

Amendment No. 1
published and effective from 31 July 1990
to BS 806 : 1990

Specification for design and construction
of ferrous piping installations for and
in connection with land boilers

First updating of BS 806 : 1990 : list of new and revised pages to be inserted

The issue number on each page indicates the relationship of the page to the original standard (see foreword to the standard). Issue 1 indicates a new page to be inserted in its correct sequence. Issue 2 indicates a revised page to replace the original page of the same number. Vertical side-lining on replacement pages indicates that a change (or changes) has been made at that point. Where only one of the two back-up pages has been revised, the appropriate text has been reprinted on the reverse so that the original sheet may be removed from the standard.

Preliminary pages

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| (i) | Replace existing page (page (ii) unchanged on back) |
| (v) | Replace existing page (back of page blank) |

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| 3/3 | Replace existing page (page 3/4 unchanged on back) |
| 3/7 and 3/8 | Replace existing pages |
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| 3/13 | Replace existing page (back of page 3/13 blank) |
| 4/1 and 4/2 | Replace existing pages |
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| 4/18 | Replace existing page (page 4/17 unchanged on front) |
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| 5/12 | Replace existing page (page 5/11 unchanged on front) |
| 6/1 and 6/2 | Replace existing pages |
| 6/3 and 6/4 | Replace existing pages |
| B/1 | Replace existing page (page B/2 unchanged on back) |
| E/6 | Replace existing page (page E/5 unchanged on front) |
| F/2 | Replace existing page (page F/1 unchanged on front) |
| Publications referred to | Replace existing page (back of page blank) |

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Publications referred to

BS 10	Specification for flanges and bolting for pipes, valves and fittings (obsolescent)	BS 3604	Specification for steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties
BS 18	Method for tensile testing of metals (including aerospace materials)	BS 3605	Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes
BS 21	Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions)	BS 3688	Methods for mechanical testing of metals at elevated temperatures
BS 143 & 1256	Specification for malleable cast iron and cast copper alloy threaded pipe fittings	BS 3799	Specification for steel pipe fittings, screwed and socket-welding for the petroleum industry
BS 759	Valves, gauges and other safety fittings for application to boilers and to piping installations for and in connection with boilers Part 1 Specification for valves, mountings and fittings	BS 3920	Derivation and verification of elevated temperature properties for steel products for pressure purposes
BS 1113	Specification for design and manufacture of water-tube steam generating plant (including superheaters, reheaters and steel tube economizers)	BS 3923	Methods for ultrasonic examination of welds Part 1 Methods for manual examination of fusion welds in ferritic steels
BS 1387	Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads	BS 3974	Specification for pipe supports
BS 1452	Specification for grey iron castings	BS 4204	Specification for flash welding of steel tubes for pressure applications
BS 1503	Specification for steel forgings for pressure purposes	BS 4232	Specification for surface finish of blast-cleaned steel for painting
BS 1504	Specification for steel castings for pressure purposes	BS 4504	Circular flanges for pipes, valves and fittings (PN designated) Section 3.1 Specification for steel flanges
BS 1560	Circular flanges for pipes, valves and fittings (Class designated) Section 3.1 Specification for steel flanges	BS 4677	Specification for arc welding of austenitic stainless steel pipework for carrying fluids
BS 1640	Specification for steel butt-welding pipe fittings for the petroleum industry	BS 4772	Specification for ductile iron pipes and fittings
BS 1740	Specification for wrought steel pipe fittings (screwed BS 21 R-series thread)	BS 4882	Specification for bolting for flanges and pressure containing purposes
BS 1821	Specification for class I oxy-acetylene welding of ferritic steel pipework for carrying fluids	BS 5046	Method for the estimation of equivalent diameters in the heat treatment of steel
BS 1965	Specification for butt-welding pipe fittings for pressure purposes Part 1 Carbon steel	BS 5500	Specification for unfired fusion welded pressure vessels
BS 2633	Specification for class I arc welding of ferritic steel pipework for carrying fluids	BS 6072	Method for magnetic particle flaw detection
BS 2640	Specification for class II oxy-acetylene welding of carbon steel pipework for carrying fluids	BS 6129	Code of practice for the selection and application of bellows expansion joints for use in pressure systems Part 1 Metallic bellows expansion joints
BS 2789	Specification for spheroidal graphite or nodular graphite cast iron	BS 6208	Methods for ultrasonic testing and for specifying quality levels of ferritic steel castings
BS 2790	Specification for design and manufacture of shell boilers of welded construction	BS 6443	Method for penetrant flaw detection
BS 2910	Methods for radiographic examination of fusion welded circumferential butt joints in steel pipes	BS 6759	Safety valves Part 1 Specification for safety valves for steam and hot water
BS 2971	Specification for class II arc welding of carbon steel pipework for carrying fluids	PD 6510	A review of the present state of the art of assessing remnant life of pressure vessels and pressurized systems designed for high temperature service
BS 3100	Specification for steel castings for general engineering purposes	Standards significant to Health and Safety at Work *†	
BS 3500	Methods for creep and rupture testing of metals	ASTM E186 [‡]	Standard reference radiographs for heavy-walled (2 to 4 1/2 in. (51 to 114 mm)) steel castings
BS 3600	Specification for dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes	ASTM E280 [‡]	Standard reference radiographs for heavy-walled (4 1/2 to 12 in. (114 to 305 mm)) steel castings
BS 3601	Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes	ASTM E446 [‡]	Standard reference radiographs for steel castings up to 2 in. (51 mm) in thickness
BS 3602	Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties Part 1 Specification for seamless and electric resistance welded including induction welded tubes Part 2 Submerged arc welded tubes	PM 60†	Steam boiler blow down systems

* Referred to in the foreword only.

† Published by the Health and Safety Executive.

‡ Published by the American Society for Testing and Materials.

BS 806 : 1990 Specification for design and construction of ferrous piping installations for and in connection with land boilers

Enquiry Cases–Introduction

In accordance with the provisions of 1.2, the publication of Enquiry Cases will be notified in *BSI News* and will be made available for inclusion in the ring-binder in a separate section following the text of the specification and the appendices. The table below is for recording cases as they are published and included in the binder, and for noting their subsequent routing.

In general, cases will be extant, as adjuncts to the standard and open to public comment, until the text of the standard is amended to incorporate the substance of particular cases. This will be done in the course of the normal updating procedure and each case so dealt with will be recorded on the final page of the relevant amendment.

When a new edition of the standard is published, embracing all previously issued amendments, the relevant enquiry cases will be removed from the list and only those remaining extant, as described above, will be referred to. Consequently, the numerical sequence of enquiry case numbers in the first column will not be continuous because of these omissions.

Enquiry Case No.	Date of publication	Subject of the Enquiry Case	Subsequent Enquiry Case routing (e.g. incorporated into BS 806)	Date of subsequent action
806/1	July 1986	Use of materials complying with API 5L, ASTM A 106, A 182, A 312 and A 335 (supersedes Enquiry Case No. BS 806/A: September 1982 to BS 806 : 1975 and extended to include austenitic steels)		Revised June 1987
806/2	November 1986	Occasional loads		Revised Jan 1989
806/3	August 1987	Designing pipework in nuclear power stations to withstand safe shutdown earthquake (SSE)		
806/4	October 1989	EFW Alloy pipe for wet steam applications		
806/5	March 1990	Single non-repeated anchor/restraint movements		

Summary of pages

	No. of sheets	
Preliminary pages:	4	{title page, Enquiry Cases– Introduction, pages i to v)
Section one:	1	(pages 1/1 to 1/2)
Section two:	2	(pages 2/1 to 2/3)
Section three:	7	(pages 3/1 to 3/13)
Section four:	16	(pages 4/1 to 4/31)
Section five:	7	(pages 5/1 to 5/14)
Section six:	3	(pages 6/1 to 6/5)
Appendix A:	1	(pages A/1 to A/2)
Appendix B:	1	(pages B/1 to B/2)
Appendix C:	2	(pages C/1 to C/4)
Appendix D:	1	(page D/1)
Appendix E:	4	(pages E/1 to E/7)
Appendix F:	4	(pages F/1 to F/7)
Concluding pages:	1	(publications referred to)
Enquiry cases		

Foreword

This British Standard, first published in 1938 and subsequently revised in 1942, 1954, 1967, 1975 and 1986, has been prepared under the direction of the Pressure Vessel Standards Policy Committee. It supersedes the 1986 edition which is withdrawn.

This British Standard forms one of a series for boiler installations, the others in the series being:

BS 1113 Specification for design and manufacture of water-tube steam generating plant (including superheaters, reheaters and steel tube economizers)

BS 2790 Specification for design and manufacture of shell boilers of welded construction

For information on the materials and the standard sizes of steel pipes applicable to this standard, reference should be made to the following standards.

BS 1387 Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads

BS 3600 Specification for dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes

BS 3601 Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes

BS 3602 Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties

Part 1 Specification for seamless and electric resistance welded including induction welded tubes

Part 2 Submerged arc welded tubes

BS 3604 Specification for steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties

BS 3605 Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes

Integral piping for water-tube boilers as determined in the scope and definition clauses of BS 1113 is excluded from this standard and is dealt with in BS 1113.

This 1990 edition incorporates all technical changes up to and including Amendment No. 4 (31 July 1989) associated with the 1986 edition. Changes of significance in these amendments have included the development of the following:

- (a) requirements for the use of cast iron pipes and fittings;
- (b) requirements for the application of screwed joints;
- (c) requirements for the non-destructive examination of welds.

In this standard pressures are expressed as 'gauge' unless otherwise stated.

Fluid pressure is expressed in bar except in the case of calculations where N/mm^2 is used. $1 \text{ bar} = 0.1 \text{ N/mm}^2 = 100 \text{ kPa}$.

A format has been adopted that will facilitate annual amendment. It is intended to keep this standard up to date by the issue of replacement or additional pages when necessary. Each replacement or added page will carry an issue number (with date) indicating its relationship to the original issue of this standard, the pages of which are marked 'Issue 1'. For example:

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

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

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

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

Because of the wide range of pipes and piping installations that may be designed and manufactured in accordance with this standard, general guidance has been given on some aspects with specific requirements being for agreement between the parties concerned according to the particular design and manufacturing details. The purpose of this standard, however, is unchanged from previous editions.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

This standard is included in the list of 'Standards significant to Health and Safety at Work' published by the UK Health and Safety Executive (HSE)* and is also referred to by HSE in giving guidance.

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

* Health and Safety Executive, Baynards House, 1 Chepstow Place, London, W2 4TF.

Table 3.2 Design stress values (a) Steel tubes and pipes																							
Material	Tube standard	Method of manufacture	Steel grade	Thickness mm	Values of f (N/mm ²) for design temperatures (°C) not exceeding																	Design lifetime h	Notes
					50	100	150	200	250	300	350	380	390	400	410	420	430	440	450	460	470		
Carbon	BS 3601	ERW	320		130	119	108	97	86	77	71	69	69	68								4	
Carbon	BS 3601	ERW, S S	360	≤16 40 65	154 150 143	140 136 131	126 122 119	111 109 107	96	86	79	77	76	75								4	
Carbon	BS 3601	ERW, S S	430	≤16 40 65	183 177 170	166 162 156	149 146 143	132 131 129	115	103	95	91	90	89								4	
Carbon	BS 3601	SAW	430	≤16 40 65	183 177 190	166 162 156	149 146 143	132 131 129	115												1.4		
Carbon	BS 3602: Part 1	HFS, CFS, } ERW, CEW HFS, CFS	360	≤16 40 65	153 150 143	139 137 134	125 120 117	111 109 107	97	87	82	80	78	77	77	76	69	60	52	44	36	4 100 000 150 000 200 000 250 000	
Carbon	BS 3602: Part 2	SAW	410		163	153	142	129	119	105	96	94	93	92								4 100 000 150 000 200 000 250 000	
Carbon	BS 3602: Part 1	HFS, CFS, } ERW, CEW, } HFS, CFS	430	≤16 40 65	183 177 170	166 163 161	149 143 140	135 129 126	120 117 115	109	101	97	96	95	95	88	79	69	60	52	44	36 100 000 150 000 200 000 250 000	
Carbon	BS 3602: Part 2	SAW	460		187	172	158	147	135	121	112	108	107	106								100 000 150 000 200 000 250 000	
Carbon	BS 3602: Part 1	HFS, CFS	500 Nb		213	204	194	178	163	148	135	129	127	125	121	105	90	77	65	56	48	42 100 000 150 000 200 000 250 000	

Table 3.2 Design stress values (continued)
(a) Steel tubes and pipes (continued)

Material	Tube standard	Method of manufacture	Steel grade	Values of f (N/mm ²) for design temperatures (°C) not exceeding																												Design lifetime h	Notes
				50	100	150	200	250	300	350	400	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620				
Alloy	BS 3604	HFS, CFS	591	260	260	260	260	260	255	249	229																			9			
Alloy	BS 3604	HFS, CFS, ERW, CEW	620-440	187	178	169	163	157	128	121	116	112	111	111	111	111	93	76	62	52	42	33	27										
																	111	102	83	67	55	44	35	29	24								
																	111	94	76	61	49	40	32	26	22								
																	107	88	70	57	45	37	30	25	20								
Alloy	BS 3604	HFS, CFS, ERW, CEW	620-460	120	120	120	120	120	120	120	116	115	115	114	113	112	93	76	62	52	42	33	27								4		
																	113	102	83	67	55	44	35	29	24								
																	113	94	76	61	49	40	32	26	22								
																	107	88	70	57	45	37	30	25	20								
Alloy	BS 3604	HFS, CFS	621	179	169	158	152	145	116	110	105	101	101	101	100	100	93	76	62	52	42	33	27										
																	100	83	67	55	44	35	29	24									
																	94	76	61	49	40	32	26	22									
																	88	70	57	45	37	30	25	20									
Alloy	BS 3604	HFS, CFS	660	196	190	184	178	161	150	144	139	135	135	135	134	134	131	115	101	89	77	65	55	45	35						2, 5		
																	134	120	105	92	78	65	54	44	35	27							
																	130	112	98	84	70	58	47	37	28	22							
																	123	106	92	78	64	52	42	32	25	20							
Alloy	BS 3604	HFS, CFS	622	183	176	169	163	157	153	149	145	137	135	132	130	118	105	94	82	72	61	53	45	39	34						2, 6		
																	132	122	108	97	85	73	63	57	48	42	36	31					
																	130	117	104	92	79	68	59	52	45	38	33	28					
																	126	113	100	87	75	65	57	49	42	36	32	27					
Alloy	BS 3604	HFS, CFS	762	306	291	275	256	241	234	230	225	215	211	208	204	201	191	173	155	138	122	107	93	80	68	58	48	40	33				
																	200	184	168	152	135	115	98	85	72	62	52	44	37	30			
																	197	180	164	146	128	110	94	80	68	58	49	41	34	28			
																	192	176	160	142	124	105	90	77	65	55	46	38	32	25			



Table 3.2 Design stress values (continued)

