ASME BPVC.I-2023

SECTION I

2023 ASME Boiler and Pressure Vessel Code

An International Code

Rules for Construction of Power Boilers



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AN INTERNATIONAL CODE

2023 ASME Boiler & Pressure Vessel Code

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I RULES FOR CONSTRUCTION OF POWER BOILERS

ASME Boiler and Pressure Vessel Committee
on Power Boilers

The American Society of Mechanical Engineers
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TABLE OF CONTENTS

List of Sections xxiv
Foreword xxv
Statement of Policy on the Use of the ASME Single Certification Mark and Code Authorization in Advertising xxvii
Statement of Policy on the Use of ASME Marking to Identify Manufactured Items xxvii
Personnel xxviii
Correspondence With the Committee l
Preamble lii
Summary of Changes liv
Cross-Referencing in the ASME BPVC lviii

Part PG **General Requirements for All Methods of Construction** 1
General 1
PG-1 Scope 1
PG-2 Service Limitations 1
PG-3 Referenced Standards 1
PG-4 Units of Measure 1
Materials 2
PG-5 General 2
PG-6 Plate 3
PG-7 Forgings 3
PG-8 Castings 3
PG-9 Pipes, Tubes, and Pressure-Containing Parts 4
PG-10 Material Identified With or Produced to a Specification Not Permitted by This Section, and Material Not Fully Identified 6
PG-11 Prefabricated or Preformed Pressure Parts Furnished Without a Certification Mark 8
PG-12 Water Level Indicators and Connector Material 10
PG-13 Stays 11
PG-14 Rivets 11
Design 11
PG-16 General 11
PG-17 Fabrication by a Combination of Methods 12
PG-18 Design Validation by Proof Test 12
PG-19 Cold Forming of Austenitic Materials 12
PG-20 Cold Forming of Carbon, Carbon-Molybdenum, and Creep Strength Enhanced Ferritic Steels 14
PG-21 Maximum Allowable Working Pressure 15
PG-22 Loadings 16
PG-23 Stress Values for Calculation Formulas 16

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PG-25	Quality Factors for Steel Castings	16
PG-26	Weld Joint Strength Reduction Factor	18
PG-27	Cylindrical Components Under Internal Pressure	18
PG-28	Components Under External Pressure	23
PG-29	Dished Heads	25
PG-30	Stayed Dished Heads	27
PG-31	Unstayed Flat Heads and Covers	27
	Openings and Compensation	31
PG-32	Openings in Shells, Headers, and Dished Heads	31
PG-33	Compensation Required for Openings in Shells and Dished Heads	32
PG-34	Flanged-In Openings in Formed Heads	35
PG-35	Compensation Required for Openings in Flat Unstayed Heads and Flat Stayed Plates	36
PG-36	Limits of Metal Available for Compensation	36
PG-37	Strength of Compensation	36
PG-38	Compensation for Multiple Openings	37
PG-39	Methods of Attachment of Pipe and Nozzle Necks to Vessel Walls	38
PG-42	General Requirements for Flanges, Pipe Fittings, and Valves	39
PG-43	Nozzle Neck Thickness	42
PG-44	Inspection Openings	42
PG-46	Stayed Surfaces	43
PG-47	Staybolts	44
PG-48	Location of Staybolts	44
PG-49	Dimensions of Staybolts	44
PG-50	Drilled Holes Not Penetrating Through a Vessel Wall	44
PG-52	Ligaments	44
PG-53	Ligaments Not Forming a Definite Pattern	47
PG-55	Supports and Attachment Lugs	49
PG-56	Loading on Structural Attachments	49
	Boiler External Piping and Boiler Proper Connections	50
PG-58	Boiler External Piping (BEP)	50
PG-59	Application Requirements for the Boiler Proper	59
	Design and Application	61
PG-60	Design and Application Requirements for Miscellaneous Pipe, Valves, and Fittings	61
PG-61	Feedwater Supply	64
	Overpressure Protection Requirements	64
PG-67	Boiler	64
PG-68	Superheater and Reheater	68
PG-69	Certification of Capacity of Pressure Relief Valves	69
PG-70	Capacity of Pressure Relief Valves	69
PG-71	Mounting of Pressure Relief Valves	69
PG-72	Operation of Pressure Relief Valves	71
PG-73	Minimum Requirements for Pressure Relief Valves	72
	Fabrication	76
PG-75	General	76

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PG-76	Cutting Plates and Other Stock	77
PG-77	Material Identification	77
PG-78	Repairs of Defects in Materials	77
PG-79	Tube Holes and Ends	77
PG-80	Permissible Out-of-Roundness of Cylindrical Shells	78
PG-81	Tolerance for Formed Heads	79
PG-82	Holes for Stays	79
	Inspection and Tests	79
PG-90	General	79
PG-91	Qualification of Inspectors	80
PG-93	Examination and Repair of Flat Plate in Corner Joints	80
PG-99	Hydrostatic Test	80
	Certification by Stamping and Data Reports	81
PG-101	Heating Surface Computation	81
PG-104	General	81
PG-105	Certification Marks	81
PG-106	Stamping of Boilers	83
PG-107	Field Assembly	85
PG-108	Stamping for Field-Assembled Boilers	86
PG-109	Stamping of Pressure Piping	86
PG-110	Stamping of Boiler Pressure Relief Valves	87
PG-111	Location of Stampings	87
PG-112	Manufacturer's Data Report Forms	88
PG-113	Master Data Report Form	90
Part PW	**Requirements for Boilers Fabricated by Welding**	91
	General	91
PW-1	General	91
	Materials	91
PW-5	General	91
	Design	92
PW-8	General	92
PW-9	Design of Welded Joints	92
PW-10	Heat Treatment	94
PW-11	Volumetric Examination of Welded Butt Joints	94
PW-13	Head-to-Flange Requirements	95
PW-14	Openings in or Adjacent to Welds	95
PW-15	Welded Connections	95
PW-16	Minimum Requirements for Attachment Welds	96
PW-17	Forged Flat Heads With Integral Hubbed Flange	103
PW-19	Welded-In Stays	103
	Fabrication	107
PW-26	General	107
PW-27	Welding Processes	107
PW-28	Welding Qualification and Weld Records	108
PW-29	Base Metal Preparation	109

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PW-31	Assembly	110
PW-33	Alignment Tolerance, Shells and Vessels (Including Pipe or Tube Used As a Shell)	110
PW-34	Alignment, Tube and Pipe	110
PW-35	Finished Longitudinal and Circumferential Joints	110
PW-36	Miscellaneous Welding Requirements	111
PW-38	Preheating and Interpass Temperatures	111
PW-39	Requirements for Postweld Heat Treatment	113
PW-40	Repair of Defects	126
PW-41	Circumferential Joints in Pipes, Tubes, and Headers	127
PW-42	Joints in Valves and Other Boiler Appurtenances	128
PW-44	Fabrication Rules for Bimetallic Tubes When the Clad Strength Is Included	128
	Inspection and Tests	131
PW-46	General	131
PW-47	Check of Welding Procedure	131
PW-48	Check of Welder and Welding Operator Performance Qualifications	131
PW-49	Check of Heat Treatment Practice	131
PW-50	Qualification of Nondestructive Examination Personnel	131
PW-51	Radiographic Examination	131
PW-52	Ultrasonic Examination	132
PW-53	Test Plates	132
PW-54	Hydrostatic Test	138
Part PR	**Requirements for Boilers Fabricated by Riveting**	139
	General	139
PR-1	Scope	139
PR-2	Responsibility	139
	Materials	139
PR-3	General	139
	Design	139
PR-4	General	139
PR-5	Strength of Plates	139
PR-6	Strength of Rivets	139
PR-7	Crushing/Compressive Strength of Plates	139
PR-8	Joint Efficiency and the Thickness of Shells and Drums	140
PR-9	Thickness of Buttstraps	140
PR-10	Longitudinal Joints	140
PR-11	Circumferential Joints	140
PR-12	Transverse Pitch (Back Pitch) of Rows of Rivets	140
PR-13	Preparation of Plate Edges for Calking	141
PR-14	Edge Distance	141
PR-15	Riveted Connections	141
PR-16	Reinforcement of Openings	142
PR-17	Reinforcing Shells of Watertube Boilers	142
	Fabrication	143
PR-18	General	143

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PR-19	Welded Connections in Riveted Boilers	143
PR-20	Buttstraps	143
PR-21	Rivet Holes	143
PR-22	Assembly of Joints	144
PR-23	Riveting	144
PR-24	Joint Tightness	144
	Inspection, Tests, and Data Reports	144
PR-25	General	144
PR-26	Hammer Test	144
PR-27	Hydrostatic Test	144
PR-28	Data Reports	144
Part PB	**Requirements for Boilers Fabricated by Brazing**	146
	General	146
PB-1	General	146
	Materials	147
PB-5	General	147
PB-6	Brazing Filler Metals	147
PB-7	Fluxes and Atmospheres	147
	Design	147
PB-8	General	147
PB-9	Strength of Brazed Joints	147
PB-10	Brazed Joint Efficiency	147
PB-14	Application of Brazing Filler Metal	147
PB-15	Permissible Types of Joints	148
PB-16	Joint Clearance	148
PB-17	Joint Brazing Procedure	148
PB-18	Openings	148
PB-19	Brazed Connections	149
	Fabrication	149
PB-26	General	149
PB-28	Qualification of Brazing Procedure	149
PB-29	Qualification of Brazers and Brazing Operators	149
PB-30	Cleaning of Surfaces to Be Brazed	150
PB-31	Clearance Between Surfaces to Be Brazed	150
PB-32	Postbrazing Operations	150
PB-33	Repair of Defective Brazing	150
	Inspection and Tests	150
PB-46	General	150
PB-47	Check of Brazing Procedure	150
PB-48	Brazer and Brazing Operator	150
PB-49	Visual Examination	150
PB-50	Exemptions	151
	Marking and Reports	151
PB-51	General	151
Part PL	**Requirements for Locomotive Boilers**	152

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

	Introduction	152
PL-1	General	152
PL-2	Scope	152
PL-3	Testing and Stamping	152
	Materials	152
PL-5	General	152
PL-6	In the Course of Preparation	155
PL-7	Allowable Stress Values for Materials	155
	Design	155
PL-17	General	155
PL-18	Cylindrical Boiler Shell	155
PL-20	Reinforcing and Doubling Plates on Unstayed Portions of the Boiler	155
PL-21	Requirements for Domes of Locomotive Boilers	156
PL-24	Flues	160
PL-27	Stayed Surfaces	160
PL-28	Mudring (Firebox Foundation Ring)	165
PL-30	Staybolts	166
PL-33	Crown Bars	168
PL-36	Braces	168
PL-39	Arch Tubes, Circulators, and Thermic Syphons	173
PL-42	Gage Glasses and Water Columns	176
PL-43	Boiler Blowoff Systems	177
PL-45	Feedwater Supply	177
PL-48	Dry Pipe	177
PL-49	Internal or Dome Throttle Valves	177
PL-54	Pressure Relief Valves	177
Part PA	**Alternative Rules for Boiler Construction**	180
PA-1	General	180
PA-2	Code Boundaries and Interfaces	180
PA-3	Design Specification and Design Report	180
PA-4	Construction	180
PA-4.1		180
PA-4.2		180
PA-5	Materials	180
PA-6	Hydrostatic Test	180
PA-7	Data Reports and Stamping	180
PA-7.1		180
PA-7.2		180
Part PWT	**Requirements for Watertube Boilers**	181
	General	181
PWT-1	General	181
	Materials	181
PWT-5	General	181
	Design	181
PWT-8	General	181

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PWT-9	Tubes and Pipe	181
PWT-11	Tube Connections	181
PWT-12	Staybolting Box-Type Headers and Waterlegs	183
PWT-13	Staying Segment of Heads	183
PWT-14	Firing Doors	183
PWT-15	Access and Firing Doors	183
Part PFT	**Requirements for Firetube Boilers**	184
	General	184
PFT-1	General	184
	Materials	184
PFT-5	General	184
	Design	184
PFT-8	General	184
PFT-9	Thickness Requirements	184
PFT-10	Shell Joints	184
PFT-11	Attachment of Heads and Tubesheets	184
PFT-12	Tubes	185
	Combustion Chambers	186
PFT-13	Combustion Chamber Tubesheet	186
PFT-14	General	187
PFT-15	Plain Circular Furnaces	187
PFT-17	Ring-Reinforced Type	187
PFT-18	Corrugated Furnaces	188
PFT-19	Combined Plain Circular and Corrugated Type	189
PFT-20	Attachment of Furnaces	189
PFT-21	Fireboxes and Waterlegs	190
	Stayed Surfaces	191
PFT-22	General	191
PFT-23	Working Pressure for Stayed Curved Surfaces	191
PFT-24	Staying Horizontal Return Tube Boilers	192
PFT-25	Staying Segments of Heads	192
PFT-26	Area Supported by Stay	192
PFT-27	Maximum Spacing	193
PFT-28	Staybolts and Stays	194
PFT-29	Flexible and Fillet-Welded Staybolts	194
PFT-30	Crown Bars and Girder Stays	194
PFT-31	Stay Tubes	197
PFT-32	Stresses in Diagonal Stays	197
	Doors and Openings	198
PFT-40	Welded Door Openings	198
PFT-41	Openings in Wrapper Sheets	198
PFT-42	Fireside Access Openings	198
PFT-43	Requirements for Inspection Openings	198
PFT-44	Opening Between Boiler and Pressure Relief Valve	198
	Domes	198

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PFT-45	Requirements for Domes	198
	Setting	199
PFT-46	Method of Support	199
	Piping, Fittings, and Appliances	199
PFT-47	Water Level Indicators	199
PFT-48	Feed Piping	200
PFT-49	Blowoff Piping	201
Part PFH	**Optional Requirements for Feedwater Heater (When Located Within Scope of Section I Rules)**	202
Part PMB	**Requirements for Miniature Boilers**	203
	General	203
PMB-1	General	203
PMB-2	Scope	203
	Materials	203
PMB-5	General	203
	Design	203
PMB-8	General	203
PMB-9	Welding	204
PMB-10	Washout Openings	204
PMB-11	Feedwater Supply	204
PMB-12	Blowoff	204
PMB-13	Gage Glasses	204
PMB-14	Fixtures and Fittings	204
PMB-15	Pressure Relief Valves	204
PMB-16	Steam Stop Valves	204
PMB-17	Automatic Devices	204
PMB-21	Hydrostatic Tests and Inspection	204
Part PEB	**Requirements for Electric Boilers**	206
	General	206
PEB-1	General	206
PEB-2	Scope	206
PEB-3	Optional Requirements for the Boiler Pressure Vessel	206
	Materials	206
PEB-5	General	206
	Design	207
PEB-8	General	207
PEB-9	Welding	207
PEB-10	Inspection Openings	207
PEB-11	Feedwater Supply	207
PEB-12	Bottom Blowoff	207
PEB-13	Water Level Indicators	207
PEB-14	Pressure Gages	208
PEB-15	Pressure Relief Valves	208
PEB-16	Automatic Devices	208
PEB-17	Hydrostatic Test	208

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PEB-18	Inspection and Stamping of Boilers	208
PEB-19	Manufacturer's Data Report for Electric Boilers	209
Part PVG	**Requirements for Organic Fluid Vaporizers**	210
	General	210
PVG-1	General	210
	Materials	210
PVG-5	General	210
	Design	210
PVG-8	General	210
PVG-9	General Requirements	210
PVG-10	Gage Glasses	210
PVG-11	Drain Valves	210
PVG-12	Pressure Relief Valves	210
Part PFE	**Requirements for Feedwater Economizers**	212
PFE-1	General	212
PFE-2	Design	212
PFE-2.1		212
PFE-2.2		212
PFE-3	Pressure Relief	212
PFE-3.1		212
PFE-3.2		212
PFE-3.3		212
PFE-4	Materials	212
Part PTFH	**Requirements for Liquid Phase Thermal Fluid Heaters**	213
	General	213
PTFH-1	General	213
PTFH-2	Scope	213
PTFH-3	Thermal Fluids	213
	Materials	213
PTFH-5	General	213
	Design	213
PTFH-8	General Requirements	213
PTFH-9	Appurtenances and External Piping	213
PTFH-10	Provisions for Thermal Expansion of the Heat Transfer Medium	214
PTFH-11	Instrumentation	214
PTFH-12	Overpressure Protection	215
PTFH-13	Temperature-Limiting Controls	216
Part PHRSG	**Requirements for Heat Recovery Steam Generators**	217
PHRSG-1	General	217
PHRSG-2	Scope	217
PHRSG-3	Requirements for Superheater and Reheater Condensate Removal Connections	217
PHRSG-3.1		217
PHRSG-3.2		217
PHRSG-3.3		217

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PHRSG-3.4 217
PHRSG-3.5 218
PHRSG-4 Desuperheater Drain Pots 218
PHRSG-5 Certification 218
Mandatory Appendix III **Criteria for Reapplication of a Certification Mark** 220
Mandatory Appendix IV **Local Thin Areas in Cylindrical Shells and in Spherical Segments of Heads** 221
IV-1 Scope 221
IV-2 Cylindrical Shells 221
IV-3 Spherical Segments of Heads 222
Mandatory Appendix V **Additional Rules for Boilers Fabricated by Riveting** 225
V-1 Scope 225
V-2 Fireboxes, Combustion Chambers, and Furnaces 225
V-2.1 General 225
V-2.2 Plain Circular Furnaces 225
V-2.3 Ring-Reinforced Type 225
V-2.4 Corrugated Furnaces 225
V-2.5 Combined Plain Circular and Corrugated Type 225
V-2.6 Attachment of Furnaces 225
V-2.7 Fireboxes and Waterlegs 225
V-3 Design of Stay Pins and Riveted Stay Attachments 226
V-4 Staying of Upper Segments of Tube Heads by Steel Structural Shapes . 226
V-5 Riveted Attachments 226
V-6 Domes 228
Mandatory Appendix VI **Establishing Governing Code Editions, Addenda, and Cases for Boilers and Replacement Parts** 229
VI-1 General 229
VI-2 Design 229
VI-3 Materials 229
VI-4 Fabrication 229
VI-5 Examination 229
VI-6 Inspection 229
VI-7 Testing 230
VI-8 Overpressure Protection 230
VI-9 Field Assembly 230
VI-10 Certification 230
Mandatory Appendix VII **Alternate Methods for Applying the ASME Certification Mark** 231
VII-1 Requirements for Alternate Methods 231
Mandatory Appendix VIII **Local Heating of Welds in Cylindrical Components of P-No. 15E Materials When Using Electric Resistance Heating** 232
VIII-1 Scope 232
VIII-2 General 232
VIII-3 Terminology for Local Heating 232
VIII-4 Local Circumferential Band Heating 233
VIII-4.1 Soak Band 233
VIII-4.2 Heated Band 233

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

VIII-4.3	Gradient Control Band	233
VIII-4.4	Axial Temperature Gradient	235
VIII-5	Measurement of Temperature	235
VIII-5.1	Temperature-Indicating Crayons and Paints	235
VIII-5.2	Selection of Thermocouples	235
VIII-5.3	Installation of Thermocouples	235
VIII-5.4	Control Thermocouples	235
VIII-5.5	Monitoring Thermocouples	235
VIII-6	Design of the Heating Process	235
VIII-6.1	Preheat	236
VIII-6.2	Postheating	236
VIII-6.3	Postweld Heat Treatment	236
VIII-6.4	Special Considerations	236
VIII-7	The Thermal Cycle, PWHT	241
VIII-8	Insulation	243
VIII-9	Quality Assurance System	243
VIII-9.1	Introduction	243
VIII-9.2	Process Control	243
VIII-9.3	Documentation	243
VIII-9.4	Control of Inspection, Measuring, and Test Equipment	243
VIII-9.5	Training	244
VIII-9.6	Servicing	244
VIII-10	Other Considerations	244
Nonmandatory Appendix A	**Explanation of the Code Containing Matter Not Mandatory Unless Specifically Referred to in the Rules of the Code**	248
	Efficiency of Joints	248
A-1	Efficiency of Riveted Joints	248
A-2	Single-Riveted Lap Joint	248
A-3	Double-Riveted Lap Joint	248
A-4	Double-Riveted Buttstrap and Double-Strap Joint	249
A-5	Triple-Riveted Buttstrap and Double-Strap Joint	249
A-6	Quadruple-Riveted Buttstrap and Double-Strap Joint	250
	Braced and Stayed Surfaces	250
A-8		250
	Method of Checking Pressure Relief Valve Capacity by Measuring Maximum Amount of Fuel That Can Be Burned	251
A-12		251
A-13	Example 1	251
A-14	Example 2	251
A-15	Example 3	251
A-16	Example 4	251
A-17		251
	Automatic Gage Glasses	252
A-18		252
	Fusible Plugs	257
A-19		257

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

A-20 . . . 258
A-21 . . . 258
Proof Tests to Establish Maximum Allowable Working Pressure . . . 258
A-22 . . . 258
A-24 Table PG-23.1 . . . 262
A-25 Table PG-23.2 . . . 262
A-26 Table PG-23.3 . . . 262
A-27 Table PG-23.4 . . . 262
A-28 Figures G and CS-1 Through CS-6 . . . 262
Suggested Rules Covering Existing Installations . . . 262
A-30 . . . 262
Pressure Relief Valves for Power Boilers . . . 262
A-44 . . . 262
A-45 . . . 262
A-46 . . . 263
A-48 . . . 263
A-63 . . . 263
A-64 Repairs to Existing Boilers . . . 263
Examples of Methods of Computation of Openings in Vessel Shells . . . 263
A-65 . . . 263
A-66 . . . 264
A-67 . . . 265
A-68 . . . 267
A-69 . . . 268
A-70 . . . 272
Examples of Computation of Allowable Loading on Structural Attachments to Tubes . . . 276
A-71 . . . 276
A-72 . . . 277
A-73 . . . 277
A-74 . . . 278
Computations of Typical Nozzle Fittings Attached by Rivets . . . 279
A-75 Example . . . 279
A-76 Examples of Methods to Determine Ligament Efficiency . . . 281
Preheating . . . 282
A-101 Heating and Cooling Rates for Postweld Heat Treatment . . . 282
Rounded Indication Charts . . . 282
A-250 Acceptance Standard for Radiographically Determined Rounded Indications in Welds . . . 282
Methods for Magnetic Particle Examination (MT) . . . 284
A-260 . . . 284
Methods for Liquid Penetrant Examination (PT) . . . 284
A-270 . . . 284
Quality Control System . . . 291
A-301 General . . . 291

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC I (ASME BPVC Section I) 2023

A-302	Outline of Features to Be Included in the Written Description of the Quality Control System	291
A-317	Cylindrical Components Under Internal Pressure	293
	Data Report Forms and Guides	294
A-350	Guides for Completing Manufacturers' Data Report Forms	294
	Codes, Standards, and Specifications Referenced in Text	338
A-360	Referenced Standards	338
	Sample Calculations for External Pressure Design	338
A-381		338
A-382		341
A-383		342
	Guidance for the Use of U.S. Customary and SI Units in the ASME Boiler and Pressure Vessel Code	344
A-391	Use of Units in Equations	344
A-392	Guidelines Used to Develop SI Equivalents	344
A-393	Soft Conversion Factors	346
A-400	Pressure Relief Valve Capacity Correction Factors	346
Nonmandatory Appendix B	**Positive Material Identification Practice**	359
B-1	Introduction	359
B-2	Definitions	359
B-3	Scope	359
B-4	Basis	359
B-5	Materials	360
B-6	Written Practice	360
B-7	Method	360
B-8	Acceptance Criteria	361
B-8.1		361
B-8.2		361
B-8.3		361
B-8.4		361
B-9	Sampling Plan	361
B-9.1		361
B-9.2	Exempt	361
B-10	Documentation	361
B-10.1		361
B-10.2		361
B-10.3		361
B-10.4		362
B-11	Identification	362
Nonmandatory Appendix C	**Local Heating of Welds in Cylindrical Components of P-No. 15E Materials When Using Electric Resistance Heating**	363
Nonmandatory Appendix D	**Design Guidelines for Corrosion, Erosion, and Steam Oxidation of Boiler Tubes**	364
D-1	Introduction	364
D-2	Corrosion — Fireside of Waterwall Boiler Tubes	364
D-2.1	Influence of Chlorine on Furnace-Wall Corrosion	365

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

D-2.2	Effect of No_x Emission Control Technology	365
D-2.3	Acid Dew-Point Corrosion	365
D-2.4	Corrosion — Fireside of Reheater and Superheater Tubes	366
D-2.5	Steam-Side Oxidation	366
D-3	Ash-Particle Impact Erosion	366
Nonmandatory Appendix E	**Alternative Method for Ultrasonic Examination**	368
E-1	Introduction	368
E-2	Examination Volume	368
E-3	Demonstration Standard	368
E-4	Procedure Qualification	368
E-5	Initial Examination	368
E-6	Personnel Qualification	368
E-7	Flaw Sizing	369
E-8	Flaw Evaluation and Acceptance Criteria	375
Nonmandatory Appendix F	**Design Guidelines for Dissimilar Metal Welds Between CSEF and Austenitic Stainless Steels**	376
F-1	Introduction	376
F-2	Best Practice Guidelines for Design and Fabrication	376
F-2.1	Location	376
F-2.2	Loading	376
F-3	Fabrication	377
F-3.1	Filler Metals	377
F-3.2	Transition Pieces	378
F-4	Alternative Weld Geometries for DMWs	378
F-5	Welding Technique	378
F-6	Postweld Heat Treatment	379
F-7	Postweld Surface Profiling	379
F-8	Tube-to-Tube Butt Welds	379
F-9	Thick-Section Welds	379
F-10	Attachments to Piping and Headers	379
F-11	Attachments to Tubing	380
F-12	Thermowells	380
F-13	Steam Flow Elements	380
F-14	Drain Lines	380
F-15	Postconstruction and Monitoring	380
Nonmandatory Appendix G	**Guide to the Relocation of Requirements for Capacity Certification of Pressure Relief Valves**	382

Figures

PG-28	Maximum Internal Projection of Welded Access or Inspection Openings	24
PG-31	Some Acceptable Types of Unstayed Flat Heads and Covers	28
PG-33.1	Nomenclature and Equations for Reinforced Openings	33
PG-33.2	Some Representative Configurations Describing the Dimensions t_e, h, and d	34
PG-33.3	Chart for Determining Value of F	35
PG-38.1-1	Example of Two Openings Spaced With Limits of Reinforcement Overlapping	37

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

PG-38.2-1	Example of More Than Two Openings Spaced With Limits of Reinforcement Overlapping	37
PG-38.4-1	Illustrations of the Rule Given in PG-38.4	38
PG-42.1	Welding End Transitions Maximum Envelope	41
PG-46.2	Acceptable Proportions for Ends of Through-Stays	43
PG-52.1	Diagram for Determining the Efficiency of Longitudinal and Diagonal Ligaments Between Openings in Cylindrical Shells	46
PG-52.2	Example of Tube Spacing With Pitch of Holes Equal in Every Row	47
PG-52.3	Example of Tube Spacing With Pitch of Holes Unequal in Every Second Row	47
PG-52.4	Example of Tube Spacing With Pitch of Holes Varying in Every Second and Third Row	47
PG-52.5	Example of Tube Spacing With Tube Holes on Diagonal Lines	47
PG-52.6	Diagram for Determining Equivalent Longitudinal Efficiency of Diagonal Ligaments Between Openings in Cylindrical Shells	48
PG-56.1.2	Method of Computation of Attachments to Tubes	49
PG-56.2	Chart for Determining Load Factor, L_f	51
PG-58.2-1	Code Jurisdictional Limits for Piping — Drum-Type Boilers	52
PG-58.2-2	Code Jurisdictional Limits for Piping — Isolable Economizers Located in Feedwater Piping and Isolable Superheaters in Main Steam Piping (Boiler Pressure Relief Valves, Blowoff, and Miscellaneous Piping for Boiler Proper Not Shown for Clarity)	53
PG-58.2-3	Code Jurisdictional Limits for Piping — Reheaters and Nonintegral Separately Fired Superheaters	54
PG-58.2-4	Code Jurisdictional Limits for Piping — an Example of Forced-Flow Steam Generators With No Fixed Steam and Waterline	55
PG-58.2-5	Code Jurisdictional Limits for Piping — an Example of Steam Separator Type Forced-Flow Steam Generators With No Fixed Steam and Waterline	56
PG-58.2-6	Code Jurisdictional Limits for Piping — Firetube Boiler	57
PG-59.1	Typical Boiler Bushings	60
PG-60.3.7	Y-Type Globe Valve	63
PG-60.3.9	Typical Arrangement of Steam and Water Connections for a Water Column	63
PG-67.4	Requirements for Overpressure Protection Forced-Flow Steam Generator	66
PG-80	Maximum Permissible Deviation From a Circular Form, *e*, for Cylindrical Parts Under External Pressure	78
PG-105.1	Official Certification Mark to Denote the American Society of Mechanical Engineers' Standard for Boilers	82
PG-106	Form of Stamping	83
PW-9.3.1	Butt Welding of Plates of Unequal Thickness	92
PW-9.3.3	Heads Attached to Shells	93
PW-9.4	Prohibited Welded Joint	94
PW-15	Examples of Weld Strength Calculations	97
PW-16.1	Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Drums, and Headers	98
PW-16.2	Some Acceptable Forms of Welds for Lugs, Hangers, and Brackets on Shells, Drums, and Headers (See PG-55)	102
PW-16.8	Some Acceptable Designs for Partial-Penetration-Weld-Type Nozzles and Other Connections Designed for 900°F (480°C) or Higher Service	104

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC I (ASME BPVC Section I) 2023

PW-17-1	Forged Flat Head With Integral Butt-Welded Hubbed Flange	106
PW-19.4(a)	Some Acceptable Types of Diagonal Braces for Installation by Welding	106
PW-19.4(b)	Unacceptable Types of Diagonal Braces for Installation by Welding	107
PW-53.1	Test Specimens From Longitudinal Welded Test Plates	134
PW-53.2	Method of Forming Longitudinal Test Plates	135
PW-53.3(a)	Details of Tension Test Specimens	136
PW-53.3(b)	Details of Bend Test Specimens	137
PR-13-1	Typical Plate Edge Beveled for Sealing by Calking in a Riveted Joint	141
PR-15.4-1	Location of Seams in Inside and Outside Calking Boundaries	142
PR-17.2-1	Boundary of Reinforcing Plate on Outside and Inside of Drum	142
PR-20.2-1	Allowable Welding of Plate Edges at Ends of Buttstraps	143
PB-15	Some Acceptable Types of Brazed Joints	148
PL-2.2-1	Steam Locomotive Boiler With Dome Throttle	153
PL-2.2-2	Steam Locomotive Boiler With Front-End Throttle	154
PL-20.4.1-1	Round Riveted Plate	156
PL-20.4.2-1	Diamond Riveted Plate	156
PL-20.5-1	Manhole Frame	157
PL-21.4.1-1	Steam Dome Top Flange	159
PL-27.5-1	Examples of Doubler Attachment Methods	163
PL-27.6.3-1	Double-Riveted Lap Seam in Stayed Area	164
PL-27.6.3-2	Double-Fillet-Welded Lap Seam in Stayed Area	164
PL-27.7-1	Upper Corner of Firebox	165
PL-28.2-1	Some Examples of Acceptable Mudring Construction	166
PL-30.4.2-1	Fillet-Welded Staybolts	167
PL-33-1	Example of Crown Bar Installation	168
PL-36.2.1-1	Support Perimeters	169
PL-36.5-1	Typical Forms of Diagonal Braces	170
PL-36.7-1	Typical Forms of Gusset Braces	171
PL-36.9-1	Tee Iron	172
PL-36.9-2	Tee-Iron Support Area	172
PL-39.1-1	Arch Tubes	174
PL-39.2.1-1	Circulators	175
PL-39.2.1-2	Circulator Attachment Section Views	175
PL-39.3-1	Example of Thermic Syphon Installation	176
PWT-11	Examples of Acceptable Forms of Tube Attachment	182
PFT-12.1	Some Acceptable Forms of Tube Attachment on Firetube Boilers	186
PFT-17.2	Acceptable Type of Ring-Reinforced Furnace	187
PFT-18.1	Morison Furnace	188
PFT-19	Connection Between Plain and Corrugated Furnace	189
PFT-20	Welding Ogee Ring	189
PFT-21	Some Acceptable Methods of Forming Waterleg Joints by Welding	190
PFT-23.1	Stayed Wrapper Sheet of Locomotive-Type Boiler	191
PFT-25	Example of Staying of Heads Adjacent to Cylindrical Furnaces	193
PFT-26.3-1	Area Supported by Stay Defined in PFT-26.3	195
PFT-27.2-1	Maximum Spacing as Defined in PFT-27.2	196

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC I (ASME BPVC Section I) 2023

PFT-27.11-1	Pitch of Staybolts Adjacent to Upper Corners of Fireboxes	196
PFT-32	Measurements for Determining Stresses in Diagonal Stays	197
PFT-46.1	Spacing and Weld Details for Wall-Support Lugs Set in Pairs on Horizontal-Return Tubular Boilers	200
PFT-46.2	Welded Bracket Connection for Horizontal-Return Tubular Boilers	200
PVG-12	Constant, C, for Vapor Related to Ratio of Specific Heats ($k = c_p/c_v$)	211
PTFH-9.1-1	Liquid Phase Thermal Fluid Heater: External Piping	214
PHRSG-4	Some Acceptable Desuperheater Spraywater Protection Device Arrangements	219
IV-2-1	Symbols	222
IV-3-1	Blend Requirements	223
IV-3-2		223
IV-3-3		223
IV-3-4		224
IV-3-5		224
V-2.2-1	Riveted Circumferential Joint for Circular Furnace Plates Over $^5/_8$ in. (16 mm)	226
V-2.2-2	Proper Location of Staybolts Adjacent to Longitudinal Joint in Furnace Sheet	226
V-4-1	Staying of Head With Steel Angles in Tubular Boiler	227
V-5-1	Method of Riveting Manhole Frames to Shells or Drums With Two Rows of Rivets	228
VIII-3-1	Definitions of Terms for Local Circumferential Band Heating of Cylindrical Component Welds	233
VIII-3-2	Definitions of Terms for Local Circumferential Band With Branch Connection Attachment Weld to Cylindrical Component	234
VIII-6.3.4-1	Location of Thermocouples (Monitoring and Control) for Pipe Sizes Up to 6 NPS (150 DN) and One Control Zone	237
VIII-6.3.4-2	Location of Thermocouples (Monitoring and Control) for Pipe Sizes 8 NPS Through 12 NPS (200 DN Through 300 DN) and Two Control Zones	238
VIII-6.3.4-3	Location of Thermocouples (Monitoring and Control) for Pipe Sizes 14 NPS Through 30 NPS (350 DN Through 750 DN) and Four Control Zones	239
VIII-6.3.4-4	Location of Monitoring Thermocouples for Branch Nozzle or Attachment	240
VIII-6.4.5-1	Example of One Approach When the Heated Band from Weld Requiring PWHT Intersects Weld Not Requiring PWHT	242
A-2-1	Single-Riveted Lap Joint, Longitudinal or Circumferential	248
A-3-1	Double-Riveted Lap Joint, Longitudinal or Circumferential	249
A-4-1	Double-Riveted Buttstrap and Double-Strap Joint	249
A-5-1	Triple-Riveted Buttstrap and Double-Strap Joint	250
A-6-1	Quadruple-Riveted Buttstrap and Double-Strap Joint	251
A-6-2	Joints That May Be Used to Avoid Eccentric Stresses	252
A-8	Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers	253
A-19	Typical Forms of Fusible Plugs	257
A-66	Example for Typical Nozzle Computations	264
A-67	Example for Typical Nozzle Computations	266
A-68	Example for Typical Nozzle Computations	267
A-69	Example for Typical Nozzle Computations	269

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

A-70.1 Example for Typical Nozzle Computations 273
A-70.2 Example for Typical Nozzle Computations 275
A-71 Structural Attachment With Radial Load 277
A-72 Structural Attachment With Eccentric Load 277
A-73 Structural Attachment With Moment Load 277
A-74 Structural Attachment on Tube Bend 277
A-75-1 Example of Nozzle Attached by Riveting 279
A-76-1 Example of Determining Ligament Efficiency per PG-53.2.1 and PG-53.2.2 282
A-250.3.4-1 Aligned Rounded Indications 285
A-250.3.4-2 Groups of Aligned Rounded Indications 286
A-250.3.6-1 Charts for t $^{1}/_{8}$ in. (3 mm) to $^{1}/_{4}$ in. (6 mm), Inclusive 287
A-250.3.6-2 Charts for t Over $^{1}/_{4}$ in. (6 mm) to $^{3}/_{8}$ in. (10 mm), Inclusive 287
A-250.3.6-3 Charts for t Over $^{3}/_{8}$ in. (10 mm) to $^{3}/_{4}$ in. (19 mm), Inclusive 288
A-250.3.6-4 Charts for t Over $^{3}/_{4}$ in. (19 mm) to 2 in. (50 mm), Inclusive 288
A-250.3.6-5 Charts for t Over 2 in. (50 mm) to 4 in. (100 mm), Inclusive 289
A-250.3.6-6 Charts for t Over 4 in. (100 mm) 290
E-7-1 Single Indications 370
E-7-2 Multiple Planar Flaws Oriented in Plane Normal to Pressure-Retaining Surface 371
E-7-3 Surface and Subsurface Flaws 372
E-7-4 Nonaligned Coplanar Flaws in Plane Normal to Pressure-Retaining Surface (Illustrative Flaw Configurations) 373
E-7-5 Multiple Aligned Planar Flaws 374
F-2.2-1 Difference in Mean Coefficient of Thermal Expansion for Grade 91 and Common Nickel-Base Filler Metals 377
F-4-1 Examples of Improved Performance DMW Joint Designs 379

Tables

PG-4-1 Standard Units for Use in Equations 2
PG-19 Post Cold-Forming Strain Limits and Heat-Treatment Requirements for Austenitic Materials and Nickel-Based Alloys 13
PG-20 Post Cold-Forming Strain Limits and Heat-Treatment Requirements . . 14
PG-26 Weld Strength Reduction Factors to Be Applied When Calculating Maximum Allowable Working Pressure or Minimum Required Thickness of Components Fabricated With a Longitudinal Seam Weld 19
PG-39 Minimum Number of Threads per Connection 39
PG-56.2 Tube Attachment Angle Design Factor, K 50
PW-11 Required Volumetric Examination of Welded Butt Joints 95
PW-33 Alignment Tolerance of Sections to Be Butt Welded 110
PW-38-1 Recommended Preheat Temperatures for Welding of Pressure Parts and Attachments 112
PW-39-1 Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 1 115
PW-39-2 Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 3 116
PW-39-3 Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 4 117

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC I (ASME BPVC Section I) 2023

PW-39-4	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 5A and P-No. 5B	118
PW-39-5	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 15E	119
PW-39-6	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 6	120
PW-39-7	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 7	120
PW-39-8	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 8	121
PW-39-9	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 10H	121
PW-39-10	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 10I	122
PW-39-11	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 31	122
PW-39-12	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 43	122
PW-39-13	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 45	123
PW-39-14	Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 51	123
PW-39.1	Alternate Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels	123
PW-39.2	Mandatory Requirements for Postweld Heat Treatment Temperature Ranges for Welds Between P-No. 1, 3, 4, 5A, 5B Group 1, 6, 7, 8, and 15E Group 1	124
PR-9-1	Minimum Thickness of Buttstraps	140
PR-15.3-1	Allowable Stress on Rivets in Tension	141
PB-1	Maximum Design Temperatures for Brazing Filler Metal	147
PB-16	Recommended Joint Clearance at Brazing Temperature	149
PL-21.3.4-1	Thickness of Riveted Reinforcing Rings for Dome Openings	158
PL-24.1-1	Maximum Allowable Working Pressure for Steel Flues for Firetube Locomotive Boilers	161
PL-28.4-1	Radii for Firebox Mudrings	167
PL-30.4.5-1	Fillet-Welded Staybolt: Examples of Nominal Dimensions Permitted ±0.02 in. (±0.5 mm)	168
PHRSG-4	Minimum Drain Pot Size	218
V-4-1	Sizes of Angles Required for Staying Segments of Heads	227
VIII-6.3.2-1	Control Zones	236
A-44	Guide for Estimating Steaming Capacity Based on Heating Surface	262
A-75-1		281
A-250.3.2	Maximum Permissible Size of Rounded Indication (Examples Only)	283
A-351	Guide for Completing Manufacturer's Data Report, Form P-2 (See PG-112.2.1)	297
A-351.1	Guide for Completing Manufacturer's Data Report, Form P-2A (See PG-112.2.1.1)	302
A-351.2	Guide for Completing Manufacturer's Data Report, Form P-2B (See PG-112.2.1.2)	306

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

A-352 Guide for Completing Manufacturer's Data Report, Form P-3 (See PG-112.2.2) . . . 311
A-353 Guide for Completing Engineering-Contractor Data Report for a Complete Boiler Unit, Form P-3A (See PG-112.2.3) . . . 314
A-354 Guide for Completing Manufacturer's Partial Data Report, Form P-4 (See PG-112.2.4) . . . 318
A-354.1 Guide for Completing Manufacturer's Data Report, Form P-4A (See PG-112.2.5) . . . 322
A-355 Guide for Completing Summary Data Report for Process Steam Generators, Form P-5 (See PG-112.2.6) . . . 325
A-356 Guide for Completing Manufacturer's Data Report for Pressure Relief Valves, Form P-7 (See PG-112.2.8) . . . 329
A-357 Guide to Data Report Forms Distribution . . . 330
A-358 Guide for the Preparation of Manufacturer's or Assembler's Certificate of Conformance, Form P-8 . . . 332
A-359 Guide for Completing Manufacturer's Data Report for Locomotive Boilers, Form PL-1 (See PG-112.2.9) . . . 337
A-360 Codes, Standards, and Specifications Referenced in Text . . . 339
A-400 Supercritical Correction Factor, K_{SC} . . . 347
A-400M Supercritical Correction Factor, K_{SC} . . . 350
A-401 Superheat Correction Factor, K_{sh} . . . 354
A-401M Superheat Correction Factor, K_{sh} . . . 356
B-1 Identification Elements . . . 360
E-3-1 Flaw Acceptance Criteria for $^{1}/_{2}$ in. (13 mm) to Less Than 1 in. (25 mm) Thick Weld . . . 369
E-3-2 Flaw Acceptance Criteria for 1 in. (25 mm) to 12 in. (300 mm) Thick Weld 369
E-3-3 Flaw Acceptance Criteria for Larger Than 12 in. (300 mm) Thick Weld 369

Forms

VIII-9.2-1 Standard Procedure for Local Heating . . . 245
VIII-9.3-1 Standard Documentation Checklist for Local Heating . . . 247
P-2 Manufacturer's Data Report for All Types of Boilers Except Watertube and Electric . . . 295
P-2A Manufacturer's Data Report for All Types of Electric Boilers . . . 299
P-2B Manufacturer's Data Report for Electric Superheaters and Reheaters . . . 304
P-3 Manufacturer's Data Report for Watertube Boilers, Superheaters, Waterwalls, and Economizers . . . 308
P-3A Engineering-Contractor Data Report for a Complete Boiler Unit . . . 312
P-4 Manufacturer's Partial Data Report . . . 315
P-4A Manufacturer's Data Report for Fabricated Piping . . . 320
P-5 Summary Data Report for Process Steam Generators . . . 324
P-6 Manufacturer's Data Report Supplementary Sheet . . . 326
P-7 Manufacturer's Data Report for Pressure Relief Valves . . . 327
P-8 Manufacturer's or Assembler's Certificate of Conformance for Pressure Relief Valves . . . 331
PL-1 Manufacturer's Data Report for Locomotive Boilers . . . 333

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC I (ASME BPVC Section I) 2023

Endnotes 383

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

(23)

LIST OF SECTIONS

SECTIONS

I Rules for Construction of Power Boilers

II Materials
- Part A — Ferrous Material Specifications
- Part B — Nonferrous Material Specifications
- Part C — Specifications for Welding Rods, Electrodes, and Filler Metals
- Part D — Properties (Customary)
- Part D — Properties (Metric)

III Rules for Construction of Nuclear Facility Components
- Subsection NCA — General Requirements for Division 1 and Division 2
- Appendices
- Division 1
  - Subsection NB — Class 1 Components
  - Subsection NCD — Class 2 and Class 3 Components
  - Subsection NE — Class MC Components
  - Subsection NF — Supports
  - Subsection NG — Core Support Structures
- Division 2 — Code for Concrete Containments
- Division 3 — Containment Systems for Transportation and Storage of Spent Nuclear Fuel and High-Level Radioactive Material
- Division 4 — Fusion Energy Devices
- Division 5 — High Temperature Reactors

IV Rules for Construction of Heating Boilers

V Nondestructive Examination

VI Recommended Rules for the Care and Operation of Heating Boilers

VII Recommended Guidelines for the Care of Power Boilers

VIII Rules for Construction of Pressure Vessels
- Division 1
- Division 2 — Alternative Rules
- Division 3 — Alternative Rules for Construction of High Pressure Vessels

IX Welding, Brazing, and Fusing Qualifications

X Fiber-Reinforced Plastic Pressure Vessels

XI Rules for Inservice Inspection of Nuclear Reactor Facility Components
- Division 1 — Rules for Inspection and Testing of Components of Light-Water-Cooled Plants
- Division 2 — Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Reactor Facilities

XII Rules for Construction and Continued Service of Transport Tanks

XIII Rules for Overpressure Protection

ASMENORMDOC.COM : Click to view the full PDF of ASME BPVC.I (ASME BPVC Section I) 2023

FOREWORD*

In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

(a) Committee on Power Boilers (I)
(b) Committee on Materials (II)
(c) Committee on Construction of Nuclear Facility Components (III)
(d) Committee on Heating Boilers (IV)
(e) Committee on Nondestructive Examination (V)
(f) Committee on Pressure Vessels (VIII)
(g) Committee on Welding, Brazing, and Fusing (IX)
(h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
(i) Committee on Nuclear Inservice Inspection (XI)
(j) Committee on Transport Tanks (XII)
(k) Committee on Overpressure Protection (XIII)
(l) Technical Oversight Management Committee (TOMC)

Where reference is made to "the Committee" in this Foreword, each of these committees is included individually and collectively.

