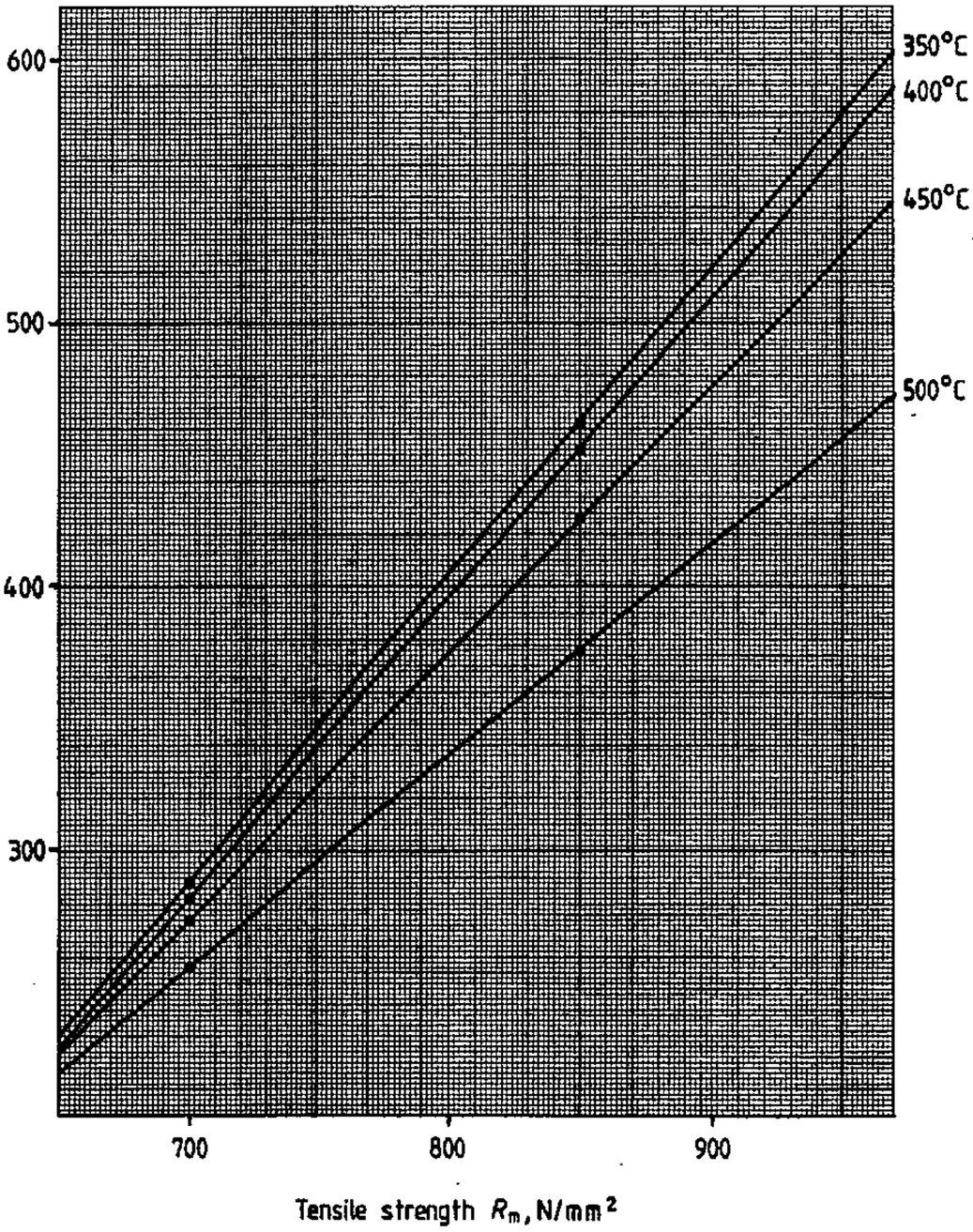

Figure 1. Example of lower confidence lines (for steel 762)

Table 21. Parameters for lower confidence lines: steel 360

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	300 N/mm²	500 N/mm²
°C	N/mm²	N/mm²
250	108	199
300	90	183
350	79	169
400	72	161
450	70	153

Table 22. Parameters for lower confidence lines: steel 440

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	360 N/mm²	550 N/mm²
°C	N/mm²	N/mm²
250	155	225
300	124	209
350	104	197
400	99	186
450	85	180