(b) Steel castings

Material	Casting standard	Steel grade	Values of r (N/mm ²) for design temperatures (°C) not exceeding																												Design lifetime h	Notes
			50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580			
Carbon	BS 1504	161-430A	153	139	126	119	115	104	95	87																				7		
Carbon	BS 1504	161-430E	153	139	126	119	115	104	95	93	93	92	84	71	60	51	44	37												100 000 150 000 200 000 250 000	7	
											93	89	75	63	54	46	38	30														
											92	82	69	58	49	42	34															
											88	78	65	54	46	38																
Carbon	BS 1504	161-480A	163	153	143	136	128	115	105	101																				7		
Carbon	BS 1504	161-480E	163	153	143	136	128	115	109	107	107	106	99	84	71	60	51	44	37											100 000 150 000 200 000 250 000	7	
											107	100	89	75	63	54	46	38	30													
											103	92	82	69	58	49	42	34														
											99	88	78	65	54	46	38															
Carbon	BS 1504	161-540A	186	176	165	154	144	130	119	109																				7		
Alloy	BS 1504	245E	173	167	161	155	140	121	116	113				110															100 000 150 000 200 000 250 000	7		
Alloy	BS 1504	621A	187	175	161	146	141	136	123	114				108															100 000 150 000 200 000 250 000	7		
Alloy	BS 1504	660A	196	180	168	156	145	137	128	118				112																7		
Alloy	BS 1504	622E	217	212	208	203	197	193	187	182				176	174	170	153	137	120	107	95	85	76	65	61	53	45	39	34	100 000 150 000 200 000 250 000	2, 6, 7	
														174	161	144	129	112	98	88	77	68	63	56	48	41	36	31				
														172	156	139	124	107	94	83	71	63	59	52	45	38	33	28				
														170	152	135	119	103	91	79	68	60	57	49	42	36	32	27				

Table 3.2 Design stress values (continued)
(c) Steel forgings

Material	Forging standard	Steel grade	Ruling section mm	Values of f (N/mm ²) for design temperatures (°C) not exceeding																	Design lifetime h	Notes
				50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470	480		
Carbon	BS 1503	164	≤ 100 150	203 187	187 173	171 159	156 145	142 137	128	121	116	115	114	105	90	77	65	56	48	42	8	100 000 150 000 200 000 250 000
													111	95	81	68	58	50	43	38		
													104	88	75	63	54	46	40	34		
													98	83	70	59	51	43	37	32		
Carbon	BS 1503	221-410	≤ 100 > 100	143 137	134 126	125 116	121 113	112 108	100	95	92	92	92	92	90	77	65	56	48	42	8	100 000 150 000 200 000 250 000
														92	81	68	58	50	43	38		
														88	75	63	54	46	40	34		
														83	70	59	51	43	37	32		
Carbon	BS 1503	221-430	≤ 100 > 100	150 143	141 133	133 124	129 121	119 115	107	102	99	99	99	98	90	77	65	56	48	42	8	100 000 150 000 200 000 250 000
														99	81	68	58	50	43	38		
														99	88	75	63	54	46	40		34
														98	83	70	59	51	43	37		32
Carbon	BS 1503	221-460	≤ 100 > 100	163 157	154 146	145 135	140 131	129 125	117	112	109	108	108	105	90	77	65	56	48	42	8	100 000 150 000 200 000 250 000
														108	95	81	68	58	50	43		38
														104	88	75	63	54	46	40		34
														98	83	70	59	51	43	37		32
Carbon	BS 1503	221-490	≤ 100 > 100	177 170	167 158	157 146	151 141	140 135	128	122	119	118	118	105	90	77	65	56	48	42	8	100 000 150 000 200 000 250 000
														118	111	95	81	68	58	50		43
														118	104	88	75	63	54	46		40
														115	98	83	70	59	51	43		37
Carbon	BS 1503	221-510	≤ 100	190	177	165	159	147	135	129	125	124	121	105	90	77	65	56	48	42	8	100 000 150 000 200 000 250 000
														124	111	95	81	68	58	50		43
														121	104	88	75	63	54	46		40
														115	98	83	70	59	51	43		37
Carbon	BS 1503	223-410	≤ 100 > 100	163 153	150 141	138 129	130 121	120 115	106	99	93	92	92	91	90	77	65	56	48	42	8	100 000 150 000 200 000 250 000
														91	81	68	58	50	43	38		
														88	75	63	54	46	40	34		
														83	70	59	51	43	37	32		
Carbon	BS 1503	223-430	≤ 100 > 100	173 163	160 149	148 134	139 129	128 123	114	107	101	100	99	98	90	77	65	56	48	42	8	100 000 150 000 200 000 250 000
														99	81	68	58	50	43	38		
														99	88	75	63	54	46	40		34
														98	83	70	59	51	43	37		32

Table 3.2 Design stress values (continued)																						
(c) Steel forgings (continued)																						
Material	Forging standard	Steel grade	Ruling Section mm	Values of r (N/mm ²) for design temperatures (°C) not exceeding																	Design lifetime h	Notes
				50	100	150	200	250	300	350	390	400	410	420	430	440	450	460	470	480		
Carbon	BS 1503	223-460	≤ 100 > 100	193 180	179 166	164 153	151 141	140 135	127 119	113	111	110	105	90	77	65	56	48	42	8		
												110	95	81	68	58	50	43	38			
												104	88	75	63	54	46	40	34			
												98	83	70	59	51	43	37	32			
Carbon	BS 1503	223-490	≤ 100 > 100	209 197	194 182	179 167	165 153	152 146	139 131	125	123	121	105	90	77	65	56	48	42	8		
											123	111	95	81	68	58	50	43	38			
											121	104	88	75	63	54	46	40	34			
											115	98	83	70	59	51	43	37	32			
Carbon	BS 1503	223-510	≤ 100	217	203	190	173	159	147	138	132	131	121	105	90	77	65	56	48	42	8	
											128	111	95	81	68	58	50	43	38			
											121	104	88	75	63	54	46	40	34			
											115	98	83	70	59	51	43	37	32			
Carbon	BS 1503	224-410	≤ 100 > 100	157 147	146 137	136 127	125 117	114 109	101	94	90	89	88	88	88	77	65	56	48	42	8	
													88	81	68	58	50	43	38			
													88	75	63	54	46	40	34			
													83	70	59	51	43	37	32			
Carbon	BS 1503	224-430	≤ 100 > 100	167 157	156 146	145 135	133 123	121 117	108	101	97	96	95	95	90	77	65	56	48	42	8	
													95	81	68	58	50	43	38			
													88	75	63	54	46	40	34			
													83	70	59	51	43	37	32			
Carbon	BS 1503	224-460	≤ 100 > 100	183 170	170 158	157 147	145 135	132 127	118	111	106	105	105	104	90	77	65	56	48	42	8	
													105	95	81	68	58	50	43			
													104	88	75	63	54	46	40			
													98	83	70	59	51	43	37			
Carbon	BS 1503	224-490	≤ 100 > 100	203 187	187 173	171 159	156 145	142 137	128	121	116	115	115	105	90	77	65	56	48	42	8	
													115	111	95	81	68	58	50			
													115	104	88	75	63	54	46			
													115	98	83	70	59	51	43			
Carbon	BS 1503	224-510	≤ 100	210	194	179	163	149	135	128	124	122	121	105	90	77	65	56	48	42	8	
													122	111	95	81	68	58	50			
													121	104	88	75	63	54	46			
													115	98	83	70	59	51	43			
Carbon	BS 1503	225-490	≤ 100 > 100	209 200	199 187	189 173	172 163	160 154	147 145	137	131	130	121	105	90	77	65	56	48	42	8	
													128	111	95	81	68	58	50			
													121	104	88	75	63	54	46			
													115	98	83	70	59	51	43			



Table 3.2 Design stress values (continued)
(c) Steel forgings (continued)

Material	Forging standard	Steel grade	Ruling section mm	Values of r (N/mm ²) for design temperatures (°C) not exceeding																												Design lifetime h	Notes				
				50	100	150	200	250	300	350	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600			610	620		
Alloy	BS 1503	620-440		183	166	149	142	131	123	113	108		105					101	101	93	76	62	52	42	33	27							100 000 150 000 200 000 250 000	8			
Alloy	BS 1503	620-540	≤ 200	230	224	219	210	202	196	189	186		182	181	180	162	136	112	93	76	62	52	42	33	27								100 000 150 000 200 000 250 000	8			
Alloy	BS 1503	621-460		183	173	163	156	145	137	127	122		117					115	114	112	93	76	62	52	42	33	27							100 000 150 000 200 000 250 000	8		
Alloy	BS 1503	660-460		196	190	184	178	161	150	144	139		135					134	133	131	115	101	89	77	65	55	45	35						100 000 150 000 200 000 250 000	8.5		
Alloy	BS 1503	271-560		238	229	220	215	208	204	199	192		188	186	181	155	129	107	87	69	54	41	30											100 000 150 000 200 000 250 000	2.8		
Alloy	BS 1503	622-490		183	176	169	163	157	153	149	145		137	135	132	131	118	105	94	82	72	61	53	45	39	34								100 000 150 000 200 000 250 000	2.6, 8		
Alloy	BS 1503	622-560		238	231	224	219	213	209	201	197	196	195	194	183	170	157	143	131	118	105	94	82	72	61	53	45	39	34						100 000 150 000 200 000 250 000	2.6.8	
Alloy	BS 1503	762-690	≤ 250	294	276	259	249	240	233	227	219		206					190	187	173	155	138	122	107	93	80	68	58	48	40	33			100 000 150 000 200 000 250 000	8		

Table 3.2 Design stress values (concluded)
(c) Steel forgings (concluded)

Material	Forging standard	Steel grade	Ruling section mm	Values of f (N/mm ²) for design temperatures (°C) not exceeding																								Design lifetime h	Notes
				50	100	150	200	250	300	350	400	450	500	520	540	550	560	580	590	600	620	640	650	660	680	700	720		
Austenitic	BS 1503	304 S11		143	127	111	101	95	90	86	81	80																	
Austenitic	BS 1503	304 S31		153	136	119	109	103	98	93	89	87																	
Austenitic	BS 1503	304 S51		153	136	119	109	103	98	93	89	87	85	84	84	83	81	68	63	57	47	38	35	31	23	18	6		
															84	83	76	62	57	52	42	33	30	26	20	15			
															84	78	72	58	53	48	38	31	27	24	18				
															82	75	68	56	51	45	36	28	25	22	17				
Austenitic	BS 1503	316 S31 & S33		160	143	127	118	111	106	101	99	96																	
Austenitic	BS 1503	316 S11 & S13		150	134	119	110	103	99	94	91	88																	
Austenitic	BS 1503	316 S51		160	143	127	118	111	106	101	99	96	93	90	89	88	88	88	88	74	58	53	46	35	28	23	6		
															88	85	66	52	46	41	32	25	19						
															88	79	62	48	43	38	29	22	18						
															85	75	58	45	40	35	27	22	18						
Austenitic	BS 1503	321 S51-490		127	115	103	97	93	87	84	81	79	78	77	76	76	76	68	55	49	44	34	26						
															76	72	58	46	41	35	27								
															76	68	55	44	38	33	25								
Austenitic	BS 1503	321 S31		157	145	133	127	121	117	113	110	107																	
Austenitic	BS 1503	321 S51-510		157	145	133	127	121	117	113	110	107	104	103	103	102	102	86	78	71	57	42	36	31					
															103	101	93	78	72	64	49	36	32	27					
															103	97	89	74	66	58	45	33	28	25					
															100	93	85	71	62	55	42	31	26	22					
Austenitic	BS 1503	347 S31		160	151	142	135	127	123	120	118	116																	
Austenitic	BS 1503	347 S51		160	151	142	135	127	123	120	118	116	115	114	113	113	99	91	82	66	53	47	41	31	23				
															113	112	93	84	75	61	48	42	37	28	22				
															113	106	88	79	72	58	45	39	34	25	19				
															112	102	85	76	68	55	42	37	32	24	19				

Notes to table 3.2

General notes

- (a) Table 3.2 gives the nominal design stress (f) of various British Standard materials for design temperatures ($^{\circ}\text{C}$) not exceeding those stated at the head of each column. Time-dependent values which are given for lifetimes of 100 000, 150 000, 200 000 and 250 000 h are italicized. Values at intermediate temperatures and intermediate times shall be obtained by linear interpolation; values obtained by linear interpolation involving only one italicized value may be regarded as time-independent.
- (b) The design temperature as defined in section two should not exceed the upper temperature for which a value of (f) is given; where extrapolation of the values given is required, this shall be on a basis agreed between the purchaser and manufacturer (see 1.4.2.2(b)).
- (c) Overall thickness limits are as defined in the relevant material specification. In the case of forgings, the term 'ruling section' shall be interpreted in accordance with BS 5046.
- (d) For values between the thicknesses stated, design stresses shall be obtained by linear interpolation.

Notes applicable to individual materials

1. The use of this material shall be limited to pressures not exceeding 21 bar.
2. At temperatures at or above 580°C the effect of scaling becomes significant and due allowance shall be made for this.
3. Deleted.

4. Design stress values are not strictly based on specified yield/proof stress values in the relevant material standard (see appendix B).
5. Time-dependent values at 540°C and above are lower than those established by experience and established values up to 10% higher may be permitted subject to fitness-for-continued-service reviews being instituted at two-thirds of the design lifetime (see 2.8) and by agreement between the purchaser and manufacturer (see 1.4.2.2(c)). Between 530°C and 540°C values may be interpolated on the basis of the higher value at 540°C .
6. The time-dependent values are lower than those established by experience and established values up to 10% higher may be permitted subject to fitness-for-continued-service reviews being instituted at two-thirds of the design lifetime (see 2.8) and by agreement between the purchaser and the manufacturer (see 1.4.2.2(c)) providing the resulting value does not exceed the lowest time-independent stress value given.
7. An appropriate casting quality factor as specified in 4.5 should be applied to these values.
8. Material will (or may) be supplied in the quenched and tempered condition, in which case time-dependent properties may be susceptible to degradation as a result of subsequent fabrication processes.
9. For grade 591 it has not yet been possible to establish confidence limits, therefore an elevated temperature proof test shall be carried out. Values above 400°C are not included due to absence of data.
10. Time-dependent design stress values apply only if the minimum carbon content equals or exceeds 0.04% .

Section four. Design

4.1 General

The pipes and piping installations shall be designed in accordance with 4.2 to 4.13 to withstand the design pressure (see section two) at the design temperature (see section two) sustained, where relevant, for the design lifetime (see 2.8).

NOTE 1. This section also covers the assessment of stresses arising from the thermal expansion and deadweight loading of piping systems.

NOTE 2. Pipework designed in accordance with this section is suitable for 10^4 cycles at full pressure (zero to design pressure) and/or full temperature (ambient to design temperature).