The Committee's function is to establish rules of safety relating to pressure integrity, which govern the construction** of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

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* The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

** *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://go.asme.org/BPVCPublicReview to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in this Section, the singular shall be interpreted as the plural, and vice versa, and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

The words "shall," "should," and "may" are used in this Standard as follows:

- *Shall* is used to denote a requirement.
- *Should* is used to denote a recommendation.
- *May* is used to denote permission, neither a requirement nor a recommendation.

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STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code." An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

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(23)

CORRESPONDENCE WITH THE COMMITTEE

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ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Section of the ASME Boiler and Pressure Vessel Code (BPVC) should be sent to the staff secretary noted on the Section's committee web page, accessible at https://go.asme.org/CSCommittees.

NOTE: See ASME BPVC Section II, Part D for guidelines on requesting approval of new materials. See Section II, Part C for guidelines on requesting approval of new welding and brazing materials ("consumables").

Revisions and Errata

The committee processes revisions to this Code on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata and Special Notices at http://go.asme.org/BPVCerrata. Errata and Special Notices become effective on the date posted. Users can register on the committee web page to receive e-mail notifications of posted errata and Special Notices.

This Code is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code.

(c) The committee will consider proposed cases concerning the following topics only:

(1) equipment to be marked with the ASME Single Certification Mark, or

(2) equipment to be constructed as a repair/replacement activity under the requirements of Section XI

(d) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code Section and the paragraph, figure, or table number(s) to which the proposed case applies

(4) the edition(s) of the Code to which the proposed case applies

(e) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Cases that have been approved will appear in the next edition or supplement of the Code Cases books, "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements.

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Supplements will be sent or made available automatically to the purchasers of the Code Cases books until the next edition of the Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. The status of any case is available at http://go.asme.org/BPVCCDatabase. An index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases is available at http://go.asme.org/BPVCC.

Interpretations

(a) Interpretations clarify existing Code requirements and are written as a question and reply. Interpretations do not introduce new requirements. If a revision to resolve conflicting or incorrect wording is required to support the interpretation, the committee will issue an intent interpretation in parallel with a revision to the Code.

(b) Upon request, the committee will render an interpretation of any requirement of the Code. An interpretation can be rendered only in response to a request submitted through the online Interpretation Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic e-mail confirming receipt.

(c) ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers may track the status of their requests at http://go.asme.org/Interpretations.

(d) ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not “approve,” “certify,” “rate,” or “endorse” any item, construction, proprietary device, or activity.

(e) Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings

The ASME BPVC committees regularly hold meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the applicable committee. Information on future committee meetings can be found at http://go.asme.org/BCW.

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(23)

PREAMBLE

This Code covers rules for construction of power boilers,[1] electric boilers,[2] miniature boilers,[3] high-temperature water boilers,[4] heat recovery steam generators,[5] solar receiver steam generators,[6] certain fired pressure vessels,[7] and liquid phase thermal fluid heaters[8] to be used in stationary service and includes those power boilers used in locomotive, portable, and traction service. Reference to a paragraph includes all the subparagraphs and subdivisions under that paragraph.

The Code does not contain rules to cover all details of design and construction. Where complete details are not given, it is intended that the manufacturer, subject to the acceptance of the Authorized Inspector, shall provide details of design and construction which will be as safe as otherwise provided by the rules in the Code.

The scope of jurisdiction of Section I applies to the boiler proper and to the boiler external piping.

Superheaters, economizers, and other pressure parts connected directly to the boiler without intervening valves shall be considered as parts of the boiler proper, and their construction shall conform to Section I rules.

Boiler external piping shall be considered as that piping which begins where the boiler proper or isolable superheater or isolable economizer terminates at:

(a) the first circumferential joint for welding end connections; or

(b) the face of the first flange in bolted flanged connections; or

(c) the first threaded joint in that type of connection; and which extends up to and including the valve or valves required by this Code.

ASME Code Certification (including Data Forms and stamping the Certification Mark[9] with appropriate Designator[10]), and/or inspection by the Authorized Inspector, when required by this Code, is required for the boiler proper and the boiler external piping.

Construction rules for materials, design, fabrication, installation, and testing of the boiler external piping are contained in ASME B31.1, Power Piping. Piping beyond the valve or valves required by Section I is not within the scope of Section I.

The material for forced-circulation boilers, boilers with no fixed steam and water line, and high-temperature water boilers shall conform to the requirements of the Code. All other requirements shall also be met except where they relate to special features of construction made necessary in boilers of these types, and to accessories that are manifestly not needed or used in connection with such boilers, such as gage glasses and water columns.

Reheaters receiving steam which has passed through part of a turbine or other prime mover and separately fired steam superheaters which are not integral with the boiler are considered fired pressure vessels and their construction shall comply with Code requirements for superheaters, including safety devices. Piping between the reheater connections and the turbine or other prime mover is not within the scope of the Code. Steam piping to the inlet connections and from the outlet connections of nonintegral separately fired superheaters is not within the scope of this Code.

Economizers that are located outside the limits of boiler external piping are considered fired pressure vessels. Piping to and from the connections to such economizers is not within the scope of this Code.

A pressure vessel in which steam is generated by the application of heat resulting from the combustion of fuel (solid, liquid, or gaseous) or from solar radiation shall be classed as a fired steam boiler.

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[1] Power boiler — a boiler in which steam or other vapor is generated at a pressure of more than 15 psi (100 kPa) for use external to itself.

[2] Electric boiler — a power boiler or a high-temperature water boiler in which the source of heat is electricity.

[3] Miniature boiler — a power boiler or a high-temperature water boiler in which the limits specified in PMB-2 are not exceeded.

[4] High-temperature water boiler — a water boiler intended for operation at pressures in excess of 160 psi (1.1 MPa) and/or temperatures in excess of 250°F (120°C).

[5] Heat recovery steam generator (HRSG) — a boiler that has as its principal source of thermal energy a hot gas stream having high-ramp rates and temperatures such as the exhaust of a gas turbine.

[6] Solar receiver steam generator — a boiler system in which water is converted to steam using solar energy as the principal source of thermal energy. The solar energy is typically concentrated onto the solar receiver through the use of an array of mirrors that focuses solar radiation on the heat transfer surface.

[7] Fired pressure vessel — reheaters, isolable superheaters, economizers located outside the limits of boiler external piping, and nonintegral separately fired superheaters.

[8] Liquid phase thermal fluid heater — a pressure vessel where a fluid other than water is heated but in which no vaporization of the fluid takes place.

[9] Certification Mark — an ASME symbol identifying a product as meeting Code requirements.

[10] Certification Designator (Designator) — the symbol used in conjunction with the Certification Mark for the scope of activity described in a Manufacturer's Certificate of Authorization.

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Unfired pressure vessels in which steam is generated shall be classed as unfired steam boilers with the following exceptions:

(a) vessels known as evaporators or heat exchangers

(b) vessels in which steam is generated by the use of heat resulting from operation of a processing system containing a number of pressure vessels such as used in the manufacture of chemical and petroleum products

Unfired steam boilers shall be constructed under the provisions of Section I or Section VIII.

Liquid phase thermal fluid heaters may be constructed under the provisions of Section I or Section VIII.

Expansion tanks connected to high-temperature water boilers without intervening valves shall be constructed to the requirements of Section I or Section VIII.

A pressure vessel in which an organic fluid is vaporized by the application of heat resulting from the combustion of fuel (solid, liquid, or gaseous) or from solar radiation shall be constructed under the provisions of Section I. Vessels in which vapor is generated incidental to the operation of a processing system, containing a number of pressure vessels such as used in chemical and petroleum manufacture, are not covered by the rules of Section I. Liquified petroleum gas vaporizers are not covered by the rules of Section I.

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SUMMARY OF CHANGES

Changes listed below are identified on the pages by a margin note, **(23)**, placed next to the affected area. In addition, gender pronouns have been eliminated throughout Section I.

Page	*Location*	*Change*
xxiv	List of Sections	(1) Under Section III, Division 4 added (2) Title of Section XI and subtitle of Section XI, Division 2 revised (3) Information on interpretations and Code cases moved to "Correspondence With the Committee"
xxviii	Personnel	Updated
l	Correspondence With the Committee	Added (replaces "Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees")
lii	Preamble	In last paragraph, last sentence added
lviii	Cross-Referencing in the ASME BPVC	Updated
1	PG-1	Revised
2	Table PG-4-1	(1) Second and third columns revised (2) Notes added
2	PG-5.1	Last sentence revised
3	PG-5.5	Revised
10	PG-11.5	Revised
10	PG-11.5.2	First Sentence revised
10	PG-11.5.8	Revised
12	PG-19	Revised in its entirety
13	Table PG-19	General Note revised
14	Table PG-20	General Note revised
22	PG-27.4.6	In-text table revised in its entirety
28	Figure PG-31	Illustration (a) revised
39	PG-42.1	Endnote 12 revised (see Endnotes)
40	PG-42.2	Revised
47	PG-53	Revised in its entirety
49	Figure PG-53.2.2-1	Deleted
49	PG-56.1.1	Nomenclature revised
49	PG-56.1.2	Nomenclature revised
53	Figure PG-58.2-2	Revised
55	Figure PG-58.2-4	Revised
56	Figure PG-58.2-5	Revised
58	PG-58.4	(1) PG-58.4.3 revised (2) PG-58.4.4 added and subsequent paragraph redesignated
64	PG-67.1	Revised
65	PG-67.2.1.4	"lb" revised to "lbm"
65	PG-67.2.1.6	"lb" revised to "lbm"
67	PG-67.4.3.1	"lb" revised to "lbm"
68	PG-67.5	(1) Revised (2) Tables PG-67.5 and PG-67.5M moved to Nonmandatory Appendix A, redesignated as Tables A-400 and A-400M, respectively, and revised in their entirety
68	PG-68	(1) PG-68.1, PG-68.2, PG-68.3, and PG-68.7 revised (2) Tables PG-68.7 and PG-68.7M moved to Nonmandatory Appendix A and redesignated as Tables A-401 and A-401M, respectively

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Page	*Location*	*Change*
69	PG-69	(1) First sentence revised
		(2) PG-69.1.2, PG-69.1.3, PG-69.1.5, and PG-69.6 deleted
		(3) PG-69.2 revised
70	PG-71.3	Revised in its entirety
75	PG-73.5.3	Subparagraph (a)(3) added
76	PG-75	Revised
77	PG-76.1	Revised
81	PG-104.1	Last paragraphs and Note (2) revised
81	PG-105	Subparagraph (g) revised
82	Figure PG-105.1	Illustration (g) revised
84	PG-106.7	PG-106.7.1 and PG-106.7.2 revised
84	PG-106.8.1	Revised
87	PG-110	Subparagraphs (e) and (h) revised
89	PG-112.2.5	Revised
89	PG-112.2.8	"lb" revised to "lbm"
95	Table PW-11	General Notes (g) and (h) revised
98	Figure PW-16.1	Callout for illustrations (a) and (c) revised
107	PW-26	Revised
107	PW-27	PW-27.4 added and subsequent paragraphs redesignated
108	PW-28	Revised in its entirety
110	PW-35	PW-35.1 and PW-35.4 revised
112	PW-38.6	Revised
114	PW-39.2	Revised
115	Table PW-39-1	In General Note (b)(2), last sentence deleted by errata
118	Table PW-39-4	In General Note (a), (6)(d) revised
119	Table PW-39-5	(1) Third column deleted by errata
		(2) General Note (a) corrected by errata
124	Table PW-39.2	In columns 5A and 5B, third entry "1,250–1,300 (675–705)" corrected by errata to "1,250–1,350 (675–730)"
127	PW-41.2.2	Revised
131	PW-50	Revised in its entirety
131	PW-51	Revised in its entirety
132	PW-52	PW-52.1, PW-52.2, and PW-52.3 revised
139	PR-7	Revised
141	PR-15.4	Definition of L_R revised
142	PR-17.2	Subparagraph (a) revised
155	PL-17	Cross-reference revised
157	PL-21.2.2	Subparagraph (b) revised
173	PL-36.9.1	In nomenclature, definition of W revised
177	PL-49	Added
192	PFT-26.1	Revised
194	PFT-29	(1) Title revised
		(2) Existing paragraph designated as PFT-29.1 and PFT-29.2 added
203	PMB-5	(1) PMB-5.1 revised
		(2) PMB-5.5 added and subsequent paragraph redesignated
206	PEB-5.3	Revised
208	PEB-15.2	"lb" revised to "lbm"
210	PVG-12.1	First sentence revised
211	PVG-12.6	Definitions of C and h revised
212	PFE-3.1	Cross-reference to Section VIII revised
219	Figure PHRSG-4	Revised

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Page	Location	Change
220	Mandatory Appendix III	(1) Revised in its entirety
		(2) Form III-1A deleted
225	V-2.2	In nomenclature, definition of *P* revised
228	V-6	Subparagraph (b) revised
231	VII-1	Subparagraph (d) added
243	VIII-8	In subpara. (a), "lb" revised to "lbm"
250	Braced and Stayed Surfaces	(1) In A-12, nomenclature revised
		(2) In A-13, A-14, A-15, and A-17, "lb" revised to "lbm"
253	Figure A-8	Cross-reference to "PW-11.4" corrected by errata to "PW-11" in three places
260	A-22.6.1.4	Revised
260	A-22.6.2.4	Second paragraph revised
261	A-22.6.3.2	Revised
262	A-44	First paragraph revised
262	Table A-44	In column heads below U.S. Customary Units, "pounds" revised to "pound mass"
264	A-66	"lb" revised to "lbf" in four places
265	A-67	"lb" revised to "lbf" in four places
268	A-69	"lb" revised to "lbf" in five places
276	A-70.2.4	"lb" revised to "lbf" in three places
276	A-71	"lb" revised to "lbf" in four places
277	Figure A-71	"lb" revised to "lbf"
277	Figure A-72	"lb" revised to "lbf"
277	Figure A-73	"lb" revised to "lbf"
277	Figure A-74	"lb" revised to "lbf" in two places
277	A-72	"lb" revised to "lbf" in five places
277	A-73	"lb" revised to "lbf" in six places
278	A-74	"lb" revised to "lbf" in four places
279	A-75	"lb" revised to "lbf" in six places
281	A-76	Added
282	Figure A-76-1	Added
284	Method for Magnetic Particle Examination (MT)	(1) Note added
		(2) A-260 revised in its entirety
284	Methods for Liquid Penetrant Examination	(2) A-270 revised in its entirety
		(1) Note revised
292	A-302.11	First cross-reference updated
292	A-311	Deleted
293	A-317.1	Cross-references to PG updated
295	Form P-2	Second page revised
299	Form P-2A	Second and third pages revised
304	Form P-2B	Revised
308	Form P-3	Second and third pages revised
312	Form P-3A	Revised
314	Table A-353	In item (7), "lb" revised to "lbf"
315	Form P-4	Second page revised
318	Table A-354	(1) Items (12) and (20) revised
		(2) Items (35) through (37) added
320	Form P-4A	(1) Revised
		(2) For "P-4A ID No.," circled number "31" corrected by errata to "22"
322	Table A-354.1	Item (15) revised
323	Form P-4B	Deleted
323	Table A-354.2	Deleted
324	Form P-5	Under "Certificate of Compliance," parenthesized text below "Name" revised
329	Table A-356	Items (1) and (19) revised

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Page	*Location*	*Change*
330	Table A-357	Revised
333	Form PL-1	Third and fourth pages revised
339	Table A-360	Revised
346	A-393	In-text table revised
346	A-400	Added
363	Nonmandatory Appendix C	Deleted
382	Nonmandatory Appendix G	Deleted

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(23)

CROSS-REFERENCING IN THE ASME BPVC

Paragraphs within the ASME BPVC may include subparagraph breakdowns, i.e., nested lists. The following is a guide to the designation and cross-referencing of subparagraph breakdowns:

(a) Hierarchy of Subparagraph Breakdowns

(1) First-level breakdowns are designated as (a), (b), (c), etc.

(2) Second-level breakdowns are designated as (1), (2), (3), etc.

(3) Third-level breakdowns are designated as (-a), (-b), (-c), etc.

(4) Fourth-level breakdowns are designated as (-1), (-2), (-3), etc.

(5) Fifth-level breakdowns are designated as (+a), (+b), (+c), etc.

(6) Sixth-level breakdowns are designated as (+1), (+2), etc.

(b) Cross-References to Subparagraph Breakdowns. Cross-references within an alphanumerically designated paragraph (e.g., PG-1, UIG-56.1, NCD-3223) do not include the alphanumerical designator of that paragraph. The crossreferences to subparagraph breakdowns follow the hierarchy of the designators under which the breakdown appears. The following examples show the format:

(1) If X.1(c)(1)(-a) is referenced in X.1(c)(1), it will be referenced as (-a).

(2) If X.1(c)(1)(-a) is referenced in X.1(c)(2), it will be referenced as (1)(-a).

(3) If X.1(c)(1)(-a) is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).

(4) If X.1(c)(1)(-a) is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).

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PART PG
GENERAL REQUIREMENTS FOR ALL METHODS OF CONSTRUCTION

GENERAL

(23) PG-1 SCOPE

The requirements of Part PG apply to the following:

(a) power boiler

(b) high-pressure, high-temperature water boilers

(c) liquid phase thermal fluid heaters

(d) parts and appurtenances of the above

These shall be used in conjunction with the specific requirements in the applicable Parts of this Section that pertain to the methods of construction used.

PG-2 SERVICE LIMITATIONS

PG-2.1 The rules of this Section are applicable to the following services:

(a) boilers in which steam or other vapor is generated at a pressure of more than 15 psig (100 kPa) for use external to itself

(b) high-temperature water boilers intended for operation at pressures exceeding 160 psig (1.1 MPa) and/or temperatures exceeding 250°F (120°C)

PG-2.2 For services below those specified in PG-2.1 it is intended that rules of Section IV apply; however, boilers for such services may be constructed and stamped in accordance with this Section provided all applicable requirements are met.

PG-2.3 Coil-type hot water boilers where the water can flash into steam when released directly to the atmosphere through a manually operated nozzle may be exempted from the rules of this Section provided the following conditions are met:

(a) There is no drum, header, or other steam space.

(b) No steam is generated within the coil.

(c) Tubing outside diameter does not exceed 1 in. (25 mm).

(d) Pipe size does not exceed NPS ¾ (DN 20).

(e) Nominal water capacity does not exceed 6 gal (23 L).

(f) Water temperature does not exceed 350°F (175°C).

(g) Adequate pressure relief valves and controls are provided.

PG-3 REFERENCED STANDARDS

The Manufacturer shall establish the effective Code Edition, Addenda, and Code Cases for boilers and replacement parts in accordance with Mandatory Appendix VI. Specific editions of standards referenced in this Section are shown in Table A-360.

PG-4 UNITS OF MEASURE

(a) Either U.S. Customary, SI, or any local customary units may be used to demonstrate compliance with all requirements of this edition (related to materials, fabrication, examination, inspection, testing, certification, and overpressure protection).

(b) A single system of units shall be used for all aspects of design except where otherwise permitted by this Section. When components are manufactured at different locations where local customary units are different than those used for the general design, the local units may be used for the design and documentation of that component, subject to the limitations given in (c). Similarly, for proprietary components or those uniquely associated with a system of units different than that used for the general design, the alternate units may be used for the design and documentation of that component.

(c) For any single equation, all variables shall be expressed in a single system of units. Calculations using any material data published in this Section or Section II, Part D (e.g., allowable stresses, physical properties, external pressure design factor B, etc.) shall be carried out in one of the standard units in Table PG-4-1. When separate equations are provided for U.S. Customary and SI units, those equations must be executed using variables in the units associated with the specific equation. Data expressed in other units shall be converted to U.S. Customary or SI units for use in these equations. The result obtained from execution of these equations or any other calculations carried out in either U.S. Customary or SI units may be converted to other units.

(d) Production, measurement and test equipment, drawings, welding procedure specifications, welding procedure and performance qualifications, and other fabrication documents may be in U.S. Customary, SI, or local customary units in accordance with the fabricator's practice. When values shown in calculations and analysis,

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(23)

Table PG-4-1
Standard Units for Use in Equations

Quantity	U.S. Customary Units	SI Units
Linear dimensions (e.g., length, height, thickness, radius, diameter)	inches (in.)	millimeters (mm)
Area	square inches ($in.^2$)	square millimeters (mm^2)
Volume	cubic inches ($in.^3$)	cubic millimeters (mm^3)
Section modulus	cubic inches ($in.^3$)	cubic millimeters (mm^3)
Moment of inertia of section	$inches^4$ ($in.^4$)	$millimeters^4$ (mm^4)
Mass (weight)	pound mass (lbm)	kilograms (kg)
Force (load)	pound force (lbf)	newtons (N)
Bending moment	inch-pound force (in.-lbf)	newton-millimeters (N·mm)
Pressure, stress, stress intensity, and modulus of elasticity	pound force per square inch (psi) [Note (1)]	megapascals (MPa) [Note (2)]
Energy (e.g., Charpy impact values)	foot-pound force (ft-lbf)	joules (J)
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)
Absolute temperature	Rankine (°R)	kelvin (K)
Fracture toughness	ksi square root inches ($ksi\sqrt{in.}$)	MPa square root meters ($MPa\sqrt{m}$)
Angle	degrees or radians	degrees or radians
Boiler capacity	Btu/hr	watts (W)

NOTES:
(1) "psig" shall be used to describe gage pressure.
(2) "MPaG" shall be used to describe gage pressure.

fabrication documents or measurement and test equipment are in different units, any conversions necessary for verification of Code compliance, and to ensure that dimensional consistency is maintained, shall be in accordance with the following:

(1) Conversion factors shall be accurate to at least four significant figures.

(2) The results of conversions of units shall be expressed to a minimum of three significant figures.

(e) Conversion of units, using the precision specified above shall be performed to ensure that dimensional consistency is maintained. Conversion factors between U.S. Customary and SI units may be found in Nonmandatory Appendix A, A-391 through A-393. Whenever local customary units are used, the Manufacturer shall provide the source of the conversion factors which shall be subject to verification and acceptance by the Authorized Inspector or Certified Individual.

(f) Material that has been manufactured and certified to either the U.S. Customary or SI material specification (e.g., SA-516M) may be used regardless of the unit system used in design. Standard fittings (e.g., flanges, elbows, etc.) that have been certified to either U.S. Customary or SI units may be used regardless of the units system used in design.

(g) All entries on a Manufacturer's Data Report and data for Code-required nameplate marking shall be in units consistent with the fabrication drawings for the component using U.S. Customary, SI, or local customary units. It is acceptable to show alternate units parenthetically. Users of this Code are cautioned that the receiving jurisdiction should be contacted to ensure the units are acceptable.

MATERIALS

PG-5 GENERAL

PG-5.1 Except as otherwise permitted in PG-8.2, PG-8.3, PG-10, and PG-11, material subject to stress due to pressure shall conform to one of the specifications given in Section II and shall be limited to those that are listed in the Tables of Section II, Part D. The Manufacturer shall ensure that the correct material has been received and is properly identified before proceeding with construction (see A-302.4). Materials shall not be used at temperatures above those for which stress values are limited, for Section I construction, in the Tables of Section II, Part D. Specific additional requirements described in PG-5 through PG-14 shall be met as applicable. (23)

PG-5.2 Material covered by specifications in Section II is not restricted as to the method of production unless so stated in the specification, and as long as the product complies with the requirements of the specification.

PG-5.3 If, in the development of the art of boiler construction, it is desired to use materials other than those herein described, data should be submitted to the Boiler and Pressure Vessel Committee in accordance with the requirements of Section II, Part D, Mandatory

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Appendix 5. Material not completely identified with any approved Code specifications may be used in the construction of boilers under the conditions outlined in PG-10.

PG-5.4 Size Limits and Tolerances.

PG-5.4.1 Materials outside the limits of size or thickness given in the title or scope clause of any specification in Section II may be used if the material is in compliance with the other requirements of the specification, and no similar limitation is given in the rules for construction.

PG-5.4.2 Pipe having a tolerance of ±1% on either the O.D. or the I.D., rather than the tolerance specified in the material specification, may be used, provided the material complies with all other requirements of the specifications. When used under external pressure, such pipe shall be limited to a maximum of 24 in. (600 mm) in diameter. The pipe shall include the designation 1% O.D. or 1% I.D., as appropriate, in any required documentation and marking of the material.

(23) **PG-5.5** The use of austenitic alloy steel is permitted for boiler pressure parts that are steam touched in normal operation. Except as specifically provided in PG-9.1.1, PG-12, PEB-5.3, PMB-5.5, and PFE-4, the use of such austenitic alloys for boiler pressure parts that are water wetted in normal service is prohibited.[1]

PG-5.6 P-No. 15E, Group 1 Materials.

PG-5.6.1 If during any phase of manufacturing or erection any portion of the component that does not contain a weld is heated to a temperature greater than 1,470°F (800°C), one of the following actions shall be performed:

(a) The component shall be reaustenitized and retempered in its entirety in accordance with the specification requirements.

(b) That portion of the component heated above 1,470°F (800°C), including the heat-affected zone created by the local heating, must be replaced or must be removed, reaustenitized, and retempered in accordance with the specification requirements and then replaced in the component.

(c) If the allowable stress values to be used are less than or equal to those provided in Section II, Part D, Subpart 1, Table 1A for Grade 9 (e.g., SA-213 T9, SA-335 P9, or equivalent product specifications) at the design temperature, then the requirements stated above may be waived, provided that the portion of the component heated above 1,470°F (800°C) is retempered in accordance with the specification requirements.

The use of this provision shall be noted in the Remarks section on the Manufacturer's Data Report. Information to be noted shall describe the affected component, its design condition, and location in sufficient detail so as to be able to positively locate it after assembly in the boiler.

PG-5.6.2 If during any phase of manufacturing or erection of the component, any portion that does contain a weld is heated above 1,445°F (785°C), then the requirements of Notes (3) and (4) of Table PW-39-5 for P-No. 15E, Group 1 Materials, shall apply for reheat treatment.

PG-6 PLATE

PG-6.1 Steel plates for any part of a boiler subject to pressure, whether or not exposed to the fire or products of combustion, shall be of pressure vessel quality in accordance with one of the following specifications:

SA-204, Pressure Vessel Plates, Alloy Steel, Molybdenum

SA-240, (Type 405 only) Pressure Vessel Plates, Alloy Steel (Ferritic Stainless), Chromium

SA-285, Pressure Vessel Plates, Carbon Steel, Low-and Intermediate-Tensile Strength

SA-299, Pressure Vessel Plates, Carbon Steel, Manganese-Silicon

SA-302, Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel

SA-387, Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum

SA-515, Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service

SA-516, Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

SA/AS 1548, Fine Grained, Weldable Steel Plates for Pressure Equipment

SA/EN-10028-2, Flat Products Made of Steels for Pressure Purposes

SA/GB 713, Steel Plates for Boilers and Pressure Vessels

SA/JIS G3118, Carbon Steel Plates for Pressure Vessels for Intermediate and Moderate Temperature Service

PG-7 FORGINGS

PG-7.1 Seamless steel drum forgings made in accordance with SA-266 for Carbon-Steel and SA-336 for Alloy Steel may be used for any part of a boiler for which pressure vessel quality is specified or permitted.

PG-7.2 Forged flanges, fittings, nozzles, valves, and other pressure parts of the boiler shall be of material that conforms to one of the forging specifications as listed in PG-9.

PG-7.3 Drums, shells, or domes may be of seamless drawn construction, with or without integral heads, provided the material conforms to the requirements of the Code for shell material.

PG-8 CASTINGS

PG-8.1 Except for the limited usage permitted by PG-8.2 and PG-8.3, cast material used in the construction of vessels and vessel parts shall conform to one of the specifications listed in PG-9 for which maximum allowable

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stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B. The allowable stress values shall be multiplied by the applicable casting quality factor given in PG-25 for all cast materials except cast iron.

When cast iron is used as allowed in PG-11.1 for standard pressure parts, it shall conform to one of these standards

ASME B16.1, Gray Iron Pipe Flanges and Flanged Fittings

ASME B16.4, Cast Iron Threaded Fittings

Material conforming to ASTM A126 may be used subject to all requirements of the particular standard. Such usage is subject also to all the requirements for the use of cast iron given in PG-8.2 and other paragraphs of this Section.

PG-8.2 Cast Iron.

PG-8.2.1 Cast iron shall not be used for nozzles or flanges attached directly to the boiler for any pressure or temperature.

PG-8.2.2 Cast iron as designated in SA-278 may be used for boiler and superheater connections under pressure, such as pipe fittings, water columns, valves and their bonnets, for pressures up to 250 psi (1.7 MPa), provided the steam temperature does not exceed 450°F (230°C).

PG-8.3 Cast Nodular Iron. Cast nodular iron as designated in SA-395 may be used for boiler and superheater connections under pressure, such as pipe fittings, water columns, and valves and their bonnets, for pressures not to exceed 350 psi (2.5 MPa), provided the steam temperature does not exceed 450°F (230°C).

PG-8.4 Nonferrous. Bronze castings shall conform to SB-61, SB-62, and SB-148, and may be used only for the following:

PG-8.4.1 For flanges and flanged or threaded fittings complying with the pressure and temperature requirements of ASME B16.15 or B16.24, except that such fittings shall not be used where steel or other material is specifically required. Threaded fittings shall not be used where flanged types are specified.

PG-8.4.1.1 For valves at allowable stress values not to exceed those given in Section II, Part D, Subpart 1, Table 1B, with maximum allowable temperatures of 550°F (290°C) for SB-61 and SB-148, and 406°F (208°C) for SB-62.

PG-8.4.1.2 For parts of pressure relief valves subject to limitations of PG-73.3.4.

PG-9 PIPES, TUBES, AND PRESSURE-CONTAINING PARTS

Pipes, tubes, and pressure-containing parts used in boilers shall conform to one of the specifications listed in this paragraph for which maximum allowable stresses are given in Section II, Part D, Subpart 1, Tables 1A and 1B. The stress values given in these tables include the applicable joint efficiency factor for welded pipes and tubes.

Open-hearth, electric furnace, or basic oxygen steel shall be used for boiler pressure parts exposed to the fire or products of combustion. When used for internal pressure, the material stress and dimensions shall meet the appropriate requirements of PG-27 and Part PW and be in accordance with the following:

PG-9.1 Boiler parts shall be of the following specifications only:

SA-53, Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless (excluding galvanized)

SA-105, Carbon Steel Forgings for Piping Applications

SA-106, Seamless Carbon Steel Pipe for High-Temperature Service

SA-178, Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes

SA-181, Carbon Steel Forgings, for General-Purpose Piping

SA-182, Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service (ferritic only)

SA-192, Seamless Carbon Steel Boiler Tubes for High Pressure Service

SA-209, Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

SA-210, Seamless Medium-Carbon Steel Boiler and Superheater Tubes

SA-213, Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat Exchanger Tubes (ferritic only)

SA-216, Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service

SA-217, Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

SA-234, Pipe Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High-Temperature Service

SA-250, Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes

SA-266, Carbon Steel Forgings for Pressure Vessel Components

SA-268, Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service

SA-333, Seamless and Welded Steel Pipe for Low-Temperature Service

SA-335, Seamless Ferritic Alloy Steel Pipe for High-Temperature Service

SA-336, Alloy Steel Forgings for Pressure and High-Temperature Parts

SA-350, Carbon and Low-Alloy Steel Forgings Requiring Notch Toughness Testing for Piping Components

SA-423, Seamless and Electric-Welded Low Alloy Steel Tubes

SA-660, Centrifugally Cast Carbon Steel Pipe for High-Temperature Service

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SA-731, Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe
SA/EN 10216-2, Seamless Steel Tubes for Pressure Purposes — Part 2: Technical Delivery Conditions for Non-Alloy and Alloy Steel Tubes With Specified Elevated Temperature Properties
SA/EN 10222-2, Steel Forgings for Pressure Purposes — Part 2: Ferritic and Martensitic Steels With Specified Elevated Temperature Properties

PG-9.1.1 Boiler parts on once-through boilers shall be any of the specifications listed in PG-9.1 or any of the following:[2]
SB-407, Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
SB-408, Nickel-Iron-Chromium Alloy Rod and Bar
SB-409, Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
SB-423, Nickel-Iron-Chromium-Molybdenum-Copper Alloy Seamless Pipe and Tube
SB-424, Nickel-Iron-Chromium-Molybdenum-Copper Alloy Plate, Sheet, and Strip
SB-425, Nickel-Iron-Chromium-Molybdenum-Copper Alloy Rod and Bar
SB-515, Welded Nickel-Iron-Chromium Alloy Tubes
SB-564, Nickel Alloy Forgings

PG-9.1.2 Materials for use in connector piping or tubing and the pressure chamber for remote water level-sensing devices, as referenced in PG-12.2, shall be one of the specifications listed in PG-9.1 or one of the following:
SA-213, Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
SA-312, Seamless and Welded Austenitic Stainless Steel Pipes
SB-163, Seamless Nickel and Nickel Alloy Condenser and Heat-Exchanger Tubes
SB-167, Nickel-Chromium-Iron Alloys and Nickel–Chromium–Cobalt Molybdenum Alloy Seamless Pipe and Tube
SB-407, Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
SB-423, Nickel-Iron-Chromium-Molybdenum-Copper Alloy Seamless Pipe and Tube
SB-515, Welded Nickel-Iron-Chromium Alloy Tubes
SB-516, Welded Nickel-Chromium-Iron Alloy Tubes
SB-517, Welded Nickel-Chromium-Iron Alloy Pipe
SB-619, Welded Nickel and Nickel-Cobalt Alloy Pipe
SB-622, Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube
SB-626, Welded Nickel and Nickel-Cobalt Alloy Tube

PG-9.2 Superheater parts shall be of any one of the specifications listed in PG-9.1, PG-9.1.1, or one of the following:
SA-182, Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
SA-213, Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
SA-240, Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
SA-249, Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes
SA-312, Seamless and Welded Austenitic Stainless Steel Pipes
SA-351, Castings, Austenitic, Austenitic-Ferritic (Duplex) for Pressure-Containing Parts (Duplex excluded)
SA-369, Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
SA-376, Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
SA-479, Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
SA-965, Steel Forgings, Austenitic, for Pressure and High Temperature Parts
SA/JIS G 4303, Specification for Stainless Steel Bars
SB-163, Seamless Nickel and Nickel Alloy Condenser and Heat Exchanger Tubes
SB-166, Nickel-Chromium Iron Alloys and Nickel-Chromium-Cobalt-Molybdenum Alloy Rod, Bar, and Wire
SB-167, Nickel-Chromium Iron Alloys and Nickel-Chromium-Cobalt-Molybdenum Alloy Seamless Pipe and Tube
SB-168, Nickel-Chromium Iron Alloys and Nickel-Chromium-Cobalt-Molybdenum Alloy Plate, Sheet, and Strip
SB-366, Factory-Made Wrought Nickel and Nickel Alloy Fittings
SB-435, N06230 Plate, Sheet, and Strip
SB-443, Nickel-Chromium-Molybdenum-Columbium Alloy Plate, Sheet, and Strip
SB-444, Nickel-Chromium-Molybdenum-Columbium Alloy Pipe and Tube
SB-446, Nickel-Chromium-Molybdenum-Columbium Alloy Rod and Bar
SB-462, Forged or Rolled Nickel Alloy Pipe Flanges, Forged Fittings, and Valves and Parts for Corrosive, High-Temperature Service
SB-511, Nickel-Iron-Chromium-Silicon Alloy Bars and Shapes
SB-516, Welded Nickel-Chromium-Iron Alloy Tubes
SB-517, Welded Nickel-Chromium-Iron Alloy Pipe
SB-535, Nickel-Iron-Chromium-Silicon Alloys Seamless Pipe and Tube
SB-536, Nickel-Iron-Chromium-Silicon Alloys Plate, Sheet, and Strip
SB-572, Nickel-Molybdenum-Chromium-Iron Alloy Rod

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SB-574, Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Molybdenum-Chromium-Tantalum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Rod

SB-575, Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip

SB-619, Welded Nickel and Nickel-Cobalt Alloy Pipe

SB-622, Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube

SB-626, Welded Nickel and Nickel-Cobalt Alloy Tube

PG-9.3 Copper or copper alloy pipe or tubes shall not be used in the boiler proper for any service where the temperature exceeds 406°F (208°C). Except as provided in PFT-12.1.1, copper and copper alloys shall be seamless, having a thickness not less than ASME Schedule 40 standard pipe, and shall comply to one of the following specifications: SB-42, Seamless Copper Pipe, Standard Sizes; SB-43, Seamless Red Brass Pipe, Standard Sizes; SB-75, Seamless Copper Tube; or SB-111, Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock.