Table 23. Parameters for lower confidence lines: steel 243

Temperature	0.2 % proof stress at two levels of room temperature 1.0 % proof stress	
	450 N/mm²	550 N/mm²
°C	N/mm²	N/mm²
250	188	244
300	154	216
350	138	208
400	134	204
450	128	200
500	125	193

Table 24. Parameters for lower confidence lines: steel 620-460

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	460 N/mm²	560 N/mm²
°C	N/mm²	N/mm²
350	174	218
400	168	210
450	163	201
500	159	194
550	156	188

Table 25. Parameters for lower confidence lines: steel 622-490

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	440 N/mm²	540 N/mm²
°C	N/mm²	N/mm²
350	134	246
400	130	240
450	118	226
500	110	210
550	100	185

Table 26. Parameters for lower confidence lines: steel 629-470

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	460 N/mm²	620 N/mm²
°C	N/mm²	N/mm²
350	96	195
400	93	192
450	90	189
500	87	187

Table 27. Parameters for lower confidence lines: steel 629-590

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	620 N/mm²	720 N/mm²
°C	N/mm²	N/mm²
350	322	416
400	316	408
450	310	396
500	290	352
550	235	298

Table 28. Parameters for lower confidence lines: steel 762

Temperature	0.2 % proof stress at two levels of room temperature tensile strength	
	700 N/mm²	850 N/mm²
°C	N/mm²	N/mm²
350	287	462
400	281	451
450	273	424
500	256	376

Table 29. Parameters for lower confidence lines: steel 304S51

Temperature	1.0 % of proof stress at two levels of room temperature 1.0 % proof stress	
	250 N/mm²	350 N/mm²
°C	N/mm²	N/mm²
250	138	207
300	132	199
350	126	190
400	120	184
450	117	180
500	115	177
550	112	173
600	109	168
650	104	155
700	99	138

Table 30. Parameters for lower confidence lines: steels 316S51 and 316S52

Temperature	1.0 % proof stress at two levels of room temperature 1.0 % proof stress	
	250 N/mm²	350 N/mm²
°C	N/mm²	N/mm²
250	143	215
300	136	207
350	131	200
400	126	194
450	122	190
500	118	184
550	115	180
600	113	177
650	110	173
700	108	168

Table 31. Parameters for lower confidence lines: steel 321S51 (1010) and 321S51 (1105)

Temperature	1.0 % proof stress at two levels of room temperature 1.0 % proof stress	
	250 N/mm²	350 N/mm²
°C	N/mm²	N/mm²
250	160	247
300	153	240
350	148	233
400	144	227
450	139	220
500	136	215
550	134	211
600	131	204
650	127	194
700	121	180

Table 32. Parameters for lower confidence lines: steel 347S51

Temperature	1.0 % proof stress at two levels of room temperature 1.0 % proof stress	
	250 N/mm²	350 N/mm²
°C	N/mm²	N/mm²
250	164	254
300	158	248
350	153	242
400	150	238
450	149	232
500	148	228
550	146	221
600	145	210

Table 33. Parameters for lower confidence lines: steel 215S15

Temperature	1.0 % proof stress at two levels of room temperature 1.0 % proof stress	
	230 N/mm²	330 N/mm²
°C	N/mm²	N/mm²
250	146	223
300	143	219
350	141	216
400	139	213
450	137	210
500	136	207
550	135	202
600	133	198
650	131	190

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Committees responsible for this British Standard

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

Associated Offices Technical Committee
BEAMA Ltd. (Power Generation Association)
British Compressed Air Society
British Gas plc
British Shipbuilders
British Steel Industry
Electricity Supply Industry in England and Wales
Engineering Equipment and Materials Users' Association
High Pressure Pipework Consultative Committee
Lloyd's Register of Shipping
Process Plant Association
Seamless Steel Tube Association
Water-tube Boilermakers' Association
Welding Institute
Coopted members

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

British Fluid Power Association
British Forging Industry Association
British Industrial Truck Association
British Welded Steel Tube Association
Confederation of British Industry
Energy Industries Council
Coopted member