4.2 Thickness of wrought steel straight pipes

The minimum thickness t_f (in mm) of straight pipes shall be calculated in accordance with either (a) or (b):

- (a) using the outside diameter as the basis for calculation:

$$t_f = \frac{pD}{2fe + p} \quad (4)$$

- (b) using the inside diameter as the basis for calculation:

$$t_f = \frac{pd}{2fe - p} \quad (5)$$

For (a) and (b) above

- p is the design pressure (in N/mm²);
- D is the mean outside diameter (in mm);
- d is the mean inside diameter (in mm);
- f is the maximum permissible design stress (in N/mm²) for the material in accordance with 3.2;
- e is a factor, having the following values:
 - $e = 1.0$ for seamless and for electric resistance welded and induction welded pipes complying with BS 3601, BS 3602 : Part 1, BS 3604 and BS 3605;
 - $e = 1.0$ for submerged arc welded pipes complying with BS 3602 : Part 2, test category 1, notch depth N5;
 - $e = 0.95$ for submerged arc welded pipes complying with BS 3602 : Part 2, test category 2;
 - $e = 0.9$ for submerged arc welded pipes complying with BS 3601.

NOTE 1. The value of t_f determined from equations (4) and (5) is the minimum thickness of straight tubes and further provision will be needed for minus thickness tolerances, where necessary.

NOTE 2. Designers' attention is drawn to 5.3.3.1(c).

4.3 Wrought steel bent pipes

NOTE. Pipe bends may be made by various forming processes or by welding together halves pressed from plate. The design thickness requirements specified in this clause apply to all processes.

4.3.1 Thickness of bends

Bends shall have a minimum wall thickness not less than t_f except in the cases of 4.3.2.1(b) and (c). The minimum thickness t_b of a straight pipe from which a pipe bent to a radius in accordance with table 4.3.1 is to be made shall be determined from equations (6) or (7), except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t_f at any point after bending.

For pipes 219.1 mm outside diameter and below, and for pipes above 219.1 mm outside diameter bent to the radii given in column 2 of table 4.3.1, t_b shall be given by:

$$t_b = 1.125t_f \quad (6)$$

For pipes above 219.1 mm outside diameter, where t_f is 32 mm or more, bent to the radii given in column 3 of table 4.3.1, t_b shall be given by:

$$t_b = 1.1t_f \quad (7)$$

The value of t_b is the minimum thickness and provision shall be made for minus tolerances.

NOTE. Manufacturing considerations may make it necessary for pipes thicker than this minimum to be used.

4.3.2 Radii of bends

4.3.2.1 Pipes complying with BS 1387 and BS 3601 shall not be bent to radii less than those given in table 4.3.1.

Other pipes of a thickness determined as in 4.3.1 shall not be bent to radii less than those given in table 4.3.1 unless:

- (a) it can be demonstrated that the use of this thickness will not reduce the thickness at any point after bending to below t_f ; and
- (b) where the design stress is time-dependent and the bend radius is less than 3 times the inside diameter, the intrados thickness t_i (in mm) shall not be less than that calculated from the following:

$$t_i = t_f \times \frac{2R - r}{2R - 2r} ; \text{ or} \quad (8)$$

- (c) where the design stress is time-independent and the bend radius is less than 1.5 times the inside diameter, the intrados thickness t_i (in mm) shall not be less than that calculated from the following:

$$t_i = \frac{t_f}{1.25} \times \frac{2R - r}{2R - 2r} \quad (9)$$

For (b) and (c) above

R is the radius of the bend (in mm);

r is the mean radius of the pipe (in mm).

4.3.2.2 There is a minimum thickness for each size of pipe, dependent on bending procedure, below which the allowance for thinning will be exceeded, and in such cases the radius given in table 4.3.1 shall be increased, where necessary, to ensure that the thickness is not below t_f at any point after bending.

4.3.2.3 Minimum radii of bends of carbon manganese niobium and alloy steel pipes which are cold bent without subsequent heat treatment, shall comply with 5.2.2.

4.3.2.4 For pipes rolled to a specified inside diameter, the minimum bending radii and corresponding thinning allowance shall be that applicable to the nearest outside diameter listed in table 4.3.1 greater than that resulting from the specified inside diameter plus $2t_b$.

Table 4.3.1 Minimum bending radii for wrought steel bent pipes		
Outside diameter	Radii measured to centre line of pipe	
	$t_b = 1.125 t_f$ for all thicknesses	$t_b = 1.1 t_f$ where $t_f = 32$ mm or above
mm	mm	mm
26.9	65	
33.7	75	
42.4	100	
48.3	115	
60.3	150	
76.1	190	
88.9	230	
101.6	265	
114.3	305	
139.7	380	
168.3	460	
193.7	630	
219.1	710	
244.5	810	1140
273.0	1020	1270
323.9	1220	1520
355.6	1500	1780
406.4	1730	2030
457.0	2030	2280

4.4 Gusseted bends

4.4.1 General

There are two types of gusseted bends: mitred (segmental) bends which shall comply with 4.4.2 and cut-and-shut bends, which shall comply with 4.4.3.

4.4.2 Design of gusseted bends: mitred (segmental)

4.4.2.1 Mitred bends shall not be used at a design temperature above 400 °C.

4.4.2.2 Mitred bends shall be fabricated from separate pieces of pipe cut in a plane other than perpendicular to the pipe axis and welded together. Mitred joints shall be made only by cutting the faces of adjacent segments at the same angle which shall not exceed 15 °, as shown in figure 4.4.2.2.

4.4.2.3 The ratio of the inside diameter to the mean thickness of the bend shall be not less than 20 nor more than 200.

4.4.2.4 The minimum thickness t_g (in mm) of the pipe wall at a mitred bend shall be not less than the following.

Where the outside diameter is the basis for the calculation:

$$t_g = \frac{D}{2X + 1} \quad (10)$$

Where the inside diameter is the basis for the calculation:

$$t_g = \frac{d}{2X - 1} \quad (11)$$

where

D is the mean outside diameter (in mm);

d is the mean inside diameter (in mm);

X is found from figure 4.4.2.4 with e , f and p as defined in 4.2.

The value of t_g is the minimum thickness for mitred bends, and provision shall be made for any minus tolerance.

NOTE. Manufacturing considerations may make it necessary for pipes thicker than this minimum to be used.

4.4.2.5 The distance between mitred joints measured along the centre line of the pipe shall be not less than L_m (in mm) (see figure 4.4.2.2):

$$L_m = Cr \quad (12)$$

where

r is the mean radius of the pipe, based on mean thickness (in mm);

$$C = \frac{1.833}{\sqrt{r/t}} + 2 \tan \alpha; \quad (13)$$

α is as shown in figure 4.4.2.2;

t is the mean thickness of the pipe (in mm).

NOTE. It may be necessary to increase the distance between mitred joints to a figure greater than L_m either from constructional considerations or to satisfy the requirements for attachment of branches or brackets.

4.4.2.6 The minimum thickness, t_g , shall be maintained for a distance of at least L_m on either side of the joint measured axially along the centre line of the pipe (see figure 4.4.2.2).

4.4.2.7 It is permissible to weld attachments to bends designed in accordance with 4.4.2.5 for supporting and other purposes. If attachments are made across one or more mitred joints, the distance measured from the edge of an attachment to the centre line of the next mitred joint shall be at least $1.833 \sqrt{rt}$ (see figure 4.4.2.2). Where attachments are made across mitred joints, flexibility factors require special consideration.

4.4.3 Cut-and-shut bends

Cut-and-shut bends shall not be used for design pressure or temperature conditions exceeding 21 bar or 260 °C.

4.5 Thickness of cast steel straight pipes and bends

The use of cast steel pipes and bends shall be restricted to inspection categories I, II and V of BS 1504.

Cast steel straight pipes and bends shall be used only by agreement between the purchaser and the manufacturer (see 1.4.2.3(c)). Where such pipes and bends are used, the areas to be inspected and the inspection techniques to be adopted shall also be agreed between the purchaser and the manufacturer (see 1.4.2.3(c)).

Where cast steel straight pipes and bends are to be butt welded to wrought pipes, the butt weld ends shall be included in the areas of inspection and, if the casting is manufactured from 2½ % Cr or CrMoV steels, the suitability for ultrasonic examination shall be confirmed by attenuation checks in accordance with 9.3 of BS 6208 : 1982.

The minimum thickness t_f (in mm) of cast steel straight pipes and bends, determined from equation (14), shall not be less than 9.5 mm:

$$t_f = \frac{pd}{2fF - p} \quad (14)$$

where

- p is the design pressure (in N/mm²);
- d is the inside diameter of the pipe (in mm);
- f is the maximum permissible design stress (in N/mm²) for the material (see 3.2);
- F is the casting quality factor, the value of which is dependent on the inspection category as follows:
 - (a) 1.0 for plain cylindrical areas local to butt weld ends up to a maximum distance of $2.5t$, where t is the mean thickness of the pipe (in mm) from the butt weld and where the whole of this area is inspected to a standard not less than severity level I of ASTM E186, E280 or E446* whichever is applicable;
 - (b) 0.9 for castings inspected to category I of BS 1504 except butt weld ends as specified in (a);
 - (c) 0.8 for castings inspected to category II of BS 1504 except butt weld ends as specified in (a);
 - (d) 0.7 for castings inspected to category V of BS 1504, except butt weld ends as specified in (a).

* ASTM E186 'Standard reference radiographs for heavy-walled (2 to 4½ in. (51 to 114 mm)) steel castings'

ASTM E280 'Standard reference radiographs for heavy-walled (4½ to 12 in. (114 to 305 mm)) steel castings'

ASTM E446 'Standard reference radiographs for steel castings up to 2 in. (51 mm) in thickness'

The ASTM standards are published by the American Society for Testing and Materials (ASTM) and copies of the radiographs may be examined at the offices of the Steel Castings Research and Trade Association (SCRATA) at the following address, by prior appointment only, at no charge: 5 East Bank Road, Sheffield S2 3PT.

4.6 Thickness of cast iron pipes and fittings

Cast iron pipes shall not be used for steam or blowdown duties under any conditions.

Grey iron pipes and fittings shall not be used when the design temperature exceeds 220 °C.

Ductile iron pipes and fittings shall not be used when the design temperature exceeds 350 °C.

The minimum thickness for grey iron pipes and fittings when used for duties other than steam or blowdown shall be in accordance with BS 4622 for the applicable conditions.

The minimum thickness for ductile iron pipes and fittings when used for duties other than steam or blowdown shall be in accordance with BS 4772 for the applicable conditions.

4.7 Joints

4.7.1. The flanges and bolting for ordinary bolted flange joints shall comply with BS 4504 : Section 3.1 or BS 1560 : Section 3.1 for flanges which are dimensioned in millimetres or with BS 10 for flanges which are dimensioned in inches. Gasket selection (material, thickness, etc.) shall be such that the gasket factor and seating stress are consistent with the flanges and bolting.

NOTE. Special joints and special types of flange may be used provided that they are shown to be suitable for the design conditions.

4.7.2 Butt welded joints shall comply with 5.3.

4.7.3 It is permissible to use socket weld joints with carbon and low alloy steel pipes not exceeding 60.3 mm outside diameter, but such joints shall not be used where fatigue, severe erosion or crevice corrosion is expected to occur.

The thickness of socket weld fittings shall be in accordance with 4.2, but shall be not less than 1.25 times the nominal thickness of pipe or tube. The throat dimension of the fillet weld shall be not less than the nominal thickness of the pipe or tube. The material shall be compatible with the associated piping.

Socket weld fittings shall be of forged steel. The dimensions and clearances of the socket end shall comply with BS 3799.

The welding of socket weld joints shall be in accordance with BS 2633, BS 2971 or BS 4677, as appropriate.

4.7.4 Screwed joints shall not be used in service where severe erosion, crevice corrosion, shock or fatigue is expected to occur.

Where screwed joints are used they shall comply with the following.

- (a) Screwed joints between pipes complying with BS 1387 and fittings complying with BS 1740 are permitted at temperatures not exceeding 260 °C and within the pressure limits given in table 4.7.4(1).
- (b) Screwed joints with fittings complying with BS 143 & 1256 are permitted at temperatures not exceeding 260 °C and within the pressure limits given in table 4.7.4(1) but subject to further limitation given in BS 143 & 1256.
- (c) Screwed joints are permitted at temperatures exceeding 260 °C and size/pressure limits in excess of those given in table 4.7.4(1) providing the following conditions are satisfied:

- (1) all threads are tapered unless pressure tightness depends on a seal weld or a seating surface other than the threads and experience or test demonstrates the suitability of the joint;
- (2) pressure/temperature ratings in appropriate component standards, e.g. BS 3799, are not exceeded;
- (3) the minimum specified tensile strength of screwed pipe is greater than 330 N/mm²;
- (4) the thickness of screwed pipe is not to be less than that given in table 4.7.4(2);
- (5) the design temperature does not exceed 495 °C;
- (6) the pressure limits given in table 4.7.4(3) are not exceeded.

(d) Screwed joints are permitted for temperatures in excess of 495 °C and pressures in excess of those given in table 4.7.4(3) for instrument insertions and tappings and for plugs for access openings for radiographic inspection providing the following conditions are satisfied:

- (1) they do not exceed 50 mm nominal size or one-quarter of nominal pipe size, whichever is the smaller;
- (2) the minimum thread engagement is not less than:
 - 6 for up to and including 20 mm nominal bore;
 - 7 for over 20 mm up to and including 40 mm nominal bore;
 - 8 for over 40 mm up to and including 50 mm nominal bore;
- (3) the connection is seal welded;
- (4) the design of instrument insertion withstands the fluid characteristics, fluid flow and any vibrations.

(e) Screwed joints are permitted for pressures in excess of those given in table 4.7.4(3) up to 345 bar for dead end instrument lines at the outlet end and downstream of shut-off valves and instruments, control apparatus or discharge of a sample cooler providing that the nominal size of pipe does not exceed 12 mm.

4.7.5 Sleeve welded joints shall not be used.

Table 4.7.4(1) Maximum permissible pressures for screwed joints using pipe complying with BS 1387 and fittings complying with BS 1740

Nominal pipe size	Maximum pressure for temperatures not exceeding 260 °C	Joint type
mm	bar	
6	10.5	Taper/parallel
8	10.5	Taper/parallel
10	10.5	Taper/parallel
15	10.5	Taper/parallel
20	10.5	Taper/parallel
25	10.5	Taper/parallel
32	9.0	Taper/parallel
40	9.0	Taper/parallel
50	12.5	Taper/taper
65	12.5	Taper/taper
80	10.5	Taper/taper
100	9.0	Taper/taper

NOTE. The efficiency of the taper/parallel screwed joints is highly dependent on the degree of care taken in assembly and on the jointing compound used.

Taper/taper screwed joints are less sensitive to jointing techniques and external forces.