PG-9.4 Bimetallic tubes, having a core of an acceptable boiler and superheater material, and having an external cladding of another metal alloy, may be used provided the requirements of PG-27.2.1.5 are met. In applying the rules of PG-27.2.1, tubes that are diffusion coated shall not be permitted to include the strength of the clad. The permissible variation in wall thickness tolerance of SA-450 or SB-163, as applicable, shall apply to the total wall thickness. The thickness and over and under tolerances of the cladding shall be included in the ordering information. Marking of the bimetallic tubular product shall meet the specification requirements of the core material, but shall also suitably identify the cladding alloy.

PG-9.5 ERW products shall be limited to a maximum thickness of ½ in. (13 mm) for internal pressure applications. For external pressure applications, ERW products shall be limited to a maximum thickness of ½ in. (13 mm) and a maximum size of NPS 24 (DN 600). The thickness and diameter limitations noted above shall be within tolerances stated by the product material specification.

PG-9.6 In addition to other materials permitted by this Section, instrument wells may be fabricated from one of the following titanium alloys:

(a) SB-265, titanium and titanium alloy strip, sheet, and plate

(b) SB-338, seamless and welded titanium and titanium alloy tubes for condensers and heat exchangers

(c) SB-348, titanium and titanium alloy bars and billets

(d) SB-861, titanium and titanium alloy seamless pipe

(e) SB-862, titanium and titanium alloy welded pipe

PG-9.7 In addition to other materials permitted by this Section, the following materials are permitted only for use in economizers or feedwater heaters and associated piping:

(a) SA-182, Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Pressure Service (S31803 only)

(b) SA-240, Pressure Vessel Plate, Alloy Steel (Ferritic Stainless), Chromium (S31803 only)

(c) SA-479, Stainless Steel Bars and Shapes (S31803 only)

(d) SA-789, Seamless and Welded Ferritic Austenitic Stainless Steel Tubing (S31803 only)

(e) SA-790, Seamless and Welded Ferritic Austenitic Stainless Steel Pipe (S31803 only)

(f) SA-815, Wrought Ferritic, Ferritic Austenitic, and Martensitic Stainless Steel Piping Fittings (S31803 only)

PG-10 MATERIAL IDENTIFIED WITH OR PRODUCED TO A SPECIFICATION NOT PERMITTED BY THIS SECTION, AND MATERIAL NOT FULLY IDENTIFIED

PG-10.1 Identified With Complete Certification From the Material Manufacturer. Material identified with a specification not permitted by this Section, or material procured to chemical composition requirements and identified to a single production lot as required by a permitted specification may be accepted as satisfying the requirements of a specification permitted by this Section provided the conditions set forth in PG-10.1.1 or PG-10.1.2 are satisfied.

PG-10.1.1 Recertification by an organization other than the boiler or part manufacturer:

PG-10.1.1.1 All requirements, including but not limited to, melting method, melting practice, deoxidation, quality, and heat treatment, of the specification permitted by this Section, to which the material is to be recertified, have been demonstrated to have been met.

PG-10.1.1.2 A copy of the certification by the material manufacturer of the chemical analysis required by the permitted specification, with documentation showing the requirements to which the material was produced and purchased, and which demonstrates that there is no conflict with the requirements of the permitted specification, has been furnished to the boiler or part manufacturer.

PG-10.1.1.3 A certification that the material was manufactured and tested in accordance with the requirements of the specification to which the material is recertified, excluding the specific marking requirements, has been furnished to the boiler or part manufacturer,

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together with copies of all documents and test reports pertinent to the demonstration of conformance to the requirements of the permitted specification.

PG-10.1.1.4 The material, and the Certificate of Compliance or the Material Test Report have been identified with the designation of the specification to which the material is recertified and with the notation "Certified per PG-10."

PG-10.1.2 Recertification by the boiler or part manufacturer.

PG-10.1.2.1 A copy of the certification by the material manufacturer of the chemical analysis required by the permitted specification, with documentation showing the requirements to which the material was produced and purchased, which demonstrates that there is no conflict with the requirements of the permitted specification, is available to the Inspector.

PG-10.1.2.2 For applications in which the maximum allowable stresses are subject to a note of Section II, Part D, Subpart 1, Table 1A, requiring the use of killed steel, documentation is available to the Inspector that establishes that the material is a killed steel.

PG-10.1.2.3 Documentation is available to the Inspector that demonstrates that the metallurgical structure, mechanical property, and hardness requirements of the permitted specification have been met.

PG-10.1.2.4 For material recertified to a permitted specification that requires a fine austenitic grain size or that requires that a fine grain practice be used during melting, documentation is available to the Inspector that demonstrates that the heat treatment requirements of the permitted specification have been met, or will be met during fabrication.

PG-10.1.2.5 The material has marking, acceptable to the Inspector, for identification to the documentation.

PG-10.1.2.6 When the conformance of the material with the permitted specification has been established, the material has been marked as required by the permitted specification.

PG-10.2 Material Identified to a Particular Production Lot as Required by a Specification Permitted by This Section but That Cannot Be Qualified Under PG-10.1. Any material identified to a particular production lot as required by a specification permitted by this Section, but for which the documentation required in PG-10.1 is not available, may be accepted as satisfying the requirements of the specification permitted by this Section provided that the conditions set forth below are satisfied.

PG-10.2.1 Recertification by an organization other than the boiler or part manufacturer — not permitted.

PG-10.2.2 Recertification by the boiler or part manufacturer.

PG-10.2.2.1 Chemical analyses are made on different pieces from the lot to establish a mean analysis which is to be accepted as representative of the lot. The pieces chosen for analyses shall be selected at random from the lot. The number of pieces selected shall be at least 10% of the number of pieces in the lot, but not less than three. For lots of three pieces or less, each piece shall be analyzed. Each individual analysis in the permitted specification and the mean for each element shall conform to the heat analysis limits of that specification. Analyses need to be made for only those elements required by the permitted specification. However, consideration should be given to making analyses for elements not specified in the specification but which would be deleterious if present in excessive amounts.

PG-10.2.2.2 Mechanical property tests are made in accordance with the requirements of the permitted specification and the results of the tests conform to the specified requirements.

PG-10.2.2.3 For applications in which the maximum allowable stresses are subject to a note of Section II, Part D, Subpart 1, Table 1A, requiring the use of killed steel, documentation is available to the Inspector which establishes that the material is a killed steel.

PG-10.2.2.4 When the requirements of the permitted specification include metallurgical structure requirements (i.e., fine austenitic grain size), tests are made and the results are sufficient to establish that those requirements of the specification have been met.

PG-10.2.2.5 When the requirements of the permitted specification include heat treatment, the material is heat treated in accordance with those requirements, either prior to or during fabrication.

PG-10.2.2.6 When the conformance of the material with the permitted specification has been established, the material has been marked as required by the permitted specification.

PG-10.3 Material Not Fully Identified. Material which cannot be qualified under the provisions of either PG-10.1 or PG-10.2, such as material not fully identified as required by the permitted specification or as unidentified material, may be accepted as satisfying the requirements of a specification permitted by this Section provided that the conditions set forth below are satisfied.

PG-10.3.1 Qualification by an organization other than the boiler or part manufacturer — not permitted.

PG-10.3.2 Qualification by the boiler or part manufacturer.

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PG-10.3.2.1 Each piece is tested to show that it meets the chemical composition for product analysis and the mechanical properties requirements of the permitted specification. Chemical analyses need only be made for those elements required by the permitted specification. However, consideration shall be given to making analyses for elements not specified in the specification but which would be deleterious if present in excessive amounts. For plates, when the direction of final rolling is not known, both a transverse and a longitudinal tension test specimen shall be taken from each sampling location designated in the permitted specification. The results of both tests shall conform to the minimum requirements of the specification, but the tensile strength of only one of the two specimens need conform to the maximum requirement.

PG-10.3.2.2 The provisions of PG-10.2.2.3, PG-10.2.2.4, and PG-10.2.2.5 are met.

PG-10.3.2.3 When the identity of the material with the permitted specification has been established in accordance with PG-10.3.2.1 and PG-10.3.2.2, each piece (or bundle, etc., if permitted in the specification) is marked with a marking giving the permitted specification number and grade, type, or class as applicable and a serial number identifying the particular lot of material. A suitable report, clearly marked as being a "Report on Tests of Nonidentified Material," shall be completed and certified by the boiler or part manufacturer. This report, when accepted by the Inspector, shall constitute authority to use the material in lieu of material procured to the requirements of the permitted specification.

PG-11 PREFABRICATED OR PREFORMED PRESSURE PARTS FURNISHED WITHOUT A CERTIFICATION MARK

PG-11.1 General. In general, all prefabricated or preformed pressure parts shall be certified as meeting the rules of this Section via ASME Data Reports and conformity marking requirements included elsewhere in this Section. Where stamping directly on the material is prohibited and a nameplate is used for those required markings, if the nameplate interferes with further fabrication, installation, or service, it may be removed by the Manufacturer of the completed boiler with the concurrence of the Authorized Inspector. Such removal of the nameplate shall be noted in the "Remarks" section of the boiler Manufacturer's Data Report, and the nameplate shall be destroyed.

Prefabricated or preformed pressure parts supplied under the provisions of PG-11.2 through PG-11.4 are exempt from the requirements for ASME Data Reports and conformity markings included elsewhere in this Section. The rules of PG-11.2 through PG-11.4 shall not be applied to welded shells or heads. A part furnished under the requirements of PG-11.2, PG-11.3, and PG-11.4 need not be manufactured by a Certificate Holder. The Manufacturer of the completed boiler or of the part stamped with the Certification Mark into which the preformed or prefabricated part is incorporated shall first ensure the parts meet all applicable Code requirements. Prefabricated or preformed pressure parts may be supplied as indicated in PG-11.2 through PG-11.4.

PG-11.2 Cast, Forged, Rolled, or Die-Formed Nonstandard Pressure Parts. Pressure parts such as shells, heads, and removable and access-opening cover plates that are wholly formed by casting, forging, rolling, or die forming may be supplied basically as materials. All such parts shall be made of materials permitted under this Section, and the manufacturer of the part shall furnish identification in accordance with PG-5. Such parts shall be marked with the name or trademark of the parts manufacturer and with such other markings as will serve to identify the particular parts with accompanying material identification. The Manufacturer of the completed vessel shall be satisfied the part is suitable for the design conditions specified for the completed vessel in accordance with the rules of this Section.

PG-11.3 Cast, Forged, Rolled, or Die-Formed Standard Pressure Parts, Either Welded or Nonwelded, That Comply With an ASME Product Standard.

PG-11.3.1 PG-11.3 applies to pressure parts such as pipe fittings, valves, flanges, nozzles, welding caps, manhole frames and covers, and pump casings that are a part of the boiler circulating system, that comply with an ASME product standard accepted by reference in PG-42 and are so marked. The ASME product standard establishes the basis for the pressure–temperature rating and marking unless modified in PG-42.

PG-11.3.2 Materials for standard pressure parts shall be either as permitted by this Section or as specifically listed in the ASME product standard.

PG-11.3.3 When welding is performed, in addition to meeting all requirements of the ASME product standard, the welding shall meet either the requirements of Part PW of this Code or the welding requirements of ASME specification SA-234 for parts conforming to ASME B16.9 and ASME B16.11 only.

PG-11.3.4 If heat treatment [including postweld heat treatment (PWHT), postforming heat treatment, or any heat treatment needed to achieve material properties or mitigate material degradation mechanisms] is required, it may be performed either in the location of the parts manufacturer or in the location of the Manufacturer of the vessel to be marked with the Certification Mark. If heat treatment is performed by other than the Manufacturer of the completed boiler, the heat treatment procedure, including mitigation heat treatment procedures for alloys that may be affected by the environment

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(e.g., those subject to stress corrosion cracking) between the time they are welded and the time PWHT is performed, shall be specified by the Manufacturer. These activities shall be documented and provided to the Manufacturer.

PG-11.3.5 If radiography or other volumetric examination is required by the rules of this Section, it may be performed at the location of the Manufacturer of the completed boiler or the location of the pressure parts manufacturer.

PG-11.3.6 Pressure parts meeting the requirements of PG-11.3 do not require inspection, mill test reports, or Manufacturer's Partial Data Reports.

PG-11.3.7 The Manufacturer of the completed boiler shall have the following responsibilities when using standard pressure parts that comply with an ASME product standard:

(a) Ensure all standard pressure parts comply with applicable rules of this Section.

(b) Ensure all standard pressure parts are suitable for the design conditions of the completed boiler.

(c) When volumetric examination is required by the rules of this Section, obtain the completed radiographs or duplicate thereof, properly identified, with a radiographic examination report, or any other applicable volumetric examination report.

PG-11.3.8 The Manufacturer shall fulfill the responsibilities of PG-11.3.7 by obtaining, when necessary, documentation as provided below, providing for retention of this documentation until the final boiler stamping has been completed, and having such documentation available for review by the Authorized Inspector when requested. The documentation shall contain at a minimum

(a) material used

(b) the pressure–temperature rating of the part

(c) the basis for establishing the pressure–temperature rating

PG-11.4 Cast, Forged, Rolled, or Die-Formed Standard Pressure Parts, Either Welded (Including Brazed) or Nonwelded, That Comply With a Standard Other Than an ASME Product Standard.

PG-11.4.1 Standard pressure parts, such as pipe fittings, valves, flanges, nozzles, welding caps, manhole frames and covers, and pump casings, that are a part of the boiler circulating system, that are either welded or nonwelded and comply with a manufacturer's proprietary standard, a standard other than an ASME product standard, or an ASME product standard not adopted by this Section may be supplied by a Certificate Holder or a pressure parts manufacturer.

PG-11.4.2 Parts of small size falling within this category for which it is impossible to obtain identified material or which may be stocked and for which identification cannot be obtained and is not customarily furnished may be used as non-pressure-bearing attachments and need not conform to the specifications for the material to which they are attached or to a material specification permitted in this Section. If attached to the boiler by welding, such parts shall be of weldable quality.

PG-11.4.3 Materials for these parts shall be as permitted by this Section only.

PG-11.4.4 When welding is performed, it shall meet the requirements of Part PW of this Section. When brazing is performed, it shall meet the requirements of Part PB of this Section.

PG-11.4.5 Pressure parts such as welded standard pipe fittings, welding caps, and flanges that are fabricated by one of the welding processes recognized by this Section do not require Authorized Inspection or Partial Data Reports, provided the requirements of PG-11.4 are met.

PG-11.4.6 If postweld heat treatment is required by the rules of this Section, it may be performed either in the location of the parts manufacturer or in the location of the Manufacturer of the completed boiler. If postweld heat treatment is performed by other than the Manufacturer of the completed boiler, the heat treatment procedure shall be documented and provided to the Manufacturer.

PG-11.4.7 If volumetric examination is required, it may be performed at the location of the Manufacturer of the completed boiler, the location of the parts Manufacturer, or the location of the pressure parts manufacturer.

PG-11.4.8 Marking for these parts shall be as follows:

(a) the name or trademark of the Certificate Holder or the pressure part manufacturer and any other markings as required by the proprietary standard or other standard used for the pressure part

(b) a permanent or temporary marking that will serve to identify the part with the Certificate Holder's or the pressure part manufacturer's written documentation of the particular items, and which defines the pressure–temperature rating of the part

PG-11.4.9 The Manufacturer of the completed boiler shall have the following responsibilities when using standard pressure parts:

(a) Ensure all standard pressure parts comply with applicable rules of this Section.

(b) Ensure all standard pressure parts are suitable for the design conditions of the completed boiler.

(c) When volumetric examination is required by the rules of this Section, obtain the completed radiographs or duplicate thereof, properly identified, with a radiographic examination report, or any other applicable volumetric examination report for retention until the final boiler stamping has been completed.

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PG-11.4.10 The Manufacturer of the completed boiler shall fulfill the responsibilities of PG-11.4.9 by one of the following methods:

(a) Obtain, when necessary, documentation as provided in PG-11.4.11, provide for retention of this documentation until the final boiler stamping has been completed, and have such documentation available for review by the Authorized Inspector when requested.

(b) Perform an analysis of the pressure part in accordance with the rules of this Section subject to the acceptance of the Authorized Inspector, while being mindful this Section does not contain rules to cover all details of design and construction. It is intended the Manufacturer shall provide details of design and construction that will be as safe as those provided by the rules of this Section. This analysis shall be included in the documentation and shall be made available for inspection by the Authorized Inspector when requested.

PG-11.4.11 The documentation shall contain at a minimum

(a) material used

(b) the pressure–temperature rating of the part

(c) the basis for establishing the pressure–temperature rating

(d) written certification by the pressure parts manufacturer that all welding complies with Code requirements

(23) **PG-11.5** A Manufacturer holding an ASME Certificate of Authorization may provide standard pressure parts in accordance with PG-11.4. In lieu of the requirements of PG-11.4.4, such organizations may subcontract for welding (including brazing) services to an individual or an organization that does not hold an ASME Certificate of Authorization, provided the conditions of PG-11.5.1 through PG-11.5.10 are met.

PG-11.5.1 The activities to be performed by the subcontractor shall be included within the Certificate Holder's quality control system.

(23) **PG-11.5.2** The Certificate Holder's quality control system shall provide for the following activities associated with subcontracting of welding (including brazing) operations, and these provisions shall be acceptable to the Manufacturer's Authorized Inspection Agency:

(a) the welding processes permitted by this Section that are permitted to be subcontracted

(b) welding operations

(c) Authorized Inspection activities

(d) placement of the Certificate Holder's marking in accordance with PG-11.4.8

PG-11.5.3 The Certificate Holder's quality control system shall provide for the Manufacturer of the boiler to arrange for the Authorized Inspector to have free access to such parts of all plants as are concerned with the supply or manufacture of materials for the boiler, when so requested. The Authorized Inspector shall be permitted free access, at all times while work on the boiler is being performed, to all parts of the Manufacturer's shop that concern the construction of the vessel and to the site of field-erected vessels during the period of assembly and testing of the vessel. The Manufacturer shall keep the Authorized Inspector informed of the progress of the work and shall notify the Inspector reasonably in advance for any required tests or inspections.

PG-11.5.4 The Certificate Holder shall be responsible for reviewing and accepting the quality control programs of the subcontractor.

PG-11.5.5 The Certificate Holder shall ensure that the subcontractor uses written procedures and welding operations that have been qualified as required by this Section.

PG-11.5.6 The Certificate Holder shall ensure that the subcontractor uses personnel that have been qualified as required by this Section.

PG-11.5.7 The Certificate Holder and the subcontractor shall describe in the quality control system the operational control of procedure and personnel qualifications of the subcontracted welding operations.

PG-11.5.8 The Certificate Holder shall be responsible for controlling the quality and ensuring that all materials and parts that are welded (including brazed) by subcontractors and submitted to the Authorized Inspector for acceptance conform to all applicable requirements of this Section. (23)

PG-11.5.9 The Certificate Holder shall describe in the quality control system the operational control for maintaining traceability of materials received from the subcontractor.

PG-11.5.10 The Certificate Holder shall receive approval for subcontracting from the Authorized Inspection Agency prior to commencing of activities.

PG-12 WATER LEVEL INDICATORS AND CONNECTOR MATERIAL

PG-12.1 Gage glass body and connector materials shall comply with a Manufacturer's standard that defines the pressure–temperature rating marked on the unit. The materials used may include austenitic stainless steels and nickel-based alloys.[1]

PG-12.2 Boilers having a maximum allowable working pressure not exceeding 900 psi (6 MPa) may use alternative methods for independent remote water level indicators or water level-sensing devices (see PG-60 for requirements for water level indicators and water columns). The sensing devices may include a magnetically coupled float inside a nonferromagnetic cylindrical pressure chamber to utilize through-the-wall sensing of float

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position. The pressure chamber stresses and dimensions shall meet the appropriate requirements of PG-27 and Part PW, shall comply with one of the specifications in PG-9.1.2, and shall be restricted to the material grades listed in PG-12.3.

PG-12.3 Connector material and the pressure chamber material of the remote water level indicator or water level-sensing devices, except for water columns, may include austenitic stainless steels and nickel-based alloys. The material shall be in the solution-annealed heat treatment condition. If filler metals are used in welding of the austenitic stainless steels, they shall be limited to low-carbon content.

The material shall be one of the grades from the following list:

Grade	UNS Number
304L	S30403
316L	S31603
800	N08800
...	N08020
825	N08825
C-276	N10276
...	N06022
690	N06690
59	N06059
625	N06625
600	N06600

The allowable stresses shall be those listed in Section II, Part D, Subpart 1, Table 1A or Table 1B for Section I. If allowable stresses are not listed for Section I but are listed for Section VIII, Division 1, the allowable stresses for Section VIII, Division 1 may be utilized. When two lines of stresses are listed in Section II, Part D, the design shall be based on the lower allowable stresses.

PG-13 STAYS

Threaded stays shall be of steel complying with SA-36, SA/CSA-G40.21, or SA-675.

Seamless steel tubes for threaded stays shall comply with SA-192 or SA-210.

Staybolts, stays, through-rods, or stays with ends for attachment by fusion welding shall comply with SA-36, SA/CSA-G40.21, or SA-675.

PG-14 RIVETS

PG-14.1 Rivets shall conform to SA-31, Specification for Steel Rivets and Bars for Rivets, Pressure Vessels.

PG-14.1.1 In lieu of SA-31, it is permissible to substitute bar which is converted to rivets from SA-36, Specification for Carbon Structure Steel, under the conditions specified in PG-14.1.1.1 and PG-14.1.1.2.

PG-14.1.1.1 In addition to compliance with SA-36, the bar shall comply with

(a) the "rivet bend tests" for SA-31 Grade B, para. 6.1.2

(b) the "rivet flattening tests" for SA-31 Grades A and B, para. 6.2

(c) the "bar bend tests" for SA-31 Grade B, para. 6.4.2

PG-14.1.1.2 The following paragraphs of SA-31 shall be applicable to the additional mechanical properties tests:

(a) paragraph 9, Number of Tests and Retests

(b) paragraph 10, Specimen Preparation

(c) paragraph 11, Test Methods

(d) paragraph 12, Inspection

(e) paragraph 13, Rejection and Reheating

PG-14.1.2 When rivets made from SA-36 bar are substituted for those made from SA-31, the design stresses for SA-31 Grade B shall apply.

PG-14.2 In computing the ultimate strength of rivets in shear, the following shear stresses in ksi (MPa) of the cross-sectional area of the rivet shank shall be used:

(a) Steel rivets, SA-31 Grade A, in single shear, 44.0 (305)

(b) Steel rivets, SA-31 Grade A, in double shear, 88.0 (605)

(c) Steel rivets, SA-31 Grade B, in single shear, 52.0 (360)

(d) Steel rivets, SA-31 Grade B, in double shear, 104.0 (715)

The cross-sectional area used in the computations shall be that of the rivet after driving.

DESIGN

PG-16 GENERAL

PG-16.1 The design of power boilers, high-temperature water boilers, and other pressure parts included within the scope of these rules shall conform to the general design requirements in the following paragraphs and in addition to the specific requirements for design given in the applicable Parts of this Section that pertain to the methods of construction used. This Section does not contain rules to cover all possible details of design. When detailed rules are not given, it is intended that the Manufacturer, subject to the acceptance of the Inspector, shall provide details of design that will be as safe as those provided by the rules of this Section. This may be done by appropriate analytical methods, the appropriate use of rules from other design codes or, as permitted by PG-18, by proof test.

PG-16.2 When the pressure parts of a forced-flow steam generator with no fixed steam and waterline are designed for different pressure levels as permitted in PG-21.3, the owner shall provide or cause to be provided a boiler pressure system design diagram, certified by a

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Professional Engineer experienced in the mechanical design of power plants, which supplies the following information.

PG-16.2.1 The relative location of the various pressure parts within the scope of Section I, with respect to the path of water-steam flow.

PG-16.2.2 A line showing the expected maximum sustained pressure as described in PG-21.3, indicating the expected variation in pressure along the path of water-steam flow.

PG-16.2.3 The maximum allowable working pressure of the various pressure parts.

PG-16.2.4 The location and set pressure of the overpressure protection devices.

Copy of this diagram shall be attached to the Master Data Report per PG-113.

PG-16.3 Minimum Thicknesses. The minimum thickness of any boiler plate under pressure shall be $\frac{1}{4}$ in. (6 mm) except for electric boilers constructed under the rules of Part PEB. The minimum thickness of plates to which stays may be applied in other than cylindrical outer shell plates shall be $\frac{5}{16}$ in. (8 mm). When pipe larger than NPS 5 (DN 125) is used in lieu of plate for the shell of cylindrical components under pressure, its minimum wall shall not be less than the smaller of $\frac{1}{4}$ in. (6 mm) or the minimum wall thickness of Standard wall pipe listed in ASME B36.10M, Table 1. The minimum thickness requirements stipulated above are exclusive of any allowances for corrosion, erosion, and forming.

PG-16.4 Undertolerance on Plates. Plate material that is not more than 0.01 in. (0.3 mm) thinner than that calculated from the formula may be used in Code constructions provided the material specification permits such plate to be furnished not more than 0.01 in. (0.3 mm) thinner than ordered.

PG-16.5 Undertolerance on Pipe and Tubes. Pipe or tube material shall not be ordered thinner than that calculated from the applicable formula of this Section. The ordered material shall include provision for the allowed manufacturing undertolerance as given in Section II in the applicable pipe or tube specification.

PG-16.6 The Code does not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters shall be considered nominal, and allowable tolerances or local variances should be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

PG-16.7 The dimensional symbols used in the design formulas throughout this Code do not include any allowance for corrosion, erosion, and forming, except where noted. Additional thickness should be provided where these allowances are applicable.

PG-17 FABRICATION BY A COMBINATION OF METHODS

A boiler and parts thereof may be designed and fabricated by a combination of the methods of fabrication given in this Section, provided the rules applying to the respective methods of fabrication are followed and the boiler is limited to the service permitted by the method of fabrication having the most restrictive requirements.

PG-18 DESIGN VALIDATION BY PROOF TEST

Where no rules are given for calculating the strength of a boiler or any part thereof, the Manufacturer may establish MAWP by testing a full-size sample in accordance with A-22, Proof Tests to Establish Maximum Allowable Working Pressure.

PG-19 COLD FORMING OF AUSTENITIC MATERIALS[3] (23)

PG-19.1 The cold-formed areas of pressure-retaining components manufactured of austenitic alloys shall be heat treated for 20 min per inch of thickness or for 10 min, whichever is greater, at the temperatures given in Table PG-19 when both of the following conditions exist:

(a) the finishing-forming temperature is below the minimum heat-treating temperature given in Table PG-19

(b) the design metal temperature and the forming strains exceed the limits shown in Table PG-19.

PG-19.2 Forming strains shall be calculated as follows:

(a) Cylinders formed from plate

$$\%Strain = \frac{50t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

(b) Spherical or dished heads formed from plate

$$\%Strain = \frac{75t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

(c) Tube and pipe bends

$$\%Strain = \frac{100r}{R}$$

where

R = nominal bending radius to centerline of pipe or tube
r = nominal outside radius of pipe or tube
R_f = mean radius after forming
R_o = original mean radius (equal to infinity for a flat plate)

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Table PG-19
Post Cold-Forming Strain Limits and Heat-Treatment Requirements for Austenitic Materials and Nickel-Based Alloys (23)

Grade	UNS Number	Limitations in Lower Temperature Range					Limitations in Higher Temperature Range			Minimum Heat-Treatment Temperature When Design Temperature and Forming Strain Limits Are Exceeded [Notes (1), (2)]	
		For Design Temperature									
		Exceeding		But Less Than or Equal to		And Forming Strains Exceeding	For Design Temperature Exceeding		And Forming Strains Exceeding		
		°F	°C	°F	°C		°F	°C		°F	°C
304	S30400	1,075	580	1,250	675	20%	1,250	675	10%	1,900	1 040
304H	S30409	1,075	580	1,250	675	20%	1,250	675	10%	1,900	1 040
...	S30432	1,000	540	1,250	675	15%	1,250	675	10%	2,000	1 095
304N	S30451	1,075	580	1,250	675	15%	1,250	675	10%	1,900	1 040
309S	S30908	1,075	580	1,250	675	20%	1,250	675	10%	2,000	1 095
310H	S31009	1,075	580	1,250	675	20%	1,250	675	10%	2,000	1 095
310S	S31008	1,075	580	1,250	675	20%	1,250	675	10%	2,000	1 095
310HCbN	S31042	1,000	540	1,250	675	15%	1,250	675	10%	2,000	1 095
316	S31600	1,075	580	1,250	675	20%	1,250	675	10%	1,900	1 040
316H	S31609	1,075	580	1,250	675	20%	1,250	675	10%	1,900	1 040
316N	S31651	1,075	580	1,250	675	15%	1,250	675	10%	1,900	1 040
321	S32100	1,000	540	1,250	675	15% [Note (3)]	1,250	675	10%	1,900	1 040
321H	S32109	1,000	540	1,250	675	15% [Note (3)]	1,250	675	10%	2,000	1 095
347	S34700	1,000	540	1,250	675	15%	1,250	675	10%	1,900	1 040
347H	S34709	1,000	540	1,250	675	15%	1,250	675	10%	2,000	1 095
347HFG	S34710	1,000	540	1,250	675	15%	1,250	675	10%	2,150	1 175
348	S34800	1,000	540	1,250	675	15%	1,250	675	10%	1,900	1 040
348H	S34809	1,000	540	1,250	675	15%	1,250	675	10%	2,000	1 095
...	N06230	1,100	595	1,400	760	15%	1,400	760	10%	2,200	1 205
600	N06600	1,075	580	1,200	650	20%	1,200	650	10%	1,900	1 040
601	N06601	1,075	580	1,200	650	20%	1,200	650	10%	1,900	1 040
617	N06617	1,200	650	1,400	760	15%	1,400	760	10%	2,100	1 150
690	N06690	1,075	580	1,200	650	20%	1,200	650	10%	1,900	1 040
800	N08800	1,100	595	1,250	675	15%	1,250	675	10%	1,800	980
800H	N08810	1,100	595	1,250	675	15%	1,250	675	10%	2,050	1 120
...	N08811	1,100	595	1,250	675	15%	1,250	675	10%	2,100	1 150
...	S30815	1,075	580	1,250	675	15%	1,250	675	10%	1,920	1 050
...	N06022	1,075	580	1,250	675	15%	...	...	...	2,050	1 120

GENERAL NOTE: The limits shown are for cylinders formed from plates, spherical or dished heads formed from plate, and tube and pipe bends. When the forming strains cannot be calculated as shown in PG-19.2, the forming strain limits shall be half those tabulated in this table (see PG-19.3).

NOTES:
(1) Rate of cooling from heat-treatment temperature not subject to specific control limits.
(2) While minimum heat-treatment temperatures are specified, it is recommended that the heat-treatment temperature range be limited to 150°F (85°C) above that minimum, and 250°F (140°C) for 310HCbN, 347, 347H, 348, and 348H.
(3) For simple bends of tubes or pipes whose outside diameter is less than 3.5 in. (89 mm), this limit is 20%.

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(23)

Table PG-20
Post Cold-Forming Strain Limits and Heat-Treatment Requirements

Grade	UNS Number	Limitations in Lower Temperature Range: For Design Temperature Exceeding °F	Exceeding °C	But Less Than or Equal to °F	But Less Than or Equal to °C	And Forming Strains	Limitations in Higher Temperature Range: For Design Temperature Exceeding °F	Exceeding °C	And Forming Strains	Required Heat Treatment When Design Temperature and Forming Strain Limits Are Exceeded
91	K90901	1,000	540	1,115	600	>25%	1,115	600	>20%	Normalize and temper [Note (1)]
		1,000	540	1,115	600	>5 to ≤25%	1,115	600	>5 to ≤20%	Postbend heat treatment [Notes (2)–(4)]

GENERAL NOTE: The limits shown are for cylinders formed from plates, spherical or dished heads formed from plate, and tube and pipe bends. The forming strain limits tabulated in the table shall be divided by two if PG-19.3 is applied. For any material formed at 1,300°F (705°C) or above, and for cold swages, flares, or upsets, normalizing and tempering is required regardless of the amount of strain.

NOTES:
(1) Normalization and tempering shall be performed in accordance with the requirements in the base material specification, and shall not be performed locally. The material shall either be heat treated in its entirety, or the cold strained area (including the transition to the unstrained portion) shall be cut away from the balance of the tube or component and heat treated separately or replaced.
(2) Postbend heat treatments shall be performed at 1,350°F to 1,445°F (730°C to 785°C) for 1 hr/in. (1 h/25 mm) or 30 min minimum. Alternatively, a normalization and temper in accordance with the requirements in the base material specification may be performed.
(3) For materials with greater than 5% strain but less than or equal to 25% strain with design temperatures less than or equal to 1,115°F (600°C), if a portion of the component is heated above the heat treatment temperature allowed above, one of the following actions shall be performed:
(a) The component in its entirety must be renormalized and tempered.
(b) The allowable stress shall be that for Grade 9 material (i.e., SA-213 T9, SA-335 P9, or equivalent product specification) at the design temperature, provided that portion of the component that was heated to a temperature exceeding the maximum holding temperature is subjected to a final heat treatment within the temperature range and for the time required in [Note (2)] above. The use of this provision shall be noted on the Manufacturer's Data Report in accordance with PG-5.6.1(c)(1).
(4) If a longitudinal weld is made to a portion of the material that is cold strained, that portion shall be normalized and tempered, prior to or following welding. This normalizing and tempering shall not be performed locally.

t = nominal thickness of the plate, pipe, or tube before forming

PG-19.3 When the forming strains cannot be calculated as shown in PG-19, the manufacturer shall have the responsibility to determine the maximum forming strain.

PG-19.4 For flares, swages, or upsets, heat treatment in accordance with Table PG-19 shall apply, regardless of the amount of strain.

PG-19.5 If the finishing-forming temperature is above the minimum heat-treating temperature given in Table PG-19, postforming heat treatment required by this paragraph is not mandatory.

PG-20 COLD FORMING OF CARBON, CARBON-MOLYBDENUM, AND CREEP STRENGTH ENHANCED FERRITIC STEELS

The cold-formed areas of pressure-retaining components manufactured of carbon steel, carbon-molybdenum steel, and creep strength enhanced ferritic steel alloys shall be heat treated and examined as described below and as listed in Table PG-20, as applicable. Cold forming is defined as any forming method that is performed at a temperature below 1,300°F (705°C) and produces strain in the material. The calculations of strain shall be made in accordance with PG-19.

PG-20.1 Carbon and Carbon-Molybdenum Tube and Pipe. Postforming heat treatment of carbon and carbon-molybdenum tube and pipe cold-formed bends that convey water or steam is required as specified in this paragraph. Tube and pipe that convey fluids or vapor other than water or steam are exempted from these rules. (See Part PTFH for alternate fluids.)

Postforming heat treatment shall consist of either a subcritical anneal performed at a temperature of at least 1,250°F (675°C), a full anneal, or a normalizing heat treatment, held for at least 30 min/in. (30 min/25 mm) of thickness but not less than 10 min. (See SA-941 for definition of heat treatments.) The heat treatment may be performed locally, provided the entire strained area of the cold-formed bend is subjected to the required heat treatment.

The following paragraphs define requirements based on boiler location, strain, and material condition and shall be considered.

PG-20.1.1 The cold-formed areas of carbon and carbon-molybdenum tube and pipe that convey water or steam shall be heat treated after cold forming when all of the following conditions are met:

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(a) when the tube and pipe are located external to the boiler membraned wall or boiler metal encased enclosure.

(b) when the design temperature of the cold-formed areas is between 620°F (327°C) and 750°F (399°C).

(c) when strain developed in the cold-formed areas exceeds 12½% when the straight tube or pipe starting material to be formed is in the subcritical annealed, full annealed, or normalized heat treated condition. Alternately, when strain developed in the cold-formed areas exceeds 5% when the straight tube or pipe starting material to be formed is in the unheat treated condition as defined below.

Some permissible material specifications allow the supply and use of tube and pipe material in the unheat treated condition, corresponding to the material condition ascooled off the tube or pipe hot mill with no further heat treatment, as produced by the tube or pipe manufacturer, often referred to as the hot-finished heat-treated condition. Allowable cold strain for this starting material is restricted to the smaller 5% strain before postforming heat treatment.

PG-20.1.2 The postforming heat treatment of carbon steel only, meeting all the conditions specified in PG-20.1.1, may be avoided when all of the following conditions are met:

(a) The tube or pipe material in the area to be cold formed had been subjected to an anneal or normalize heat treatment (see SA-941 for definition of heat treatments) prior to forming, and

(b) The entire bend area is subjected to a magnetic particle examination over 100% of the bend region between the bend tangents in accordance with Nonmandatory Appendix A, A-260, except that the following acceptance standard applies. Any relevant linear indication found during this examination that exceeds ⅛ in. (3 mm) in the longest direction shall be removed using a mechanical abrasive removal method and the abraded area reexamined. If the ground cavity results in a local thickness that is less than the required design minimum thickness, weld repair of the thinned area is permitted with a compatible filler metal. The cavity shall be examined in accordance with PW-40.3.1, and welded in accordance with Section IX and PW-28. The repair weld must be subjected to a postweld heat treatment in accordance with the requirements of PW-39 for that material. Postweld heat treatment exemptions do not apply.

PG-20.2 Creep Strength Enhanced Ferritic Material. Postforming heat treatment of creep strength enhanced material shall be in accordance with Table PG-20.

PG-21 MAXIMUM ALLOWABLE WORKING PRESSURE

The maximum allowable working pressure is the pressure determined by employing the allowable stress values, design rules, and dimensions designated in this Section.

Whenever the term maximum allowable working pressure is used in this Section of the Code, it refers to gage pressure, or the pressure above atmosphere.

PG-21.1 No boiler, except a forced-flow steam generator with no fixed steam and water line that meets the special provisions of PG-67, shall be operated at a pressure higher than the maximum allowable working pressure except when the pressure relief valve or valves are discharging, at which time the maximum allowable working pressure shall not be exceeded by more than 6%.

PG-21.2 Expected maximum sustained conditions of pressure and temperature are intended to be selected sufficiently in excess of any expected operating conditions (not necessarily continuous) to permit satisfactory boiler operation without operation of the overpressure protection devices.

PG-21.3 In a forced-flow steam generator with no fixed steam and waterline it is permissible to design the pressure parts for different pressure levels along the path of water-steam flow. The maximum allowable working pressure of any part shall be not less than that required by the rules of Part PG for the expected maximum sustained conditions of pressure and temperature to which that part is subjected except when one or more of the overpressure protection devices covered by PG-67.4 is in operation.

PG-21.4 Components With Multiple Design Conditions.

PG-21.4.1 Components with multiple design conditions may be designed considering the coincident pressures and temperatures if all of the conditions specified in PG-21.4.1.1 through PG-21.4.2 are met.

PG-21.4.1.1 The component shall be designed for the most severe condition of coincident pressure and temperature expected to be sustained during operation that results in the greatest calculated thickness for the pressure part and that will not exceed the maximum temperature or the maximum allowable stress permitted in Section II, Part D for the material.

PG-21.4.1.2 The design requirements of this Section shall be met for each design condition (coincident pressure and temperature).

PG-21.4.1.3 The maximum allowable working pressure (MAWP) selected for the part shall be sufficiently in excess of the highest pressure of the multiple design conditions to permit satisfactory boiler operation without operation of the overpressure protection

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device(s). Each design condition (coincident pressure and temperature) shall be reported on the Manufacturer's Data Report.

PG-21.4.2 Definitions.

coincident pressure and temperature: a specific combination of pressure and temperature that is coincident with a specific normal operating condition.

normal operating condition: a sustained (or steady-state) condition that is a stable mode of operation of the boiler (not a transient condition).

start-up and shutdown: transient condition of the boiler to bring it from a cold condition or low-load condition to a normal operating condition or to a shutdown condition.

sustained condition: a steady-state normal operating condition whose duration in time is significant and long running.

transient condition: a controlled transitional mode of operating the boiler to bring it from one steady-state condition of temperature and pressure to another steady-state condition of temperature and pressure.

PG-22 LOADINGS

PG-22.1 Stresses due to hydrostatic head shall be taken into account in determining the minimum thickness required unless noted otherwise. This Section does not fully address additional loadings other than those from working pressure or static head. Consideration shall be given to such additional loadings (see PG-16.1).

PG-22.2 Loading on structural attachments — refer to PG-56.