Amendments issued since publication

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Publications referred to

BS 18	Methods for tensile testing of metals
BS 3059*	Steel boiler and superheater tubes Part 1 Low tensile carbon steel tubes without specified elevated temperature properties
BS 3688	Methods for mechanical testing of metals at elevated temperatures Part 1 Tensile testing
BS 3889	Non-destructive testing of pipes and tubes Part 1 Methods of automatic ultrasonic testing for the detection of imperfections in wrought iron steel tube Part 2A Eddy current testing of ferrous pipes and tubes
BS 3894	Method for converting elongation values for steel Part 1 Carbon and low alloy steels Part 2 Method of conversion for application to austenitic steels
BS 3920	Specification for procedure for deriving and verifying the minimum elevated temperature yield or proof stress properties of steel products
BS 5383	Specification for material indentification of steel, nickel alloy and titanium alloy tubes by continuous character marking and colour coding of steel tubes
BS 5750*	Quality systems Part 2 Specification for manufacture and installation
BS 6072	Method for magnetic particle flaw detection
BS 6200	Sampling and analysis of iron, steel and other ferrous metals Part 3 Methods of analysis
BS Handbook No. 19	Methods for the sampling and analysis of iron, steel and other ferrous metals
ISO 1129*†	Steel tubes for boilers, superheaters and heat exchangers — Dimensions, tolerances and conventional masses per unit length
ISO 2604†	Steel products for pressure purposes — Quality requirements Part II Wrought seamless tubes Part III Electric resistance and induction-welded tubes

*Referred to in the foreword only.

†Published by the International Organization for Standardization and available from BSI Sales, Linford Wood, Milton Keynes MK14 6LE.

AMD 8707

BSI STANDARDS

Amendment No. 1
published and effective from 15 September 1995
to BS 3059 : Part 2 : 1990

Steel boiler and superheater tubes

Part 2. Specification for carbon, alloy and austenitic stainless steel tubes with specified elevated temperature properties

Revised text

Contents

After the entry for table 10, insert the following.
10a Estimated average stress rupture values for steel 91.

AMD 8707/September 1995

Table 2 Steel type and type number

Immediately after the seventh entry (for steel type number 629–590) insert the following new entry.

9 % chromium 1 % molybdenum, vanadium, niobium, nitrogen	91

AMD 8707/September 1995

Table 3 Chemical composition and mechanical properties at room temperature

See attached.

AMD 8707/September 1995

Table 4 Permitted deviations of the product analysis from the specified ladle analysis

In column 1 delete '629–470 and 629–590' and substitute '629–470, 629–590 and 91'.

In the second block of steels, below the entries for molybdenum, insert the following in columns 2, 3, 4 and 5.

Nickel	≤ 5.0	0.07	0.07
Niobium	≤ 0.20	0.005	0.005
Vanadium	≤ 0.35	0.03	0.03
Aluminium	≤ 0.045	0.005	0.005
Nitrogen	≤ 0.070	0.010	0.010
Copper	≤ 0.25	0.05	0.05

AMD 8707/September 1995

Clause 8.2 Elevated temperature minimum proof stress values

Delete the existing note and substitute the following.

NOTE. The values are not normally subject to verification except for steel type number 91.

AMD 8707/September 1995

Table 5 Steel type number and tube manufacturing process, final supply condition and temperature of heat treatment

Immediately after the ninth entry (for steel type number 629–590) insert the following (headings given for information only).

Steel type number and tube manufacturing process	Final supply condition	Temperature of heat treatment °C
91 (seamless, see clause 5)	Normalized and tempered	Normalizing: 1040 to 1090 Tempering: 730 to 790

AMD 8707/September 1995

Table 6 Minimum proof stress values ($R_{p0.2}$) for carbon, carbon manganese and ferritic alloy steels at elevated temperatures

Delete the existing table and substitute the revised table 6 attached.

AMD 8707/September 1995

Clause 9.2

In note 1, line 2, delete '1x' and substitute 'lux'.

AMD 8707/September 1995

Table 9. Designation of steel tubes in BS 3059 : 1990 and the nearest equivalent designations in BS 3059 : Part 2 : 1990 and the nearest equivalent designations in BS 3059 : 1978 and ISO 2604 : Parts II and III

Insert the following new note at the end of the table.

NOTE. Steel type number 91 is not included as it does not fall within any of the groups in the table, and is not yet referenced in ISO 2604 or BS 5383.

AMD 8707/September 1995

New table 10a Estimated average stress rupture values for steel 91

After table 10 insert the attached new table 10a.