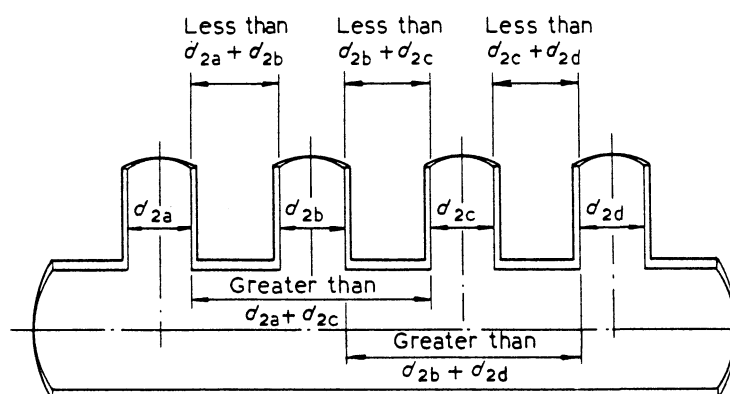
This table excludes screwed-on flanges (see 5.5.3).

Table 4.7.4(2) Minimum thickness of screwed pipe complying with 4.7.4(c)

Nominal pipe size	Minimum thickness	
	17.5 bar and less for steam 7 bar and less for water over 105 °C	Over 17.5 bar for steam Over 7 bar for water over 105 °C
mm	mm	mm
8	2.24	3.02
10	2.31	3.20
15	2.77	3.75
20	2.87	3.91
25	3.38	4.55
32	3.56	4.85
40	3.68	5.08
50	3.91	5.54
65	5.16	7.01
80	5.49	7.62

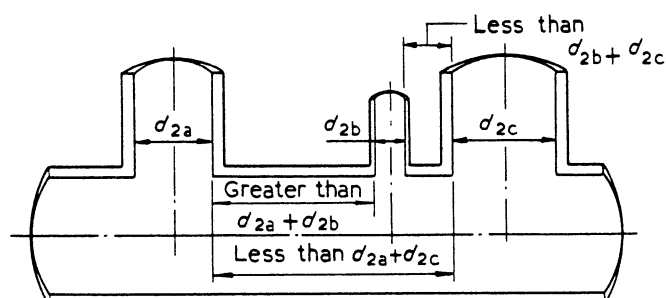
Table 4.7.4(3) Maximum pressure for screwed pipe complying with 4.7.4(c)

Nominal pipe size	Maximum pressure
mm	bar
Over 50 up to and including 80	27.5
Over 25 up to and including 50	41.5
Over 20 up to and including 25	83
Up to and including 20	103.5



d_{2a} is affected by d_{2b}
 d_{2d} is affected by d_{2c}
 d_{2b} is affected by $d_{2a} + d_{2c}$
 d_{2c} is affected by $d_{2b} + d_{2d}$

(c)



d_{2a} is affected by d_{2c}
 d_{2b} is affected by d_{2c}
 d_{2c} is affected by d_{2a} and d_{2b}

(d)

Figure 4.8.4 (concluded)

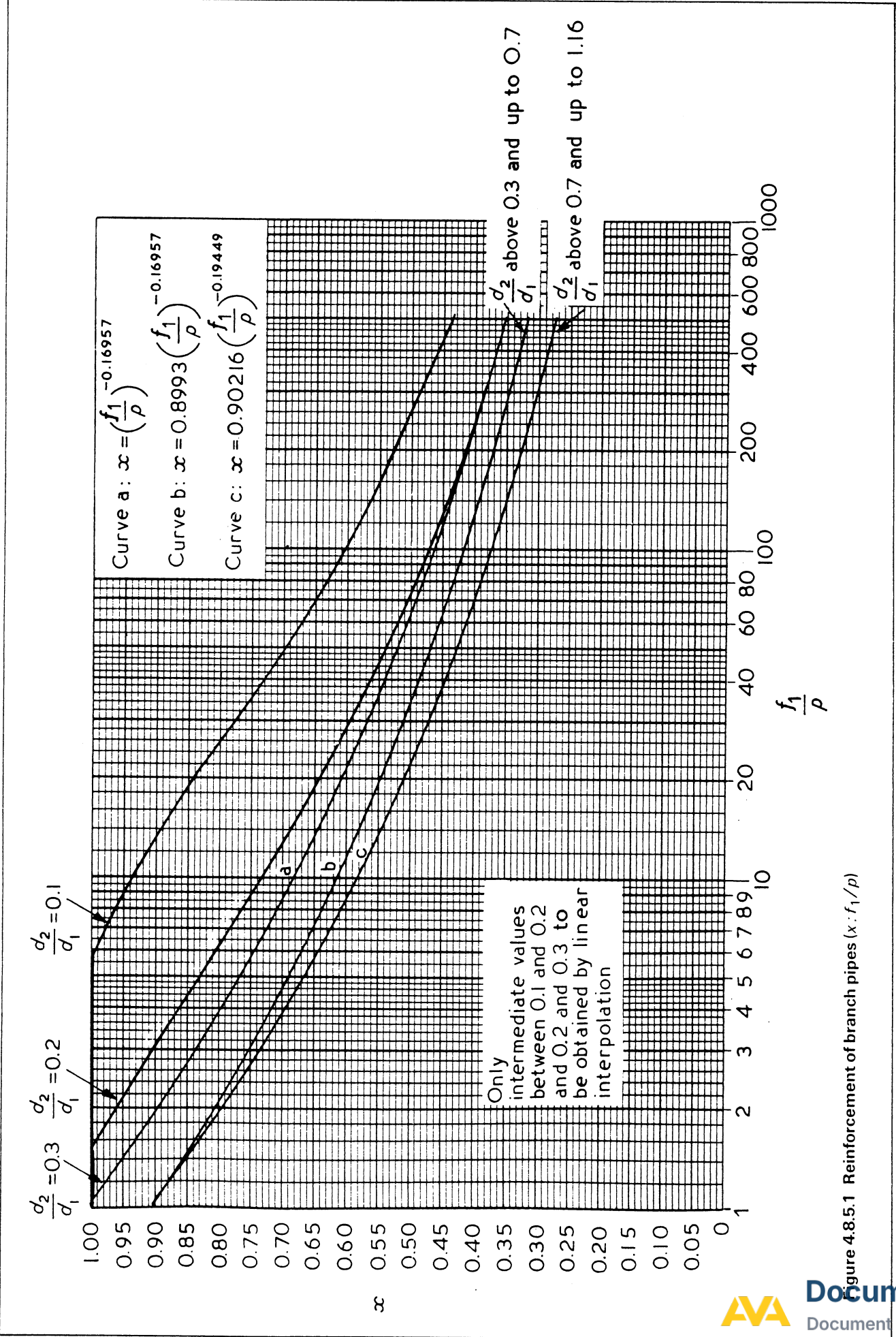


Figure 4.8.5.1 Reinforcement of branch pipes ($x: f_1/p$)

Section five. Construction and workmanship

5.1 General

Contamination of the surfaces of the pipes by corrosive or other detrimental substances, particularly by non-ferrous metals and sulphur, shall be avoided; e.g. during heating, adequate measures shall be taken to prevent sulphur pick-up. Filling sand, if used, shall be inert and no paint, labels or tools containing lead, copper, zinc or tin shall be used.

Contamination of austenitic steels by ferritic steels shall be avoided.

It is essential that alloy steel pipes, when cold, shall not be subjected to impact or hammer blows likely to cause local damage. Every precaution shall be taken to avoid such occurrences in handling and during all operations on the pipes. Care shall be taken in fabrication and manipulation to avoid the formation of notches or other sharp changes of contour likely to cause stress concentration.

5.2 Heat treatment and final condition

5.2.1 Final heat treated condition of pipes

Before erection as part of a pipework installation, all pipes, whether straight or manipulated, shall be in the heat treated condition given in table 5.2.1. Where there is subsequent welding, the heat treatment of the welds shall comply with 5.3.

5.2.2 Cold forming

Pipes of the materials given in table 5.2.1 that have been cold formed shall be supplied in the following condition:

- (a) when cold bent to a radius less than $3.5D$ (see 1.3.2), they shall be heat treated in accordance with table 5.2.1;
- (b) when cold bent to a radius of $3.5D$ or greater and they have been heat treated as specified in the materials specification before bending, no reheat treatment is required after bending.

5.2.3 Hot forming: ferritic steels

Hot forming of ferritic steels shall be carried out after heating in the range 850°C to 1100°C . Following hot forming, pipes shall be treated as given in table 5.2.1. If the pipe has been heated to normalizing temperature and the hot forming operation completed above 750°C , subsequent normalizing is not required for carbon and carbon manganese steels, excluding 500 Nb.

NOTE. Attention is drawn to the possibility of hydrogen cracking in steel 762 if heat treatment is delayed following hot working.

5.2.4 Hot forming: austenitic steels

Hot forming of austenitic steels shall be carried out after heating in the range 900°C to 1100°C . If the pipe has been heated to the solution treatment temperature, the hot forming operation completed at a temperature exceeding 900°C , and rapid cooling in air or water has

Table 5.2.1 Heat treatment of completed pipes

Figures in parentheses refer to the notes following this table.

Material	Grade	Heat treatment temperature		
		Normalized	Tempered	Solution treated
		$^{\circ}\text{C}$	$^{\circ}\text{C}$	$^{\circ}\text{C}$
C		880 to 940 (3)	—	—
C Mn		—	—	—
C Mn Nb	500 Nb	850 to 960	—	—
1 Cr $\frac{1}{2}$ Mo	620-440	900 to 960	640 to 720	—
1 Cr $\frac{1}{2}$ Mo	620-460	900 to 960	640 to 720 (1)	—
$1\frac{1}{4}$ Cr $\frac{1}{2}$ Mo	621	900 to 960	640 to 720	—
$\frac{1}{2}$ Cr $\frac{1}{2}$ Mo $\frac{1}{4}$ V	660	930 to 980	670 to 720	—
$2\frac{1}{4}$ Cr 1 Mo	622	900 to 960	650 to 750	—
12 Cr Mo V	762	1020 to 1070	680 to 780	—
15 Cr 10 Ni 6 Mn Nb V	1250E	—	—	1050 to 1150
18 Cr 10 Ni	304	—	—	1000 to 1100
18 Cr 12 Ni Mo	316	—	—	1000 to 1100
18 Cr 12 Ni Ti	321S18	—	—	950 to 1070
	S18E	—	—	
	S59E (1010)	—	—	
18 Cr 12 Ni Ti	321S59E (1105)	—	—	1070 to 1140
18 Cr 12 Ni Nb	347	—	—	1000 to 1100
$1\frac{1}{4}$ Ni Cu Mo Nb	591	900 to 980 (2)	580 to 680 (2)	—

NOTE 1. Tempering may be omitted for thicknesses not exceeding 12.5 mm.

NOTE 2. This steel may also be quenched from the range 880°C to 930°C , followed by tempering in the range 620°C to 690°C .

NOTE 3. As an alternative to normalizing, except where precluded by 5.2.2 and 5.2.3, carbon and carbon manganese steel pipes may be in the hot finished, subcritically annealed, or as welded condition permitted by the material specification.

been carried out, subsequent solution heat treatment is not required for 304, 316, 321 and 347 grades listed in table 5.2.1, except for grade 321S59E (1105), which shall be solution heat treated as specified after hot bending.

NOTE. In order to ensure uniform soaking, the temperature for normalizing should be maintained for a time proportionate to the thickness of the pipe at a rate of not less than 1.2 min/mm of maximum thickness, followed by cooling in still air.

5.2.5 Local adjustment of components

As a result of fabrication operations during the manufacture of tubular assemblies and integral piping, distortion or deformation may occur due to welding shrinkage or inaccuracy in bending operations. The adjustment of such components to acceptable dimensional tolerances, using local heating (including manual gas torches), is permitted provided that the metal temperature is not allowed to exceed the normalizing or solution treatment temperature, as appropriate.

5.3 Welding

5.3.1 General

Welds shall be either:

- (a) in accordance with BS 1821, BS 2633, BS 2640, BS 2971, BS 4204 and BS 4677; or
- (b) by agreement between the purchaser and the manufacturer, in accordance with processes, other than those covered by the standards specified in (a), that have been demonstrated as being suitable (see 1.4.2.3(e)).

5.3.2 Dressing of welds

Any dressing of welds within the provisions of the standards listed in 5.3.1 shall be such that the thickness remaining is not less than the minimum required by this standard.

5.3.3 Use of class I and class II welding for ferritic materials

5.3.3.1 Class I welding shall be used for steam services exceeding 17 bar or 220 °C, except that for a design temperature T (in °C), over 220 °C up to and including 400 °C, it is permissible to use class II welding provided all the following conditions are satisfied.

- (a) The design pressure (in bar) shall not be greater than:

$$17 \left(\frac{400 - T}{180} \right)$$

- (b) The pipework shall be of carbon steel having a carbon content not exceeding 0.25 % (m/m) *.
- (c) The actual thickness of the pipe at the butt weld shall be not less than twice the calculated design thickness.
- (d) The pipework shall be tested in either of the following ways:

* Percentage by mass.

(1) the entire circumference of all butt welds shall be non-destructively tested by an ultrasonic or radiographic method; or

(2) the pipework shall be hydraulically tested in accordance with 6.2.2 and the entire circumference of 10 % of the butt welds made by each welder, selected at random, shall be subjected to non-destructive testing by an ultrasonic or radiographic method.

5.3.3.2 Class I welding shall be used for feed services exceeding 24 bar or 200 °C.

5.3.3.3 The use of class II welding is permitted for steam and feed services whose design conditions do not exceed the relevant limits specified in 5.3.3.1 and 5.3.3.2.

NOTE. The requirements of 5.3.3 are shown in schematic form in figure 5.3.3.

5.4 Attachment of branches

Branches, bosses and drain pockets shall be welded to the pipes and the welding shall comply with 5.3.

Minimum dimensions for external profiles of class I welds at branches shall be as given in figure 5.4.

5.5 Attachment to flanges (see figures 5.5(1) to 5.5(9))

5.5.1 General

Flanges shall be secured to the pipes by welding or by screwing.

5.5.2 Welded-on flanges

5.5.2.1 Where flanges are welded on, the processes used shall be in accordance with 5.3.1.

Oxy-acetylene welding is permitted only for type 1 flanges (see figure 5.5(1)) of carbon steel or 1 % Cr ½ % Mo steel or type 7 flanges (see figure 5.5(9)).

The preparation of the welds shall be as shown in figures 5.5(1) to 5.5(9).

Flanges shall not be tight fit on the pipe. The maximum clearance between the bore of the flange and the outside diameter of the pipe shall be as given in table 5.5.2.1.