PG-23 STRESS VALUES FOR CALCULATION FORMULAS

PG-23.1 The maximum allowable stress values in Section II, Part D, Subpart 1, Tables 1A and 1B, are the unit stresses to be used in the equations of this Section to calculate the minimum required thickness or the maximum allowable working pressure of the pressure part (see Section II, Part D, Mandatory Appendix 1).

PG-23.2 The yield strength values for use in PG-28.3 may be found in Section II, Part D, Subpart 1, Table Y-1.

PG-23.3 With the publication of the 2004 Edition, Section II, Part D is published as two separate publications. One publication contains values only in U.S. Customary units and the other contains values only in SI units. The selection of the version to use is dependent on the set of units selected for analysis.

PG-25 QUALITY FACTORS FOR STEEL CASTINGS

A quality factor as specified below shall be applied to the allowable stresses for steel casting materials given in Section II, Part D, Subpart 1, Table 1A.

PG-25.1 A factor not to exceed 80% shall be applied when a casting is inspected only in accordance with the minimum requirements of the specification for the material, except when the special methods of examination prescribed by the selected specification are followed, thus permitting the use of the applicable higher factor in this paragraph.

PG-25.2 A factor not to exceed 100% shall be applied when the casting meets the requirements of PG-25.2.1 through PG-25.2.4.

PG-25.2.1 All steel castings $4\frac{1}{2}$ in. (114 mm) nominal body thickness or less, other than steel flanges and fittings complying with ASME B16.5, and valves complying with ASME B16.34, shall be examined as specified in PG-25.2.1.1 through PG-25.2.1.5.

PG-25.2.1.1 All critical areas, including the junctions of all gates, risers, and abrupt changes in section or direction and weld-end preparations, shall be radiographed in accordance with Section V, Article 2, and the radiographs shall conform to the requirements of ASTM E446 or ASTM E186, depending upon the section thickness. The maximum acceptable severity level for 100% quality factor shall be

(a) For ASTM E446

Imperfection Category	Severity Level: Up to and Including 1 in. (25 mm) Thick	Severity Level: Greater Than 1 in. (25 mm) Thick
A	1	2
B	2	3
C Types 1, 2, 3, and 4	1	3
D, E, F, and G	None acceptable	None acceptable

(b) For ASTM E186

Imperfection Category	Severity Level
A and B, Types 1 and 2 of C	2
Type 3 of C	3
D, E, and F	None acceptable

PG-25.2.1.2 All surfaces of each casting, including machined gasket seating surfaces, shall be examined after heat treatment by the magnetic particle method in accordance with PG-25.2.1.2.1 or by the liquid penetrant method in accordance with PG-25.2.1.2.2.

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PG-25.2.1.2.1 The technique for magnetic particle examination shall be in accordance with Section V, Article 7. Imperfections causing magnetic particle indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III, and exceeding degree 1 of Types IV and V of ASTM E125 are unacceptable.

PG-25.2.1.2.2 The technique for liquid penetrant examination shall be in accordance with Section V, Article 6. Surface indications determined by liquid penetrant examination are unacceptable if they exceed the following:

(a) all cracks and hot tears

(b) any group of more than six linear indications other than those in (a) in any rectangular area of 1½ in. × 6 in. (38 mm × 150 mm) or less, or any circular area having a diameter of 3½ in. (89 mm) or less, these areas being taken in the most unfavorable location relative to the indications being evaluated

(c) other linear indications more than ¼ in. (6 mm) long for thicknesses up to ¾ in. (19 mm) inclusive, more than one-third of the thickness in length for thicknesses from ¾ in. to 2¼ in. (19 mm to 57 mm), and more than ¾ in. (19 mm) long for thicknesses over 2¼ in. (57 mm) (Aligned acceptable indications separated from one another by a distance equal to the length of the longer indication are acceptable.)

(d) all indications of nonlinear imperfections that have any dimension exceeding 3⁄16 in. (5 mm)

PG-25.2.1.3 Where more than one casting of a particular design is produced, each of the first five castings shall be examined as above. Where more than five castings are being produced, the examination shall be performed on the first five plus one additional casting to represent each five additional castings. If this additional casting proves to be unacceptable, each of the remaining castings in the group shall be examined.

PG-25.2.1.4 Any indications in excess of the maximum permitted in PG-25.2.1.1 and PG-25.2.1.2 shall be cause for rejection unless the casting is repaired by welding after the base metal has been examined to ensure that the imperfection has been removed or reduced to an acceptable size. The completed repair shall be subject to reexamination by the same method as was used in the original examination and the repaired casting shall be postweld heat treated.

PG-25.2.1.5 All welding shall be performed using welding procedures qualified in accordance with Section IX. The procedure qualification shall be performed on test specimens of cast material of the same specification and subjected to the same heat treatment before and after welding as will be applied to the work. All welders and operators performing this welding shall also be qualified in accordance with Section IX.

PG-25.2.2 All steel castings having a body greater than 4½ in. (114 mm) nominal thickness shall be examined as specified in PG-25.2.2.1 through PG-25.2.2.6.

PG-25.2.2.1 All surfaces of each casting, including machined gasket seating surfaces, shall be examined after heat treatment by the magnetic particle method in accordance with PG-25.2.1.2.1 or liquid penetrant method in accordance with PG-25.2.1.2.2.

PG-25.2.2.2 All parts of castings shall be subjected to complete radiographic examination in accordance with Section V, Article 2, and the radiographs shall conform to the requirements of ASTM E280.

The maximum acceptable severity level for a 100% quality factor shall be

Imperfection Category	Severity Level
A, B, and Types 1, 2, and 3 of C	2
D, E, and F	None acceptable

PG-25.2.2.3 Any indications in excess of the maximum permitted in PG-25.2.2.1 and PG-25.2.2.2 are unacceptable. The casting may be repaired by welding after the base metal has been magnetic particle or liquid penetrant examined to ensure that the imperfection has been removed or reduced to an acceptable size.

PG-25.2.2.4 All weld repairs of depth exceeding 1 in. (25 mm) or 20% of the section thickness, whichever is less, shall be examined by radiography in accordance with PG-25.2.2.2 and by magnetic particle or liquid penetrant examination of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 1 in. (25 mm), whichever is less, and all weld repairs of sections which cannot be effectively radiographed shall be examined by magnetic particle or liquid penetrant examination of the first layer, of each ¼ in. (6 mm) thickness of deposited weld metal and of the finished weld surface. Magnetic particle or liquid penetrant examination of the finished weld surface shall be performed after postweld heat treatment.

PG-25.2.2.5 When repair welding is done after heat treatment of the casting, the casting shall be postweld heat treated.

PG-25.2.2.6 All welding shall be performed using welding procedures qualified in accordance with Section IX. The procedure qualification shall be performed on test specimens of cast material of the same specification and subjected to the same heat treatment before and after welding as will be applied to the work. All welders and operators performing this welding shall also be qualified in accordance with Section IX.

PG-25.2.3 Identification and Marking. Each casting to which a quality factor greater than 80% is applied shall be marked with the name, trademark, or other traceable

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identification of the manufacturer and the casting identification, including the casting quality factor and material designation.

PG-25.2.4 Personnel performing radiographic, magnetic particle, or liquid penetrant examinations under this paragraph shall be qualified in accordance with their employer's written practice. SNT-TC-1A[4] or CP-189 shall be used as a guideline for employers to establish their written practice for qualification and certification of their personnel. If the techniques of computed radiography (CR) or digital radiography (DR) are used, the training, experience, and examination requirements in Section V, Article 1, Mandatory Appendix II shall also be included in the employer's written practice for each technique as applicable.

When personnel have been certified according to their employer's written practice based upon an edition of SNT-TC-1A or CP-189 earlier than that referenced in A-360, their certification shall be valid for performing nondestructive examination required by this Section until their next scheduled recertification. Any recertifications, reexaminations, or new examinations shall be performed to the employer's written practice based on the edition of SNT-TC-1A or CP-189 referenced in A-360.

PG-26 WELD JOINT STRENGTH REDUCTION FACTOR

At elevated temperatures, the long-term strength of weld joints can be lower than the long-term strength of the base material. Table PG-26 specifies a weld joint strength reduction factor, w, to be used to account for this lower long-term strength in determining the required thickness of components operating in the creep range. This factor shall be applied in the design of cylinders containing longitudinal butt welds and to hemispherical heads or any other spherical sections that comprise segments joined by welding. As defined in PW-11.2, longitudinal butt welds shall be interpreted to include spiral (helical) welds. Weld strength reduction factors apply to such seams made by any welding process, with or without filler metal added, regardless whether the welding is performed as part of material manufacture or by the Certificate Holder as part of Section I fabrication. The designer is responsible for determining the applicability of weld joint strength reduction factors to other (e.g., circumferential) welds. The weld joint strength reduction factor is not required when evaluating occasional loads, such as wind and earthquake.

PG-27 CYLINDRICAL COMPONENTS UNDER INTERNAL PRESSURE

PG-27.1 General. Unless the requirements of A-317 of Nonmandatory Appendix A are selected, the equations under this paragraph shall be used to determine the minimum required thickness or the maximum allowable working pressure of piping, tubes, drums, Shells, and headers in accordance with the appropriate dimensional categories as given in PG-27.2.1 and PG-27.2.2 for temperatures not exceeding those given for the various materials listed in Section II, Part D, Subpart 1, Tables 1A and 1B.

The calculated and ordered thickness of material must include the requirements of PG-16.3, PG-16.4, and PG-16.5. Stress calculations must include the loadings as defined in PG-22 unless the formula is noted otherwise.

When required by the provisions of this Code, allowance must be provided in material thickness for threading and minimum structural stability (see PG-27.4.3, PG-27.4.5, and PWT-9.2).

If local thin areas are present in cylindrical shells, the required thickness may be less than the thickness determined in PG-27 provided the requirements of Mandatory Appendix IV are met.

PG-27.2 Equations for Calculation.

PG-27.2.1 Tubing — Up to and Including 5 in. (125 mm) Outside Diameter. The equations below apply primarily to tubing used in applications such as boiler tubes, superheater and reheater tubes, and economizer tubes in which groups of such tubular elements are arranged within some enclosure for the purpose of transferring heat through the tubes. Pipe used in a tubing application may be designed using the equations provided in this paragraph.

For plain tubes or bimetallic tubes when the strength of clad is not included,[5] use the following equations:

$$t = \frac{PD}{2Sw + P} + 0.005D + e$$

$$P = Sw\left[\frac{2t - 0.01D - 2e}{D - (t - 0.005D - e)}\right]$$

See PG-27.4.2, PG-27.4.4, PG-27.4.7 through PG-27.4.9.

For bimetallic tubes when the strength of the clad is included,[5] use the following equations:

$$tb + tc' = \frac{PD}{2Sb + P} + 0.005D + e$$

$$tc' = tc\left[\frac{Sc}{Sb}\right]$$

$$t = tb + tc$$

$$P = Sb\left[\frac{2(tb + tc') - 0.01D - 2e}{D - [(tb + tc') - 0.005D - e]}\right]$$

See PG-27.4.4, and PG-27.4.7 through PG-27.4.10.

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Table PG-26
Weld Strength Reduction Factors to Be Applied When Calculating Maximum Allowable Working Pressure or Minimum Required Thickness of Components Fabricated With a Longitudinal Seam Weld

Temperature,°F	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	1,250	1,300	1,350	1,400	1,450	1,500	1,550	1,600	1,650
Temperature,°C	371	399	427	454	482	510	538	566	593	621	649	677	704	732	760	788	816	843	871	899
Steel Group	Weld Strength Reduction Factor [Notes (1)–(6)]																			
C-Mo [Note (7)]	...	...	...	1.00	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Cr-Mo [Notes (8), (9)]	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64	NP	NP	NP	NP	NP	NP	NP	NP	NP
CSEF (N + T) [Notes (9), (10), (11)]	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77	NP	NP	NP	NP	NP	NP	NP	NP	NP
CSEF (subcrit.) [Notes (9), (11), (12)]	...	...	...	...	1.00	0.50	0.50	0.50	0.50	0.50	0.50	NP	NP	NP	NP	NP	NP	NP	NP	NP
Austenitic stainless steels and alloys 800H (N08810 and N08811) [Notes (13), (14)]	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64	0.59	0.55	0.50	NP	NP	NP
Autogenously welded austenitic stainless [Note (15)]	...	...	...	...	...	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	NP	NP	NP
Nickel base alloys																				
N06045	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64	0.59	0.55	0.50	0.50	0.50	0.50	NP	NP	NP
N06600	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64	NP	NP	NP	NP	NP	NP	NP	NP	NP
N06690	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	NP	NP	NP	NP	NP	NP	NP	NP	NP
N06601	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64	0.59	0.55	0.50	0.50	0.50	0.50	0.50
N06025	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64	0.59	0.55	0.50	0.50	0.50	0.50
N10276	...	...	...	...	...	1.00	0.95	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
N06022	...	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77	NP	NP	NP	NP	NP	NP	NP	NP
N06230	...	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
N06625	...	...	...	...	...	...	...	...	1.00	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
N06617 (except SAW) [Note (16)]	...	...	...	...	...	...	...	...	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
N06617 (SAW) [Note (17)]	...	...	...	...	...	...	...	...	1.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
N07740	...	...	...	...	...	...	...	...	1.00	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	NP	NP	NP
Autogenously welded nickel base alloys [Note (15)]	...	...	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

GENERAL NOTE: Nothing in this table shall be construed to permit materials that are not permitted by PG-5 through PG-9 of this Section or to permit use of materials at temperatures beyond limitations established by this Section. Several materials covered by this table are currently permitted for Section I application only via code case.

NOTES:

(1) Cautionary Note: There are many factors that may affect the life of a welded joint at elevated temperature, and all of those factors cannot be addressed in a table of weld strength reduction factors. For example, fabrication issues such as the deviation from a true circular form in pipe (e.g., "peaking" at longitudinal weld seams) or offset at the weld joint can cause an increase in stress that may result in reduced service life, and control of these deviations is recommended.

(2) NP = not permitted.

(3) Components made from carbon steel are exempt from the requirements of PG-26 and Table PG-26.

(4) Longitudinal seam welds in components made from materials not covered in this table operating in the creep regime are not permitted. For the purposes of this table, the creep regime temperature range is defined to begin at a temperature 50°F (25°C) below the T-note temperature listed in Section II, Part D design property tables for the base material involved.

(5) All weld filler metal shall have a minimum carbon content of 0.05% for the Cr-Mo and CSEF materials and a minimum carbon content of 0.04% for the austenitic stainless steels.

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Table PG-26
Weld Strength Reduction Factors to Be Applied When Calculating Maximum Allowable Working Pressure or Minimum Required Thickness of Components Fabricated With a Longitudinal Seam Weld (Cont'd)

NOTES: (Cont'd)

(6) At temperatures below those where WSRFs are tabulated, a value of 1.0 shall be used for the factor *w* where required by the rules of this Section; however, the additional rules of this table and notes do not apply.

(7) Longitudinal seam fusion welded construction is not permitted for C–½ Mo steel above 850°F (454°C).

(8) The Cr-Mo steels include ½Cr–½Mo, 1Cr–½Mo, 1¼Cr–½Mo–Si, 2¼Cr–1Mo, 3Cr–1Mo, and 5Cr–½Mo. Longitudinal welds shall either be normalized, normalized and tempered, or subjected to proper subcritical PWHT for the alloy.

(9) Basicity index of SAW flux ≥ 1.0.

(10) N + T = normalizing + tempering PWHT.

(11) The CSEF (creep strength enhanced ferritic) steels include Grades 91, 92, 911, 122, and 23.

(12) subcrit. = subcritical PWHT is required. No exemptions from PWHT are permitted. The PWHT time and temperature shall meet the requirements of Tables PW-39-1 through PW-39-14; the alternative PWHT requirements of Table PW-39.1 are not permitted.

(13) Certain heats of the austenitic stainless steels, particularly for those grades whose creep strength is enhanced by the precipitation of temper-resistant carbides and carbo-nitrides, can suffer from an embrittlement condition in the weld heat-affected zone that can lead to premature failure of welded components operating at elevated temperatures. A solution annealing heat treatment of the weld area mitigates this susceptibility.

(14) Alternatively, the following factors may be used as the weld joint strength reduction factor for the materials and welding consumables specified, provided the weldment is solution annealed after welding.

	Weld Strength Reduction Factor					
Materials	**950°F (510°C)**	**1,000°F (538°C)**	**1,050°F (566°C)**	**1,100°F (593°C)**	**1,150°F (621°C)**	**1,200°F (649°C)**
Type 304 stainless steel welded with SFA-5.22 EXXXT-G (16-8-2 chemistry), SFA 5.4E 16-8-2, and SFA-5.9 ER 16-8-2	1.00	1.00	1.00	1.00	1.00	1.00
Type 316 stainless steel welded with SFA-5.22 EXXXT-G (16-8-2 chemistry), SFA 5.4 E 16-8-2, and SFA-5.9 ER 16-8-2	1.00	0.85	0.90	0.97	0.99	1.00

(15) Autogenous welds (made without weld filler metal) have been assigned a WSRF of 1.0 for austenitic SS materials up to 1,500°F (816°C) and for nickel base alloys up to 1,650°F (899°C), provided that the product is solution annealed after welding and receives nondestructive electric examination, in accordance with the material specification.

(16) Includes autogenous and SMAW, GTAW, and GMAW filler metal welds.

(17) SAW filler metal welds.

PG-27.2.1.2 The wall thickness of the ends of tubes strength-welded to headers or drums need not be made greater than the run of the tube as determined by these equations.

PG-27.2.1.3 The wall thickness of the ends of tubes permitted to be attached by threading under the limitations of PWT-9.2 shall be not less than t as determined by this formula, plus $0.8/n$ $(20/n)$, where n equals the number of threads per inch (per mm).

PG-27.2.1.4 A tube in which a fusible plug is to be installed shall be not less than 0.22 in. (5.6 mm) in thickness at the plug in order to secure four full threads for the plug (see also A-20).

PG-27.2.1.5 Bimetallic tubes for which the strength of the clad is not included and meeting the requirements of PG-9.4 shall use an outside diameter, D, in the appropriate equation in PG-27.2.1 no less than the calculated outside diameter of the core material. The outside diameter of the core material shall be determined by subtracting twice the minimum thickness of the cladding from the outside diameter of the bimetallic tube, including the maximum plus tolerance of the core tube. The minimum required thickness, t, shall apply only to the core material.

Tubes for which the strength of the clad is included and meeting the requirements of PG-9.4 shall use an outside diameter, D, in the appropriate equation in PG-27.2.1 equal to the outside diameter of the bimetallic tube, including the maximum plus tolerance for both the core tube diameter and clad thickness.

PG-27.2.2 Piping, Drums, Shells, and Headers. Based on strength of weakest course.

$$t = \frac{PD}{2SE + 2yP} + C \quad \text{or} \quad \frac{PR}{SE - (1 - y)P} + C$$

$$P = \frac{2SE(t - C)}{D - 2y(t - C)} \quad \text{or} \quad \frac{SE(t - C)}{R + (1 - y)(t - C)}$$

See PG-27.4.1, PG-27.4.3, and PG-27.4.5 through PG-27.4.8.

PG-27.3 Symbols. Symbols used in the preceding equations are defined as follows:

C = minimum allowance for threading and structural stability (see PG-27.4.3)
D = outside diameter of cylinder
E = efficiency (see PG-27.4.1)
e = thickness factor for expanded tube ends (see PG-27.4.4)
P = maximum allowable working pressure (see PG-21)
R = inside radius of cylinder; for pipe, the inside radius is determined by the outside radius minus the nominal wall thickness
S = maximum allowable stress value at the design temperature of the metal, as listed in the tables specified in PG-23 (see PG-27.4.2)
Sb = maximum allowable stress value at the design temperature of the base metal, as listed in the tables specified in PG-23, for a bimetallic tube in which the clad strength is to be included (see PG-27.4.10)
Sc = maximum allowable stress value at the design temperature of the clad metal, as listed in Section II, Part D, Subpart 1, Table 1A or Table 1B, for a bimetallic tube in which the clad strength is to be included (see PG-27.4.10)
t = minimum required thickness (see PG-27.4.7)
tb = minimum required thickness of the base metal for a bimetallic tube in which the clad strength is to be included (see PG-27.4.10)
tc = minimum required thickness of the clad for a bimetallic tube in which the clad strength is to be included (see PG-27.4.10)
tc' = minimum effective clad thickness for strength purposes for a bimetallic tube in which the clad strength is to be included (see PG-27.4.10)
w = weld joint strength reduction factor per PG-26
y = temperature coefficient (see PG-27.4.6)

PG-27.4 The following paragraphs apply to PG-27 equations as referenced.

PG-27.4.1

E = 1.0 for seamless cylinders without openings spaced to form ligaments
= the ligament efficiency per PG-52 or PG-53 for seamless cylinders with ligaments
= w, the weld joint strength reduction factor per PG-26, for longitudinally welded cylinders without ligaments

For longitudinally welded cylinders with ligaments located such that no part of the longitudinal weld seam is penetrated by the openings forming the ligament, E shall be taken as the lesser of w or the ligament efficiency from PG-52 or PG-53. If any part of the longitudinal seam weld is penetrated by the openings that form the ligaments, E shall be taken as the product of w times the ligament efficiency.

PG-27.4.2 The temperature of the metal to be used in selecting the S value for tubes shall not be less than the maximum expected mean wall temperature, i.e., the sum of the outside and inside tube surface temperatures divided by 2. For tubes that do not absorb heat, the metal temperature may be taken as the temperature of the fluid within the tube but not less than the saturation temperature.

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PG-27.4.3 Any additive thickness represented by the general term C may be considered to be applied on the outside, the inside, or both. It is the responsibility of the designer using these equations to make the appropriate selection of diameter or radius to correspond to the intended location and magnitude of this added thickness. The pressure- or stress-related terms in the formula should be evaluated using the diameter (or radius) and the remaining thickness which would exist if the "additive" thickness had not been applied or is imagined to have been entirely removed.

The values of C below do not include any allowance for corrosion and/or erosion, and additional thickness should be provided where they are applicable. Likewise, this allowance for threading and minimum structural stability is not intended to provide for conditions of misapplied external loads or for mechanical abuse.

Threaded Pipe [Note (1)]	Value of C, in. (mm) [Note (2)]
$D \le {}^{3}/_{4}$ in. (19 mm) nominal	0.065 (1.65)
$D > {}^{3}/_{4}$ in. (19 mm) nominal	Depth of thread h [Note (3)]

NOTES:
(1) Steel or nonferrous pipe lighter than Schedule 40 of ASME B36.10M, Welded and Seamless Wrought Steel Pipe, shall not be threaded.
(2) The values of C stipulated above are such that the actual stress due to internal pressure in the wall of the pipe is no greater than the values of S given in Section II, Part D, Subpart 1, Table 1A, as applicable in the equations.
(3) The depth of thread h in in. (mm) may be determined from the formula $h = 0.8/n$ ($h = 20/n$), where n is the number of threads per inch (25 mm) or from the following:

n	h
8	0.100 (2.5)
$11\frac{1}{2}$	0.0696 (1.77)

PG-27.4.4

e = 0.04 (1.0) over a length at least equal to the length of the seat plus 1 in. (25 mm) for tubes expanded into tube seats, except

= 0 for tubes expanded into tube seats provided the thickness of the tube ends over a length of the seat plus 1 in. (25 mm) is not less than the following:

(a) 0.095 in. (2.41 mm) for tubes $1\frac{1}{4}$ in. (32 mm) O.D. and smaller

(b) 0.105 in. (2.67 mm) for tubes above $1\frac{1}{4}$ in. (32 mm) O.D. and up to 2 in. (50 mm) O.D., incl.

(c) 0.120 in. (3.05 mm) for tubes above 2 in. (50 mm) O.D. and up to 3 in. (75 mm) O.D., incl.

(d) 0.135 in. (3.43 mm) for tubes above 3 in. (76 mm) O.D. and up to 4 in. (100 mm) O.D., incl.

(e) 0.150 in. (3.81 mm) for tubes above 4 in. (100 mm) O.D. and up to 5 in. (125 mm) O.D., incl.

= 0 for tubes strength-welded to tubesheets, headers, and drums. Strength-welded tubes shall comply with the minimum weld sizes of PW-16.

PG-27.4.5 While the thickness given by the formula is theoretically ample to take care of both bursting pressure and material removed in threading, when steel pipe is threaded and used for steam pressures of 250 psi (1.7 MPa) and over, it shall be seamless and of a weight at least equal to Schedule 80 in order to furnish added mechanical strength.

PG-27.4.6 (23)

y = a coefficient having values as follows:

Value of T_{TD} [Note (1)]	Values of y [Note (2)]		
	$y = 0.4$	$y = 0.5$	$y = 0.7$
$T_{TD} \le 900°F$ (480°C)	DT ≤ 900°F (480°C)	DT = 950°F (510°C)	DT ≥ 1,000°F (540°C)
$T_{TD} > 900°F$ (480°C)	DT ≤ T_{TD}	DT = T_{TD} + 50°F (28°C)	DT ≥ T_{TD} + 100°F (56°C)

GENERAL NOTE: DT = design temperature

NOTES:
(1) T_{TD} = the lowest lowest temperature value listed in the maximum allowable stress tables from Section II, Part D [see Notes – Time–Dependent Properties for respective table] at which the allowable stress values are obtained from time-dependent properties.
(2) Values of y between temperatures listed may be determined by interpolation.

Values of y between temperatures listed may be determined by interpolation. For nonferrous materials not listed, y = 0.4.

PG-27.4.7 If pipe is ordered by its nominal wall thickness, as is customary in trade practice, the manufacturing tolerance on wall thickness must be taken into account. After the minimum pipe wall thickness t is determined by the formula, this minimum thickness shall be increased by an amount sufficient to provide the maximum manufacturing tolerance allowed in the applicable pipe specification. The next heavier commercial wall thickness may then be selected from Standard thickness schedules as contained in ASME B36.10M. The manufacturing tolerances are given in the several pipe specifications listed in PG-9.

PG-27.4.8 When computing the allowable pressure for a pipe of a definite minimum wall thickness, the value obtained by the equations may be rounded up to the next higher unit of 10 psi (0.1 MPa).

PG-27.4.9 The maximum allowable working pressure P need not include the hydrostatic head loading, PG-22, when used in this equation.

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PG-27.4.10 The following requirements apply to bimetallic tubes when the strength of the clad is included. For additional fabrication requirements, see PW-44. For such bimetallic tubes, the thermal conductivity of the base metal shall be equal to or greater than the thermal conductivity of the clad material. The cladding process shall achieve a metallurgical bond between the clad and the base metal (core tube).

The temperature of the metal to be used in selecting the *Sb* value for core tubes shall not be less than the maximum expected mean wall temperature calculated using the base metal thermal properties for a tube with the same outside diameter and total wall thickness as the clad tube, i.e., the sum of the outside and inside tube surface temperature of an equivalent core tube, divided by 2.

The temperature of the metal to be used in selecting the *Sc* value for the clad shall not be less than the maximum expected mean wall temperature of the clad, i.e., the sum of the outside surface temperature and the base metal-clad interface temperature, divided by 2.

The value of *Sc* shall be taken as that for an annealed wrought material with nominally equivalent strength and composition as the clad. Values applicable to either Section I or Section VIII, Division 1 may be used. If two stress values are listed for a material, the higher value may be used.

The sizing equation is subject to the following constraints:

(a) $tb \geq tc$ (excludes clads thicker than core tube)

(b) $t < D/4$ (excludes thick-walled tubes)

(c) If $\left(\frac{Sc}{Sb}\right) \geq 1$, the ratio is set to 1 in the calculation

(d) If $\left(\frac{Sc}{Sb}\right) < 1$, the actual ratio is used in the calculation

PG-28 COMPONENTS UNDER EXTERNAL PRESSURE

PG-28.1 Thickness of Cylindrical Components Under External Pressure.

PG-28.1.1 Design Temperature shall be not less than the mean expected wall temperature.

PG-28.1.1.1 Temperatures in excess of the maximum temperature listed for each material given in Section II, Part D, Subpart 1, Tables 1A and 1B, are not permitted.

PG-28.1.1.2 Temperatures in excess of the maximum temperature given on the external pressure charts are not permitted.

PG-28.1.1.3 Rounding off equation results to the next higher unit of 10 is permitted (see PG-27.4.8).

PG-28.2 Welded Access or Inspection Openings Under External Pressure.

The maximum allowable working pressure for welded access or inspection openings, with inward projections subjected to external pressure (such as manhole or handhole rings with internal covers), may be determined in accordance with the rules of PG-27 when the following requirements are met. The length of the internal projection of the ring extending past the toe of the attachment weld on the ring, shall not exceed the thickness of the ring. The length past the toe of the weld is measured at the location of the shortest ring projection into the vessel (see Figure PG-28). For elliptical rings the value of *D* to be used in the procedures of PG-27 shall be determined in accordance with the following equation for elliptical rings:

$$D = a^2/b$$

where

a = outside major axis of the ellipse
b = outside minor axis of the ellipse

This provision does not apply to flanged in manholes covered by PG-29.3, PG-29.7, and PG-29.12.

PG-28.3 Maximum Allowable External Working Pressure for Cylindrical Components.

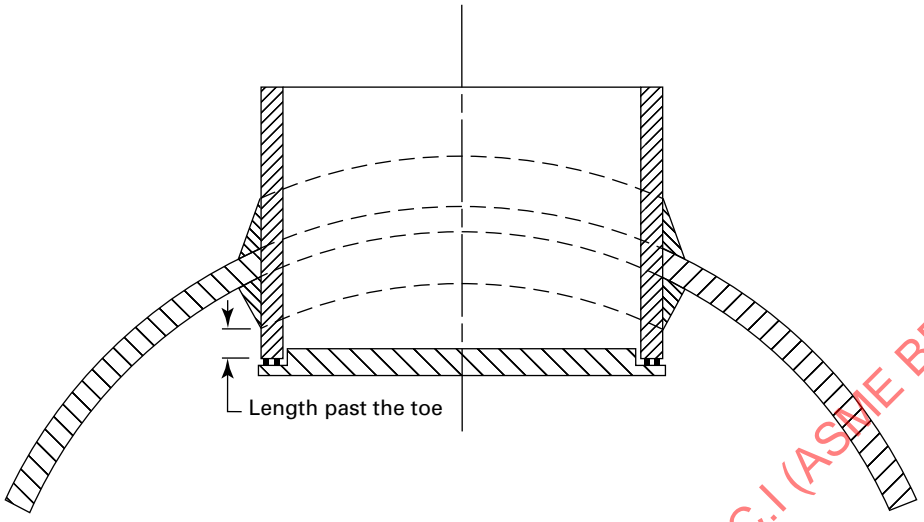
PG-28.3.1 The maximum allowable working pressure of cylindrical components under external pressure shall be as determined by the following rules. External pressure charts for use in determination of minimum requirements are given in Section II, Part D, Subpart 3. Figure numbers shown in this Article are contained in that Subpart. Section I includes design rules for stiffening rings for external pressure design for furnaces only (see PFT-17.11). For stiffening rings for other cylindrical components under external pressure, see PG-16.1.

PG-28.3.1.1 The following symbols are used in the procedures of this Article:

A = factor determined from Section II, Part D, Subpart 3, Figure G and used to enter the applicable material chart in Section II, Part D, for the case of cylinders having D_o/t values less than 10, see PG-28.3.1.2(b).
A_S = cross-sectional area of stiffening ring
B = factor determined from the applicable material chart in Section II, Part D, for maximum design metal temperature
D_o = outside diameter of cylindrical component
E = modulus of elasticity of material at design temperature. (For this value see the applicable materials chart in Section II, Part D. Interpolation may be made between the lines for intermediate temperatures.)

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Figure PG-28
Maximum Internal Projection of Welded Access or Inspection Openings



GENERAL NOTE: For other acceptable weld configurations, see Figure PW-16.1.

I_S = required moment of inertia of stiffening ring about its neutral axis parallel to the axis of the furnace

L = total length, of a cylindrical component between lines of support, or design length of a furnace taken as the largest of the following:

(a) the greatest center-to-center distance between any two adjacent stiffening rings

(b) the distance between the tubesheet and the center of the first stiffening (ring reinforced)

(c) the distance from the center of the first stiffening ring to a circumferential line on a formed head at one-third the depth from the head tangent line

L_s = one-half of the distance from the center line of the stiffening ring to the next line of support on one side, plus one-half of the center line distance to the next line of support on the other side of the stiffening ring, both measured parallel to the axis of the cylinder. (See PFT-17.11 for design of stiffening rings.) A line of support is

(a) a stiffening ring that meets the requirements of PFT-17.11

(b) a circumferential connection to a tubesheet or jacket for a jacketed section of a cylindrical shell

(c) a circumferential line on a formed head at one-third the depth of the head from the head tangent line

P = external design pressure

P_a = calculated value of allowable external working pressure for the assumed value of t

S = the maximum allowable stress value at design metal temperature

t = minimum required thickness of cylindrical components

t_S = nominal thickness of cylindrical components

PG-28.3.1.2 Cylindrical Components. The required minimum thickness of a cylindrical component under external pressure, either seamless or with longitudinal butt joints, shall be determined by the following procedure:

(a) cylinder having D_o/t values equal to or greater than 10

Step 1. Assume a value of t and determine the ratios L/D_o and D_o/t.

Step 2. Enter Section II, Part D, Subpart 3, Figure G at the value of L/D_o determined in Step 1. For values of L/D_o greater than 50, enter the chart at a value of $L/D_o = 50$. For values of L/D_o less than 0.05, enter the chart at a value of $L/D_o = 0.05$.

Step 3. Move horizontally to the line for the value of D_o/t determined in Step 1. Interpolation may be made for intermediate values of D_o/t; extrapolation is not permitted. From this point of intersection, move vertically downward to determine the value of Factor A.

Step 4. Using the value of A calculated in Step 3, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/temperature line for the design temperature. Interpolation may be made between lines for intermediate temperatures. If tabular values in Section II, Part D, Subpart 3 are used, linear interpolation or any other rational interpolation method may be used to determine a B value that lies between two adjacent tabular values for a specific temperature. Such

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interpolation may also be used to determine a B value at an intermediate temperature that lies between two sets of tabular values after first determining B values for each set of tabular values. In cases where the A value falls to the right of the end of the material temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. If tabular values are used, the last (maximum) tabulated value shall be used. For values of A falling to the left of the material/temperature line, see Step 7.

Step 5. From the intersection obtained in Step 4, move horizontally to the right and read the value of Factor B.

Step 6. Using the value of B, calculate the value of the maximum allowable external pressure, P_a, using the following equation:

$$P_a = \frac{4B}{3(D_o/t)}$$

Step 7. For values of A falling to the left of the applicable material/temperature line, the value of P_a shall be calculated using the following equation:

$$P_a = \frac{2\,AE}{3(D_o/t)}$$

If tabular values are used, determine B as in Step 4 and apply it to the equation in Step 6.

Step 8. Compare the calculated value of P_a obtained in Step 6 or Step 7 with P. If P_a is smaller than P, select a larger value for t and repeat the design procedure until a value of P_a is obtained that is equal to or greater than P.

(b) cylinders having D_o/t values of less than 10

Step 1. Using the same procedure as given in (a) above, obtain the value of B. For values of D_o/t less than 4, the value of A shall be calculated using the following equation:

$$A = \frac{1.1}{(D_o/t)^2}$$

For values of A greater than 0.10, use a value of 0.10.

Step 2. Using the value of B obtained in Step 1, calculate a value of P_{a1} using the following equation:

$$P_{a1} = \left[\frac{2.167}{D_o/t} - 0.0833\right] B$$

Step 3. Calculate a value of P_{a2} using the following equation:

$$P_{a2} = \frac{2S_B}{D_o/t}\left[1 - \frac{1}{D_o/t}\right]$$

where S_B is the lesser of 2 times the maximum allowable stress values at design metal temperature from Section II, Part D, Subpart 1, Tables 1A and 1B; or, 1.8 times the yield strength of the material at Design Metal Temperature from Section II, Part D, Subpart 1, Table Y-1.

Step 4. The smaller of the values of P_{a1} calculated in Step 2, or P_{a2} calculated in Step 3 shall be used for the maximum allowable external pressure P_a. If P_a is smaller than P, select a larger value for t and repeat the design procedure until a value for P_a is obtained that is equal to or greater than P.

PG-28.3.1.3 The design pressure or maximum allowable working pressure shall be not less than the maximum expected difference in operating pressure that may exist between the outside and the inside of the cylindrical component at any time.

PG-28.3.1.4 When necessary, furnaces shall be provided with stiffeners or other additional means of support to prevent overstress or large distortions under the external loadings listed in PG-22 other than pressure and temperature.

PG-29 DISHED HEADS

PG-29.1 The thickness of a blank unstayed dished head with the pressure on the concave side, when it is a segment of a sphere, shall be calculated by the following equation:

$$t = 5PL/4.8Sw$$

where

L = radius to which the head is dished, measured on the concave side of the head
P = maximum allowable working pressure (hydrostatic head loading need not be included)
S = maximum allowable working stress, using values given in Section II, Part D, Subpart 1, Table 1A
t = minimum thickness of head
w = weld joint strength reduction factor per PG-26

PG-29.1.1 If local thin areas are present in the spherical portion of the dished head, the required thickness may be less than the thickness determined in PG-29.1 provided the requirements of Mandatory Appendix IV are met.

PG-29.2 The radius to which a head is dished shall be not greater than the outside diameter of flanged portion of the head. Where two radii are used the longer shall be taken as the value of L in the equation.

PG-29.3 When a head dished to a segment of a sphere has a flanged-in manhole or access opening that exceeds 6 in. (150 mm) in any dimension, the thickness shall be increased by not less than 15% of the required thickness for a blank head computed by the above formula, but in no case less than ⅛ in. (3 mm) additional thickness over a blank head. Where such a dished head has a flanged opening supported by an attached flue, an increase in

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thickness over that for a blank head is not required. If more than one manhole is inserted in a head, the thickness of which is calculated by this rule, the minimum distance between the openings shall be not less than one-fourth of the outside diameter of the head.

PG-29.4 Except as otherwise provided for in PG-29.3, PG-29.7, and PG-29.12, all openings which require reinforcement, placed in a head dished to a segment of a sphere, or in an ellipsoidal head, or in a full-hemispherical head, including all types of manholes except those of the integral flanged-in type, shall be reinforced in accordance with the rules in PG-33.

When so reinforced, the thickness of such a head may be the same as for a blank unstayed head.

PG-29.5 Where the radius L to which the head is dished is less than 80% of the outside diameter of the head, the thickness of a head with a flanged-in manhole opening shall be at least that found by making L equal to 80% of the outside diameter of the head and with the added thickness for the manhole. This thickness shall be the minimum thickness of a head with a flanged-in manhole opening for any form of head and the maximum allowable working stress shall not exceed the values given in Section II, Part D, Subpart 1, Table 1A.

PG-29.6 No head, except a full-hemispherical head, shall be of a lesser thickness than that required for a seamless shell of the same diameter.

PG-29.7 A blank head of a semiellipsoidal form in which half the minor axis or the depth of the head is at least equal to one-quarter of the inside diameter of the head shall be made at least as thick as the required thickness of a seamless shell of the same diameter as provided in PG-27 or A-317. If a flanged-in manhole that meets the Code requirements is placed in an ellipsoidal head, the thickness of the head shall be the same as for a head dished to a segment of a sphere (see PG-29.1 and PG-29.5) with a dish radius equal to eight-tenths the outside diameter of the head and with the added thickness for the manhole as specified in PG-29.3.

PG-29.8 For heads made to an approximate ellipsoidal shape, the tolerance specified in PG-81 shall apply.

PG-29.9 Unstayed dished heads with the pressure on the convex side shall have a maximum allowable working pressure equal to 60% of that for heads of the same dimensions with the pressure on the concave side.

Head thicknesses obtained by using the equations in PG-29.11 for hemispherical heads and PG-29.7 for blank semiellipsoidal heads do not apply to heads with pressure on the convex side.

PG-29.11 The thickness of a blank unstayed full-hemispherical head with the pressure on the concave side shall be calculated by the following equation:

$$t = \frac{PL}{2Sw - 0.2P}$$

where

L = radius to which the head was formed, measured on the concave side of the head
P = maximum allowable working pressure
S = maximum allowable working stress, using values given in Section II, Part D, Subpart 1, Table 1A
t = minimum thickness of head
w = weld joint strength reduction factor per PG-26

The above equation shall not be used when the required thickness of the head given by this formula exceeds 35.6% of the inside radius, and instead, the following equation shall be used:

$$t = L\left(Y^{1/3} - 1\right)$$

where

$$Y = \frac{2(Sw + P)}{2Sw - P}$$

Joints in full-hemispherical heads including the joint to the shell shall be governed by and meet all the requirements for longitudinal joints in cylindrical shells, except that in a buttwelded joint attaching a head to a shell the middle lines of the plate thicknesses need not be in alignment.

If local thin areas are present in the full-hemispherical head, the required thickness may be less than the thickness determined above provided the requirements of Mandatory Appendix IV are met.

PG-29.12 If a flanged-in manhole that meets the Code requirements is placed in a full-hemispherical head, the thickness of the head shall be the same as for a head dished to a segment of a sphere (see PG-29.1 and PG-29.5), with a dish radius equal to eight-tenths the outside diameter of the head and with the added thickness for the manhole as specified in PG-29.3.

