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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 Überhitzer aus Stahl

Teil 2. Rohre aus warmfestem unlegiertem, legiertem oder austenitischem Stahl

WITHDRAWN

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under the direction of the Iron and Steel Standards Policy Committee and supersedes BS 3059 : Part 2 : 1978, which is withdrawn.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

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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/m² = 100 kPa.

Table 2. Steel type and type number

Steel type	Type number
<i>Carbon and carbon manganese steels</i>	
Carbon	360
Carbon manganese	440
<i>Ferritic alloy steels</i>	
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*
12 % chromium 1 % molybdenum, vanadium	762*
<i>Austenitic stainless steels*</i>	
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 and 4)	R ₀	R _m		A		Flattening test constant C	Drift expanding test increase in D		
		min.	max.	min.	max.	min.	max.	max.	max.	min.	max.	min.	max.	min.	max.		min.	min.	max.	min.	max.		≤0.6	>0.6	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	N/mm ²	N/mm ²	N/mm ²	%	%	%	%	%	
Carbon	360	—	0.17	0.10	0.35	0.40	0.80	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	590	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	—	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.	400	590	740	18	0.07	8	10	15	
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	0.08	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)	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.	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 1 % 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 629-550 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.

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_0 ;

L_0 is the original gauge length and is given by the expression:

$$L_0 = 5.65 \sqrt{S_0}$$

where S_0 is the original cross-sectional area of the gauge length.

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 and 629-590	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 > 0.35 ≤ 1.5	0.04* 0.05*	0.04* 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 > 1.0 ≤ 2.0 > 2.0 ≤ 7.0	0.04* 0.05* 0.10*	0.04* 0.05* 0.10*
	Sulphur	≤ 0.030 > 0.030 ≤ 0.040	0.003 0.004	— —
	Phosphorus	≤ 0.030 > 0.030 ≤ 0.040	0.003 0.004	— —
	Chromium	> 10.0 ≤ 15.0 > 15.0 ≤ 20.0	0.15* 0.20*	0.15* 0.20
	Molybdenum	> 1.0 ≤ 2.0 > 2.0 ≤ 3.0	0.05* 0.08*	0.05* 0.08*
	Nickel	> 5.0 ≤ 10.0 > 10.0 ≤ 20.0	0.10* 0.15*	0.10* 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.

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
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 to 1140
347S51 (seamless see clause 5)	Solution treated	1000 to 1100
215S15 (seamless see clause 5)	Solution treated	1050 to 1150

*In cases of dispute room temperature is to be taken as $20 \pm 5^\circ \text{C}$.

Table 6. Minimum proof stress values ($R_{p0.2}$) for carbon, 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 ($^{\circ}\text{C}$) of:							
			250	300	350	400	450	500	550	
Carbon	360	Hot finished and normalized	N/mm ² 150	N/mm ² 132	N/mm ² 120	N/mm ² 112	N/mm ² 108	N/mm ² —	N/mm ² —	
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	
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.

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.

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 ($^{\circ}\text{C}$) of:								
			250	300	350	400	450	500	550	600	650
18 % chromium, 10 % nickel	304S51	Solution treated	N/mm ² 139	N/mm ² 132	N/mm ² 125	N/mm ² 120	N/mm ² 117	N/mm ² 115	N/mm ² 112	N/mm ² 109	N/mm ² 104
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) 321S51 (1105)	Solution treated 950 $^{\circ}\text{C}$ to 1070 $^{\circ}\text{C}$ Solution treated 1070 $^{\circ}\text{C}$ to 1140 $^{\circ}\text{C}$	164 125	158 118	152 114	148 110	144 107	140 105	138 104	135 102	130 100
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.											