Table 5.5.2.1 Maximum clearance between pipes and flanges

Nominal thickness of pipe	Maximum clearance between bore of flange and outside diameter of pipe	Sum of the diametrically opposite clearances, maximum	Weld leg length, minimum
mm	mm	mm	mm
Over 5	3	5	6
Over 4 up to and including 5	2.5	4	5
Over 3 up to and including 4	2	3	4
Up to and including 3	1.5	2	3

5.5.2.2 The limiting design conditions for each type of flange shall be as given in table 5.5.2.2

Table 5.5.2.2 Limiting design conditions for flange types Figures in parentheses refer to the notes following this table.						
Flange type	Limiting flange type			Maximum temperature °C	Maximum pipe outside diameter mm	Minimum pipe bore mm
	BS 10 ⁽¹⁾	BS 1560: Section 3.1	BS 4504: Section 3.1			
	Table	Class/Code	Designation/Code			
1	No restriction	No restriction	PN 40/111	No restriction	No restriction	No restriction
2	No restriction	Not applicable	PN 40/101	No restriction	168.3 for alloy and 500 Nb steels ⁽²⁾	No restriction
3, 3A ⁽³⁾	No restriction	Not applicable	PN 40/101	No restriction	168.3 for alloy and 500 Nb steels ⁽²⁾	75
4	R	Not applicable	PN 40/101	425	No restriction	No restriction
4A		900/112	PN 40/112			
5, 5A ⁽³⁾	R	Not applicable	PN 40/101	425	No restriction	75
6	J	Not applicable	PN 40/101	425	No restriction	No restriction
6A		300/112	PN 40/112			
7	H	300/112	PN 40/112	400	168.3	No restriction
NOTE 1. This British Standard is obsolescent. NOTE 2. No restriction for carbon steels. NOTE 3. Flange types 3, 3A and 5, 5A (BS 4504 : Section 3.1) require the flange to be supplied with a bore less than the outside diameter of the pipe.						

5.5.3 Screwed-on flanges

Where flanges are secured by screwing, the screw thread shall comply with BS 21. The threads on the pipe and in the flange shall be arranged to end at a point just inside the back or boss of the flange. After the flange has been screwed on, the pipe shall be expanded into the flange by a roller expander. The use of such screwed and expanded flanges is permitted for steam for a maximum design pressure of 30 bar and a maximum design temperature of 370 °C, and for feed for a maximum design pressure of 50 bar.

5.6 Ovality of bent pipes

Ovality, calculated in accordance with equations (41) and (42), shall not exceed 5 % :

$$\text{Ovality}(\%) = \frac{(D_{\max} - D_n) 100}{D_n} \quad (41)$$

$$\text{Ovality}(\%) = \frac{(D_n - D_{\min}) 100}{D_n} \quad (42)$$

where

$D_{\max}$ is the maximum outside diameter in the bent section (in mm);

$D_{\min}$ is the minimum outside diameter in the bent section (in mm);

D_n is the average outside diameter in the straight pipe (in mm).

5.7 Gusseted bends

Gusseted bends shall be fabricated in accordance with BS 1821, BS 2633, BS 2640, BS 2971 or BS 4677 according to the limits of pressure and temperature defined in 5.3.3 for class I and class II welding, but taking into account the overall limiting conditions of use given in 4.4.2 and 4.4.3.

5.8 Condition of pipes (see also 1.4.1(f))

5.8.1 All parts of piping installations shall, as far as is practicable, be cleaned internally of rust and other foreign matter to comply with BS 4232 : 1967, third quality, excepting that for (a) and (c) following the internal cleaning shall comply with BS 4232 : 1967, second quality.

In the following cases scale, sand and other foreign matter shall be removed by pickling in inhibiting acid or by blasting with abrasive material:

- (a) all alloy steel pipes;
- (b) all carbon steel pipes where hot work has been carried out during fabrication for design pressures above 15 bar;
- (c) all pipes within the feed and steam pipes systems where the boiler design pressure exceeds 64 bar.

After cleaning and before despatch, all pipe ends shall be fitted with suitably sealed protective end covers which shall be maintained in position until immediately before erection.

5.8.2 Immediately before erection, all parts of piping installations shall be checked for internal cleanliness.

5.9 Marking of pipes

Stamps shall be of the low stress type except that stamping on the body is not permitted for alloy steel.

NOTE. Inspection or identification marks may be stamped on the end faces of plain-end pipes or on the rims of flanges or on identification plates suitably attached to the pipes. Alternatively, inspection and identification marks may be vibro-etched or painted on the pipes provided iron oxide base or titanium base paints are used (see 5.1).

5.10 Erection of pipework

5.10.1 General

Cold pull procedure shall be such as to ensure that correct angulation and rotation are imposed; for this purpose alignment marks shall be made at the cold gaps. Pipe ends at gaps shall be parallel with each other before pulling together.

Where the final joint is made by butt welding and is to be post-heat treated, the forces required to position the pipes shall be maintained by external means until completion of the heat treatment procedure.

The pipes to be pulled shall be hanging freely when the gap is measured, i.e. there should be no out-of-balance spring effort or any intermediate restraints other than those necessary to counteract any horizontal components of out-of-vertical supports. This condition shall also apply when alignment marks and end checks are made.

After the pipes have been pulled together, alignment shall be strictly maintained.

NOTE. Consideration should be given, where necessary, to the provision of temporary supports to reduce the deadweight stress due to the additional weight of test water.

5.10.2 Balanced erection

Where terminal forces and moments acting upon plant have to be maintained within close limits a site erection procedure shall be prepared and executed in a manner to demonstrate that the principles of design are achieved.

The detailed procedure shall set out the step by step method of erection for the particular installation (see 4.11.1).

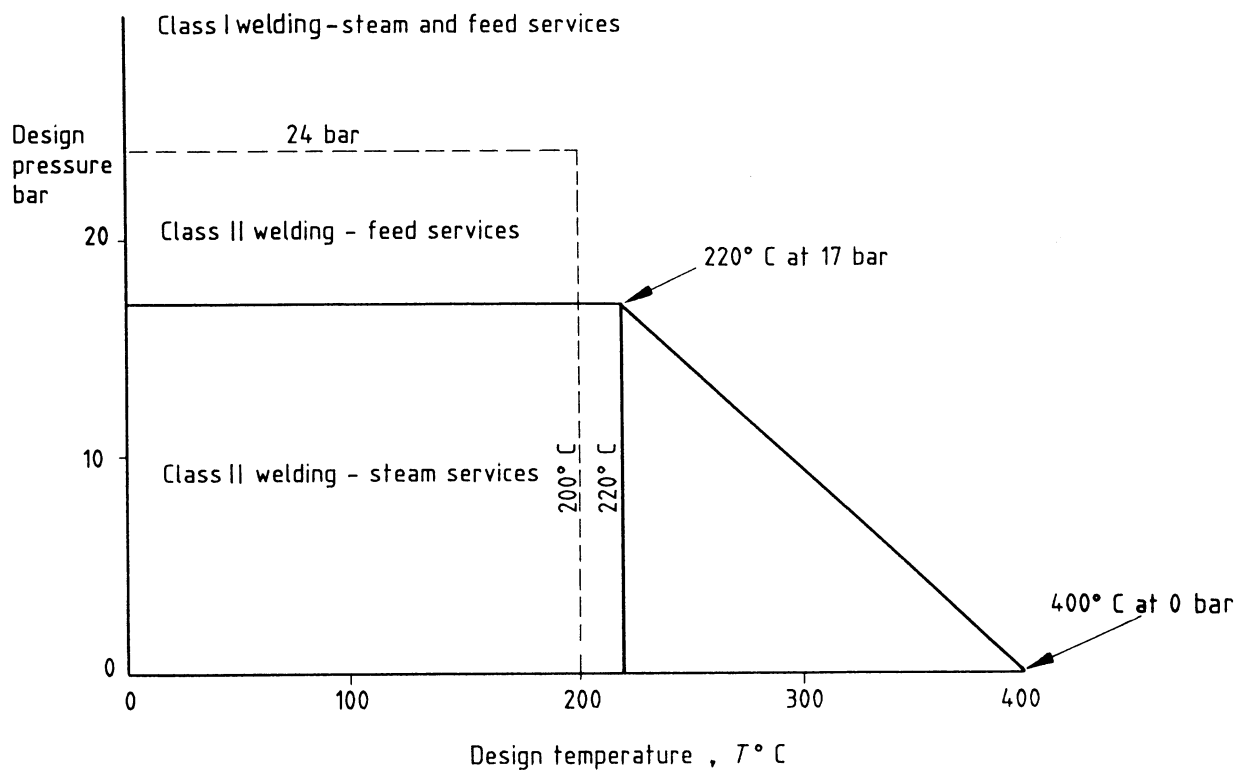
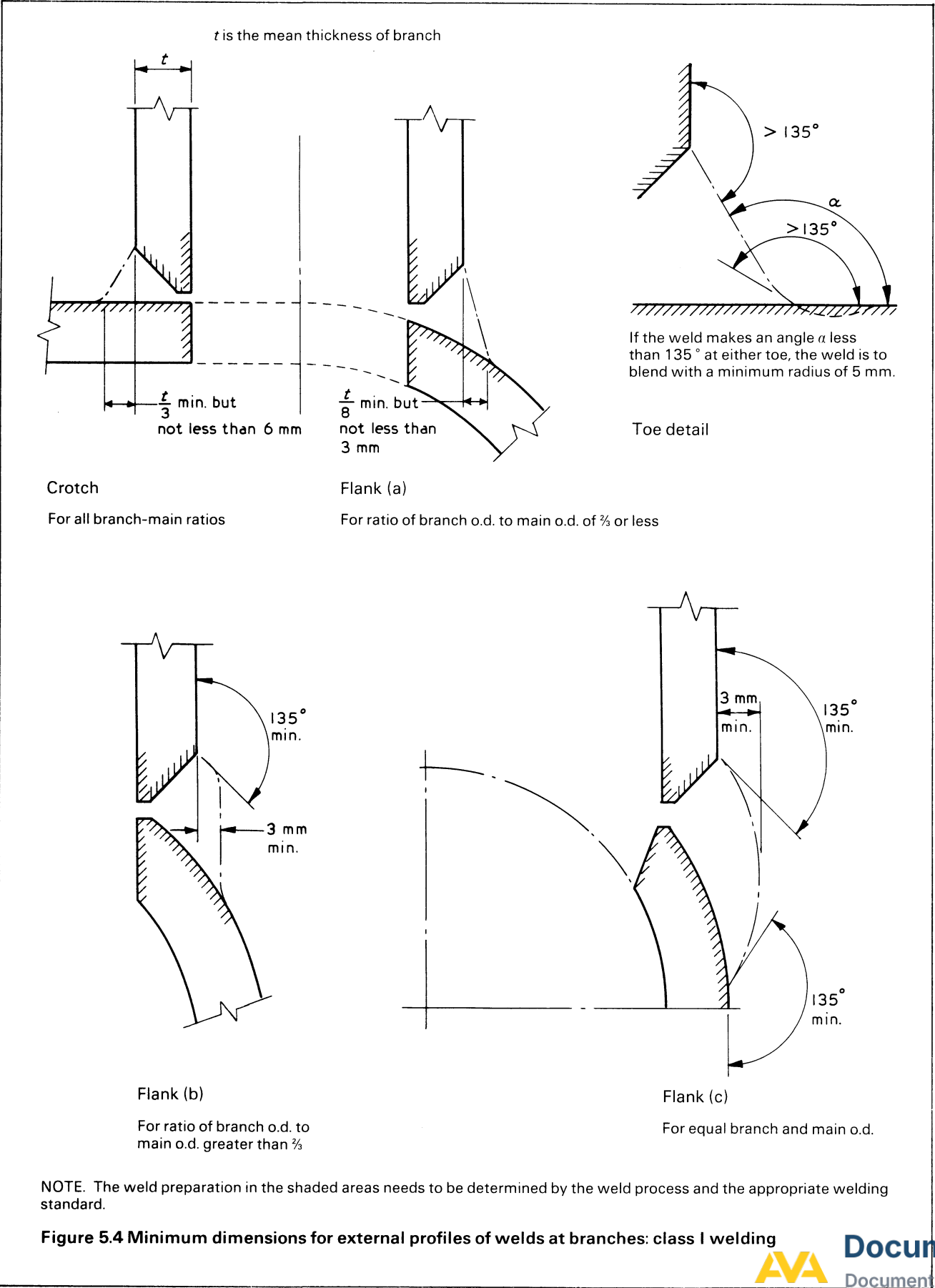
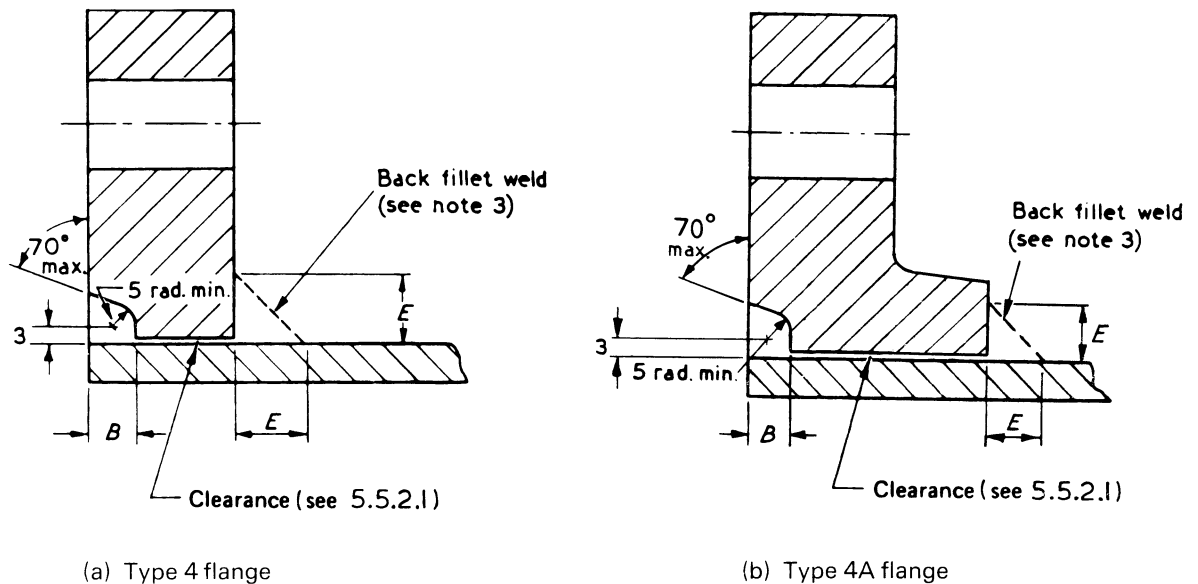