PG-29.13 The corner radius of an unstayed dished head measured on the concave side of the head shall be not less than three times the thickness of the material in the head; but in no case less than 6% of the outside diameter of the head. In no case shall the thinning-down due to the process of forming, of the knuckle portion of any dished head consisting of a segment of a sphere encircled by a part of a torus constituting the knuckle portion (torispherical), exceed 10% of the thickness required by the formula in PG-29.1. Other types of heads shall have a thickness after forming of not less than that required by the applicable equation.

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PG-29.14 If a dished head concave to pressure is formed with a flattened spot or surface, the diameter of the flat spot shall not exceed that allowable for flat heads as given by the equation in PG-31, using C = 0.25.

PG-30 STAYED DISHED HEADS

PG-30.1 When dished heads are of a thickness less than called for by PG-29, they shall be stayed as flat surfaces, no allowance being made in such staying for the holding power due to the spherical form unless all of the following conditions are met:

PG-30.1.1 That they be at least two-thirds as thick as called for by the rules for unstayed dished heads.

PG-30.1.2 That they be at least $^{7}/_{8}$ in. (22 mm) in thickness.

PG-30.1.3 That through-stays be used attached to the dished head by outside and inside nuts.

PG-30.1.4 That the maximum allowable working pressure shall not exceed that calculated by the rules for an unstayed dished head plus the pressure corresponding to the strength of the stays or braces secured by the formula for braced or stayed surfaces given in PG-46, using 1.3 for the value of C.

PG-30.2 If a stayed dished head concave to pressure is formed with a flattened spot or surface, the diameter of the flat spot shall not exceed that allowable for flat heads as given by the formula in PG-31, using C = 0.25.

PG-31 UNSTAYED FLAT HEADS AND COVERS

PG-31.1 The minimum thickness of unstayed flat heads, cover plates, and blind flanges shall conform to the requirements given in this paragraph. These requirements apply to both circular and noncircular[6] heads and covers. Some acceptable types of flat heads and covers are shown in Figure PG-31. In this figure, the dimensions of the welds do not include any allowances for corrosion and/or erosion; additional weld metal should be provided where these allowances are applicable.

PG-31.2 The notations used in this paragraph and in Figure PG-31 are defined as follows:

C = a factor depending on the method of attachment of head and on the shell, pipe, or header dimensions, and other items as listed in PG-31.4 below, dimensionless. The factors for welded covers also include a factor of 0.667 that effectively increases the allowable stress for such constructions to 1.5S.

D = long span of noncircular heads or covers measured perpendicular to short span

d = diameter, or short span, measured as indicated in Figure PG-31

h_G = gasket moment arm, equal to the radial distance from the center line of the bolts to the line of the gasket reaction, as shown in Figure PG-31, illustrations (j) and (k)

K = influence coefficient for Figure PG-31, illustration (s)
= 0.2 in. (5 mm)

L = perimeter of noncircular bolted head measured along the centers of the bolt holes

l = length of flange of flanged heads, measured from the tangent line of knuckle, as indicated in Figure PG-31, illustrations (a) and (c)

m = the ratio t_r/t_s, dimensionless

P = maximum allowable working pressure

r = inside corner radius on a head formed by flanging or forging

S = maximum allowable stress value, using values given in Section II, Part D, Subpart 1, Table 1A

t = minimum required thickness of flat head or cover

t_1 = throat dimension of the closure weld, as indicated in Figure PG-31, illustration (r)

t_f = nominal thickness of the flange on a forged head, at the large end, as indicated in Figure PG-31, illustration (b-1)

t_h = nominal thickness of flat head or cover

t_r = thickness required for pressure of seamless shell, pipe, or header

t_s = minimum specified thickness of shell, pipe, or header

t_w = thickness through the weld joining the edge of a head to the inside of a drum, pipe, or header, as indicated in Figure PG-31, illustrations (g-1) and (g-2)

W = total bolt load, as further defined in PG-31.3.2

Z = a factor for noncircular heads and covers that depends on the ratio of short span to long span, as given in PG-31.3, dimensionless

PG-31.3 The thickness of flat unstayed heads, covers, and blind flanges shall conform to one of the following three requirements.[7]

PG-31.3.1 Circular blind flanges of ferrous materials conforming to ASME B16.5 shall be acceptable for the diameters and pressure–temperature ratings in Table 2 of that Standard when of the types shown in Figure PG-31, illustrations (j) and (k).

PG-31.3.2 The minimum required thickness of flat unstayed circular heads, covers, and blind flanges shall be calculated by the following equation:

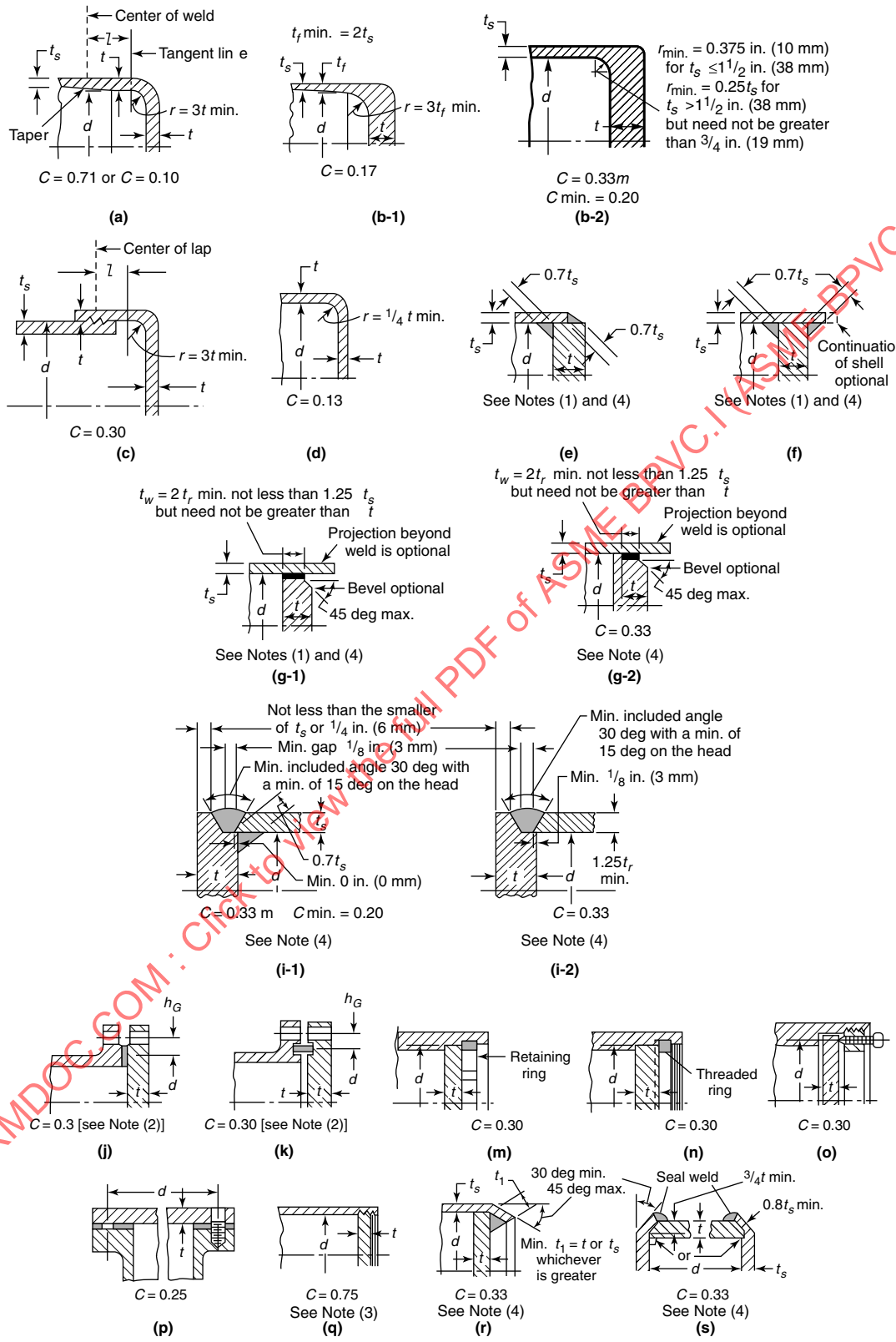
$$t = d\sqrt{CP/S} \quad (1)$$

except when the head, cover, or blind flange is attached by bolts causing an edge moment [Figure PG-31, illustrations (j) and (k)] in which case the thickness shall be calculated by the following equation:

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(23)

Figure PG-31
Some Acceptable Types of Unstayed Flat Heads and Covers



GENERAL NOTE: The above illustrations are diagrammatic only. Other designs that meet the requirements of PG-31 will be acceptable.

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Figure PG-31
Some Acceptable Types of Unstayed Flat Heads and Covers (Cont'd)

NOTES:
(1) For illustrations (e), (f), and (g-1) circular covers, $C = 0.33m$, C min. = 0.20; noncircular covers, $C = 0.33$.
(2) Use PG-31.3.2, eq. (2), or PG-31.3.3, eq. (5).
(3) When pipe threads are used, see Table PG-39.
(4) Volumetric examination is not required for any of the weld joints shown in illustrations (e), (f), (g-1), (g-2), (i-1), (i-2), (r), and (s).

$$t = d\sqrt{(CP/S) + \left(1.9Wh_G/Sd^3\right)} \quad (2)$$

When using eq. (2) the thickness t shall be calculated for both design conditions and gasket seating, and the greater of the two values shall be used. For design conditions, the value of P shall be the maximum allowable working pressure, the value of S at design temperature shall be used, and W shall be the sum of the bolt loads required to resist the end pressure load and to maintain tightness of the gasket.[8] For gasket seating, P equals zero, the value of S at atmospheric temperature shall be used, and W shall be the average of the required bolt load and the load available from the bolt area actually used.

PG-31.3.3 Flat unstayed heads, covers, or blind flanges may be square, rectangular, elliptical, obround, segmental, or otherwise noncircular. Their required thickness shall be calculated by the following equation:

$$t = d\sqrt{ZCP/S} \quad (3)$$

where

$$Z = 3.4 - \frac{2.4d}{D} \quad (4)$$

with the limitation that Z need not be greater than $2\frac{1}{2}$.

Equation (3) does not apply to noncircular heads, covers, or blind flanges attached by bolts causing a bolt edge moment [Figure PG-31, illustrations (j) and (k)]. For noncircular heads of this type, the required thickness shall be calculated by the following equation:

$$t = d\sqrt{(ZCP/S) + \left(6Wh_G/SLd^2\right)} \quad (5)$$

When using eq. (5), the thickness t shall be calculated in the same way as specified above for PG-31.3.2, eq. (2).

PG-31.4 For the types of construction shown in Figure PG-31, the minimum values of C to be used in PG-31.3.2, eqs. (1) and (2), and PG-31.3.3, eqs. (3) and (5) are:

Figure PG-31, illustration (a): $C = 0.17$ for flanged circular and noncircular heads forged integral with or buttwelded to the shell, pipe, or header, with an inside corner radius not less than three times the required head thickness, with no special requirement with regard to length of flange, and where the welding meets all the requirements for circumferential joints given in Part PW. The forged head shall meet the requirements of PW-17.

$C = 0.10$ for circular heads, where the flange length for heads of the above design is not less than

$$l = \left(1.1 - 0.8\frac{t_s^2}{t_h^2}\right)\sqrt{dt_h} \quad (6)$$

When $C = 0.10$ is used, the slope of the tapered sections shall be no greater than 1:3.

Figure PG-31, illustration (b-1): $C = 0.17$ for circular and noncircular heads forged integral with or buttwelded to the shell, pipe, or header, where the corner radius on the inside is not less than three times the thickness of the flange and where the welding meets all the requirements for circumferential joints given in Part PW. The forged head shall meet the requirements of PW-17.

Figure PG-31, illustration (b-2): $C = 0.33m$ but not less than 0.20 for forged circular and noncircular heads integral with or butt welded to the shell, pipe, or header, where the hubbed flange thickness is not less than the shell thickness, and the corner radius on the inside is not less than the following:

$r_{min} = 0.375$ in.(10 mm) for $t_s \le 1\frac{1}{2}$ in.(38 mm)

$r_{min} = 0.25t_s$ for $t_s > 1\frac{1}{2}$ in. (38 mm) but need not be greater than $\frac{3}{4}$ in. (19 mm)

The welding shall meet all requirements for circumferential joints in Part PW. The forged head shall meet the requirements of PW-17.

Figure PG-31, illustration (c): $C = 0.30$ for circular flanged plates screwed over the end of the shell, pipe, or header, with inside corner radius not less than $3t$, in which the design of the threaded joint against failure by shear, tension, or compression, resulting from the end force due to pressure, is based on a factor of safety of at least 4, and the threaded parts are at least as strong as the threads for standard piping of the same diameter. Seal welding may be used, if desired.

Figure PG-31, illustration (d): $C = 0.13$ for integral flat circular heads when the dimension d does not exceed 24 in. (600 mm); the ratio of thickness of the head to the

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dimension d is not less than 0.05 nor greater than 0.25; the head thickness t_h is not less than the shell thickness t_s, the inside corner radius is not less than $0.25t$; and the construction is obtained by special techniques of upsetting and spinning the end of the shell, pipe, or header, such as are employed in closing header ends.

Figure PG-31, illustrations (e), (f), and (g-1): $C = 0.33m$ but not less than 0.20 for circular plates and $C = 0.33$ for noncircular plates welded to the inside of a drum, pipe, or header, and otherwise meeting the requirements for the respective types of welded boiler drums, including postweld heat treatment when required for the drum, but omitting volumetric examination. If a value of m less than 1 is used in calculating t, the shell thickness, t_s, shall be maintained along a distance inwardly from the inside face of the head equal to at least $2\sqrt{dt_s}$. The throat thickness of the fillet welds in illustrations (e) and (f) shall be at least $0.7t_s$. The size of the weld t_w in illustration (g-1) shall be not less than 2 times the required thickness of a seamless shell and not less than 1.25 times the nominal shell thickness but need not be greater than the head thickness; the weld shall be deposited in a welding groove with the root of the weld at the inner face of the head as shown in the figure.

Figure PG-31, illustration (g-2): $C = 0.33$ for circular plates, welded to the inside of a drum, pipe, or header, and otherwise meeting the requirements for the respective types of welded boiler drums, including postweld heat treatment when required for the drum, but omitting volumetric examination. When the weld is not deposited at the inner face of the header, the thickness of the head that remains unwelded shall be in addition to the thickness of the head calculated per PG-31.3.2. The drum or header shall be limited to NPS 4 or less.

$C = 0.33$ for noncircular plates, welded to the inside of a drum, pipe, or header, and otherwise meeting the requirements for the respective types of welded boiler drums, including postweld heat treatment when required for the drum, but omitting volumetric examination. The throat thickness of the fillet welds in Figure PG-31, illustrations (e) and (f) shall be at least $0.7t_s$. The size of the weld t_w in illustration (g-1) shall be not less than 2 times the required thickness of a seamless shell and not less than 1.25 times the nominal shell thickness but need not be greater than the head thickness; the weld shall be deposited in a welding groove with the root of the weld at the inner face of the head as shown in the figure.

Figure PG-31, illustration (i-1): $C = 0.33m$ but not less than 0.20 for circular plates welded to the end of the drum, pipe, or header. The minimum throat thickness of the inside fillet weld shall be $0.7\ t_s$. The width at the bottom of the welding groove shall be not less than $\frac{1}{8}$ in. (3 mm) and the exposed edge not less than t_s or $\frac{1}{4}$ in. (6 mm), whichever is smaller.

Figure PG-31, illustration (i-2): $C = 0.33$ for circular plates welded to the end of the drum, pipe, or header. The thickness, t_s, shall not be less than $1.25t_r$. The width at the bottom of the welding groove shall be not less than $\frac{1}{8}$ in. (3 mm) and the exposed edge not less than t_s or $\frac{1}{4}$ in. (6 mm), whichever is smaller. The circular plate shall be inserted a minimum of $\frac{1}{8}$ in. (3 mm) into the end of the drum, pipe, or header.

Figure PG-31, illustrations (j) and (k): $C = 0.3$ for circular and noncircular heads and covers bolted to the shell, flange, or side plate as indicated in the figures. Note that PG-31.3.2, eq. (2), or PG-31.3.3, eq. (5) shall be used because of the extra moment applied to the cover by the bolting. When the cover plate is grooved for a peripheral gasket, as shown in illustration (k), the net cover plate thickness under the groove or between the groove and the outer edge of the cover plate shall be not less than

$$d\sqrt{1.9Wh_G/Sd^3}$$

for circular heads and covers, and not less than

$$d\sqrt{6Wh_G/SLd^2}$$

for noncircular heads and covers.

Figure PG-31, illustrations (m), (n), and (o): $C = 0.3$ for a circular plate inserted into the end of a shell, pipe, or header and held in place by a positive mechanical locking arrangement, and when all possible means of failure either by shear, tension, compression, or radial deformation, including flaring, resulting from pressure and differential thermal expansion, are resisted with a factor of safety of at least 4. Seal welding may be used, if desired.

Figure PG-31, illustration (p): $C = 0.25$ for circular and noncircular covers bolted with a full-face gasket to shell, flanges, or side plates.

Figure PG-31, illustration (q): $C = 0.75$ for circular plates screwed into the end of a shell, pipe, or header having an inside diameter d not exceeding 12 in. (300 mm); or for heads having an integral flange screwed over the end of a shell, pipe, or header having an inside diameter d not exceeding 12 in. (300 mm); and when the design of the threaded joint against failure by shear, tension, compression, or radial deformation, including flaring, resulting from pressure and differential thermal expansion, is based on a factor of safety of at least 4. If a tapered pipe thread is used, the requirements of Table PG-39 shall be met. Seal welding may be used, if desired.

Figure PG-31, illustration (r): $C = 0.33$ for circular plates having a dimension d not exceeding 18 in. (450 mm) inserted into the shell, pipe, or header and welded as shown, and otherwise meeting the requirements for welded boiler drums including postweld heat treatment but omitting volumetric examination. The end of the shell, pipe, or header shall be crimped over at least 30 deg, but not more than 45 deg. The crimping may be done cold only

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when this operation will not injure the metal. The throat of the weld shall be not less than the thickness of the flat head or the shell, pipe, or header, whichever is greater.

Figure PG-31, illustration (s): C = 0.33 for circular beveled plates having a diameter, d, not exceeding 18 in. (450 mm) inserted into a shell, pipe, or header, the end of which is crimped over at least 30 deg, but not more than 45 deg, and when the undercutting for seating leaves at least 80% of the shell thickness. The beveling shall be not less than 75% of the head thickness. The crimping shall be done when the entire circumference of the cylinder is uniformly heated to the proper forging temperature for the material used. For this construction, the ratio t_s/d shall be not less than the ratio P/S and not less than 0.05. The maximum allowable working pressure for this construction shall not exceed $P = SK/d$.

OPENINGS AND COMPENSATION[9]

PG-32 OPENINGS IN SHELLS, HEADERS, AND DISHED HEADS

PG-32.1 The rules for openings and compensation in PG-32 through PG-39 shall apply to all openings in shells, headers, and dished heads except as otherwise provided in PG-29.3, PG-29.7, PG-29.12, PG-32.1.2, PG-32.1.4, PG-32.1.5, and PG-35.4.

PG-32.1.1 The notations used throughout PG-32.1 are defined as follows:

D = the outside diameter of the shell, header, or dished head containing the opening, in. (mm)

d = diameter of a finished opening, in. (mm) (see PG-33.3). For nozzles that penetrate partially or fully through the shell, d = the nozzle inside diameter. For set-on nozzles, d = the diameter of the opening in the shell.

d_{max} = the maximum permissible finished opening diameter for an uncompensated opening, in. (mm) (see PG-32.1.4)

K = for openings in
(a) cylindrical shells and headers and dished heads, $K = K_1$
(b) full-hemispherical heads, $K = K_2$

K_1 = lesser of 0.990 or $PD/(1.82St)$

K_2 = lesser of 0.990 or $PD/(3.64St)$

L_{co} = the distance between centers of two openings measured on the surface of the head, shell, or header, in. (mm)

P = the maximum allowable working pressure

S = the maximum allowable stress value, taken from Section II, Part D, Subpart 1, Tables 1A and 1B

t = the nominal thickness of the head, shell, or header, in. (mm)

X_1, X_2 = the limits of compensation parallel to the vessel wall (see PG-36.2) of any two finished openings under construction, in. (mm)

PG-32.1.2 Multiple Openings. Groups of openings may be designed in accordance with the rules for ligaments in PG-52 or PG-53. Multiple openings that are not designed as ligaments shall comply with PG-38.

PG-32.1.3 Single Openings. Single openings are defined as openings that have a minimum center-to-center distance between adjacent openings not less than L_{co}, where

$$L_{co} = X_1 + X_2$$

PG-32.1.4 Openings in Shells and Headers. No calculation need be made to determine the availability of compensation for a single opening (see PG-32.1.3), not covered by PG-38, PG-52, or PG-53, in shells or headers when the diameter of the finished opening, d, as defined in PG-33.3 does not exceed the larger of (a) or (b) below.

(a) the value of d_{max} as follows:

(U.S. Customary Units)

$$d_{max} = 2.75\,[Dt\,(1 - K)]^{1/3}$$

(SI Units)

$$d_{max} = 8.08\,[Dt\,(1 - K)]^{1/3}$$

(b) the smaller of one-fourth the inside diameter of the shell or header or $2\frac{3}{8}$ in. (60 mm)

PG-32.1.5 Openings in Dished Heads. No calculation need be made to determine the availability of compensation for a single opening in dished heads under the same conditions stipulated for openings in shells and headers in PG-32.1.4, provided the following additional requirements are met.

PG-32.1.5.1 The openings shall be located completely within the center portion of a dished head bounded by the tangent line between the spherically dished portion and the knuckle radius, but not closer than the thickness of the head to the edge of this circle or to a flanged-in manway. For a 2:1 ellipsoidal head, the opening shall be located completely within the center portion of the head bounded by a circle equal to 80% of the inside diameter, but not closer than the thickness of the head to the edge of this circle.

PG-32.1.5.2 For dished heads other than full-hemispherical heads, the maximum allowable opening diameter shall not exceed that permitted in PG-32.1.4 using $K = K_1$ for an equivalent shell constructed of the

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same material, outside diameter, and the maximum allowable working pressure of the head.

PG-32.1.5.3 For full-hemispherical heads, the maximum allowable opening diameter shall not exceed that permitted in PG-32.1.4 using $K = K_2$ for an equivalent shell constructed of the same material, outside diameter, and the maximum allowable working pressure of the head.

PG-32.2 Shape of Openings.[10]

PG-32.2.1 Openings in cylindrical portions of vessels or in formed heads shall preferably be circular, elliptical, or obround.[11]

When the long dimension of an elliptical or obround opening exceeds twice the short dimension, the compensation across the short dimension shall be increased as necessary to provide against excessive distortion due to twisting moment.

PG-32.2.2 Openings may be of other shapes than those given in PG-32.2.1, and all corners shall be provided with a suitable radius. When the openings are of such proportions that their strength cannot be computed with assurance of accuracy, or when doubt exists as to the safety of a vessel with such openings, the part of the vessel affected shall meet the requirements of PG-16.1.

PG-32.3 Size of Openings.

PG-32.3.1 Properly reinforced openings in cylindrical and spherical shells are not limited as to size and shall comply with the provisions that follow, and with the additional provisions given under PG-32.3.2.

PG-32.3.2 The rules given herein for compensation apply to openings not exceeding the following dimensions:

(a) for vessels 60 in. (1 500 mm) inside diameter and less, one-half the vessel inside diameter but not over 20 in. (500 mm)

(b) for vessels over 60 in. (1 500 mm) inside diameter, one-third the vessel inside diameter but not over 40 in. (1 000 mm)

PG-32.3.3 Larger openings should be given special attention and may be provided with compensation in any suitable manner that complies with the intent of the Code rules. It is recommended that the compensation provided be distributed close to the opening. (A provision of about two-thirds of the required compensation within a distance of three-fourths times the limit established in PG-36.2 on each side of the opening as measured from the center of the opening is suggested.) Special consideration should be given to the fabrication details used and the inspection employed on critical openings; compensation often may be advantageously obtained by use of a thicker shell plate for a vessel course or inserted locally around the opening; welds may be ground to concave contour and the inside corners of the opening rounded to a generous radius to reduce stress concentrations. In extreme cases of large openings approaching full vessel diameter, openings of unusual shape, etc., the requirements of PG-16.1 may be advisable.

PG-33 COMPENSATION REQUIRED FOR OPENINGS IN SHELLS AND DISHED HEADS

PG-33.1 General. The rules in this subparagraph apply to all openings other than flanged-in openings in dished heads covered by PG-29.3, PG-29.7, and PG-29.12; openings in flat heads covered by PG-35; and openings covered within PG-32.1.2, PG-32.1.4, and PG-32.1.5.

When required, compensation shall be provided in such amount and distribution that the requirements for area of compensation are satisfied for all planes through the center of the opening and normal to the vessel surface. For a circular opening in a cylindrical shell, the plane containing the axis of the shell is the plane of greatest loading due to pressure.

PG-33.2 Area Required. The total cross-sectional area of compensation required in any given plane for a vessel under internal pressure shall be not less than A, as defined in Figure PG-33.1.

PG-33.3 The notation used in this paragraph is defined as follows:

d = diameter in the plane under consideration of the finished opening (see Figure PG-33.2). For nozzles that penetrate partially or fully through the shell, d = the nozzle inside diameter. For set-on nozzles, d = the diameter of the opening in the shell.

= the maximum diameter of the threads, in the plane under consideration, in the finished opening, for inside tapped NPT fittings

D_p = outside diameter of reinforcing element (The actual size of reinforcing element may exceed the limits of reinforcement established by PG-36; however, credit cannot be taken for any material outside these limits.)

F = factor from PG-33 and Figure PG-33.3, which compensates for the variation in pressure stresses on different planes with respect to the longitudinal axis of a cylindrical shell. $F = 1.0$ for formed or flat heads.

f_r = strength reduction factor, not greater than 1.0 (see Figure PG-33.1)

$f_{r1} = S_n/S_v$

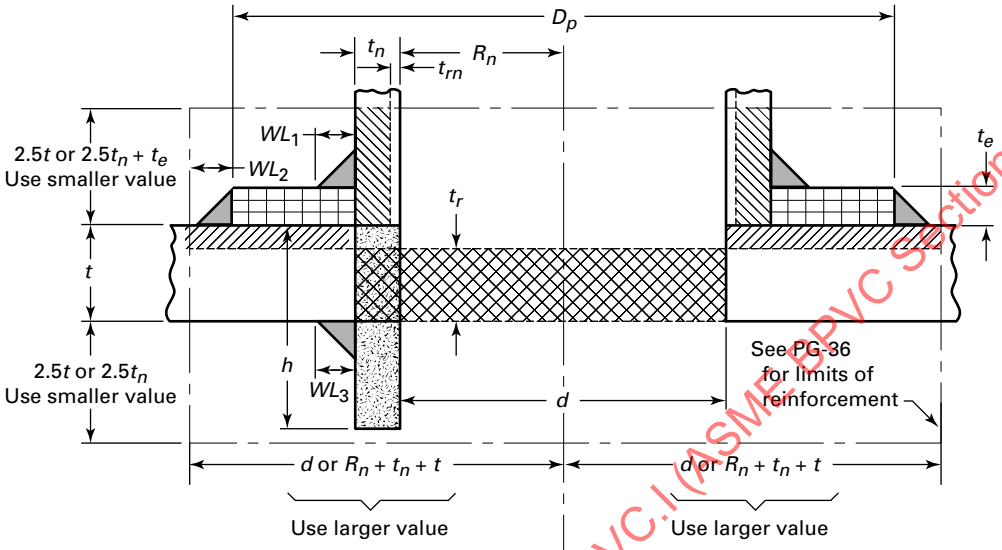
f_{r2} = (lesser of S_n or S_p)$/S_v$

$f_{r3} = S_P/S_v$

h = distance nozzle projects inward from the outer surface of the vessel wall (Extension of the nozzle beyond the inside surface of the vessel wall is not limited; however, for reinforcement calculations, credit shall not be taken for material outside the limits of reinforcement established by PG-36.)

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Figure PG-33.1
Nomenclature and Equations for Reinforced Openings



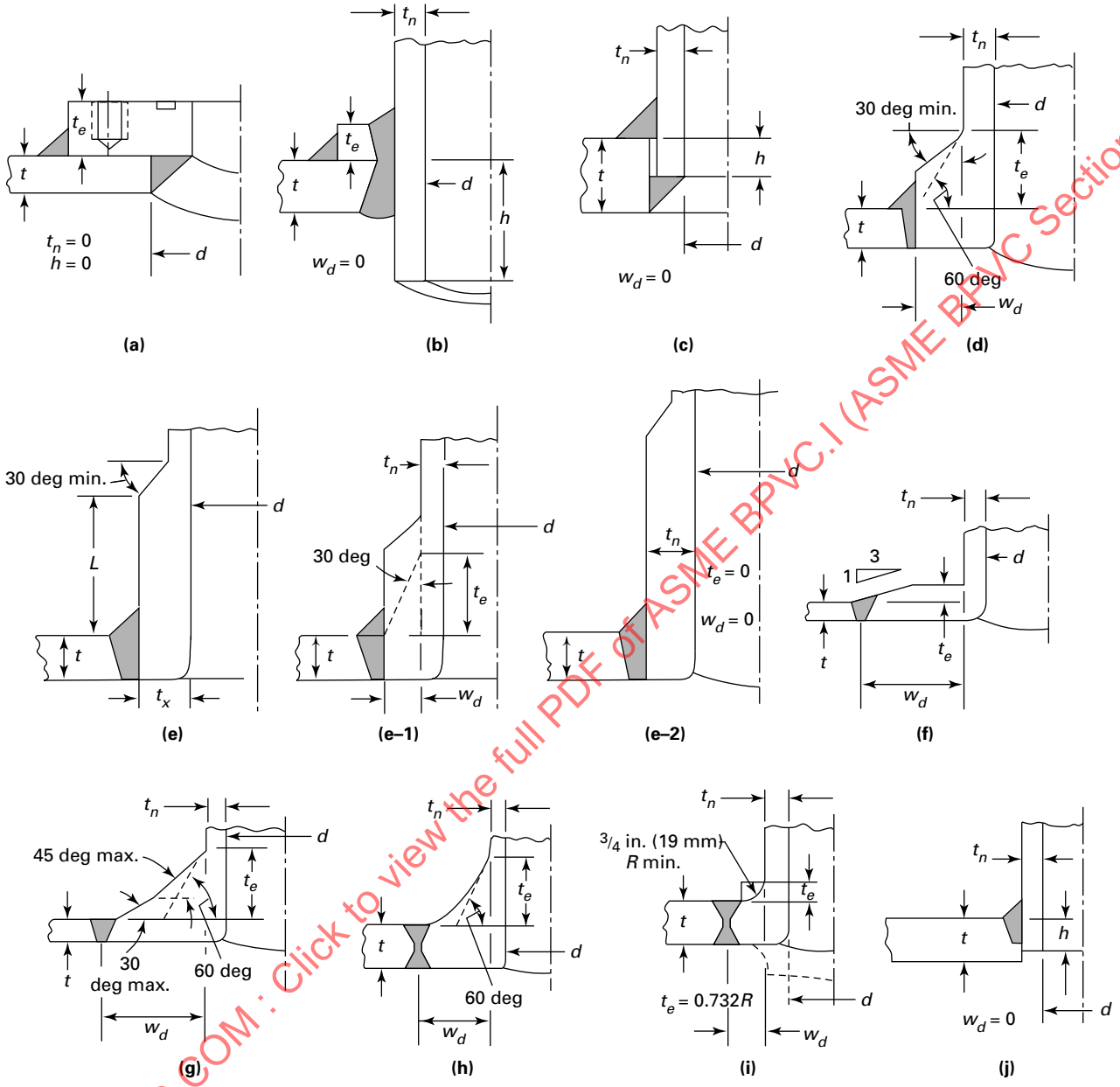
	For nozzle wall inserted through the vessel wall	For nozzle wall abutting the vessel wall
	Notes for set through nozzles, A extends to the nozzle O.D. [Note (1)]	
Area required	$A = (d + 2t_n)t_rF$	$A = dt_rF$
Area available in shell: use larger value	$A_1 = \begin{cases} (d - 2t_n)(t - Ft_r) - 2w_d(t - Ft_r)(1 - f_{r1}) \\ 2t(t - Ft_r) - 2w_d(t - Ft_r)(1 - f_{r1}) \end{cases}$	$A_1 = \begin{cases} d(t - Ft_r) \\ 2(t + t_n)(t - Ft_r) \end{cases}$
Area available in nozzle projecting outward; use smaller value	$A_2 = \begin{cases} 2(t_n - t_{rn})(2\frac{1}{2}tf_{r1}) \\ 2(t_n - t_{rn})(2\frac{1}{2}t_n + t_e)f_{r1} \end{cases}$	$A_2 = \begin{cases} 2(t_n - t_{rn})(2\frac{1}{2}tf_{r1}) \\ 2(t_n - t_{rn})(2\frac{1}{2}t_n + t_e)f_{r1} \end{cases}$
Area available in nozzle projecting inward	$A_3 = 2t_nf_{r1}h$	$A_3 = 0$
Area available in outward nozzle weld	$A_{41} = (WL_1)^2f_{r2}$	$A_{41} = (WL_1)^2f_{r2}$
Area available in inward nozzle weld	$A_{43} = (WL_3)^2f_{r1}$	$A_{43} = 0$
	If $A_1 + A_2 + A_3 + A_{41} + A_{43} > A$	Opening is adequately reinforced
	If $A_1 + A_2 + A_3 + A_{41} + A_{43} < A$	Opening is not adequately reinforced so reinforcing elements must be added and /or thickness must be increased
With reinforcing element added:		
Area available in outer element weld	$A_{42} = (WL_2)^2f_{r3}$	$A_{42} = (WL_2)^2f_{r3}$
Area available in element [Note (2)]	$A_5 = (D_p - d - 2t_n)t_ef_{r3}$	$A_5 = (D_p - d - 2t_n)t_ef_{r3}$
	If $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5 > A$	Opening is adequately reinforced

GENERAL NOTES:
(a) This figure illustrates common nozzle configurations and is not intended to prohibit other configurations permitted by the Code.
(b) See PG-33.3 and PG-36 for definitions of nomenclature.

NOTES:
(1) For the left-hand side of the illustration, $w_d = 0$.
(2) This formula is applicable for a rectangular cross-sectional element that falls within the limits of reinforcement.

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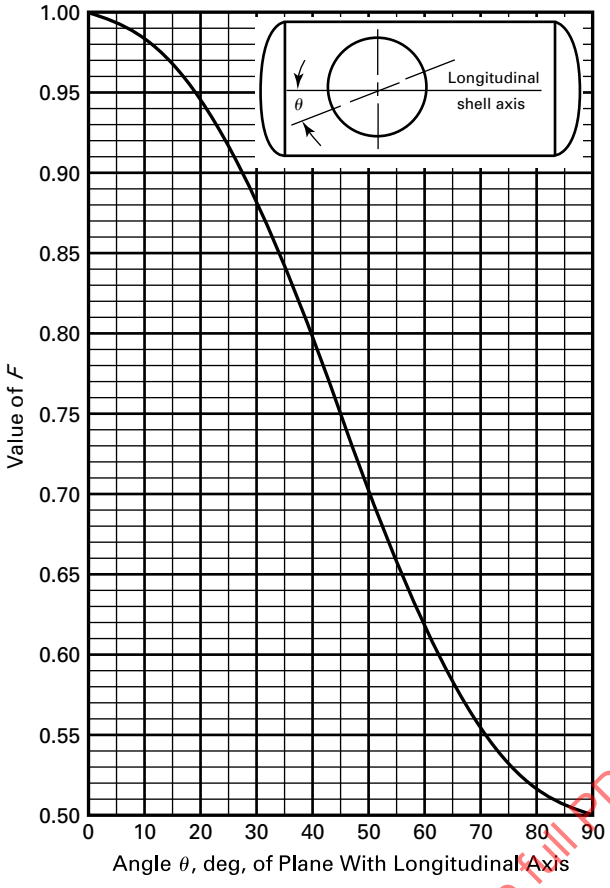
Figure PG-33.2
Some Representative Configurations Describing the Dimensions t_e, h, and d



GENERAL NOTE: Use illustration (e) to determine whether illustration (e-1) or (e-2) applies:
(1) If $L < 2.5t_x$, use illustration (e-1).
(2) If $L \geq 2.5t_x$, use illustration (e-2).
(3) The 30 deg min. transition shown at illustration (e) is typical for illustrations (e-1) and (e-2).

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Figure PG-33.3
Chart for Determining Value of *F*



GENERAL NOTE: $F = 1 - 0.5 \sin^2\theta$

R_n = inside radius of the nozzle under consideration
S = allowable stress value in tension (from Section II, Part D, Subpart 1, Tables 1A and 1B)
S_n = allowable stress in nozzle (see S)
S_P = allowable stress in reinforcing element (plate) (see S)
S_v = allowable stress in vessel (see S)
t = specified vessel wall thickness (excluding any corrosion, erosion, and forming allowances). For pipe, it is the nominal thickness less manufacturing undertolerance allowed in the pipe specification.
t_e = thickness of attached reinforcing pad or height of the largest 60 deg right triangle supported by the vessel and nozzle outside diameter projected surfaces and lying completely within the area of integral reinforcement (see Figure PG-33.2)
t_n = nozzle wall thickness (excluding any corrosion or erosion allowances). Except for pipe, this is the wall thickness not including forming allowances. For pipe, use the nominal thickness.
t_r = required thickness of a seamless shell or head computed by the rules of the Code for the designated pressure, except when
(a) the opening and its compensation are in a torispherical head and are entirely within the spherical portion; t_r is the thickness required for a seamless hemispherical head of the same radius as that of the spherical portion
(b) the opening and its compensation are in an ellipsoidal head in which one-half of the minor axis is equal to one-fourth of the inside diameter, and are located entirely within a circle the center of which coincides with the center of the head and the diameter of which is equal to 80% of the shell inside diameter; t_r is the thickness required for a seamless hemispherical head of radius equal to 90% of the inside diameter of the shell
t_{rn} = required thickness of seamless nozzle wall; found by the formula used for t_r for the shell, omitting the C factor (the value of S used in determining t_{rn} shall be based on the nozzle material). The value of t_{rn} shall be taken as zero for the entire wall of manhole and handhole rings projecting internally with the cover on the inside.
w_d = width of the nozzle inserted into the vessel wall beyond t_n, not greater than the larger of $d/2 - t_n$ or t (see Figure PG-33.2)

PG-34 FLANGED-IN OPENINGS IN FORMED HEADS

PG-34.1 All openings in torispherical, ellipsoidal, and hemispherical heads shall be provided with reinforcement in accordance with PG-33, except for heads that meet the requirements in PG-34.2 and PG-29.3, PG-29.7, and PG-29.12.

PG-34.2 A flanged-in manhole opening in a dished head shall be flanged to a depth of not less than three times the required thickness of the head for plate up to 1½ in. (38 mm) in thickness. For plate exceeding 1½ in. (38 mm) in thickness, the depth shall be the thickness of the plate plus 3 in. (75 mm). The depth of flange shall be determined by placing a straight edge across the outside opening along the major axis and measuring from the straight edge to the edge of the flanged opening. A manhole opening may be compensated by a manhole ring or other attachment in place of flanging in accordance with PG-33.

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PG-35 COMPENSATION REQUIRED FOR OPENINGS IN FLAT UNSTAYED HEADS AND FLAT STAYED PLATES

PG-35.1 General. The rules in this paragraph apply to all openings other than small openings covered by PG-32.1.4(b).

PG-35.2 Flat unstayed heads that have an opening with a diameter that does not exceed one-half of the head diameter or shortest span, as defined in PG-31, shall have a total cross-sectional area of compensation not less than 0.5 times the required area specified in PG-33.2.

As an alternative, the thickness may be increased to provide the necessary openings compensation as specified in PG-35.2.1 and PG-35.2.2

PG-35.2.1 By using $2C$ or 0.75 in place of C, whichever is less, in PG-31.3.2, eq. (1), or PG-31.3.3, eq. (3) for calculating head thickness in PG-31.3 or

PG-35.2.2 In PG-31.3.2, eq. (2), or PG-31.3.3, eq. (5) by doubling the quantity under the square root sign.

PG-35.3 Flat unstayed heads that have an opening with a diameter that exceeds one-half of the head diameter or shortest span, as defined in PG-31.3, shall be designed as provided in PG-16.1.

PG-35.4 Openings in flat stayed plates such as waterlegs and tubesheets of firetube boilers shall have a total cross-sectional area of compensation not less than 0.5 times the area specified in PG-33.2.

Compensation is not required for furnace connections or door openings in stayed plates meeting the requirements of PFT-20.6 or PFT-40.