AMD 8707/September 1995

Table 3. Chemical composition and mechanical properties at room temperature

After the seventh entry (for steel type number 629–590) insert the following new entry (headings given for information only).

Steel type	Type no.	Chemical composition (ladle analysis) (see notes 1 to 3)														Mechanical properties at room temperature (see note 5)			
		C		Si		Mn		P	S	Cr		Mo		Ni		Others (see notes 3 and 4)	R_e	R_m		A
		min. %	max. %	min. %	max. %	min. %	max. %	max. %	max. %	min. %	max. %	min. %	max. %	min. %	max. %	%	min. N/mm²	min. N/mm²	max. N/mm²	min. %
9 % chromium 1 % molybdenum, vanadium, niobium, nitrogen	91	0.08	0.12	0.20	0.50	0.30	0.60	0.020	0.020	8.00	9.50	0.85	1.05	—	0.40	Nb 0.06 to 0.10 V 0.18 to 0.25 Al_{met} 0.030 max. N 0.030 to 0.070	450	630	830	18

In the column headed 'R_m', insert '(see note 7)' after the column heading.

At the end of note 4 insert the following: 'This applies also to steel type number 91 with the exception of nickel content.'

In the column headed 'Others' delete 'see notes 3 and 4' and substitute 'see notes 3, 4 and 6'.

At the foot of the table insert the following new notes 6 and 7:

NOTE 6. For steel type number 91 a maximum copper content of 0.25 % and a maximum tin content of 0.03 % may be requested by the purchaser in order to facilitate subsequent operations of forming.

NOTE 7. For steel type number 91, a maximum tensile strength of 780 N/mm² may be requested by the purchaser.

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Table 6. Minimum proof stress values ($R_{p0.2}$) for carbon, manganese and ferritic alloy steels at elevated temperatures (see note)

Steel type	Type no.	Final supply condition	$R_{p0.2}$ min. at a temperature (°C) of:							
			250	300	350	400	450	500	550	600
			N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
Carbon	360	Hot finished and normalized	150	132	120	112	108	–	–	–
Carbon manganese	440	Hot finished and normalized	195	173	158	150	140	–	–	–
0.3% molybdenum	243	Normalized	221	192	180	176	172	166	–	–
1 % chromium 0.5 % molybdenum	620–460	Normalized	–	–	187	180	174	169	166	–
2.25 % chromium 1 % molybdenum	622–490	Normalized and tempered	–	–	224	218	204	190	168	–
9 % chromium 1 % molybdenum	629–470	Annealed	–	–	121	117	115	112	–	–
	629–590	Normalized and tempered	–	–	322	316	311	290	235	–
9 % chromium 1 % molybdenum, vanadium, niobium, nitrogen	91	Normalized and tempered	–	351	344	331	311	286	250	207
12 % chromium 1 % molybdenum, vanadium	762	Normalized and tempered	–	–	345	337	324	296	–	–

NOTE. All values are based on tests carried out in accordance with BS 3688 : Part 1 at the specified strain rate of 0.001/min to 0.003/min.

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Table 10a Estimated average stress rupture values for steel 91

NOTE. Notes to this table are located at the end of table 11.

Steel	Reference	Rupture time	Estimated average stress for rupture at a temperature in °C of:																		
			490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690
		h	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
9% chromium	91	10 000	302	283	265	248	230	214	197	182	166	151	137	124	111	99	89	79	71	63	55	48	41
1 % molybdenum		30 000	284	266	248	231	213	197	181	165	150	135	122	109	97	87	77	68	60	53	46	37	—
vanadium		50 000	276	258	240	223	205	189	173	157	142	128	115	102	91	81	72	64	56	49	41	—	—
niobium																							
nitrogen		100 000	265	247	229	212	194	178	162	146	132	118	105	94	83	74	65*	57*	50*	42*	—	—	—
		150 000	259	240	222	205	188	171	155	140	126	112	100	89	78	69	61*	54*	46*	37*	—	—	—
		200 000	254*	236*	218*	200*	183*	167*	151*	136*	121*	108*	96*	85*	75*	67*	58*	51*	43*	—	—	—	—
		250 000	250*	232*	214*	197*	180*	163*	147*	132*	118*	105*	93*	83*	73*	64*	56*	49*	41*	—	—	—	—

[AMD 8707]