Figure 5.3.3 Use of class I and class II welding for ferritic materials

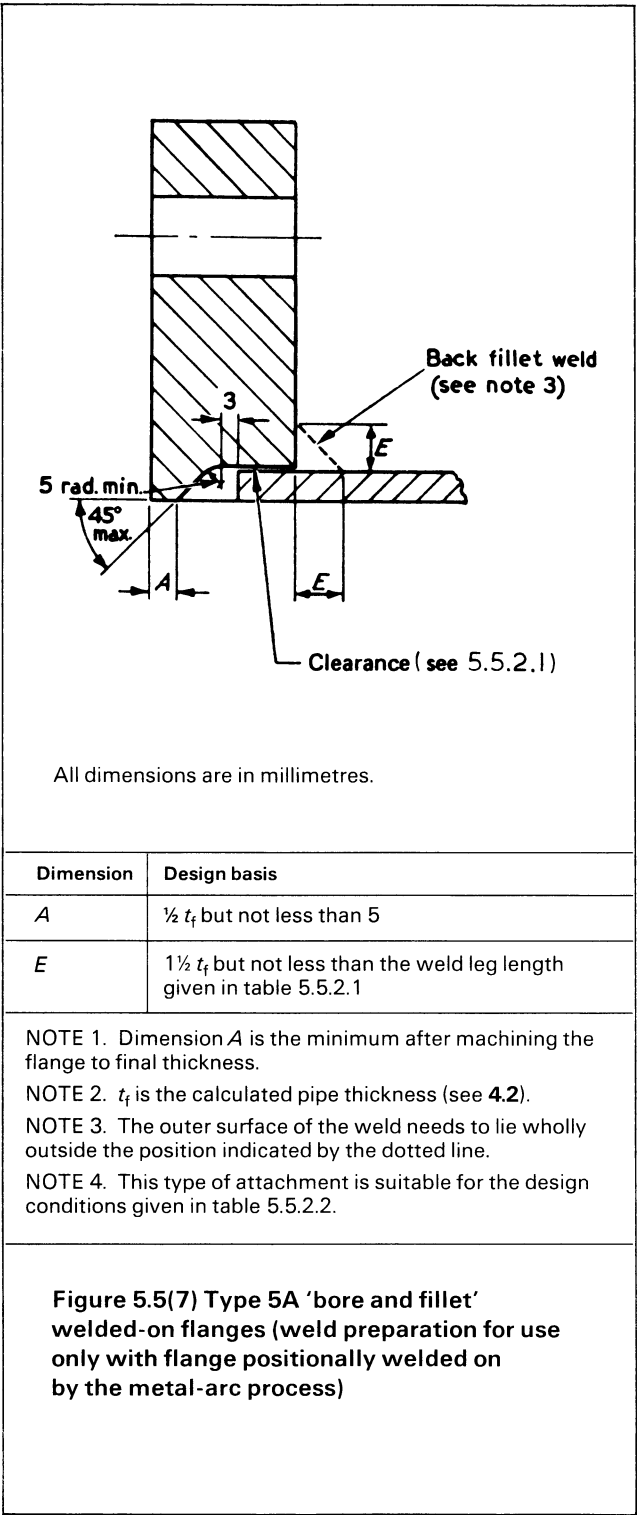
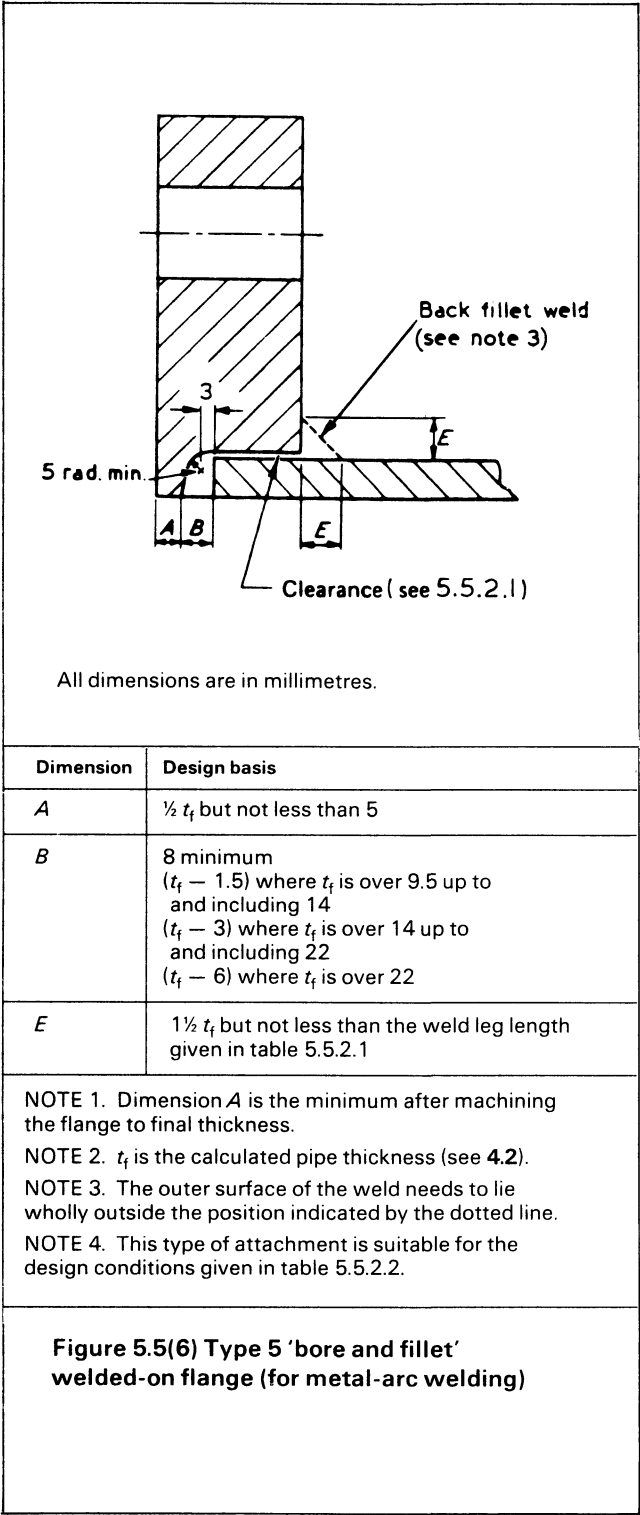




All dimensions are in millimetres.

Dimension	Design basis
B	t_f but not less than the weld leg length given in table 5.5.2.1
E	$1\frac{1}{2} t_f$ but not less than the weld leg length given in table 5.5.2.1
NOTE 1. Dimension B is the minimum after machining the flange to final thickness. NOTE 2. t_f is the calculated pipe thickness (see 4.2). NOTE 3. The outer surface of the weld needs to lie wholly outside the position indicated by the dotted line. NOTE 4. This type of attachment is suitable for the design conditions given in table 5.5.2.2.	

**Figure 5.5(5) Types 4 and 4A 'face and fillet' welded-on flanges
(for metal-arc welding)**



Section six. Inspection and testing

6.1 Tests on pipes and fittings

6.1.1 Except as specified in 6.1.3, completed wrought steel pipes and fittings shall be tested by hydraulic pressure.

Where hydraulic testing is required, compliance shall be demonstrated either by individual testing of components before erection or, alternatively (subject to the adequacy of the support system), a test of the pipe system after erection (see 6.2). In the latter case it shall be possible to examine visually all parts of the components.

The test pressure P_t (in N/mm²) shall be determined from equation (43) subject to a maximum pressure equal to $1.5p$.

$$P_t = \frac{0.83pR_e}{f} \quad (43)$$

where

p is the design pressure (in N/mm²);

R_e is the specified minimum yield stress selected from table 6.1.1 (in N/mm²);

f is the maximum permissible design stress (in N/mm²) at the design temperature (see 3.2).

The test pressure for a forged and/or cast pipe or fitting shall be that for equivalent wrought steel pipe for the same design conditions.

NOTE. Water is normally used as the pressurizing agent. Where other liquids are used, additional precautions may be necessary depending on the nature of the liquid. Attention is drawn to the need to control the chloride content of test water in the case of austenitic stainless steel pipes. To avoid the risk of freezing it is recommended that the temperature of the water, if used, during the test should be not less than 7 °C.

Table 6.1.1 Values of the specified minimum yield stress (R_e)			
Tube standard	Steel grade	Thickness	R_e
BS 3601	320	mm	N/mm ²
			195
	360	≤ 16	235
		$> 16 \leq 40$	225
		$> 40 \leq 65$	215
	430	≤ 16	275
		$> 16 \leq 40$	265
		$> 40 \leq 65$	255
BS 3602	360	≤ 16	235
		$> 16 \leq 40$	225
		$> 40 \leq 65$	215
	410		245
	430	≤ 16	275
		$> 16 \leq 40$	265
		$> 40 \leq 65$	255
	460		280
	500Nb	≤ 16	355
		$> 16 \leq 40$	345
		$> 40 \leq 65$	335
BS 3604	591		440
	620-460		180
	620-440		290
	621		275
	660		300
	622		275
	762		470
BS 3605	304S14, S14E		205
	S18, S18E, S59E		235
	316S14, S14E		215
	S18, S18E, S59E		245
	321S18, S18E, S59E(1010)		235
	S59E(1105)		195
	347S18, S18E, S59E		245
	125OE		270

6.1.2 Pipes and fittings with flanges of rating equivalent to or higher than PN 25 of BS 4504 shall be tested either fully assembled or in sections with blank flanges bolted on.

NOTE. Other pipes, if straight, may, unless otherwise arranged between the purchaser and the manufacturer, be tested between the heads of a hydraulic pipe testing machine.

Blowdown pipes and drain pipes shall be treated as steam pipes in accordance with section two.

6.1.3 Waiver of the hydraulic pressure test requirement specified in 6.1.1 shall be permitted when both (a) and (b) following are satisfied.

(a) Any of the following conditions apply:

- (1) the pipes have been ultrasonically tested in accordance with test category 1 of BS 3602 : Part 1, BS 3604 or BS 3605;
- (2) the pipes have been hydraulically tested in accordance with BS 3601, test category 2 of BS 3602 : Part 1, BS 3602 : Part 2, test category 2 of BS 3604 or BS 3605 and at a test pressure equal to or greater than that determined from equation (43);
- (3) the pipes have been eddy current tested in accordance with BS 3601, test category 2 of BS 3602 : Part 1 or test category 2 of BS 3604 and the test pressure determined from equation (43) does not exceed 140 bar.

(b) If the work of manipulation and fabrication has only involved one or more of the following:

- (1) end preparation for welding;
- (2) welding of minor attachments such as pressure and temperature tapings subject to internal pressure by agreement between the purchaser and the manufacturer (see 1.4.2.3(f));
- (3) butt welding where the butt welds have been non-destructively examined in accordance with 6.3.

- 6.1.4** Drain vessels shall be hydraulically tested to 1.5 times the design pressure.
- 6.1.5** With the exception of unworked pipe as defined in **6.1.3**, the test pressure shall be maintained at the required pressure for a sufficient length of time to permit a visual examination to be made of all surfaces and joints, and the test pressure shall be sustained for the minimum times given in table 6.1.5 prior to visual inspection.

Table 6.1.5 Minimum duration for the hydraulic test		
Outside diameter	Minimum duration of test	
	Pressure up to and including 7 N/mm ²	Pressure above 7 N/mm ²
mm Up to and including 273	min 10	min 15
Greater than 273	20	25

6.2 Hydraulic tests on pipe systems after erection

- 6.2.1** A hydraulic test to a test pressure determined from equation (43), subject to a maximum pressure of 1.5*p*, where *p* is the design pressure, shall be applied to the pipe system after erection in the following cases.
- (a) Class I butt welded or fully flanged systems where the requirements of **6.1.1** have not been complied with before erection.
 - (b) All class II butt welded systems (including systems in which some flanged joints are used).
- NOTE. If agreed between the manufacturer and the purchaser (see **1.4.2.2** (e)), it is permissible to omit the hydraulic test on the completed installation provided that the requirements of **6.1.1** have been satisfied before erection and non-destructive examination in accordance with **6.3.4** is carried out.
- 6.2.2** Where the system contains piping components of differing calculated test pressures then the lowest test pressure shall be applied.
- Where there are connected components which are not covered by this standard, the manufacturer shall ascertain that such components are suitable for the application of this test pressure or, if they are not, that the components are isolated from the system under test.
- 6.2.3** Safety valve escape piping, including that which incorporates bellows expansion joints, shall not be subjected to a hydraulic test after erection. Where bellows expansion joints are fitted, supports, anchors and guides shall be designed in accordance with BS 6129 : Part 1.

6.3 Visual and non-destructive examination

6.3.1 Visual examination

All welds shall be visually examined in accordance with

BS 1821, BS 2633, BS 2640, BS 2971 or BS 4677 as appropriate.

6.3.2 General requirements for non-destructive examination

6.3.2.1 Procedures for non-destructive examination.

Non-destructive examination shall be carried out to written procedures provided by the manufacturer and in accordance with the following British Standard methods:

magnetic particle	BS 6072
penetrant	BS6443
radiography (butt welds)	BS 2910
ultrasonic	BS 3923 : Part 1 (except where specific variance is indicated in the following sections)

Type and extent of examination shall be as specified in **6.3.3** and **6.3.4**.

Surface finish requirements of pressure containment welds to facilitate examination shall be as specified in **6.3.5**.

6.3.2.2 *Timing of non-destructive examination.* The non-destructive examination shall be carried out after any required final heat treatment except in the case of carbon, carbon manganese, grade 620 and grade 621 alloy steels where it is permissible to carry out the examination before heat treatment in the following cases:

- (a) butt welds;
- (b) branch, socket and attachment welds, subject to agreement between the manufacturer and the purchaser (see **1.4.2.3**(g)).

6.3.2.3 Non-destructive examination personnel

NOTE. The successful application of non-destructive examination depends on the knowledge and experience of the personnel responsible for producing the examination procedures and the technical competence and ability of the practitioner to carry out the procedural requirements and interpret results.

Unless otherwise agreed between the contracting parties, (see **1.4.2.3**(h)) the appropriate level and category of certification of personnel shall be in terms of those obtained from an agreed nationally accredited certification scheme, e.g. the Personnel Certification in Non-Destructive Testing (PCN) scheme.

6.3.3 Type and extent of non-destructive examination for ferritic class I and austenitic welds

Type and extent of non-destructive examination for ferritic class I and austenitic welds shall be as specified in table 6.3.3.

The acceptable limitations in faults revealed by non-destructive examination shall be as specified in BS 2633 and BS 4677.

Table 6.3.3 Type and extent of non-destructive examination for ferritic class I and austenitic welds

Material grade (2)	Butt welds and welds attaching branches (5)		Socket welds	
	Pipe thickness <25 mm and outside diameter <170 mm (7) (8)	Pipe thickness ≥25 mm or outside diameter ≥170mm	Design temperature ≤400 °C	Design temperature >400 °C
C, C Mn, 620 621, 622	10 % RAD or USE (3) (6) and 10 % MPI (6)	100 % RAD or USE (3) and 100 % MPI	10 % MPI (6)	100 % MPI
591	100 % RAD or USE (3) and 100 % MPI	100 % RAD or USE (3) and 100 % MPI	Not to be used for this material	
762	100 % RAD or USE (3) and 100 % MPI or DPI (3)	100 % RAD or USE (3) and 100 % MPI or DPI (3)	Not to be used for this material	
660(4)	100 % USE (4) and 100 % MPI	100 % USE (4) and 100 % MPI	Not to be used for this material	
Austenitic steels	10 % RAD (6) and 10 % DPI (6)	100 % RAD and 100 % DPI	10 % DPI (6)	100 % DPI

NOTE 1. Notation

RAD = Radiography
USE = Ultrasonic examination
MPI = Magnetic particle inspection
DPI = Dye penetrant inspection

NOTE 2. Where dissimilar grades of metals are joined together, the extent of non-destructive examination shall be that of the higher grade.