PG-36 LIMITS OF METAL AVAILABLE FOR COMPENSATION

PG-36.1 The boundaries of the cross-sectional area in any plane normal to the vessel wall and passing through the center of the opening within which area metal must be located in order to have value as compensation are designated as the limits of compensation for that plane (see Figure PG-33.1).

PG-36.2 The limits of compensation, measured parallel to the vessel wall, shall be at a distance, on each side of the axis of the opening, equal to the greater of the following:

PG-36.2.1 The diameter of the finished opening.

PG-36.2.2 The radius of the finished opening plus the thickness of the vessel wall, plus the thickness of the nozzle wall.

PG-36.3 The limits of compensation, measured normal to the vessel wall, shall conform to the contour of the surface at a distance from each surface equal to the smaller of the following:

PG-36.3.1 $2\frac{1}{2}$ times the nominal shell thickness.

PG-36.3.2 $2\frac{1}{2}$ times the nozzle-wall thickness plus the thickness of any added compensation, exclusive of weld metal on the side of the shell under consideration.

PG-36.4 Metal within the limits of reinforcement that may be considered to have reinforcing value shall include the following:

PG-36.4.1 Metal in the vessel wall over and above the thickness required to resist pressure. The area of the vessel wall available as compensation is the larger of the values of A_1 given by the equations shown in Figure PG-33.1.

PG-36.4.2 Metal over and above the thickness required to resist pressure in that part of a nozzle wall extending outside the vessel wall. The maximum area in the nozzle wall available as compensation is the smaller of the values of A_2 given by the equations shown in Figure PG-33.1.

All metal in the nozzle wall extending inward from the outer surface of the vessel wall may be included. No allowance shall be taken for the fact that a differential pressure on an inwardly extending nozzle may cause opposing stress to that of the stress in the shell around the opening.

PG-36.4.3 Metal added as compensation (continuously about the nozzle) when welded to both the vessel and nozzle, and metal provided in attachment welds.

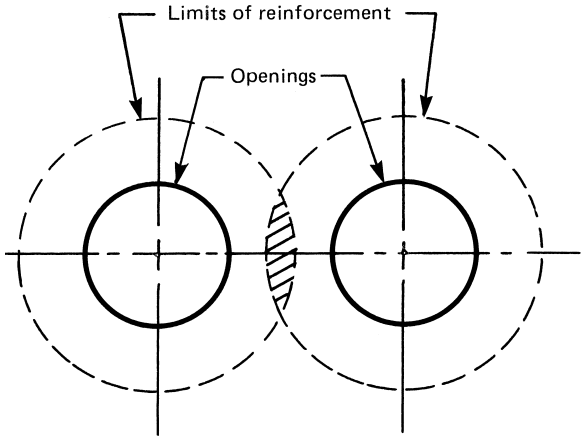
PG-36.5 Typical examples of the application of the above rules are presented in A-65 through A-69.

PG-37 STRENGTH OF COMPENSATION

PG-37.1 Material used for compensation shall have an allowable stress value equal to or greater than that of the material in the vessel wall, except that material of lower strength may be used provided the area of compensation is increased in inverse proportion to the ratio of the allowable stress values of the two materials to compensate for the lower allowable stress value of the compensation. No credit may be taken for the additional strength of any compensation having a higher allowable stress value than that of the vessel wall. Deposited weld metal outside of either the vessel wall or any reinforcing pad used as reinforcement shall be credited with an allowable stress value equivalent to the weaker of the materials connected by the weld. Vessel-to-nozzle or pad-to-nozzle attachment weld metal within the vessel wall or within the pad may be credited with a stress value equal to that of the vessel wall or pad, respectively.

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Figure PG-38.1-1
Example of Two Openings Spaced With Limits of Reinforcement Overlapping



PG-37.2 The welds that attach elements of compensation that are not an integral part of the vessel wall shall have a strength, W, not less than the load carried by those elements defined as follows:

$$W = (A - A_1) S_v$$

where A, A_1, and S_v are defined in PG-33.3 and Figure PG-33.1.

PG-37.3 When a reinforcing pad is required by the rules of PG-33, the welds attaching the nozzle to the pad and shell shall be checked independently to assure that the loads carried by the individual elements can be transmitted by the attaching welds. For detailed requirements and examples of calculating the strength of welds, see PW-15.

PG-37.4 Welds attaching elements of compensation need not satisfy the weld strength requirements of PG-37.2 under the following circumstances:

(a) openings that are exempt in PG-32 from compensation calculations

(b) openings designed by ligaments rules of PG-52 and PG-53 and/or

(c) openings with elements of compensation attached by full penetration welds as listed in PW-15.1.6

PG-37.5 The minimum weld sizes shall not be smaller than the minimum required by PW-16.

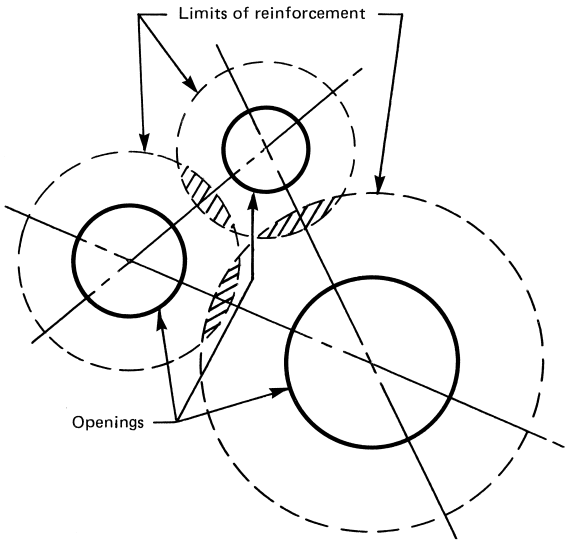
PG-38 COMPENSATION FOR MULTIPLE OPENINGS

PG-38.1 When any two adjacent openings that require compensation are spaced at less than two times the distance defined in PG-36.2 so that their limits of compensation overlap (see Figure PG-38.1-1), the two openings shall be compensated in the plane connecting the centers of the openings in accordance with PG-33 with a compensation that has an area equal to the combined area of the compensation required for the separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area. The available area of the head or shell between openings having an overlap area shall be proportioned between the two openings by the ratio of their diameters.

PG-38.2 When more than two openings are spaced at less than two times the distance defined in PG-36.2 so that their limits overlap with each other (see Figure PG-38.2-1) and are to be provided with a combined reinforcement, the minimum distance between centers of any two of these openings shall be $1\frac{1}{3}$ times their average diameter, and the area of reinforcement between any two openings shall be at least equal to 50% of the total required for the two openings. If the distance between centers of two such openings is less than $1\frac{1}{3}$ times their average diameter, no credit for reinforcement shall be taken for any of the material between these openings. Such openings must be reinforced as described in PG-38.3.

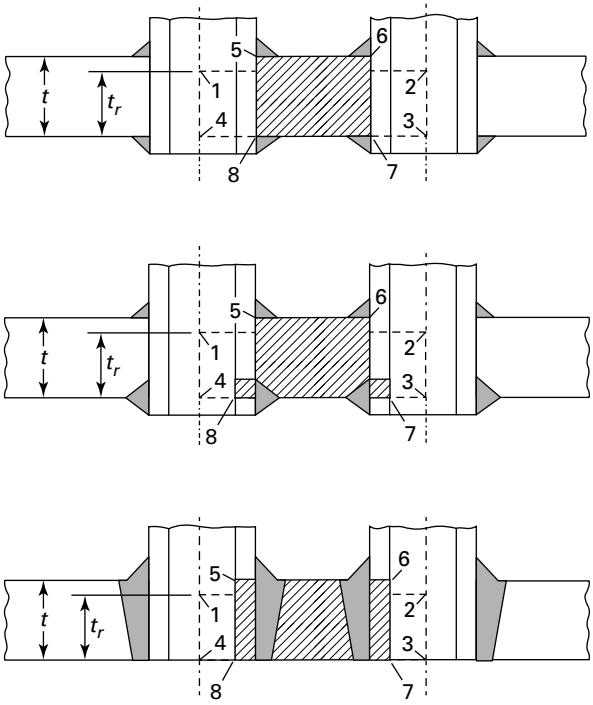
PG-38.3 Alternatively, any number of adjacent openings, in any arrangement, may be reinforced by using an assumed opening enclosing all such openings. The limits for reinforcement of the assumed opening shall be those given in PG-36.2.1 and PG-36.3.1. The nozzle walls of the actual openings shall not be considered to have reinforcing value. For shells and headers, when the diameter of

Figure PG-38.2-1
Example of More Than Two Openings Spaced With Limits of Reinforcement Overlapping



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Figure PG-38.4-1
Illustrations of the Rule Given in PG-38.4



GENERAL NOTE: The cross-sectional area represented by 5, 6, 7, and 8 shall be at least equal to the area of the rectangle represented by 1, 2, 3, and 4 multiplied by 0.7F, in which F is a value from Figure PG-33.3 and t_r is the required thickness of a seamless shell.

the assumed opening exceeds the limits in PG-32.3.2, the recommendations in PG-32.3.3 may be considered.

PG-38.4 When a shell or drum has a series of openings (three or more) in a definite pattern, the distance between centers of any two adjacent finished openings shall not be less than 1⅓ times their average diameter, and shall be reinforced per PG-38.1 for any two adjacent finished openings. Also, the net cross-sectional area between these adjacent openings within the limits of the actual shell wall, excluding the portion of the compensation not fused to the shell wall, shall equal at least 0.7F of the cross-sectional area obtained by multiplying the center-to-center distance of the openings by the required thickness of a seamless shell, where the factor F is taken from Figure PG-33.3 for the plane under consideration (see Figure PG-38.4-1). Alternately, per PG-32.1.2, groups of openings may be designed in accordance with the rules for ligaments in PG-52 or PG-53.

PG-38.5 When a group of openings is provided with compensation by a thicker section buttwelded into the shell or head, the edges of the inserted section shall be tapered as prescribed in PW-9.3.

PG-39 METHODS OF ATTACHMENT OF PIPE AND NOZZLE NECKS TO VESSEL WALLS

PG-39.1 General. Except as limited in PG-32, nozzles may be attached to the shell or head of a vessel by any of the methods of attachment given in this paragraph.

PG-39.2 Welded Connections. Attachment by welding shall be in accordance with the requirements of PW-15 and PW-16.

PG-39.4 Studded Connections. Connections may be made by means of bolt studs. The vessel shall have a flat surface machined on the shell, or on a built-up pad, or on a properly attached plate or fitting. Drilled holes to be tapped for straight threads shall not penetrate within one-fourth of the wall thickness from the inside surface of the vessel, unless at least the minimum thickness required as above is maintained by adding metal to the inside surface of the vessel. Where tapped holes are provided for studs, the threads shall be full and clean and shall engage the stud for a length not less than the larger of d_s or

$$0.75d_s \times \frac{\text{Maximum allowable stress value of stud material at design temperature}}{\text{Maximum allowable stress value of tapped material at design temperature}}$$

in which d_s is the diameter of the stud, except that the thread engagement need not exceed 1½d_s. Studded connections shall meet the requirements for compensation. No credit for compensation shall be allowed for any areas attached by studs only.

PG-39.5 Threaded Connections.

PG-39.5.1 Where a threaded connection is to be made to a boiler component it shall be into a threaded hole. The threads shall conform to the requirements of ASME B1.20.1 and provide for the pipe to engage the minimum number of threads specified in Table PG-39 after allowance has been made for curvature of the vessel wall. A built-up pad or properly attached plate or fitting may be used to provide the metal thickness and number of threads required in Table PG-39, or to furnish compensation when required.

PG-39.5.2 Threaded joints for boiler connections for external piping shall be in accordance with the following size and pressure limitations and shall not be used where the temperature exceeds 925°F (495°C).

Maximum Size, NPS (DN)	Maximum Pressure, psi (MPa)
3 (80)	400 (3)
2½ (65)	500 (3.5)
2 (50)	600 (4)
1½ (40)	900 (6)
1¼ (32)	1,000 (7)

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Table PG-39
Minimum Number of Threads per Connection

Pressure	Size of Pipe Connection NPS (DN)	Threads Engaged	Minimum Plate Thickness Required, in. (mm)
Up to and including 300 psi (2 MPa)	1 and 1¼ (25 and 32)	4	0.348 (9)
	1½ and 2 (40 and 50)	5	0.435 (11)
	2½ to 4 (65 to 100)	7	0.875 (22)
	5 and 6 (125 and 150)	8	1.0 (25)
	8 (200)	10	1.25 (32)
	10 (250)	12	1.5 (38)
	12 (300)	13	1.625 (41)
Above 300 psi (2 MPa)	½ and ¾ (15 and 20)	6	0.43 (11)
	1 and 1½ (25 to 40)	7	0.61 (16)
	2 (50)	8	0.70 (18)
	2½ and 3 (65 and 80)	8	1.0 (25)
	4 to 6 (100 and 150)	10	1.25 (32)
	8 (200)	12	1.5 (38)
	10 (250)	13	1.625 (41)
	12 (300)	14	1.75 (44)

Table continued

Maximum Size, NPS (DN)	Maximum Pressure, psi (MPa)
1 (25)	1,200 (8)
¾ (20) and smaller	1,500 (10)

PG-39.5.3 Threaded connections for plug closures used for inspection openings, end closures, and similar purposes may be used within the size and pressure limitations of Table PG-39.

PG-39.6 Expanded Connections. Provided the requirements for compensation are met, a pipe, tube, or forging not exceeding 6 in. (150 mm) in outside diameter may be attached to shells, heads, headers, or fittings by inserting through an opening and expanding in accordance with the rules for tube attachment in Parts PWT and PFT, whichever is applicable.

The sharp edges left in drilling tube holes shall be removed on both sides of the plate with a file or other tool. The inner surface of the tube hole in any form of attachment may be grooved or chamfered.

PG-39.7 All welded connections shall be postweld heat treated after attachment unless specifically allowed otherwise.

PG-42 GENERAL REQUIREMENTS FOR FLANGES, PIPE FITTINGS, AND VALVES

(23) **PG-42.1** The following standards covering flanges and pipe fittings are acceptable for use under this Section in accordance with the requirements of PG-11. Pressure–temperature ratings shall be in accordance with the appropriate standard except that the pressure–temperature ratings for ASME B16.9 and ASME B16.11 fittings shall be calculated as for straight seamless pipe in accordance with the rules of this Section, including the maximum allowable stress for the material. The thickness tolerance of the ASME standards shall apply.

ASME B16.1, Gray Iron Pipe Flanges and Flanged Fittings, Classes 25, 125, and 250[12]

ASME B16.3, Malleable Iron Threaded Fittings, Classes 150 and 300

ASME B16.4, Gray Iron Threaded Fittings, Classes 125 and 250

ASME B16.5, Pipe Flanges and Flanged Fittings, NPS ½ Through NPS 24 Metric/Inch Standard (see PG-11.3)

– Pressure–temperature ratings per Table 2-1.1 through 2-3.19

– Facing dimensions (other than ring-joint) per Table 4

– Facing dimensions for ring-joint flanges per Table 5

– Dimensions of flanges for pressure rating classes per Tables 8 through 22

ASME B16.9, Factory-Made Wrought Buttwelding Fittings

NOTE: When pressure ratings are established under the provisions of ASME B16.9, para. 2.1, they shall be calculated as for straight seamless pipe in accordance with this Section. Parts such as lap-joint stub ends fabricated by welding with filler metal added may not be used in Code construction, unless they are fabricated in accordance with PG-11.

ASME B16.11, Forged Fittings, Socket-Welding and Threaded (see PG-11.3)

ASME B16.15, Cast Copper Alloy Threaded Fittings, Classes 125 and 250 (see PG-8.4 and PG-42.4.11)

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ASME B16.20, Metallic Gaskets for Pipe Flanges, Ring-Joint, Spiral-Wound, and Jacketed

ASME B16.24, Cast Copper Alloy Pipe Flanges and Flanged Fittings, Classes 150, 300, 600, 900, 1500, and 2500 (see PG-8.4)

ASME B16.25, Buttwelding Ends

ASME B16.34, Valves — Flanged, Threaded, and Welding End (see PG-11.3 and PG-42.4.3)

ASME B16.42, Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300 (see PG-8.3)

PG-42.1.1 A forged nozzle flange may use the ASME B16.5 and ASME B16.47 pressure–temperature ratings for the flange material being used, provided all of the following are met:

(a) For ASME B16.5 applications, the forged nozzle flange shall meet all dimensional requirements of a flanged fitting given in ASME B16.5 with the exception of the inside diameter. The inside diameter of the forged nozzle flange shall not exceed the inside diameter of the same size lap-joint flange given in ASME B16.5. For ASME B16.47 applications, the inside diameter shall not exceed the weld hub diameter, *A*, given in the ASME B16.47 tables.

(b) For ASME B16.5 applications, the outside diameter of the forged nozzle neck shall be at least equal to the hub diameter of the same size and class ASME B16.5 lap-joint flange. For ASME B16.47 applications, the outside diameter of the hub shall at least equal the *X* diameter given in the ASME B16.47 tables. Larger hub diameters shall be limited to nut stop diameter dimensions. See Section VIII, Division 1, Figure 2-4, illustrations (12) and (12a).

(23) **PG-42.2 Marking.** All valves and fittings shall be marked in accordance with the ASME product standard except that the pressure-rating marking may be omitted from:

PG-42.2.1 Cast iron threaded fittings for Class 125 (PN 20) working pressure

PG-42.2.2 Malleable iron threaded fittings for Class 150 (PN 20) working pressure

PG-42.2.3 Nonferrous threaded fittings for Classes 125 (PN 20) and 250 (PN 50) working pressure

PG-42.2.4 Cast iron and nonferrous companion flanges

PG-42.2.5 Additional markings for buttwelding fittings, as called for by several Code Standards for all valves and fittings, are recommended if the size and shape of the valve or fitting permit.

PG-42.3 Flange Materials. Flanges shall be made of materials permitted by this Section or of materials specifically listed in the applicable product standards listed in PG-42.1, but not of materials specifically prohibited or beyond the use limitations listed in this Section. Rolled or forged flanges may be made from material conforming to any forging specification among these permitted materials, except that SA-181 shall not be used for flanges whose pressure rating is higher than Class 300 (PN 50). Hub-type flanges shall not be cut or machined from plate material.

PG-42.4 Additional Requirements. Flanges made of other materials permitted under this Section shall be at least equal to the strength requirements, and the facing dimensions and bolt circles shall agree with the Standard otherwise required.

PG-42.4.1 The thickness of all fitting and valve bodies subject to pressure shall be not less than that required by the applicable ASME Standard listed in PG-42.1 for the corresponding maximum allowable working pressure and temperature for the material used. The cylindrical ends of cast steel welding end valves and fittings conforming to ASME B16.5 or ASME B16.34 may be proportioned with a casting quality factor of 100% provided these areas are finish-machined both inside and outside, are carefully inspected, and that the contour of the welding end transition complies with PG-42.4.2.

PG-42.4.2 The welding ends of component bodies such as fittings and valves, whether constructed of cast products, wrought products, or any other fabrication process acceptable under the Code, shall provide a gradual change in thickness from that of the adjoining pipe to that of the component body. Any configuration of weld end transition that lies entirely within the envelope shown in Figure PG-42.1 is acceptable, provided that

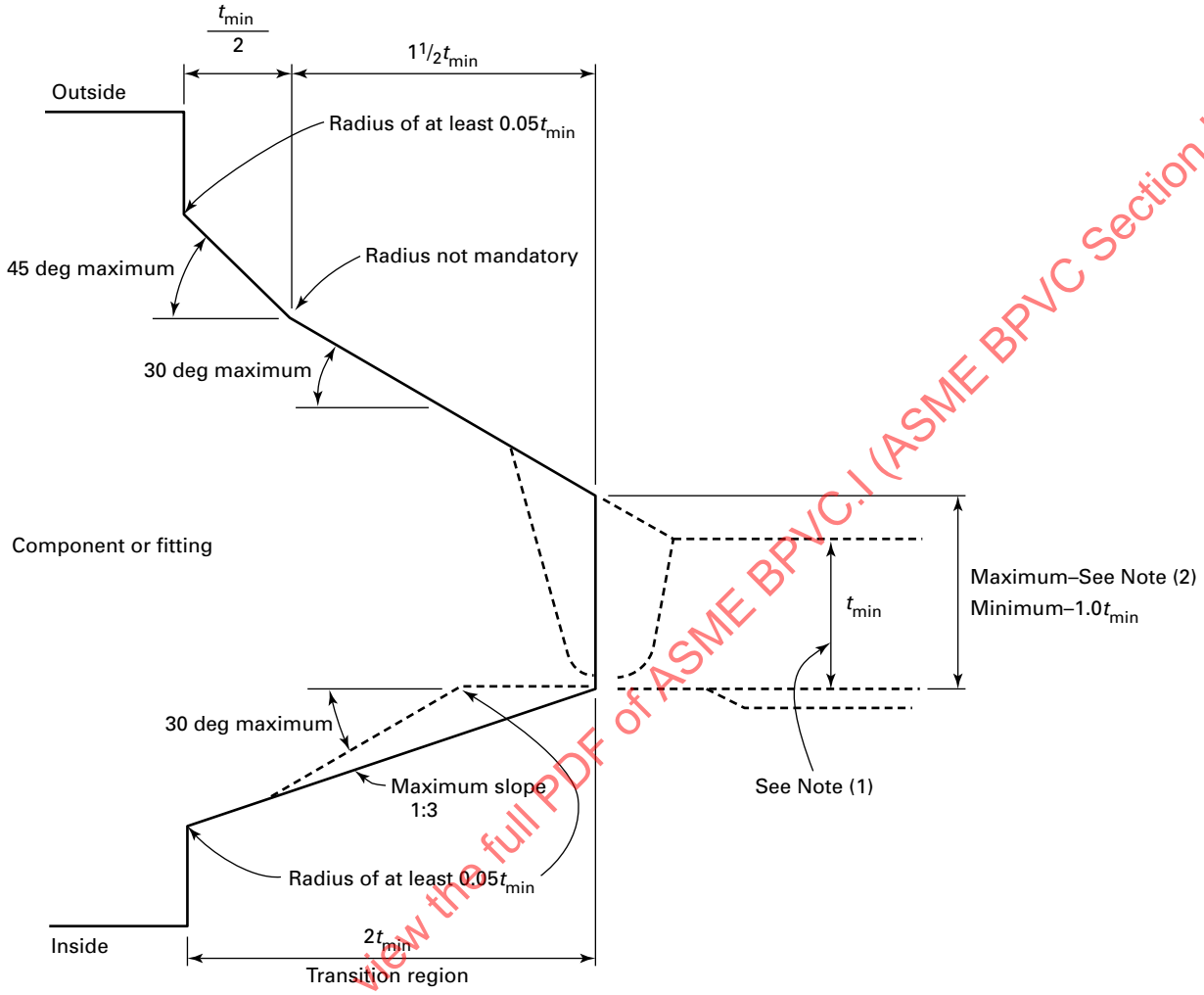
(a) the wall thickness in the transition region is not less than the smaller of the fitting or valve thickness required by PG-42.4.1 or the minimum value of the pipe thickness t_{min} defined under Figure PG-42.1.

(b) the transition region including the weld joint shall avoid sharp reentrant angles and abrupt changes in slope. When the included angle between any two adjoining surfaces of a taper transition is less than 150 deg, the intersection or corner (except for the weld reinforcement) shall be provided with a radius of at least $0.05t_{min}$.

The configurations and tolerances suggested by such weld end standards as ASME B16.9 and ASME B16.25 are acceptable only to the extent that the resulting product and weld joint will comply with these requirements of PG-42.4.2. In Figure PG-42.1 the thickness in the plane at the end of the fitting or valve shall not be less than t_{min} and shall not exceed a maximum of either: the greater of [t_{min} + 0.15 in. (4 mm)] or $1.15t_{min}$ when ordered on a minimum wall basis, or the greater of [t_{min} + 0.15 in. (4 mm)] or $1.10t_{nom}$ when ordered on a nominal wall basis.

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Figure PG-42.1
Welding End Transitions Maximum Envelope



GENERAL NOTES:
(a) Weld bevel is shown for illustration only.
(b) The weld reinforcement permitted by PW-35 may be outside the maximum envelope.

NOTES:
(1) The value of t_{min} is whichever of the following is applicable:
(a) the minimum ordered wall thickness of the pipe; or
(b) the minimum ordered wall thickness of the tube; or
(c) 0.875 times the nominal wall thickness of pipe ordered to a pipe schedule wall thickness that has an undertolerance of 12.5%; or
(d) the minimum ordered wall thickness of the cylindrical welding end of a component or fitting (or the thinner of the two) when the joint is between two components
(2) The maximum thickness at the end of the component is
(a) the greater of [t_{min} + 0.16 in. (4 mm)] or $1.15t_{min}$ when ordered on a minimum wall basis
(b) the greater of [t_{min} + 0.16 in. (4 mm)] or 1.10 times the nominal wall thickness when ordered on a nominal wall basis

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PG-42.4.3 Fittings in which there are minor changes in the center-to-face dimensions or in which the angles of elbows differ from those given in an ASME Standard in PG-42.1 may be considered to fall within the scope of the standard provided the other requirements for materials, dimensions, and thickness are met.

PG-42.4.4 Flanges and flanged fittings meeting the requirements of ASME B16.5 or valves meeting the requirements of ASME B16.34 may be used at the pressure–temperature ratings established by those standards. Standard Class, Special Class, or Limited Class valves may be used, provided that all parts of the valves are suitable for the pressure–temperature conditions at which they are to be used. Valves of intermediate rating or class, as described in ASME B16.34, are permitted.

PG-42.4.5 When the service requirements exceed the permissible values given in ASME B16.5 or ASME B16.34, the requirements of the Code will be met if the bolting material, flange thickness, and/or body thickness are increased so that the deflection limits are no greater and the factor of safety is no less than that of the nearest Pressure Rating Class in ASME B16.5 or ASME B16.34.

PG-42.4.6 Steel buttwelding fittings may be used provided they are at least equal to the requirements of ASME B16.9.

PG-42.4.7 ASME Standard slip-on flanges shall not exceed NPS 4 (DN 100). Attachment of slip-on flanges shall be by double fillet welds. The throats of the fillet welds shall not be less than 0.7 times the thickness of the part to which the flange is attached.

PG-42.4.8 ASME Standard socket welded flanges may be used in piping or boiler nozzles provided the dimensions do not exceed NPS 3 (DN 80) for Class 600 (PN 110) and lower, and NPS 2½ (DN 65) in Classes 900 (PN 150) and 1,500 (PN 260).

PG-42.4.9 Threaded fittings of cast iron or malleable iron conforming to the requirements of the ASME Standards for Classes 125 (PN 20), 150 (PN 20), 250 (PN 50), and 300 (PN 50) pressure may be used except where otherwise specifically prohibited or where flanged fittings are specifically required. They shall not be used for temperatures over 450°F (230°C).

PG-42.4.10 Cast- or forged-steel threaded fittings or valves that are at least equal to the strength requirements of the ASME Standard fittings that would otherwise be required may be used in all cases except where flanged fittings are specifically required.

PG-42.4.11 The casting quality factors given in PG-25 do not apply to ASME Standard cast steel fittings whose dimensions and ratings are incorporated in the Code.

Bronze threaded or flanged type fittings or valves may be used provided they are at least equal to the strength requirements of ASME B16.1 gray iron fittings that would otherwise be required. Bronze threaded fittings may be used if they comply with ASME B16.15. The material shall comply with PG-8.4 and the allowable working stresses are not to exceed the values given in Section II, Part D, Subpart 1, Table 1B, except as provided in PG-73.3.4. Bronze shall not be used where steel or other material is specifically required. Threaded-type fittings shall not be used where flanged types are specified.

PG-42.4.12 Clamped connectors meeting PG-11.4 or PG-16.1 may be used in Section I construction. Connectors shall be provided with two or more bolts per connector lug unless a redundant method is used to hold the clamps together independently in the operating condition in case of failure of the primary bolting. Clamp hub friction shall not be considered as a redundant method. The redundant method shall be such that the failure of a single locking component while the connection is pressurized (or contains a static head of liquid acting at the connection) will

(a) not cause or allow the connection to open or leak, or

(b) not increase the stress in any other holding element by more than 50% above the allowable stress of the element

PG-43 NOZZLE NECK THICKNESS

The minimum thickness of the neck of all nozzles, access openings, and openings for inspection shall not be less than the thickness required for all applicable loadings plus corrosion and erosion allowances, if applicable. Except for access openings and openings for inspection, the minimum thickness of a nozzle neck shall also be not less than the smaller of the following:

(a) the minimum required thickness of a seamless shell or head to which it is attached plus corrosion or erosion allowances, if applicable

(b) the minimum wall thickness of Standard wall pipe listed in ASME B36.10M plus corrosion and erosion allowances, if applicable

PG-44 INSPECTION OPENINGS

PG-44.1 All boilers or parts thereof shall be provided with suitable manhole, handhole, or other inspection openings for examination or cleaning, except for special types of boilers where such openings are manifestly not needed or used.

Specific requirements for access openings in certain types of boilers appear in other paragraphs.

An elliptical manhole opening shall be not less than 12 in. × 16 in. (300 mm × 400 mm) in size.

A circular manhole opening shall be not less than 15 in. (380 mm) in diameter.

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A handhole opening in a boiler drum or shell shall be not less than $2\frac{3}{4}$ in. × $3\frac{1}{2}$ in. (70 mm × 89 mm), but it is recommended that, where possible, larger sizes be used.

Manhole, handhole, inspection, and washout openings in a shell or unstayed head shall be designed in accordance with the rules of PG-32 to PG-42.

When a threaded opening is to be used for inspection or washout purposes, it shall be not less than 1 in. (25 mm) pipe size. The closing plug or cap shall be of nonferrous material except for pressures of over 250 psi (1.7 MPa).

The thread shall be a standard tapered pipe thread, except that a straight thread of equal strength may be used if other sealing surfaces to prevent leakage are provided.

PG-44.2 Manhole and handhole cover plates and yokes shall be of rolled, forged, or cast steel except that for pressures not exceeding 250 psi (1.7 MPa), and/or temperatures not exceeding 450°F (230°C), either handhole cover plates or yokes may be made of cast iron complying with SA-278.

The strength of all such parts together with the bolts and yokes, if any, shall be proportioned for the service for which they are used.

PG-44.3 The minimum width of bearing surface for a gasket on a manhole opening shall be $\frac{11}{16}$ in. (17 mm). No gasket for use on a manhole or handhole of any boiler shall have a thickness greater than $\frac{1}{4}$ in. (6 mm), when compressed.

PG-46 STAYED SURFACES

PG-46.1 The minimum thickness and maximum allowable working pressure for stayed flat plates and those parts that, by these rules, require staying as flat plates with stays or staybolts of uniform diameter symmetrically spaced, shall be calculated by the following equations:

$$t = p\sqrt{\frac{P}{SC}} \quad (1)$$

$$P = \frac{t^2SC}{p^2} \quad (2)$$

where

C = 2.1 for welded stays or stays screwed through plates not over $\frac{7}{16}$ in. (11 mm) in thickness with ends riveted over
= 2.2 for welded stays or stays screwed through plates over $\frac{7}{16}$ in. (11 mm) in thickness with ends riveted over
= 2.5 for stays screwed through plates and fitted with single nuts outside of plate, or with inside and outside nuts, omitting washers
= 2.8 for stays with heads not less than 1.3 times the diameter of the stays screwed through plates or made a taper fit and having the heads formed on the stay before installing them, and not riveted over, said heads being made to have a true bearing on the plate
= 3.2 for stays fitted with inside and outside nuts and outside washers where the diameter of washers is not less than $0.4p$ and thickness not less than t

P = maximum allowable working pressure, psi (MPa)

p = maximum pitch measured between straight lines passing through the centers of the staybolts in the different rows, which lines may be horizontal and vertical, or radial and circumferential, in. (mm)

S = maximum allowable stress given in Section II, Part D, Subpart 1, Table 1A, psi (MPa)

t = minimum thickness of plate, in. (mm)

PG-46.2 The minimum thickness of plates to which stays may be applied, in other than cylindrical or spherical outer shell plates, shall be $\frac{5}{16}$ in. (8 mm), except for welded construction covered by PW-19.

PG-46.3 When two plates are connected by stays and only one of these plates requires staying, the value of C shall be governed by the thickness of the plate requiring staying.

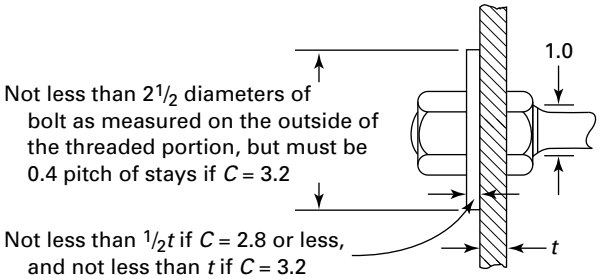
PG-46.4 Acceptable proportions for the ends of through-stays with washers are indicated in Figure PG-46.2.

PG-46.5 The maximum pitch shall be $8\frac{1}{2}$ in. (215 mm) except that for welded-in staybolts the pitch may be greater provided it does not exceed 15 times the diameter of the staybolt.

For the application of PG-48 and PFT-26, see Figure A-8.

PG-46.6 Where the staybolting of shells is unsymmetrical by reason of interference with butt straps or other construction, it is permissible to consider the load carried by each staybolt as the area calculated by taking the distance from the center of the spacing on one side of the bolt to the center of the spacing on the other side.

Figure PG-46.2
Acceptable Proportions for Ends of Through-Stays



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PG-46.7 The ends of stays fitted with nuts shall not be exposed to the direct radiant heat of the fire.

PG-46.8 Stays exceeding 120 diameters in length shall be supported at intervals not exceeding 120 diameters, or the cross-sectional area of the stay shall be increased by not less than 15% of its required area.

PG-46.9 Stays shall be installed such that the longitudinal axis of the stay is aligned to a straight line projected between the centers of the stay attachment points. Stays shall not be arched, bent, kinked, or curved except for the ends of diagonal stays as shown in Figure PW-19.4(a) and Figure PFT-32.

PG-47 STAYBOLTS

PG-47.1 The ends of staybolts or stays screwed through the plate shall extend beyond the plate not fewer than two threads when installed, after which they shall be riveted over or upset by an equivalent process without excessive scoring of the plates; or they shall be fitted with threaded nuts through which the bolt or stay shall extend. The thread lead of both ends and both plates being stayed shall be synchronized to permit the bolt to be installed without stripping the threads. Both ends of solid staybolts 8 in. (200 mm) and less in length, if of uniform diameter throughout their length, shall be drilled with telltale holes at least $^{3}/_{16}$ in. (5 mm) in diameter to a depth extending at least $^{1}/_{2}$ in. (13 mm) beyond the inside of the plate. If such staybolts are reduced in section between their ends below their diameter at the root of the thread, the telltale holes shall extend at least $^{1}/_{2}$ in. (13 mm) beyond the point where the reduction in section commences. Hollow staybolts may be used in place of solid staybolts with drilled ends. Solid staybolts over 8 in. (200 mm) long and flexible staybolts of either the jointed or ball-and-socket type need not be drilled. Staybolts used in waterlegs of watertube and firetube boilers shall be hollow or drilled at both ends, in accordance with the requirements above stated, irrespective of their length. All threaded staybolts not normal to the stayed surface shall have not less than three engaging threads of which at least one shall be a full thread, but if the thickness of the material in the boiler is not sufficient to give one full engaging thread, the plates shall be sufficiently reinforced by a steel plate welded thereto. Except for locomotive boilers, telltale holes are not required in staybolts attached by welding.

PG-47.2 The ends of steel stays upset for threading shall be fully annealed after upsetting.

PG-47.3 Requirements for welded-in staybolts are given in PW-19.

PG-48 LOCATION OF STAYBOLTS

PG-48.1 For staybolts adjacent to the riveted edges bounding a stayed surface, the value of p in PG-46, eqs. (1) and (2) may be taken as the distance from the edge of a staybolt hole to a straight line tangent to the edges of the rivet holes [see Figure A-8, illustrations (g-1) and (g-2)].

PG-48.2 When the edge of a flat stayed plate is flanged, the distance from the center of the outermost stays to the inside of the supporting flange shall not be greater than the pitch of the stays plus the inside radius of the flange.

PG-49 DIMENSIONS OF STAYBOLTS

PG-49.1 The required area of a staybolt at its minimum cross section shall be obtained by dividing the load on the staybolt, computed in accordance with PFT-26, by the allowable stress value in accordance with Section II, Part D, Subpart 1, Table 1A, and multiplying the results by 1.10.

PG-49.2 The diameter of a screw stay shall be taken at the bottom of the thread or wherever it is of the least diameter.

PG-50 DRILLED HOLES NOT PENETRATING THROUGH A VESSEL WALL

Radially drilled holes for instrumentation probes, which do not penetrate through the thickness of a shell, header, or head, may be considered as having inherent reinforcement, provided the following requirements are met:

(a) The diameter of the drilled holes shall not exceed 2 in. (50 mm).

(b) The drilled holes satisfy the requirements of PG-32.1.4.

(c) The remaining wall thickness satisfies the requirements of PG-31.3.2 for a flat closure, but shall not be less than 0.25 in. (6 mm). In making the flat head calculations, a value of $C = 0.20$ shall be used.

(d) The centerline distance between any two such drilled holes shall be at least equal to two times their average diameter.

(e) Edges and corners of the finished holes shall have a minimum radius of $^{1}/_{16}$ in. (1.5 mm).

PG-52 LIGAMENTS

PG-52.1 The rules of PG-52 apply to groups of openings that form a definite pattern in pressure parts, see Figures PG-52.2 through PG-52.5 for examples of groups of openings in a definite pattern. (For patterns not definite, see PG-53.)

The symbols defined below are used in the equations of PG-52.

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d = diameter of openings, in. (mm)
E = efficiency of ligament
n = number of openings in length p_1
p = longitudinal pitch of adjacent openings, in. (mm)
p' = diagonal pitch of adjacent openings, in. (mm)
p_1 = pitch between corresponding openings in a series of symmetrical groups of openings, in. (mm)
p_c = circumferential pitch of adjacent openings, in. (mm)
s = longitudinal dimension of diagonal pitch = $p' \cos \theta$
θ = angle of diagonal with longitudinal line, deg

The pitch shall be determined at the mean radius of the cylinder. The efficiency of the ligament between the tube holes shall be determined as indicated in PG-52.2 through PG-52.5 (see Figure PG-52.1).

PG-52.2 Openings Parallel to Vessel Axis.

PG-52.2.1 When the pitch of the tubes on every tube row is equal (as in Figure PG-52.2), the equation is

$$E = \frac{p - d}{p}$$

Example: Pitch of tube holes in the drum as shown in Figure PG-52.2 = $5\frac{1}{4}$ in. Diameter of tube = $3\frac{1}{4}$ in. Diameter of tube holes = $3\frac{9}{32}$ in.

$$\frac{p - d}{p} = \frac{5.25 - 3.281}{5.25}$$

$$= 0.375 \text{ efficiency of ligament}$$

PG-52.2.2 When the pitch of the tube holes on any one row is unequal with a definite repeating pattern (as in Figure PG-52.3 or Figure PG-52.4), the equation is

$$E = \frac{p_1 - nd}{p_1}$$

Example: Spacing shown in Figure PG-52.3. Diameter of tube holes = $3\frac{9}{32}$ in.

$$\frac{p_1 - nd}{p_1} = \frac{12 - 2 \times 3.281}{12}$$

$$= 0.453 \text{ efficiency of ligament}$$

Example: Spacing shown in Figure PG-52.4. Diameter of tube holes = $3\frac{9}{32}$ in.

$$\frac{p_1 - nd}{p_1} = \frac{29.25 - 5 \times 3.281}{29.25}$$

$$= 0.439 \text{ efficiency of ligament}$$

PG-52.3 Openings Transverse to Vessel Axis. The equivalent longitudinal efficiency of circumferential ligaments if used in the equations of PG-27.2.2 or A-317 shall be

$$2(p_c - d)/p_c$$

PG-52.4 Holes Along a Diagonal.

PG-52.4.1 When a shell or drum is drilled for tube holes as shown in Figure PG-52.5, the equivalent longitudinal efficiency of these ligaments shall be that given by the diagram in Figure PG-52.1. The abscissa $(p - d)/p$ and the ratio p'/p shall be computed. With these values the efficiency may be read off the ordinate. Should the point fall above the curve of equal efficiency for the diagonal and longitudinal ligaments, the longitudinal ligaments will be the weaker, in which case the efficiency is computed from the following equation:

$$\frac{p - d}{p} \quad (1)$$

Examples:

(1) Diagonal pitch of tube holes in drum as shown in Figure PG-52.5 = 6.42 in. Diameter of holes = $4\frac{1}{32}$ in. Longitudinal pitch of tube holes = $11\frac{1}{2}$ in.

$$\frac{p - d}{p} = \frac{11.5 - 4.031}{11.5} = 0.649 \quad (2)$$

$$\frac{p'}{p} = \frac{6.42}{11.5} = 0.558 \quad (3)$$

The point corresponding to these values is shown at A on the diagram in Figure PG-52.1, and the corresponding efficiency is 37.0%. As the point falls below the curve of equal efficiency for the diagonal and longitudinal ligaments, the diagonal ligament is the weaker.

(2) Diagonal pitch of tube holes in drum = $6\frac{35}{64}$ in. Diameter of tube holes = $4\frac{1}{64}$ in. Longitudinal pitch of tube holes = 7 in.

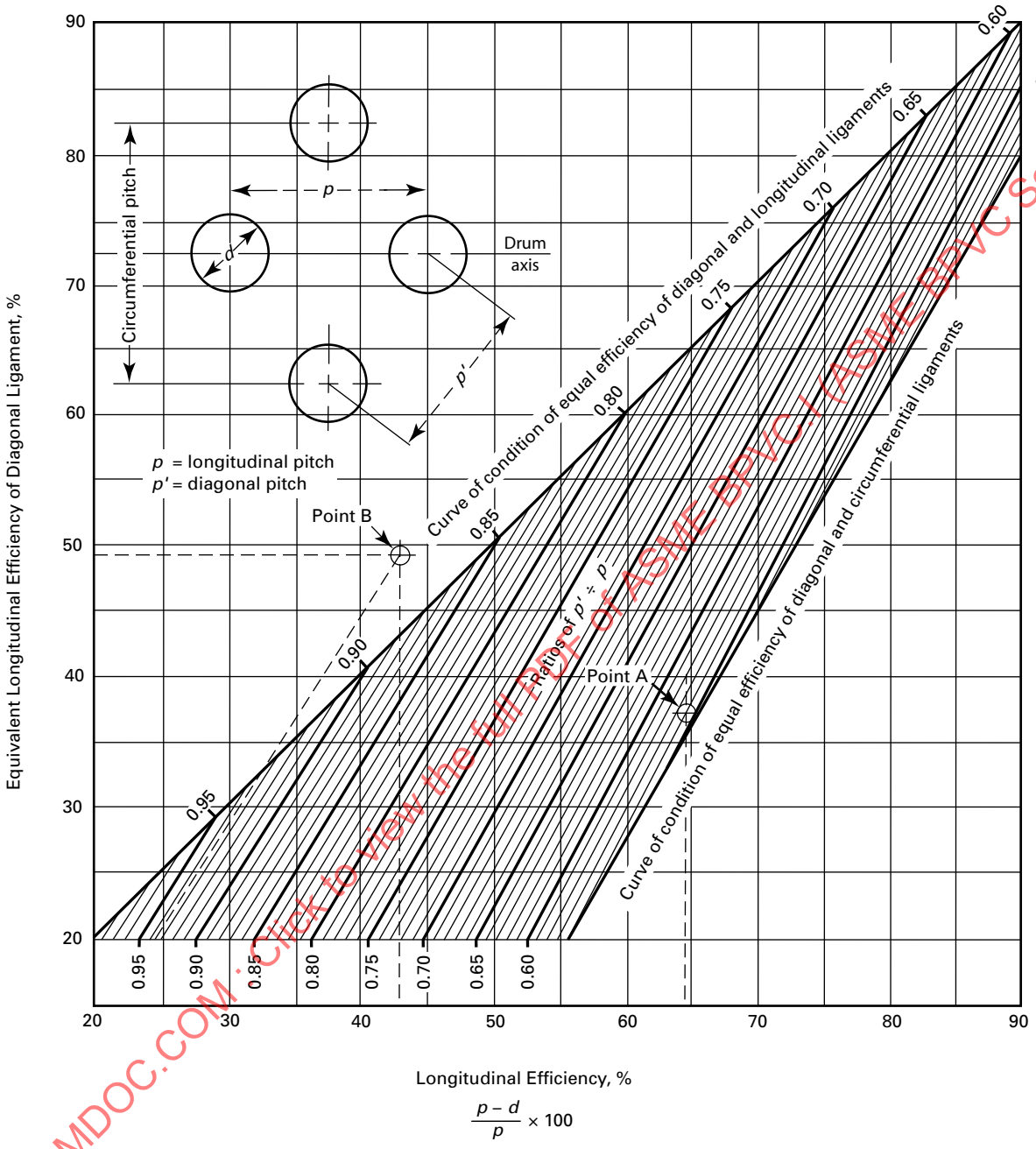
$$\frac{p - d}{p} = \frac{7 - 4.0156}{7} = 0.426$$
$$\frac{p'}{p} = \frac{6.547}{7} = 0.935 \quad (4)$$

The point corresponding to these values is shown at B on the diagram in Figure PG-52.1, and it will be seen that it falls above the line of equal efficiency for the diagonal and longitudinal ligaments, in which case the efficiency is computed from eq. (1). Applying eq. (1), we have

$$\frac{7 - 4.0156}{7} = 0.426, \text{ efficiency of ligament, or } 42.6\%$$

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Figure PG-52.1
Diagram for Determining the Efficiency of Longitudinal and Diagonal Ligaments Between Openings in Cylindrical Shells



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GENERAL NOTES:

(a) Equations are provided for the user's option in General Notes (b), (c), and (d) below. The use of these equations is permitted for values beyond those provided by Figure PG-52.1.

(b) Diagonal efficiency, % $= \dfrac{J + 0.25 - \left(1 - 0.01E_{\text{long}}\right)\sqrt{0.75 + J}}{0.00375 + 0.005J}$, where $J = \left(p' / p_1\right)^2$.

(c) Curve of condition of equal efficiency of diagonal and circumferential ligaments,

diagonal efficiency, % $= \dfrac{200M + 100 - 2\left(100 - E_{\text{long}}\right)\sqrt{1 + M}}{(1 + M)}$, where $M = \left[\left(100 - E_{\text{long}}\right) / \left(200 - 0.5E_{\text{long}}\right)\right]^2$.

(d) Longitudinal efficency, % $= E_{long} = \left[\left(p_1 - d\right) / p_1\right]100$.

Figure PG-52.2
Example of Tube Spacing With Pitch of Holes Equal in Every Row

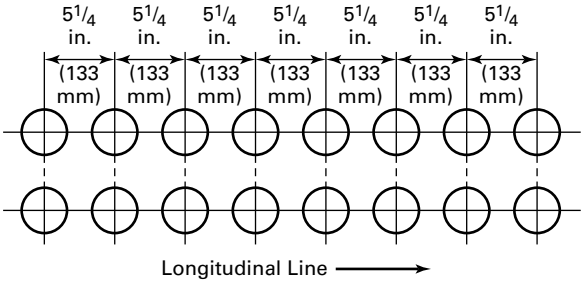


Figure PG-52.3
Example of Tube Spacing With Pitch of Holes Unequal in Every Second Row

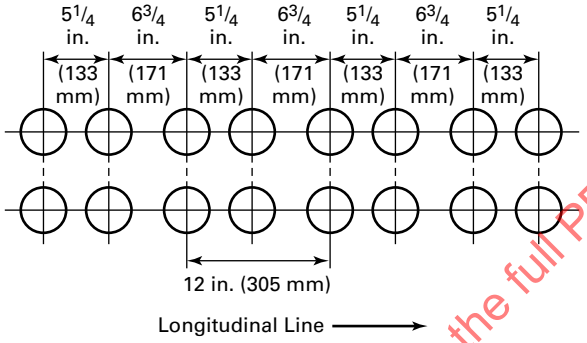
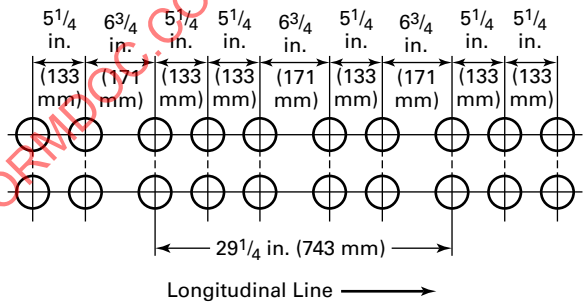


Figure PG-52.4
Example of Tube Spacing With Pitch of Holes Varying in Every Second and Third Row



PG-52.4.2 When the angle of diagonal with longitudinal, θ, diagonal pitch, p', and diameter of opening, d, are known, Figure PG-52.6 may be used in lieu of Figure PG-52.1 to calculate the equivalent longitudinal ligament of the diagonal ligament.

PG-52.5 For all tube-hole pattern arrangements, the equivalent longitudinal ligament efficiency for any diagonal and circumferential ligaments shall be calculated using either Figure PG-52.1 or Figure PG-52.6 and compared to the longitudinal ligament efficiency. The lesser value of the longitudinal ligament efficiency or the equivalent longitudinal ligament efficiencies shall be used to calculate the minimum required thickness and maximum allowable working pressure for the associated cylindrical section.

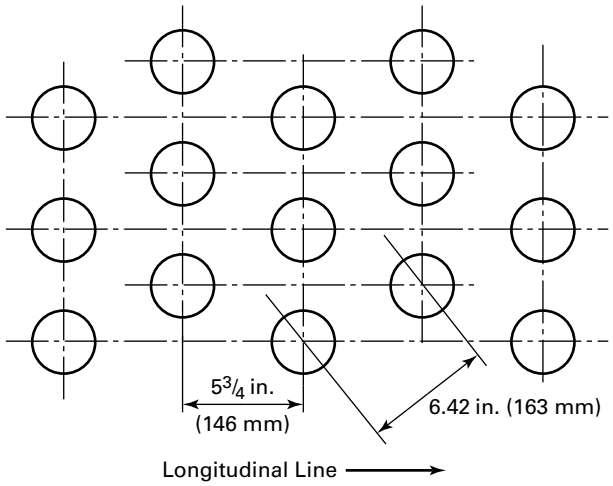
PG-53 LIGAMENTS NOT FORMING A DEFINITE PATTERN (23)

PG-53.1 The rules in this paragraph apply to groups of three or more openings that do not form a definite pattern in pressure parts (e.g., drums and headers). (For definite patterns, see PG-52.)

PG-53.2 The efficiency of the ligament between tube holes shall be determined by calculations described in PG-53.2.1 and PG-53.2.2. Examples for the application of these rules are given in Nonmandatory Appendix A, A-76.

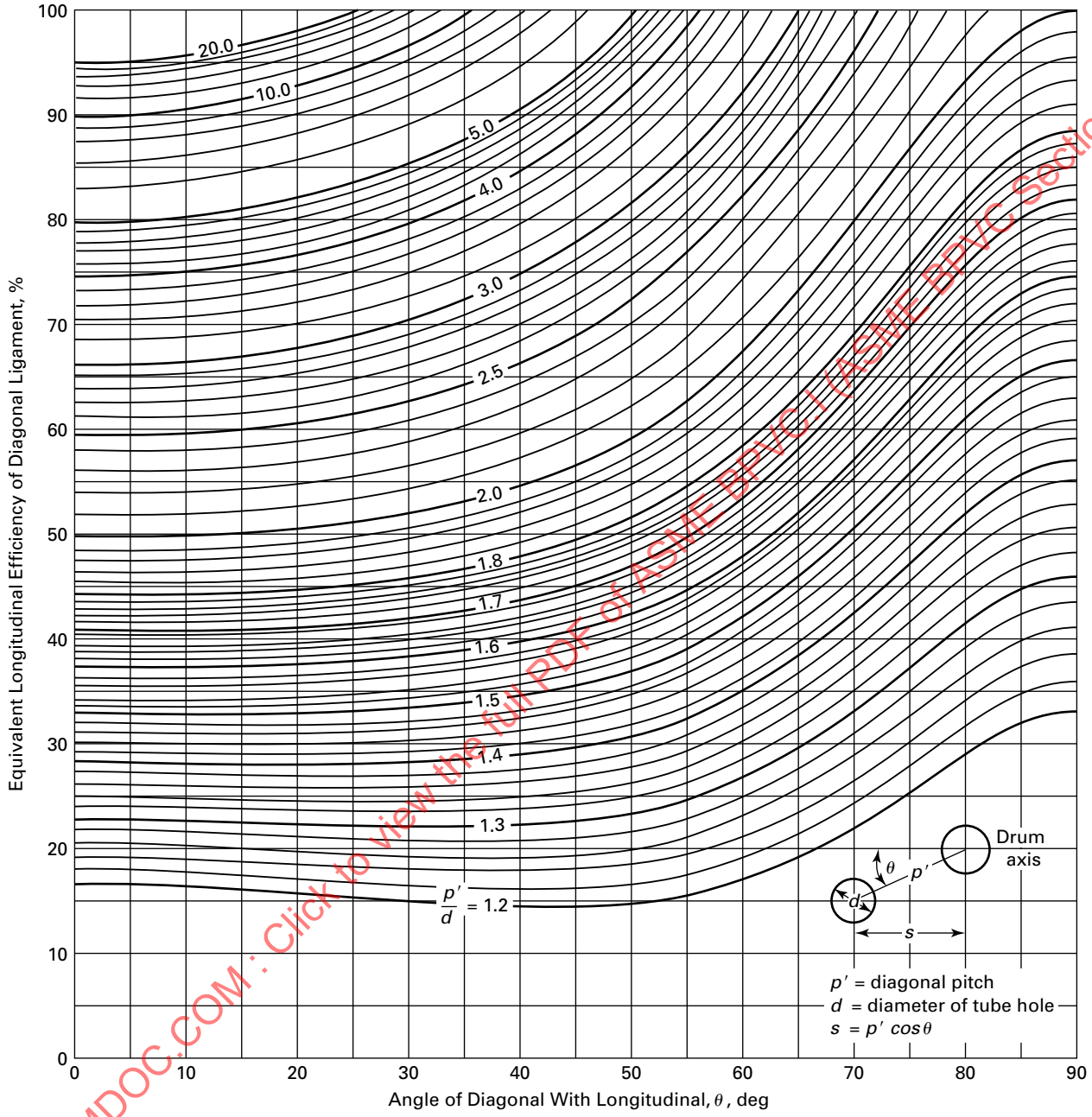
PG-53.2.1 For a length less than or equal to the inside diameter of the drum for the position that gives the minimum efficiency, the average ligament efficiency shall be not less than that on which the maximum allowable working pressure is based. When the diameter of the

Figure PG-52.5
Example of Tube Spacing With Tube Holes on Diagonal Lines



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Figure PG-52.6
Diagram for Determining Equivalent Longitudinal Efficiency of Diagonal Ligaments Between Openings in Cylindrical Shells



GENERAL NOTES:

(a) The equation in (b) below is provided for the user's option. The use of the equation is prohibited beyond the range of the abscissa and ordinate shown.

(b) Equivalent longitudinal efficiency,

$$\% = \frac{\sec^2\theta + 1 - \left(\frac{\sec\theta}{p'/d}\right)\sqrt{3 + \sec^2\theta}}{0.015 + 0.005\sec^2\theta}$$

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Figure PG-53.2.2-1

(23)

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drum exceeds 60 in. (1 500 mm), the length shall be taken as 60 in. (1 500 mm) in applying this rule. See Nonmandatory Appendix A, A-76(a).

PG-53.2.2 For a length less than or equal to the inside radius of the drum for the position that gives the minimum efficiency, the average ligament efficiency shall be not less than 80% of that on which the maximum allowable working pressure is based. When the radius of the drum exceeds 30 in. (750 mm), the length shall be taken as 30 in. (750 mm) in applying this rule. See Nonmandatory Appendix A, A-76(b).

PG-55 SUPPORTS AND ATTACHMENT LUGS

PG-55.1 Lugs or hangers when used to support a boiler of any type shall be properly fitted to the surfaces to which they are attached.

PG-55.2 Lugs, hangers, or brackets may be attached by fusion welding provided the welding meets the requirements of Part PW, including stress relieving but omitting volumetric examination and provided they are attached by full penetration welds, combination groove and fillet welds, or by fillet welds along the entire periphery or contact edges. Some acceptable forms of welds for lugs, hangers, or brackets are shown in Figure PW-16.2. The materials for lugs, hangers, or brackets are not limited to those listed in Section II, Part D, Subpart 1, Tables 1A and 1B, but shall be of weldable quality. The allowable load on the fillet welds shall equal the product of the weld area based on minimum leg dimension, the allowable stress value in tension of the material being welded, and the factor 0.55. When using welded pipe, the stress values given in Section II, Part D, Subpart 1, Table 1A, may be increased to that of the basic material by eliminating the stated weld efficiencies.

PG-56 LOADING ON STRUCTURAL ATTACHMENTS

PG-56.1 Loads imposed on steel tube walls by welded or mechanical attachments, which produce bending stresses that are additive to bursting stresses, shall conform to PG-56.1.1 and PG-56.1.2. Alternatively, stresses at structural attachments may be evaluated using one of the following methods:

(a) Welding Research Council (WRC) Bulletin Number 537, Precision Equations and Enhanced Diagrams for Local Stresses in Spherical and Cylindrical Shells Due to External Loadings for Implementation of WRC Bulletin 107

(b) WRC Bulletin 198, Part 1: Secondary Stress Indices for Integral Structural Attachments to Straight Pipe, and Part 2: Stress Indices at Lug Supports on Piping Systems

(c) other analytical methods as permitted by PG-16.1

PG-56.1.1 The following inequality: (23)

$$L \leq L_a$$

where

L = actual unit load calculated from PG-56.1.2, lbf/in. (N/mm)
L_a = maximum allowable unit load, lbf/in. (N/mm) of attachment from PG-56.2

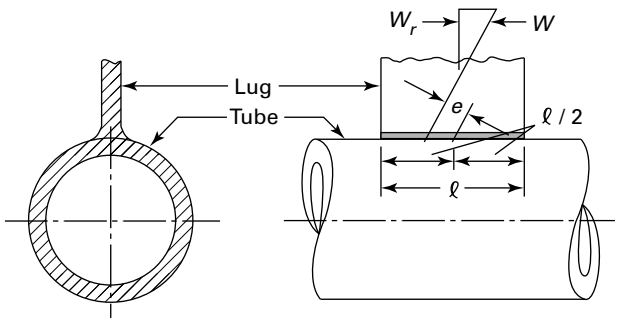
PG-56.1.2 The following equation: (23)

$$L = W_r/\ell \pm 6We/\ell^2$$

where

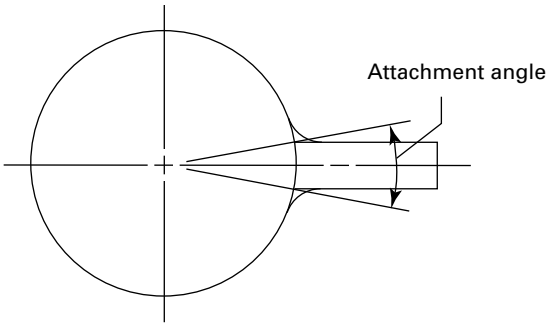
e = eccentricity of W (see Figure PG-56.1.2), in. (mm)
ℓ = length of attachment of tube, in. (mm)
W = eccentric load applied to lug, lbf (N)
W_r = load component normal to tube axis, lbf (N)

Figure PG-56.1.2
Method of Computation of Attachments to Tubes



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Table PG-56.2
Tube Attachment Angle Design Factor, *K*



Angle of attachment, deg	0	5	10	15	20	25	30	35	40	45
Design factor, *K*	1.000	1.049	1.108	1.162	1.224	1.290	1.364	1.451	1.545	1.615
Angle of attachment, deg	50	55	60	65	70	75	80	85	90	...
Design factor, *K*	1.730	1.836	1.949	2.076	2.221	2.341	2.513	2.653	2.876	...

In determining the allowable loading per unit length of attachment on a tube bend, the allowable unit load determined by using the outside diameter of the tube shall be increased by the amount of allowable compression or tension unit load, as applicable, for a tube having an outside diameter equivalent to the outside diameter of the bend and having a wall thickness the same as that of the tube bend (see Figure A-74). For an alternative method of determining the maximum allowable loading on structural attachments to tubes, see A-73.2 for conducting tests on full-size sections of tubes.

PG-56.2 Procedure for determining L_a in the equation in PG-56.1.1.

Step 1. Determine K from Table PG-56.2.

Step 2. Determine load factor, L_f, for compression or tension loading on lug from Figure PG-56.2, or from (a) or (b), when the range of the curves in Figure PG-56.2 does not extend far enough to cover specific cases.

(a) Compression Loading

$$L_f = 1.618X^{[-1.020 - 0.014 \log X + 0.005 (\log X)^2]}$$

(b) Tension Loading

$$L_f = 49.937X^{[-2.978 + 0.898 \log X - 0.139 (\log X)^2]}$$

Step 3. Determine available stress, S_t.

$$S_t = 2.0\, S_a - S$$

Step 4. Using values obtained in Steps 1 through 3, determine maximum allowable unit load, L_a.

$$L_a = Kb\left(L_f\right)S_t$$

where

D = outside diameter of tube, in. (mm)
K = tube attachment width design factor from Table PG-56.2, dimensionless
L_f = a compression or tension load factor, dimensionless
log = logarithm to base 10
S = pressure stress in tube determined by the equation in PG-27.2.1, psi (MPa)
S_a = allowable stress value from Section II, Part D, Subpart 1, Table 1A, psi (MPa)
S_t = portion of allowable stress available for attachment loading, from Step 3, psi (MPa)
t = tube wall thickness, in. (mm)
X = bD/t^2, a parameter used to determine L_f, dimensionless, where
b = unit width = 1.0 in. (25.4 mm)

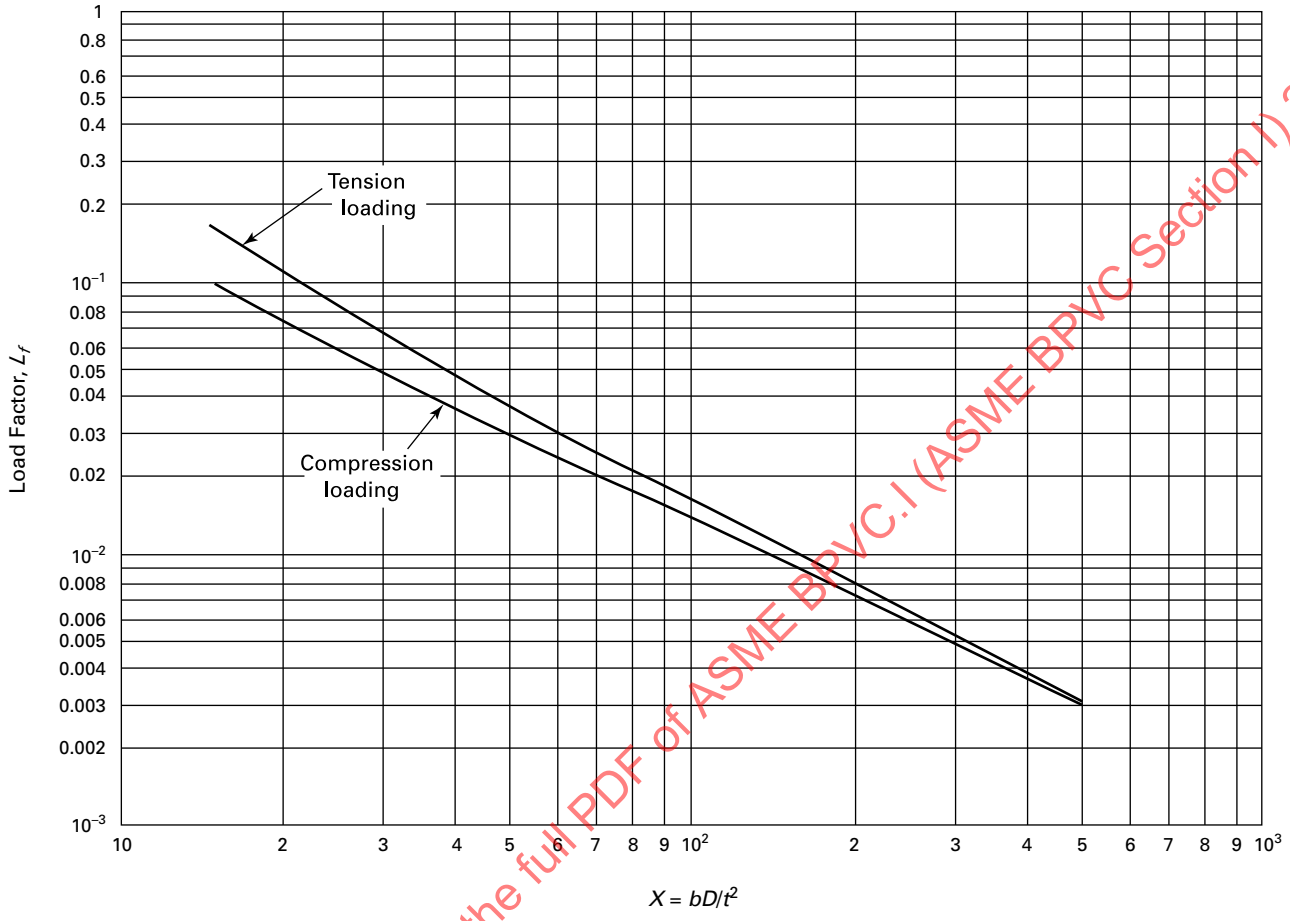
BOILER EXTERNAL PIPING AND BOILER PROPER CONNECTIONS

PG-58 BOILER EXTERNAL PIPING (BEP)

PG-58.1 General. The rules of this subparagraph apply to the boiler external piping as defined in the Preamble. All boiler external piping connected to a boiler for any purpose shall be attached to one of the types of joints listed in PG-59.1.1.1, PG-59.1.1.2, and PG-59.1.1.3 and is subject to the requirements of PG-104 for proper Code certification.

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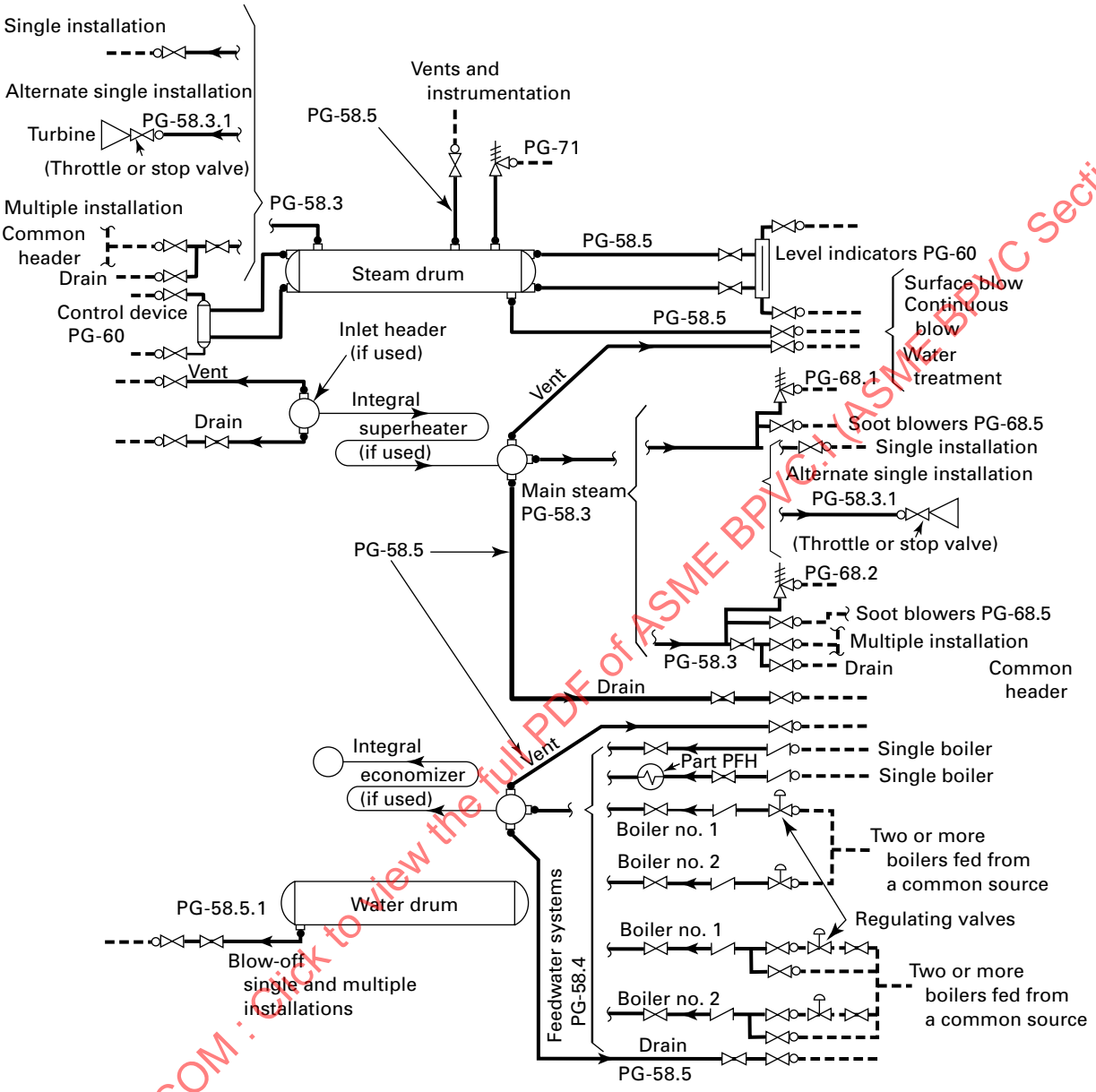
Figure PG-56.2
Chart for Determining Load Factor, L_f



PG-58.2 BEP Limits. The following defines the Code Jurisdictional Limits of the boiler external piping systems, including general requirements, valves, and inspection. The limits are also shown in Figures PG-58.2-1 through PG-58.2-6. The materials, design, fabrication, installation, and testing shall be in accordance with ASME B31.1, Power Piping.

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Figure PG-58.2-1
Code Jurisdictional Limits for Piping — Drum-Type Boilers



Administrative Jurisdiction and Technical Responsibility

Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble)

Boiler External Piping and Joint — The ASME BPVC has total administrative jurisdiction (mandatory certification by stamping the Certification Mark with appropriate Designator, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.

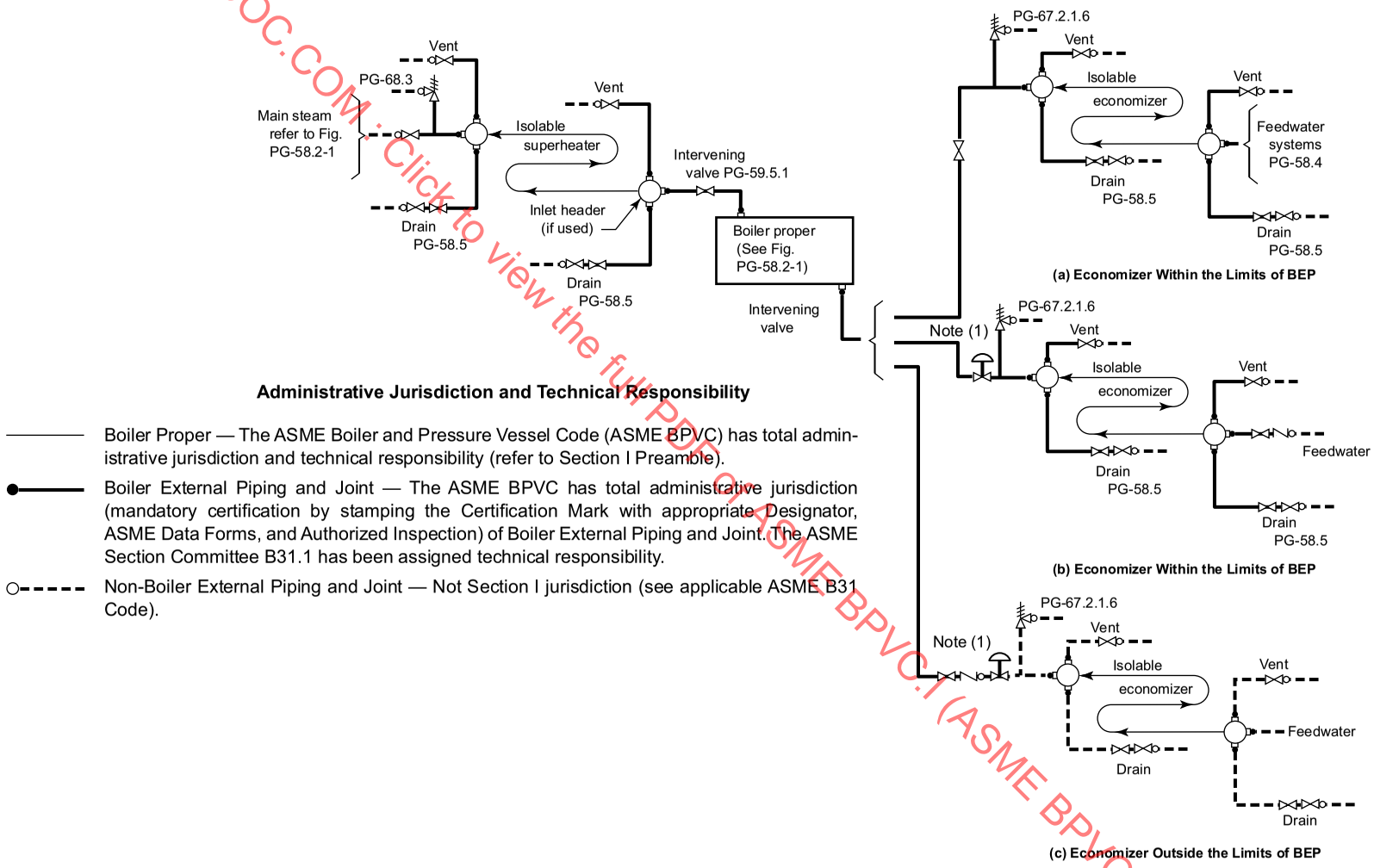
Non-Boiler External Piping and Joint — Not Section I jurisdiction (see applicable ASME B31 Code).

GENERAL NOTE: This figure provides references to other paragraphs of the Code for information only.

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Figure PG-58.2-2
Code Jurisdictional Limits for Piping — Isolable Economizers Located in Feedwater Piping and Isolable Superheaters in Main Steam Piping (Boiler Pressure Relief Valves, Blowoff, and Miscellaneous Piping for Boiler Proper Not Shown for Clarity)

(23)

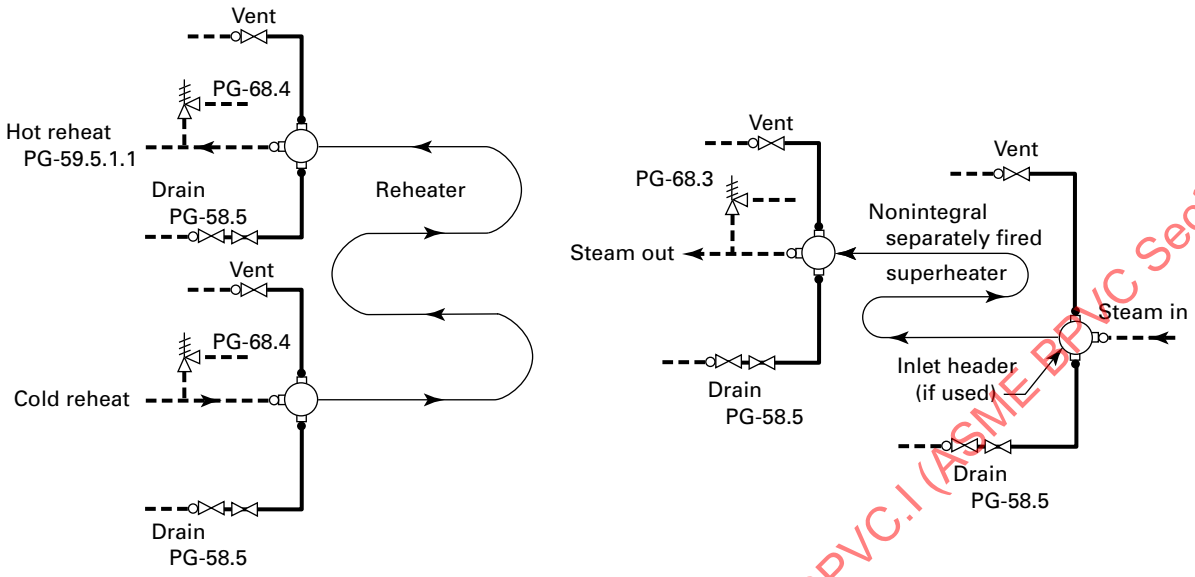


GENERAL NOTE: This figure provides references to other paragraphs of the Code for information only.

NOTE: (1) With feedwater regulator located between the boiler and economizer, the economizer may be constructed utilizing austenitic stainless steel (see Part PFE).

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Figure PG-58.2-3
Code Jurisdictional Limits for Piping — Reheaters and Nonintegral Separately Fired Superheaters



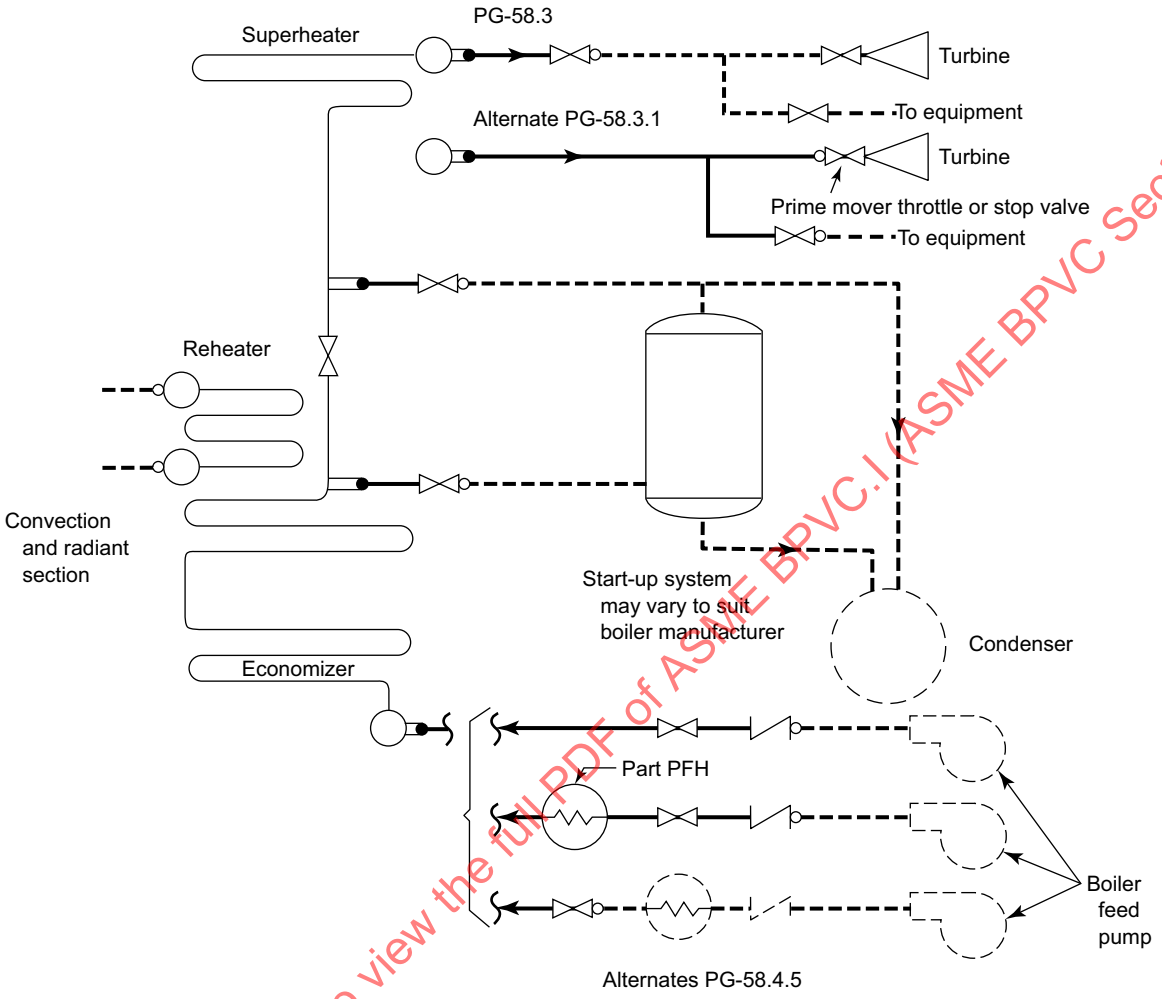
Administrative Jurisdiction and Technical Responsibility

———	Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble)
●———	Boiler External Piping and Joint — The ASME BPVC has total administrative jurisdiction (mandatory certification by stamping the Certification Mark with appropriate Designator, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.
○- - - -	Non-Boiler External Piping and Joint — Not Section I jurisdiction (see applicable ASME B31 Code).