NOTE 3. For materials where the method of non-destructive examination is optional and the purchaser has not specified one of the options, the manufacturer may choose the method to be adopted.

NOTE 4. For material grade 660, where the geometric shape of the connecting pipes partially or fully restricts the ultrasonic examination of the joint, radiographic examination may be used in the affected areas.

The examination is considered restricted when the full weld volume, including fusion faces, heat-affected zones and root areas, cannot be fully covered by both normal and angle beams due to limited access for scanning or lack of acoustic contact on the relevant scanning surfaces.

NOTE 5. All attachment welds other than branch welds shall be examined by the surface flaw detection technique and extent specified for the grade of material and dimensions of the pipe to which the attachment is welded.

NOTE 6. Percentage non-destructive examination entails examination of a percentage of the number of joints per process per welder. The joints selected for non-destructive examination shall be subjected to the appropriate volumetric and surface examinations.

NOTE 7. Due to restricted access on branches of 50 mm bore and below, radiography may be waived.

NOTE 8. BS 3923 : Part 1 is not applicable to pipes of wall thickness less than 6 mm or outside diameter less than 100 mm. Where BS 3923 : Part 1 does not apply, then radiography may be substituted.

When random radiographic or ultrasonic examination reveals unacceptable defects in a weld, at least two further welds in the group represented by this weld shall be examined by the same method. If the examination of these further welds in the group reveals no unacceptable defects, the defects in the first weld shall be repaired and re-examined by the original method. If the repair is satisfactory, the group of welds shall be accepted. If examination of either of the further welds in the group reveals unacceptable defects, each weld in the group shall be examined by the same method over its complete circumference. Unacceptable defects shall be repaired and then re-examined by the original method.

Where examination specified in table 6.3.3 reveals faults which are not within the limitations for class I welds, the faults shall be removed and the exposed part of the junction rewelded as necessary and re-examined.

6.3.4 Type and extent of non-destructive examination for carbon steel class II welds

Type and extent of non-destructive examination for carbon steel class II welds other than for butt welds applied to steam services which are in the range 220 °C to 400 °C, shall be as specified in table 6.3.4 except where hydraulic testing in accordance with 6.2.2 has been carried out, in which case non-destructive examination is not required.

Type and extent of non-destructive examination for carbon steel class II butt welds applied to steam services in the range 220 °C to 400 °C shall be as specified in 5.3.3.1 (d).

The acceptable limitations in faults revealed by non-destructive examination shall be as specified in BS 2971.

When random radiographic or ultrasonic examination of all or part of a weld reveals unacceptable defects, one further weld in the group represented by this weld shall be tested to the same extent. If this further weld shows no unacceptable defects, the defects in the first weld shall be repaired and then re-examined by the original method. If the repair is satisfactory, the group of welds shall be accepted. If the further weld shows unacceptable defects, each weld in the group shall be tested by the same method and to the same extent. Unacceptable defects shall be repaired and then re-examined by the original method.

Where examination specified in table 6.3.4 reveals faults which are not within the limitations for class II welds, the faults shall be removed and the exposed part of the junction rewelded as necessary and re-examined.

Table 6.3.4 Type and extent of non-destructive examination for carbon steel class II welds

(Applicable where welds have not been hydraulically tested in accordance with 6.2.2.)

Butt welds and welds attaching branches		Attachment welds
Outside diameter < 170 mm (5)	Outside diameter ≥ 170 mm (4)	
10 % RAD or USE (2) (3)	100% RAD or USE (2)	10 % MPI (3)

NOTE 1. NOTATION

RAD = Radiography
USE = Ultrasonic examination
MPI = Magnetic particle inspection

NOTE 2. Choice between radiography and ultrasonics shall be at the discretion of the manufacturer.

Where neither method is feasible then the surface flaw detection technique specified for attachment welds shall be used.

NOTE 3. Percentage non-destructive examination entails the examination of a percentage of the number of joints per process per welder. The joints selected shall be subjected to the appropriate volumetric and surface examinations.

NOTE 4. For pipes where for manufacturing reasons the actual minimum thickness at the weld is greater than twice the thickness calculated by equations (4) and (5), the entire circumference of 10% of the butt welds and welds attaching branches of this thickness made by each welder, selected at random with a minimum of one weld per welder, shall be subjected to non-destructive examination by either radiographic or ultrasonic methods.

NOTE 5. All butt welds complying with BS 2971 in carbon steel steam vent pipes shall be subjected to non-destructive examination by either radiographic or ultrasonic methods over their entire circumference.

6.3.5 for the combination of non-destructive examination procedures.

Table 6.3.5 Weld external surface finish

Material grade	Non-destructive examination procedure			
	Magnetic particle	Radiography	Ultrasonic	Dye penetrant
	Finish number	Finish number	Finish number	Finish number
C, C Mn 620, 621	SP1/SP6	SP1/SP6	SP1/SP6 (see note 1)	SP1/SP6
591, 622, 762	SP1/SP6	SP1/SP6	SP4/SP7	SP1/SP6
660	See note 2	See note 2	SP4/SP7	See note 2
Austenitic steels	Not applicable	SP1/SP6	Not applicable	SP1/SP6

NOTE 1. Finish SP4 shall be applied instead of SP1 where the pipe outside diameter geometry restricts the ultrasonic examination.

NOTE 2. Welds joining chromium molybdenum vanadium pipes shall be dressed to a smooth contour, blending weld and parent metal, and the reinforcement shall be ground smooth to ensure the removal of all surface fissures and undercut (see clause 21 of BS 2633 : 1987).

External finish categories are illustrated in figure 6.3.5.1, based on appendix B of BS 3923 : Part 1 : 1986 and are as follows.

(a) *Finishes SP1 and SP6.* No dressing shall be required except where necessary to remove the source of any confusing ultrasonic signals or surface features which may interfere with the interpretation of the weld when other non-destructive examination methods are employed.

(b) *Finish SP4.* The weld, and where necessary the adjacent parent material, shall be dressed to a sufficiently high standard to allow ultrasonic probes to be scanned smoothly over the surface while maintaining satisfactory and reproducible coupling. The conditions required for this are as follows.

(1) The maximum permitted deviation of the surface from its ideal shape is 1.5 mm in any 50 mm length of surface.

On flat or straight sections, this shall be assessed by measuring the maximum gap which can develop under a 50 mm long straight edge placed against the surface.

For butt welds connecting to welding elbows or other curved surfaces, the maximum permissible deviation in surface flatness is 1.5 mm in any 50 mm length over and above the normal radius of the curved surface. If acoustic contact is not attainable with the surface finish specified, then further dressing may be carried out providing the remaining thickness is equal to or greater than the minimum pipe thickness.

(2) For wall thicknesses up to and including 100 mm the centreline average, R_a , of surface finish from which ultrasonic scanning is to be carried out shall be

6.3.5 Surface finish requirements for pressure containment welds

6.3.5.1 External finish.

NOTE. The external finish of pressure containment welds made in accordance with the appropriate welding standard may inhibit the non-destructive examination of welds.

Where non-destructive examination is required, the weld external finish and/or surfaces adjacent to the weld over which angled ultrasonic probes are scanned shall be at least in accordance with the highest finish number given in table

Appendix B. Derivation of material nominal design stresses

B.1 General

This appendix describes the principles used to derive the nominal design stresses given in table 3.2 which, unless otherwise stated, are related to the relevant property values given in:

- | BS 1503 : 1989, BS 1504 : 1976, BS 3601 : 1987,
BS 3602 : Part 1 : 1987, BS 3602 : Part 2 : 1978,
BS 3604 : 1978 and BS 3605 : 1973.

Appropriate amendments to this appendix will be issued as necessary to cover future revisions of the above standards or additions to table 3.2.

B.2 Terminology

- R_m is the minimum tensile strength (in N/mm²) specified, for the grade of steel concerned, at room temperature (tested in accordance with BS 18)
- R_e is the minimum yield or proof stress (in N/mm²) specified for the grade of steel concerned at room temperature (tested in accordance with BS 18)
- $R_{e(T)}$ is the yield stress (in N/mm²) at temperature T (in °C) of the grade of steel concerned (related to values obtained when tested in accordance with BS 3688); applicable to carbon, carbon manganese and ferritic alloy steels and austenitic stainless steels
- S_{Rt} is the mean value of stress (in N/mm²) required to produce rupture in time t (in h) at temperature T (in °C) for the grade of steel in question (testing in accordance with BS 3500)
- f_E is the nominal design stress (in N/mm²) corresponding to the short-term tensile strength characteristics
- f_F is the nominal design stress (in N/mm²) corresponding to the creep characteristics
- f is the nominal design stress (in N/mm²) which has been taken as the lower of f_E and f_F

B.3 Time-independent design stress, f_E

B.3.1 General

British Standards listed in B.1 which have been revised in or after 1978 specify minimum elevated temperature yield/proof stress values derived in most cases in accordance with the procedures specified in BS 3920 : Part 1.

These values show some differences from the properties specified in previous standards which were based on individual assessments of the data then available. The

procedure described in BS 3920 is essentially empirical and properties derived by it are regarded as characteristic values (to be used for quality control purposes as specified in the relevant materials standards) rather than as critical properties in the design context. Nevertheless it is reasonable and convenient to base permissible design stresses directly on these characteristic yield/proof stress values unless this would result in design stresses for which there is no justification in terms of previous experience and current understanding of structural behaviour. This has been done except in a few cases where design stresses based on the simple relationships detailed in B.3.2 would have resulted in an unwarranted reduction in the strength levels which have previously been established for the materials in question.

The time-independent design stress criteria may be applied to materials not included in the standards listed in B.1 provided they comply with 3.1.2. Values of $R_{e(T)}$ for such materials shall be verified by tests in accordance with BS 3688 : Part 1 at the appropriate temperature, unless the values were derived in accordance with BS 3920.

B.3.2 Carbon, carbon manganese and ferritic alloy steels

B.3.2.1 Material with specified elevated temperature values.

The time-independent design stress is determined as follows.

- (a) Up to and including 50 °C:

$$f_E = \frac{R_e}{1.5} \text{ or } \frac{R_m}{2.35} \quad (50)$$

whichever is the lower.

- (b) 150 °C and above:

$$f_E = \frac{R_{e(T)}}{1.5} \text{ or } \frac{R_m}{2.35} \quad (51)$$

whichever is the lower.

- (c) Between 50 °C and 150 °C: f_E has been based on linear interpolation between values obtained from equations (50) and (51).

B.3.2.2 Material without specified elevated temperature values (see note). The time-independent design stress is determined as follows.

- (a) Up to and including 50 °C:

$$f_E = \frac{R_e}{1.5} \text{ or } \frac{R_m}{2.35} \quad (52)$$

whichever is the lower.

- (b) 150 °C and above:

$$f_E = \frac{R_{e(T)}}{1.6} \text{ or } \frac{R_m}{2.35} \quad (53)$$

whichever is the lower.

- (c) Between 50 °C and 150 °C: f_E has been based on linear interpolation between values obtained from equations (52) and (53).

NOTE. Values for $R_{e(T)}$ have been taken as equal to those specified for otherwise similar materials having specified elevated temperature values, except where:

- (1) no $R_{e(T)}$ values are available; or
- (2) design stresses in table 3.2 for similar materials having specified elevated temperature values are not directly based on specified $R_{e(T)}$ values; or

(3) the resultant values of f_E would be less than were permitted for such material in appendix G of BS 1515 : Part 1 : 1965 (now withdrawn);

when values of f_E that were given in appendix G of BS 1515 : Part 1 : 1965 (now withdrawn) have been adopted.

Where no relevant $R_{e(T)}$ values are available or were given in appendix G of BS 1515 : Part 1 : 1965 (now withdrawn), for example as in the case of BS 1504, design stress values have been based upon consideration of:

- (i) the trend of relevant properties of equivalent materials in other product forms related to the $R_e/1.5$ at 50 °C and $R_m/4$ at 300 °C for the material in question;
- (ii) the design stresses permitted for equivalent materials in other national standards.

B.3.2.3 Austenitic stainless steels. The time-independent design stress is determined as follows.

(a) Material with specified elevated temperature values.

(1) Up to and including 50 °C:

$$f_E = \frac{R_e}{1.5} \text{ or } \frac{R_m}{2.5} \quad (54)$$

whichever is the lower.

(2) 150 °C and above:

$$f_E = \frac{R_{e(T)}}{1.35} \text{ or } \frac{R_m}{2.5} \quad (55)$$

whichever is the lower.

(3) Between 50 °C and 150 °C: f_E has been based on linear interpolation between values obtained from equations (54) and (55).

(b) Material without specified elevated temperature values (see note).

(1) Up to and including 50 °C:

$$f_E = \frac{R_e}{1.5} \text{ or } \frac{R_m}{2.5} \quad (56)$$

whichever is the lower.

(2) 150 °C and above:

$$f_E = \frac{R_{e(T)}}{1.45} \text{ or } \frac{R_m}{2.5} \quad (57)$$

whichever is the lower.

(c) Between 50 °C and 150 °C: f_E has been based on linear interpolation between values obtained from equations (56) and (57).

NOTE. Values for $R_{e(T)}$ have been taken as equal to those specified for otherwise similar materials having specified elevated temperature values, except where values of $R_{e(T)}$ are not available when f_E has been based on values that were permitted in appendix G of BS 1515 : Part 2 : 1968 (now withdrawn), or on conservative interpretation of other available information.

B.4 Time-dependent design stress, f_F

The time-dependent design stress is determined as follows.

$$f_F = \frac{S_{Rt}}{1.3} \quad (\text{see notes 1 and 2}) \quad (58)$$

NOTE 1. The appropriate S_{Rt} properties agreed by Subcommittee 10 of Technical Committee 17 of the International Organization for Standardization (ISO) have been used wherever possible. These do not necessarily correspond to those specified in the British Standards listed in B.1. In general time-dependent values are not given for materials that are unsuitable or are unlikely to be used in the creep range.

NOTE 2. In most cases the S_{Rt} properties agreed by ISO for lifetimes in excess of 100 000 h have been obtained by extended extrapolation of time (more than three times on actual data) and those towards the upper end of the temperature range by extended stress extrapolation. Tabulated design stresses that are significantly lower than values well established by experience are identified in table 3.2 which permits values up to 10 % higher to be used provided fitness-for-continued-service reviews are instituted at two-thirds of the agreed design lifetime.

Table E.3(2) 1 % proof stress values for steel forgings complying with BS 1503

Steel grade	Values of 1 % proof stress (N/mm ²) at temperatures (°C) not exceeding													
	20	100	150	200	250	300	350	400	450	500	550	600	650	700
304 S11	215	168	150	137	128	122	116	110	108					
304 S31	230	178	160	147	139	132	125	120	117					
304 S51	230	178	160	147	139	132	125	120	117	115	112	109	104	99
347 S31	240	204	192	182	172	166	162	159	157					
347 S51	240	204	192	182	172	166	162	159	157	155	153	151		
321 S51-490	190	149	139	131	125	118	114	110	107	105	104	102	100	97
321 S31	235	192	180	172	164	158	152	148	144					
321 S51-510	235	192	180	172	164	158	152	148	144	140	138	135	130	124
316 S11	225	177	161	149	139	133	127	123	119					
316 S13	225	177	161	149	139	133	127	123	119					
316 S31	240	189	172	159	150	143	137	133	129					
316 S33	240	189	172	159	150	143	137	133	129					
316 S51	240	189	172	159	150	143	137	133	129	125	121	119	116	113

Table E.3(3) Average rupture stress values for steel forgings complying with BS 1503

Figures in parentheses refer to the notes following this table.

[illegible]

Appendix F. Worked example of stress calculation in a sectionalized pipe system

F.1 General

The calculation of bending moments and the identification of maxima where various modes of operation can apply becomes a lengthy exercise if undertaken manually, and it is expected that where such systems are required to be analysed recourse will have to be made to a computer analysis using a program developed to comply with this standard.

This appendix does, nevertheless, show how moment data are to be abstracted.

A specimen configuration is considered and moment data are tabulated to facilitate the various combinations required to carry out the calculations required by this standard. One particular point of high stress is investigated in depth, values are calculated for hot stress and stress range under all modes of operation as required by the standard and the limiting values specified by this standard for stress range and hot stress are also identified and calculated.

For the example considered in this appendix, and in particular for the point considered in depth, it will be seen that in practice many of the steps need not be taken if the calculation is to be carried out manually, e.g. it is seen that in every case the combined transverse stress is greater than the combined longitudinal stress, and obviously the latter need not be calculated beyond the first case here.

F.2 Identification of planes

The particular point considered in depth occurs on a bend where the in-plane and out-of-plane directions are easily identified. In-plane and out-of-plane directions are also easily identified at branch junctions, but there is no apparent planar logic to apply to a straight pipe.

However, as the calculation of stress levels at points that are subject to varying modes of operation requires the inclusion of moment levels not occurring simultaneously, it is necessary to have a recognized terminology for planar direction of straight sections.

While no direction is given in this standard on this identification of planes in straight pipes, the following separation of planes is intended.

If a plane is considered as lying between a straight pipe and the vertical axis then this plane is in 'in-plane' of that pipe.

Where a vertical straight pipe is being considered, then the planar direction is that of the upper end bend or junction. Where no such bend or junction exists, then the lower end bend or branch is taken to identify the vertical straight pipe plane.

F.3 Specimen configuration and design data

The specimen configuration is shown in figure F.3.

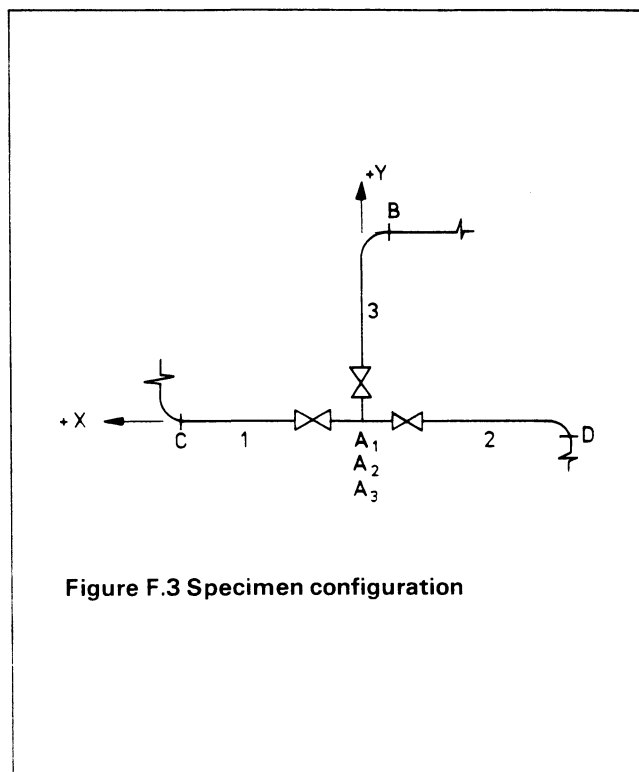


Figure F.3 Specimen configuration

Design conditions

Design life 100 000 h

Pipe	Pressure bar	Temperature °C
1 and 2	13	340
2	13	450
3	13	450
Tee A1, A2 and A3	13	450

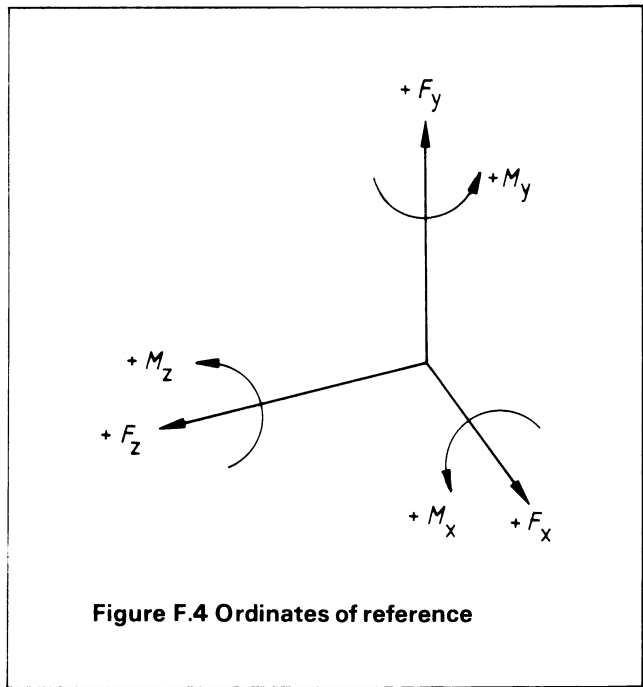
Material: BS 3602 : Part 2 : 1978. Steel 410 HFS

Pipe dimensions

Pipe	Outside diameter mm	Pipe wall thickness mm	Tee wall mm
1 and 2	168.3	8	9.5
3	114.3	6.3	7.1

F.4 Ordinates of reference

The ordinates of reference are shown in figure F.4.



F.5 Modes of operation

The modes of operation are as follows.

- (a) Pipe 1: cold (20 °C); pipes 2 and 3 at 450 °C and 13 bar.
- (b) Pipe 2: cold (20 °C); pipes 1 and 3 at 250 °C and 13 bar.
- (c) Pipe 2: cold (20 °C); pipe 1 at 340 °C and 13 bar; pipe 3 at 450 °C and 13 bar.
- (d) All pipes cold 20 °C.
- (e) All pipes hot at 13 bar; pipe 1 at 340 °C; pipes 2 and 3 at 450 °C.

F.6 Determination of moments

Moments tables F.6(1) to F.6(4) show the values and combinations.

All moments are expressed in N·mm × 10⁶.

Table F.6(1) gives moments as calculated on the basis of complete thermal expansion of the all-hot mode (e) (see F.5). No credit is given for cold pull.

Table F.6(1) Stress range: cold-to-hot (see 4.11.3.1(a) (1))				
Mode	Position	Moments (N·mm × 10 ⁶)		
		M _x	M _y	M _z
Range (d) to (e)	A1	1.6	0.5	2.0
	A2	1.2	1.0	0.8
	A3	0.4	0.5	1.2
	B	1.3	0.3	1.0
	C	0.8	0.4	0.8
	D	1.6	0.2	0.3

In this case there is only one all-hot condition. Where there is more than one all-hot condition, or when there is no all-hot condition, then each cold-to-hot mode would need to be considered separately to establish the most onerous condition at any point (see note).

The moments given in table F.6(1) are used to calculate the maximum stress range as defined in 4.11.3.1(a) (1) to comply with the limitations of 4.11.2(a) (1) or (2).

NOTE. Where there is no cold-to-hot or where there is more than one cold-to-hot, the maximum moment in each plane for all modes (in the case of no cold-to-hot) and all-hot modes (in the case of more than one all-hot) should be first considered and, if the permissible limit is not exceeded, then the limits will not be exceeded under any individual mode. This will ensure that the necessity to identify the worst case will apply only where the permissible limit is exceeded.

Table F.6(2) gives moments calculated on the basis of complete thermal expansion for combined modes (a), (b), (c) and (e). No credit is given for the cold pull.

Amendment No. 2
published and effective from 31 July 1991
to BS 806 : 1990

**Specification for design and construction
of ferrous piping installations for and
in connection with land boilers**

Second updating of BS 806 : 1990 : list of new and revised pages to be inserted

The issue number on each page indicates the relationship of the page to the original standard (see foreword to the standard). Issue 1 indicates a new page to be inserted in its correct sequence. Issue 2 indicates a revised page to replace the original or added page of the same number. Issue 3 indicates a revised page to replace the previously revised page of the same number. Vertical side-lining on replacement pages indicates that a change (or changes) has been made at that point. Where only one of two back-up pages has been revised, the appropriate text has been reprinted on the reverse so that the original sheet may be removed from the standard.

Preliminary pages

(i) and (ii)	Replace existing pages
(iii) and (iv)	Replace existing pages
(v)	Replace existing page (back of page blank)

Page

1/2	Replace existing page (page 1/1 unchanged on front)
2/3	Replace existing page (back of page blank)
3/1	Replace existing page (page 3/2 unchanged on back)
3/4	Replace existing page (page 3/3 unchanged on front)
3/5	Replace existing page (page 3/6 unchanged on back)
3/11 and 3/12	Replace existing pages
3/13	Replace existing page (back of page blank)
4/1	Replace existing page (page 4/2 unchanged on back)
4/8	Replace existing page (page 4/7 unchanged on front)
4/9	Replace existing page (page 4/10 unchanged on back)
5/1 and 5/2	Replace existing pages
5/2a*	Insert new page (back of page blank)
6/1	Replace existing page (page 6/2 unchanged on back)
6/3 and 6/4	Replace existing pages
B/1 and B/2	Replace existing pages
E/1 and E/2	Replace existing pages
E/3	Replace existing page (page E/4 unchanged on back)
E/6	Replace existing page (page E/5 unchanged on front)
E/7	Replace existing page (back of page blank)
F/2	Replace existing page (page F/1 unchanged on front)
G/1 and G/2	Insert new pages
Publications referred to	Replace existing page (back of page blank)

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*Page 5/2a contains unamended text from page 5/2.

BS 806 : 1990 Specification for design and construction of ferrous piping installations for and in connection with land boilers

Enquiry Cases–Introduction

In accordance with the provisions of 1.2, the publication of Enquiry Cases will be notified in *BS/News* and will be made available for inclusion in the ring-binder in a separate section following the text of the specification and the appendices. The table below is for recording cases as they are published and included in the binder, and for noting their subsequent routing.

In general, cases will be extant, as adjuncts to the standard and open to public comment, until the text of the standard is amended to incorporate the substance of particular cases. This will be done in the course of the normal updating procedure and each case so dealt with will be recorded on the final page of the relevant amendment.

When a new edition of the standard is published, embracing all previously issued amendments, the relevant enquiry cases will be removed from the list and only those remaining extant, as described above, will be referred to. Consequently, the numerical sequence of enquiry case numbers in the first column will not be continuous because of these omissions.

Enquiry Case No.	Date of publication	Subject of the Enquiry Case	Subsequent Enquiry Case routing (e.g. incorporated into BS 806)	Date of subsequent action
806/1	July 1986	Use of materials complying with API 5L, ASTM A 106, A 182, A 312 and A 335 (supersedes Enquiry Case No. BS 806/A: September 1982 to BS 806 : 1975 and extended to include austenitic steels)		Revised June 1987 January 1991
806/2	November 1986	Occasional loads		Revised January 1989 July 1991
806/3	August 1987	Designing pipework in nuclear power stations to withstand safe shutdown earthquake (SSE)		Revised July 1991
806/4	October 1989	EFW Alloy pipe for wet steam applications		
806/5	March 1990	Single non-repeated anchor/restraint movements		Revised January 1991
806/6	January 1991	Use of butt welding pipe fittings		
806/7	July 1991	Testing of pipe bends		

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4.1.1.1(4)	Maximum out-of-plane longitudinal stress factor (bends)	4/24	C.2	Example 2 of branch pipe design	C/4
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Foreword

This British Standard, first published in 1938 and subsequently revised in 1942, 1954, 1967, 1975 and 1986, has been prepared under the direction of the Pressure Vessel Standards Policy Committee. It supersedes the 1986 edition which is withdrawn.

This British Standard forms one of a series for boiler installations, the others in the series being:

BS 1113 Specification for design and manufacture of water-tube steam generating plant (including superheaters, reheaters and steel tube economizers)

BS 2790 Specification for design and manufacture of shell boilers of welded construction

For information on the materials and the standard sizes of steel pipes applicable to this standard, reference should be made to the following standards.

BS 1387 Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads

BS 3600 Specification for dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes

BS 3601 Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes

BS 3602 Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties

Part 1 Specification for seamless and electric resistance welded including induction welded tubes

Part 2 Submerged arc welded tubes

BS 3604 Steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties

Part 1 Specification for seamless and electric resistance welded tubes

BS 3605 Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes

Integral piping for water-tube boilers as determined in the scope and definition clauses of BS 1113 is excluded from this standard and is dealt with in BS 1113.

This 1990 edition incorporates all technical changes up to and including Amendment No. 4 (31 July 1989) associated with the 1986 edition. Changes of significance in these amendments have included the development of the following:

- (a) requirements for the use of cast iron pipes and fittings;
- (b) requirements for the application of screwed joints;
- (c) requirements for the non-destructive examination of welds.

In this standard pressures are expressed as 'gauge' unless otherwise stated.

Fluid pressure is expressed in bar except in the case of calculations where N/mm^2 is used. $1 \text{ bar} = 0.1 \text{ N/mm}^2 = 100 \text{ kPa}$.

A format has been adopted that will facilitate annual amendment. It is intended to keep this standard up to date by the issue of replacement or additional pages when necessary. Each replacement or added page will carry an issue number (with date) indicating its relationship to the original issue of this standard, the pages of which are marked 'Issue 1'. For example:

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

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

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

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

This British Standard sets forth engineering requirements deemed necessary for the design and construction of ferrous pipework for and in conjunction with land boilers.

Because of the wide range of pipes and piping installations that may be designed and manufactured in accordance with this standard, general guidance has been given on some aspects with specific requirements being for agreement between the parties concerned according to the particular design and manufacturing details. The purpose of this standard, however, is unchanged from previous editions.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

The purchaser is recommended as an aid to demonstrating the pipework supplier's capability of achieving the required quality level, to specify in his contract, that the manufacturer operates a quality system in compliance with the appropriate Parts of BS 5750.

This standard is included in the list of 'Standards significant to Health and Safety at Work' published by the UK Health and Safety Executive (HSE)* and is also referred to by HSE in giving guidance.

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

* Health and Safety Executive, Baynards House, 1 Chepstow Place, London, W2 4TF.