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Figure PG-58.2-4
Code Jurisdictional Limits for Piping — An Example of Forced-Flow Steam Generators With No Fixed Steam and Waterline (23)



Administrative Jurisdiction and Technical Responsibility

Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble)

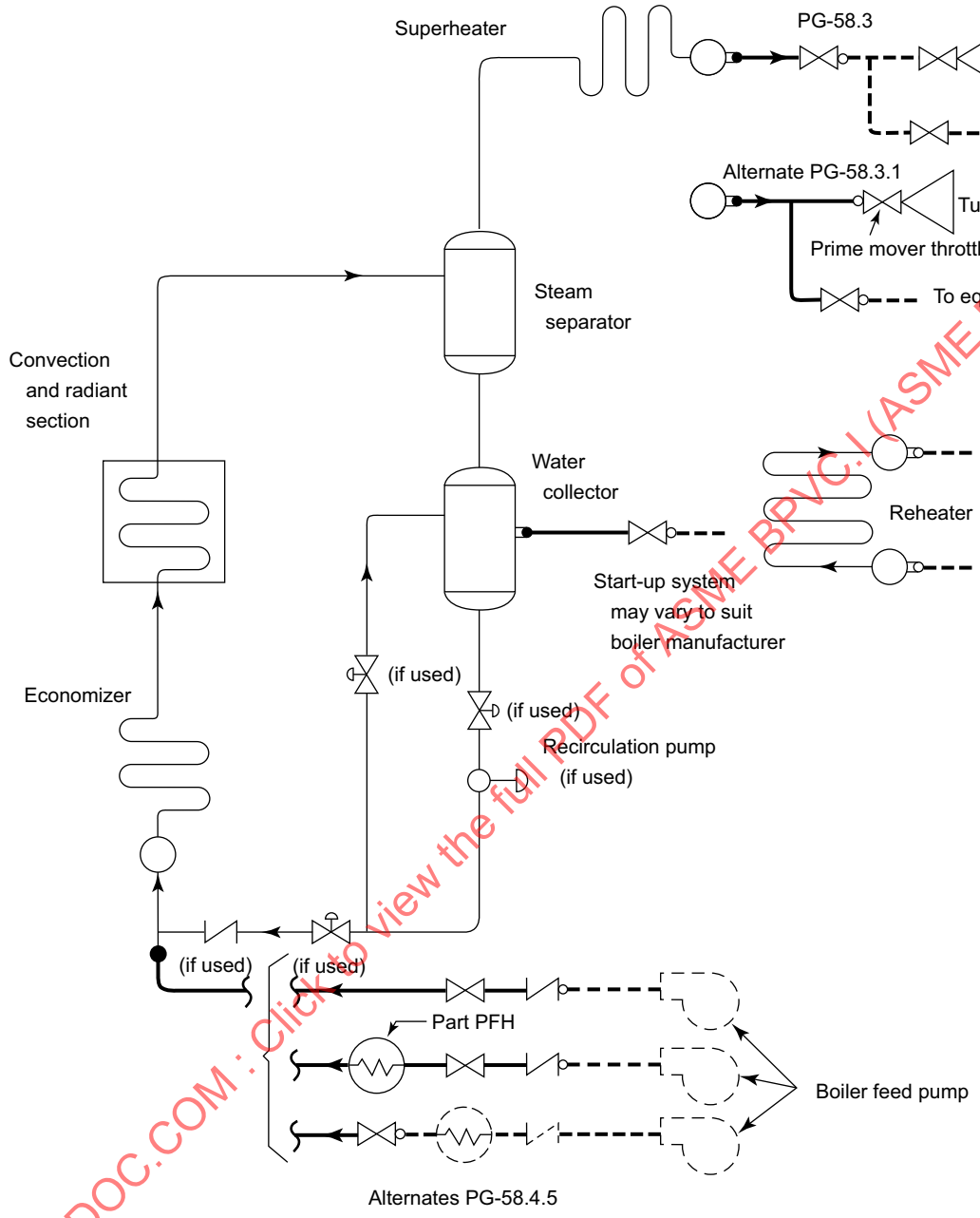
Boiler External Piping and Joint — The ASME BPVC has total administrative jurisdiction (mandatory certification by stamping the Certification Mark with appropriate Designator, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint.

The ASME Section Committee B31.1 has been assigned technical responsibility.

Non-Boiler External Piping and Joint — Not Section I jurisdiction (see applicable ASME B31 Code).

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Figure PG-58.2-5
(23) **Code Jurisdictional Limits for Piping — An Example of Steam Separator Type Forced-Flow Steam Generators With No Fixed Steam and Waterline**



Administrative Jurisdiction and Technical Responsibility

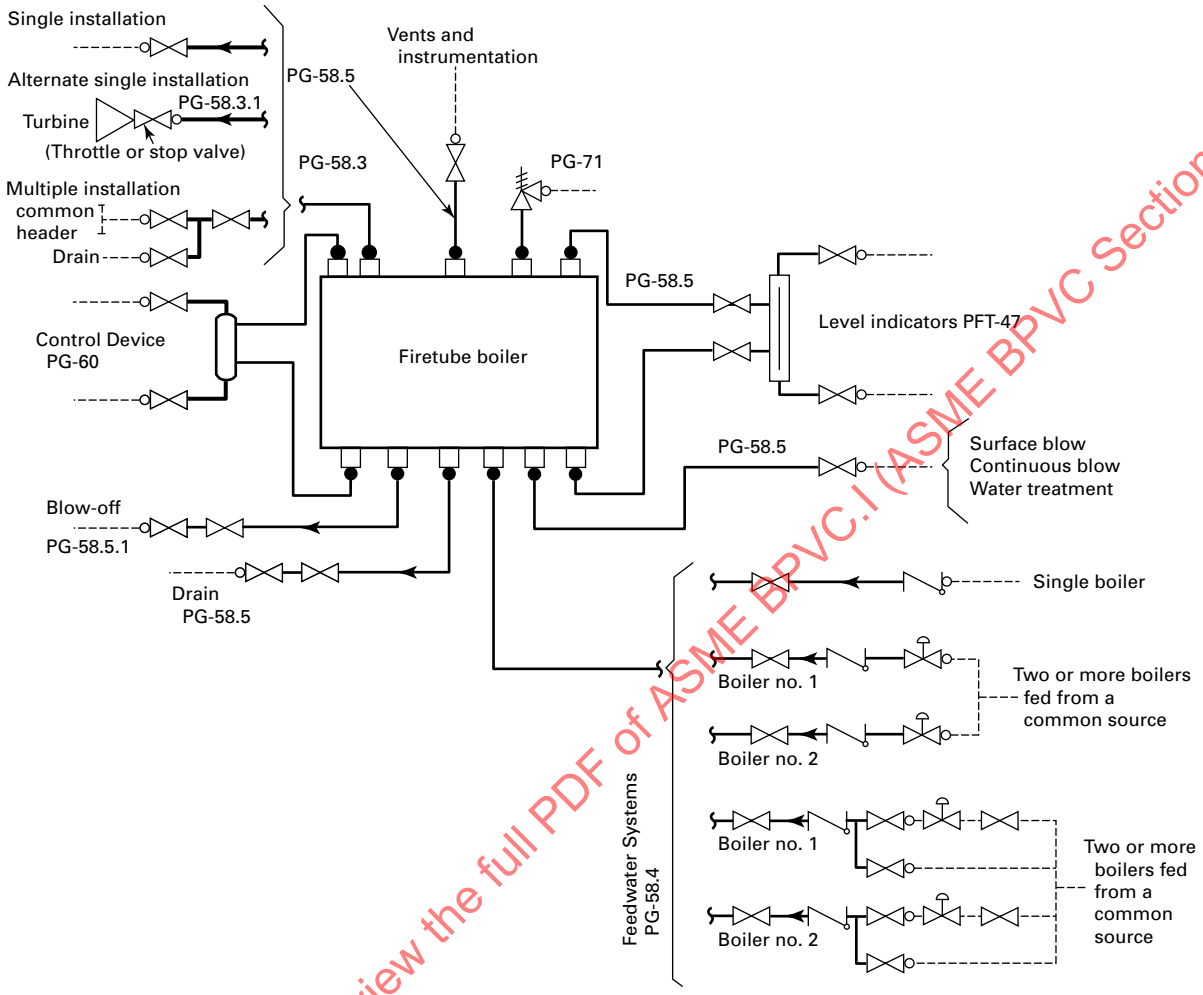
Boiler Proper – The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble).

Boiler External Piping and Joint – The ASME BPVC has total administrative jurisdiction (mandatory certification by stamping the Certification Mark with appropriate Designator, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.

Non-Boiler External Piping and Joint – Not Section I jurisdiction (see applicable ASME B31 Code).

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Figure PG-58.2-6
Code Jurisdictional Limits for Piping — Firetube Boiler



Administrative Jurisdiction and Technical Responsibility

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Boiler External Piping and Joint — The ASME BPVC has total administrative jurisdiction (mandatory certification by stamping the Certification Mark with appropriate Designator, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.

Non-Boiler External Piping and Joint — Not Section I jurisdiction (see applicable ASME B31 Code).

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PG-58.3 Outlet BEP. The steam piping connected to the boiler drum or to the superheater outlet header shall extend up to and including the first stop valve in each connection.

PG-58.3.1 In the case of a single boiler and prime mover installation, the stop valve required herein may be omitted, provided the prime mover stop valve or throttle valve is

(a) equipped with an indicator to show whether the valve is open or closed

(b) designed to withstand the required hydrostatic pressure test of the boiler

The limit of boiler external piping ends at the connection to such prime mover valves and does not include the connection.

PG-58.3.2 For an isolable or separately fired superheater that discharges steam directly to a process stream, the stop valve required by PG-58.3 and the safety valve(s) required by PG-68 may be omitted, provided the following conditions are satisfied:

(a) The boiler is a drum-type boiler in a single-boiler installation.

(b) The steam discharge passes through the process stream to the atmosphere with no intervening valves.

(c) The system shall be designed so that the process stream through which the steam discharge passes cannot be obstructed in such a way as to cause the pressure in the superheater to exceed that permitted by PG-67.2, with maximum steam flow from the boiler to the superheater. Flow and pressure calculations demonstrating that the superheater will not be overpressurized under any steam flow conditions shall be documented and made available to the Inspector. These calculations shall be certified by a Professional Engineer experienced in the mechanical design of power plants.

(d) There is no valve on the discharge side of the superheater.

(e) Section I jurisdiction shall include the pressure parts between and including the superheater inlet valve and the outlet at

(1) the first circumferential joint for welding end connections

(2) the face of the first flange in bolted flange connections or

(3) the first threaded joint in that type of connection

PG-58.3.3 When two or more boilers are connected to a common steam header, or when a single boiler is connected to a header having another steam source (e.g., a turbine extraction line), the connection from each boiler having a manhole opening shall be fitted with two stop valves having an ample free-blow drain between them. The boiler external piping includes all piping from the boiler proper up to and including the second stop valve and the free-blow drain valve.

PG-58.4 Inlet BEP. Feedwater piping for all boilers, (23) except high-temperature water boilers and forced-flow steam generators complying with PG-58.4.5, shall extend through the required stop valve and up to and including the check valve except as required by PG-58.4.3.

PG-58.4.1 On a single boiler-turbine unit installation the boiler feed shutoff valve may be located upstream from the boiler feed check valve.

PG-58.4.2 If a feedwater heater or heaters meeting the requirements of Part PFH are installed between the required stop valve and the boiler, and are fitted with isolation and bypass valves, provisions must be made to prevent the feedwater pressure from exceeding the maximum allowable working pressure of the piping or feedwater heater, whichever is less. Control and interlock systems are permitted in order to prevent overpressure.

PG-58.4.3 When two or more boilers are fed from a common source, the boiler external piping shall be up to and including a globe or regulating valve located between the check valve required in PG-58.4 and the source of supply.

PG-58.4.3.1 The boiler feed shutoff valve may be located upstream from the boiler feed check valve.

PG-58.4.3.2 If the regulating valve is equipped with an isolation valve and a bypass valve, the piping shall be up to and including both the isolation valve downstream from the regulating valve and the shutoff valve in the bypass.

PG-58.4.4 When there is a regulating valve located downstream of the economizer as shown in Figure PG-58.2-2, illustration (b), the piping shall extend up to and including the stop-and-check valve required by PG-58.4. An additional globe or regulating valve upstream of the check valve is not required.

PG-58.4.5 Feedwater piping for a forced-flow steam generator with no fixed steam and waterline may terminate up to and including the stop valve near the boiler and omitting the check valve near the boiler, provided that a check valve having a pressure rating no less than the boiler inlet design pressure is installed at the discharge of the boiler feed pump or elsewhere in the feedline between the feed pump and the feed stop valve. If the feedwater heater(s) is fitted with isolation and bypass valves, the applicable requirements of PG-58.4.2 must be met.

PG-58.5 Miscellaneous BEP. Miscellaneous piping shall include any piping, not otherwise described herein, that extends to or from the boiler proper up to the first stop valve, instrument, or instrument connection. Examples include piping for such items as drains, vents, surface blowoff, steam and water piping for water columns, gage glasses, water treatment, pressure gages, and water treatment connections. When a drain

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is not intended for blowoff purposes (when the boiler is under pressure), a single valve is acceptable; otherwise two valves in series are required except as permitted by PG-58.5.1.

PG-58.5.1 Blowoff piping for all boilers, except forced-flow steam generators with no fixed steam and waterline, high-temperature water boilers, and those used for traction and/or portable purposes, when the maximum allowable working pressure exceeds 100 psi (700 kPa) shall extend through and include the second valve. Blowoff piping for all traction and/or portable boilers and for forced circulation and electric boilers having a normal water content not exceeding 100 gal (380 L) are required to extend through only one valve.

PG-58.5.2 Boiler external piping for single high-temperature water boilers shall extend from the connections to the boiler up to and including the first stop valve and shall be classified as miscellaneous piping.

When multiple high-temperature water boilers are connected to common supply and return piping, and contain openings of a size that permit entry into the vessel, the supply and return piping systems shall meet the requirements of PG-58.3.3, including the requirement for a free-blow drain.

PG-59 APPLICATION REQUIREMENTS FOR THE BOILER PROPER

PG-59.1 Common to Steam, Feedwater, Blowoff, and Drain Systems.

PG-59.1.1 Outlets of a boiler to which piping is to be attached for any purpose, and which piping comes within the Code requirements, shall meet the requirements of PG-39 and shall be

PG-59.1.1.1 A tapped opening.

PG-59.1.1.2 Bolted flanged joints including those of the Van Stone type.

PG-59.1.1.3 Welding ends of the butt or socket welding type.

PG-59.1.1.4 Piping within the boiler proper may be expanded into grooved holes, seal welded if desired. Blowoff piping of firetube boilers shall be attached by threading into a tapped opening with a threaded fitting or valve at the other end if exposed to products of combustion, or by PG-59.1.1.1 or PG-59.1.1.2 if not so exposed (see PFT-49).

PG-59.1.2 Steam Mains. Provisions shall be made for the expansion and contraction of steam mains connected to boilers, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler. Steam reservoirs shall be used on steam mains when heavy pulsations of the steam currents cause vibration of the boiler shell plates.

PG-59.1.3 Figure PG-59.1 illustrates a typical form of connection for use on boiler shells for passing through piping such as feed, surface blowoff connections, etc., and which permits the pipes' being threaded in solid from both sides in addition to the reinforcing of the opening of the shell. The pipes shall be attached as provided in PG-59.1.1.

In these and other types of boilers where both internal and external pipes making a continuous passage are employed, the boiler bushing or its equivalent shall be used.

PG-59.2 Requirements for Feedwater Connections.

The feedwater shall be introduced into a boiler in such a manner that the water will not be discharged directly against surfaces exposed to gases of high temperature or to direct radiation from the fire. For pressures of 400 psi (3 MPa) or over, the feedwater inlet through the drum shall be fitted with shields, sleeves, or other suitable means to reduce the effects of temperature differentials in the shell or head. Feedwater, other than condensate returns as provided for in PG-59.3.6, shall not be introduced through the blowoff.

PG-59.3 Requirements for Blowoffs.

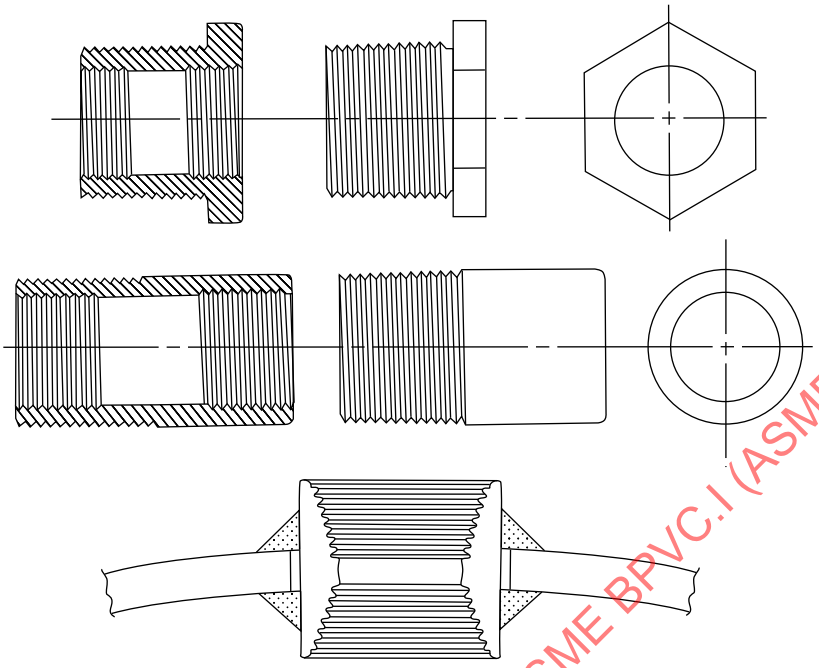
PG-59.3.1 A blowoff as required herein is defined as a pipe connection provided with valves located in the external piping through which the water in the boiler may be blown out under pressure, excepting drains such as are used on water columns, gage glasses, or piping to feedwater regulators, etc., used for the purpose of determining the operating condition of such equipment. Piping connections used primarily for continuous operation, such as deconcentrators on continuous blowdown systems, are not classed as blowoffs but the pipe connections and all fittings up to and including the first shutoff valve shall be equal at least to the pressure requirements for the lowest set pressure of any pressure relief valve on the boiler drum and with the corresponding saturated-steam temperature.

PG-59.3.2 When a surface blowoff connection is provided, the size shall not exceed NPS $2\frac{1}{2}$ (DN 65), and the internal pipe and the terminal connection for the external pipe, when used, shall form a continuous passage, but with clearance between their ends and arranged so that the removal of either will not disturb the other. A properly designed steel bushing, similar to or the equivalent of those shown in Figure PG-59.1, or a flanged connection shall be used.

PG-59.3.3 Each boiler except forced-flow steam generators with no fixed steam and waterline and high-temperature water boilers shall have a bottom blowoff outlet in direct connection with the lowest

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Figure PG-59.1
Typical Boiler Bushings



water space practicable for external piping conforming to PG-58.5.1.

PG-59.3.4 All waterwalls and water screens that do not drain back into the boiler, and all integral economizers, shall be equipped with outlet connections for a blowoff or drain line and conform to the requirements of PG-58.5 or PG-58.5.1.

PG-59.3.5 Except as permitted for miniature boilers in Part PMB, for electric boilers in Part PEB, and for boilers with 100 ft^2 (9.3 m^2) of heating surface or less, the minimum size of bottom blowoff connections shall be NPS 1 (DN 25) and the maximum size shall be NPS 2½ (DN 65). Boilers with 100 ft^2 (9.3 m^2) or less but more than 20 ft^2 (1.9 m^2) of heating surface may have a minimum size blowoff connection of NPS ¾ (DN 20). Boilers with 20 ft^2 (1.9 m^2) or less of heating surface may have a minimum size blowoff connection of NPS ½ (DN 15).

PG-59.3.6 Condensate return connections of the same size or larger than the size herein specified may be used, and the blowoff may be connected to them. In such case the blowoff shall be so located that the connection may be completely drained.

PG-59.3.7 A bottom blowoff pipe when exposed to direct furnace heat shall be protected by firebrick or other heat resisting material that is so arranged that the pipe may be inspected.

PG-59.3.8 An opening in the boiler setting for a blowoff pipe shall be arranged to provide free expansion and contraction.

PG-59.4 Requirements for Drains.

PG-59.4.1 Ample drain connections shall be provided where required to permit complete drainage of all piping, superheaters, waterwalls, water screens, economizers, and all other boiler components in which water may collect. Piping shall conform to the requirements of PG-58.5 or PG-58.5.1.

PG-59.4.1.1 Each superheater shall be equipped with at least one drain connection so located as to most effectively provide for the proper operation of the apparatus.

PG-59.4.1.2 Each high-temperature water boiler shall have a bottom drain connection of at least NPS 1 (DN 25) in direct connection with the lowest water space practical for external piping conforming to PG-58.5.2.

PG-59.5 Requirements for Valves and Fittings. The following requirements apply to the use of valves and fittings in the boiler proper.

PG-59.5.1 Steam Stop Valves.

PG-59.5.1.1 If a shutoff valve is used between the boiler and its superheater, the pressure relief valve capacity on the boiler shall comply with the requirements of PG-67.2 and PG-70, except as provided for in

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PG-59.5.1.2, no credit being taken for the pressure relief valve on the superheater, and the superheater must be equipped with pressure relief valve capacity as required by PG-68. A stop valve is not required at the inlet or the outlet of a reheater or separately fired superheater.

PG-59.5.1.2 When stop valves are installed in the water-steam flow path between any two sections of a forced-flow steam generator with no fixed steam and waterline, the pressure relief valves shall satisfy the requirements of PG-67.4.4.

DESIGN AND APPLICATION

PG-60 DESIGN AND APPLICATION REQUIREMENTS FOR MISCELLANEOUS PIPE, VALVES, AND FITTINGS

Piping referred to in this paragraph shall be designed in accordance with the applicable requirements of ASME B31.1.

PG-60.1 Water Level Indicators. All boilers having a fixed water level (steam and water interface) shall have at least one gage glass (a transparent device that permits visual determination of the water level). Gage glass designs that utilize transverse structural members (cross webbing) as a means to strengthen the body of the gage, which are not continuous over the entire vertical length of the gage glass, are not permitted.[13] The gage glass shall cover the full operating water level range. Except as provided in Parts PI, PEB, PMB, and PFT, the lowest visible water level in the gage glass shall be not less than 2 in. (50 mm) and not more than 3 in. (75 mm) above the lowest permissible water level, as determined by the boiler manufacturer.

Gage glass assemblies having multiple sections, whether of tubular or other construction, shall be designed in such a manner that will ensure a minimum of 1 in. (25 mm) overlap of all adjoining sections in which the water level may be visible, except that ported gages or reflex gages that use refraction of light to aid ready determination of the liquid level, may omit the requirement for overlapping sections.

PG-60.1.1 Boilers having a maximum allowable working pressure of 400 psi (3 MPa) or less shall have at least one gage glass in service at all times. Boilers having a maximum allowable working pressure exceeding 400 psi (3 MPa) shall have two gage glasses. Instead of one of the two required gage glasses, two independent remote water level indicators (two discrete systems that continuously measure, transmit, and display water level) may be provided and the required gage glass may be shut off, but shall be maintained in serviceable condition.

Electrode-type electric boilers are required to have only one gage glass, regardless of MAWP.

Boilers not having a fixed water level, such as forced-flow steam generators and high-temperature water boilers of the forced circulation type, are not required to have a gage glass.

PG-60.1.1.1 When the water level in at least one gage glass is not readily visible to the operator in the area where control actions are initiated, either a fiber optic cable (with no electrical modification of the optical signal) or mirrors shall be provided to transfer the optical image of the water level to the control area. Alternatively, any combination of two of the following shall be provided:

(a) an independent remote water level indicator

(b) an independent continuous transmission and display of an image of the water level in a gage glass

PG-60.1.1.2 The display of a remote water level indicator shall cover the full operating water level range and have a clearly marked minimum water level reference at least 2 in. (50 mm) and not more than 3 in. (75 mm) above the lowest permissible water level, as determined by the Manufacturer.

PG-60.1.1.3 Independent remote level indicators that contain sensing devices that include a magnetically coupled float inside a nonferromagnetic cylindrical pressure chamber to utilize through-the-wall sensing of float position shall be restricted to the requirements of PG-12.2.[14] The design and construction of such devices shall include provisions for ease of cleaning and maintenance. Attachment of any control devices for use other than indicating water level is prohibited.

PG-60.1.2 Each gage glass or externally mounted water-level-sensing or water-level-controlling device shall be fitted with a drain cock or valve having an unrestricted drain opening of not less than $\frac{1}{4}$ in. (6 mm) diameter to facilitate cleaning. When the boiler MAWP exceeds 100 psi (700 kPa), the gage glass shall be furnished with a connection to install a valved drain to a point of safe discharge.

Each gage glass or externally mounted water-level-sensing or water-level-controlling device shall be equipped with a top and a bottom shutoff valve of such through-flow construction as to prevent stoppage by deposits of sediments. See PG-60.3.7(a) through PG-60.3.7(e) for examples of acceptable valve construction. If either the top or bottom valve is more than 7 ft (2 m) above the floor or platform from which it is operated, the operating mechanism shall indicate by its position whether the valve is open or closed. A means of manually opening and closing the valves from the valve operating floor or platform shall be provided. The pressure–temperature rating of valves, fittings, and piping shall be at least equal to the boiler MAWP and the corresponding saturated-steam temperature.

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Straight-run globe valves shall not be used on such connections. Automatic shutoff valves as referenced here, are valves intended to automatically restrict flow in the event of a gage glass failure without human intervention, and, if provided, shall conform to the requirements given in A-18.

PG-60.1.3 As used in this section, "automated isolation valve" shall be taken to mean a device that is actuated electrically, pneumatically, or hydraulically to temporarily isolate a gage glass. It is required that the closing and opening sequences of such a device be manually initiated by the operator.

Automated isolation valves may be used, provided that

(a) all piping and fittings between the sight glass and the boiler, or sight glass and water column, are designed for internal inspection and cleaning, or are designed to allow passage internally of a rotary cleaning tool. The valves shall be of such through-flow construction as to prevent stoppage by deposits of sediment.

(b) the valves are equipped with opened and closed indicators that can readily be seen from the valve operating floor or platform. The design of the valves shall be such as to prevent indicating a false opened or closed condition.

(c) a means of manually opening and closing the valves from the valve operating floor or platform is provided.

(d) automated isolation valves are designed to fail-safe in the as-is condition.

PG-60.2 Water Columns.

PG-60.2.1 A water column shall be so mounted that it will be correctly positioned, relative to the normal water level under operating conditions.

PG-60.2.3 Each water column shall be furnished with a connection of at least NPS $\frac{3}{4}$ (DN 20) to install a valved drain to a safe point of discharge.

PG-60.2.4 The design and material of a water column shall comply with the requirements of PG-8.2, PG-8.3, and PG-42.

PG-60.3 Connections.

PG-60.3.1 Gage glasses that are required by PG-60.1 shall be connected to the shell or drum of the boiler or to an intervening water column. When two gage glasses are required, both may be connected to a single water column. Except as permitted or required by PG-60.3.4, PG-60.3.6, PG-60.3.7, and PG-60.3.8, piping from the gage glass to the drum or water column and between the water column and the drum shall be free of any device that has a function not related to level sensing. Additional water-level sensing devices may be connected to the same piping provided that they in no way impede the function of the gage glasses required by PG-60.1.

PG-60.3.2 The lower edge of the steam connection between a water column, gage glass, or austenitic stainless steel or nickel-based alloy water level-sensing device in the boiler shall not be below the highest visible water level in the gage glass. There shall be no sag or offset in the piping that will permit the accumulation of water.

PG-60.3.3 The upper edge of the water connection between a water column, gage glass, or austenitic stainless steel or nickel-based alloy water level-sensing device and the boiler shall not be above the lowest visible water level in the gage glass. No part of this pipe connection shall be above the point of connection at the water column.

PG-60.3.4 Connections from the boiler to the water column shall be at least NPS 1 (DN 25). Connections for gage glasses connected directly to the boiler or to an intervening water column shall be at least NPS $\frac{1}{2}$ (DN 15). Connections from the boiler to the remote level indicator shall be at least NPS $\frac{3}{4}$ (DN 20) to and including the isolation valve and from there to the remote level indicator at least $\frac{1}{2}$ in. (13 mm) O.D. tubing.

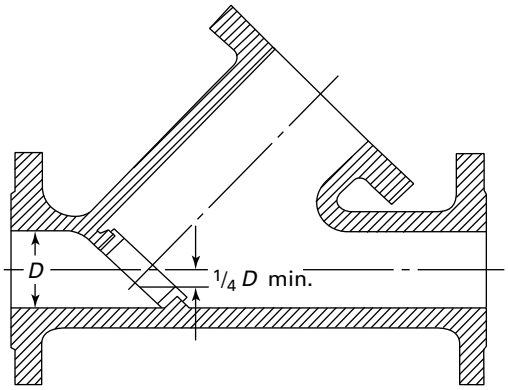
PG-60.3.5 When the boiler MAWP exceeds 400 psi (3 MPa), lower connections to drums for water columns and remote level indicators shall be provided with shields, sleeves, or other suitable means to reduce the effect of temperature differentials in the shells or heads.

PG-60.3.6 The steam and water connections to a water column, gage glass, or austenitic stainless steel or nickel-based alloy water level-sensing device shall be readily accessible for internal inspection and cleaning. Some acceptable methods of meeting this requirement are by providing a cross or fitting with a back outlet at each right-angle turn to permit inspection and cleaning in both directions, or by using pipe bends or fittings of a type that does not leave an internal shoulder or pocket in the pipe connection and with a radius of curvature that will permit the passage of a rotary cleaner. Screwed plug closures using threaded connections as allowed by PG-39.5.3 are acceptable means of access for this inspection and cleaning. When the boiler MAWP exceeds 400 psig (3 MPa), socket-welded plugs may be used for this purpose in lieu of screwed plugs. If the water connection to the water column has a rising bend or pocket that cannot be drained by means of the water-column drain, an additional drain shall be placed on this connection so that it may be blown off to clear any sediment from the pipe.

PG-60.3.7 Shutoff valves, including automated valves as described in PG-60.1.3, if provided in the pipe connections between a boiler and a water column or between a boiler and the shutoff valves required for the gage glass, or austenitic stainless steel or nickel-based alloy water level-sensing device (PG-60.1.2), shall be of such through-flow construction as to

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Figure PG-60.3.7
Y-Type Globe Valve



prevent stoppage by deposits of sediment and shall indicate whether they are in open or closed position of the operating mechanism.

Some examples of acceptable valves are:

(a) outside-screw-and-yoke-type gate valve

(b) lever-lifting-type gate valve with permanently fastened lever

(c) stopcock with the plug held in place by a guard or gland

(d) ball valve

(e) Y-type globe valve with rising stem so constructed that the lowest edge of the seat is at least 25% of the inside diameter below the centerline of the valve as shown in Figure PG-60.3.7.

Such valves shall be locked or sealed open except under the following additional conditions:

(1) The boiler MAWP shall not exceed 250 psig (1.7 MPa).

(2) The boiler shall not be hand fired or fired with solid fuel not in suspension.

(3) Interlocks between the valve and the burner control system shall stop fuel supply and prevent firing whenever the valve between the drum and the water column is not in the fully open position.

(4) The minimum valve size shall be NPS 1 (DN 25).

PG-60.3.7.1 Automated isolation valves (as described in PG-60.1.3) need not be locked or sealed open as noted above.

PG-60.3.8 Except for control devices such as damper regulators and feedwater regulators, drains, steam pressure gages, or apparatus of such form as does not permit the escape of an appreciable amount of steam or water therefrom, no outlet connections shall be placed on the piping connecting a water column or gage glass to a boiler. No outlet connections shall be placed on the piping connecting a remote level indicator to the boiler or to a water column for any function other than water level indication.

PG-60.3.9 An acceptable arrangement is shown in Figure PG-60.3.9.

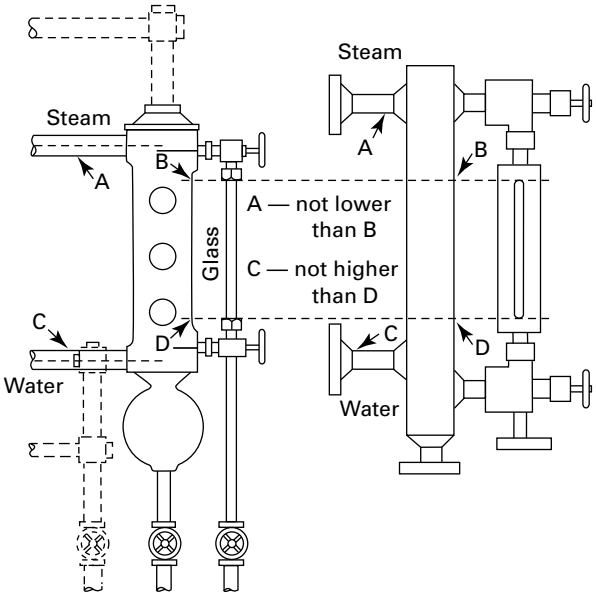
PG-60.4 Gage Cocks. Not required.

PG-60.5 Water Fronts. Each boiler fitted with a water jacketed boiler-furnace mouth protector, or similar appliance having valves on the pipes connecting them to the boiler shall have these valves locked or sealed open. Such valves, when used, shall be of the straightway type.

PG-60.6 Pressure Gages.

PG-60.6.1 Each boiler shall have a pressure gage so located that it is easily readable. The pressure gage shall be installed so that it shall at all times indicate the pressure in the boiler. Each steam boiler shall have the pressure gage connected to the steam space or to the water column or its steam connection. A valve or cock shall be placed in the gage connection adjacent to the gage. An additional valve or cock may be located near the boiler providing it is locked or sealed in the open position. No other shutoff valves shall be located between the gage and the boiler. The pipe connection shall be of ample size and arranged so that it may be cleared by blowing out. For a steam boiler the gage or connection shall contain a syphon or equivalent device that will develop and maintain a water seal that will prevent steam from entering the gage tube. Pressure gage connections shall be suitable for the maximum allowable working pressure and

Figure PG-60.3.9
Typical Arrangement of Steam and Water Connections for a Water Column



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temperature, but if the temperature exceeds 406°F (208°C), brass or copper pipe or tubing shall not be used. The connections to the boiler, except the syphon, if used, shall not be less than NPS ¼ (DN 8) but where steel or wrought iron pipe or tubing is used, they shall not be less than ½ in. (13 mm) inside diameter. The minimum size of a syphon, if used, shall be ¼ in. (6 mm) inside diameter. The dial of the pressure gage shall be graduated to approximately double the pressure at which the safety valve is set, but in no case to less than 1½ times this pressure.

PG-60.6.2 Each forced-flow steam generator with no fixed steam and waterline shall be equipped with pressure gages or other pressure measuring devices located as specified in PG-60.6.2.1 through PG-60.6.2.3.

PG-60.6.2.1 at the boiler or superheater outlet (following the last section, which involves absorption of heat)

PG-60.6.2.2 at the boiler or economizer inlet (preceding any section that involves absorption of heat), and

PG-60.6.2.3 upstream of any shutoff valve that may be used between any two sections of the heat-absorbing surface

PG-60.6.3 Each boiler shall be provided with a valve connection at least NPS ¼ (DN 8) for the exclusive purpose of attaching a test gage when the boiler is in service, so that the accuracy of the boiler pressure gage can be ascertained.

PG-60.6.4 Each high-temperature water boiler shall have a temperature gage so located and connected that it shall be easily readable. The temperature gage shall be installed so that it at all times indicates the temperature in degrees Fahrenheit (Celsius) of the water in the boiler, at or near the outlet connection.

PG-61 FEEDWATER SUPPLY

PG-61.1 Except as provided for in PG-61.2 and PG-61.4, boilers having more than 500 ft^2 (47 m^2) of water-heating surface shall have at least two means of feeding water. Except as provided for in PG-61.3, PG-61.4, and PG-61.5, each source of feeding shall be capable of supplying water to the boiler at a pressure of 3% higher than the highest setting of any pressure relief valve on the boiler proper. For boilers that are fired with solid fuel not in suspension, and for boilers whose setting or heat source can continue to supply sufficient heat to cause damage to the boiler if the feed supply is interrupted, one such means of feeding shall not be susceptible to the same interruption as the other, and each shall provide sufficient water to prevent damage to the boiler.

PG-61.2 Except as provided for in PG-61.1, a boiler fired by gaseous, liquid, or solid fuel in suspension, or heated by combustion turbine engine exhaust or solar radiation, may be equipped with a single means of feeding water, provided means are furnished for the shutting off of its heat input prior to the water level reaching the lowest permissible level established by PG-60.

PG-61.3 For boilers having a water-heating surface of more than 100 ft^2 (9.3 m^2), the feed water connection to the boiler shall be not less than NPS ¾ (DN 20).

For boilers having a water-heating surface of 100 ft^2 (9.3 m^2) or less, the feed water connection to the boiler shall be not less than NPS ½ (DN 15).

Boilers with 20 ft^2 (1.9 m^2) or less of water heating surface may have the feed water delivered through the blowoff opening.

PG-61.4 High-temperature water boilers shall be provided with means of adding water to the boiler or system while under pressure.

PG-61.5 A forced-flow steam generator with no fixed steam and waterline shall be provided with a source of feeding capable of supplying water to the boiler at a pressure not less than the expected maximum sustained pressure at the boiler inlet, as determined by the boiler Manufacturer, corresponding to operation at maximum designed steaming capacity with maximum allowable working pressure at the superheater outlet.

OVERPRESSURE PROTECTION REQUIREMENTS

PG-67 BOILER

PG-67.1 Minimum Number of Pressure Relief Valves Required (23)

(a) Each boiler shall have at least one pressure relief valve.

(b) Boilers with more than 500 ft^2 (47 m^2) of bare tube water-heating surface shall have two or more pressure relief valves.

(c) Boilers with combined bare tube and extended water-heating surface exceeding 500 ft^2 (47 m^2) shall have two or more pressure relief valves when the maximum designed steaming capacity, as determined by the Manufacturer, exceeds 4,000 lbm/hr (1 800 kg/h).

(d) Electric boilers with a power input more than 1,100 kW shall have two or more pressure relief valves.

(e) Organic fluid vaporizer generators require special consideration as given in Part PVG.

PG-67.2 The total combined relieving capacity for each boiler (except as noted in PG-67.2.1.6, PG-67.4, and PL-54) shall be such that all the steam that can be generated by the boiler is discharged without allowing the pressure to rise more than 6% above the highest

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pressure at which any valve is set and in no case to more than 6% above the maximum allowable working pressure (MAWP).

PG-67.2.1 The minimum required relieving capacity of the pressure relief valves for all types of boilers shall be not less than the maximum designed steaming capacity at the MAWP of the boiler, as determined by the Manufacturer and shall be based on the capacity of all the fuel burning equipment as limited by other boiler functions.

PG-67.2.1.1 The steam generated when all pressure relief valves are relieving at full lift on a boiler that has a steam-generating surface located downstream (in the gas stream of) a superheater and/or reheater surface may exceed the maximum designed steaming capacity at the MAWP of the boiler. The Manufacturer shall address this by one of the following methods:

PG-67.2.1.1.1 The minimum required relieving capacity of the pressure relief valves shall not be less than the steam that may be generated with all pressure relief valves relieving at full lift. For boilers that use auxiliary firing in combination with the primary heat source, the Manufacturer shall include the effect of such firing in the total required capacity.

PG-67.2.1.1.2 The minimum required relieving capacity of the pressure relief valves shall not be less than the maximum designed steaming capacity at the MAWP of the boiler, and the boiler shall be provided with controls responsive to steam pressure, which include not less than the following:

(a) a control that reduces that total heat input to the boiler such that the steam generated does not exceed the maximum designed steaming capacity at the MAWP of the boiler

(b) a control that trips the heat input to the boiler if the pressure reaches 106% of the MAWP of the boiler

PG-67.2.1.2 The minimum required relieving capacity for a waste heat boiler shall be determined by the Manufacturer. When auxiliary firing is to be used in combination with waste heat recovery, the maximum output as determined by the boiler Manufacturer shall include the effect of such firing in the total required capacity. When auxiliary firing is to be used in place of waste heat recovery, the minimum required relieving capacity shall be based on auxiliary firing or waste heat recovery, whichever is higher.

PG-67.2.1.3 The minimum required relieving capacity for electric boilers shall be in accordance with PEB-15.

(23) **PG-67.2.1.4** The minimum required relieving capacity in lbm/hr (kg/h) for a high-temperature water boiler shall be determined by dividing the maximum output in Btu/hr (W) at the boiler nozzle, produced by the highest heating value fuel for which the boiler is designed, by 1,000 (646).

PG-67.2.1.5 The minimum required relieving capacity for organic fluid vaporizers shall be in accordance with PVG-12. The minimum required relieving capacity for miniature boilers shall be in accordance with PMB-15.

PG-67.2.1.6 Any economizer that may be partially (23) or completely shut off from the boiler, thereby permitting the economizer to become a fired pressure vessel, shall have one or more pressure relief valves with a total discharge capacity, in lbm/hr (kg/h), calculated from the maximum expected heat absorption in Btu/hr (W), as determined by the Manufacturer, divided by 1,000 (646). This absorption shall be stated in the stamping (PG-106.4). For overpressure conditions where the fluid relieved is water, the discharge capacity of the pressure relief valve, or valves shall be sufficient to prevent the pressure from rising more than 10% or 3 psi (20 kPa), whichever is greater, above the maximum allowable working pressure.

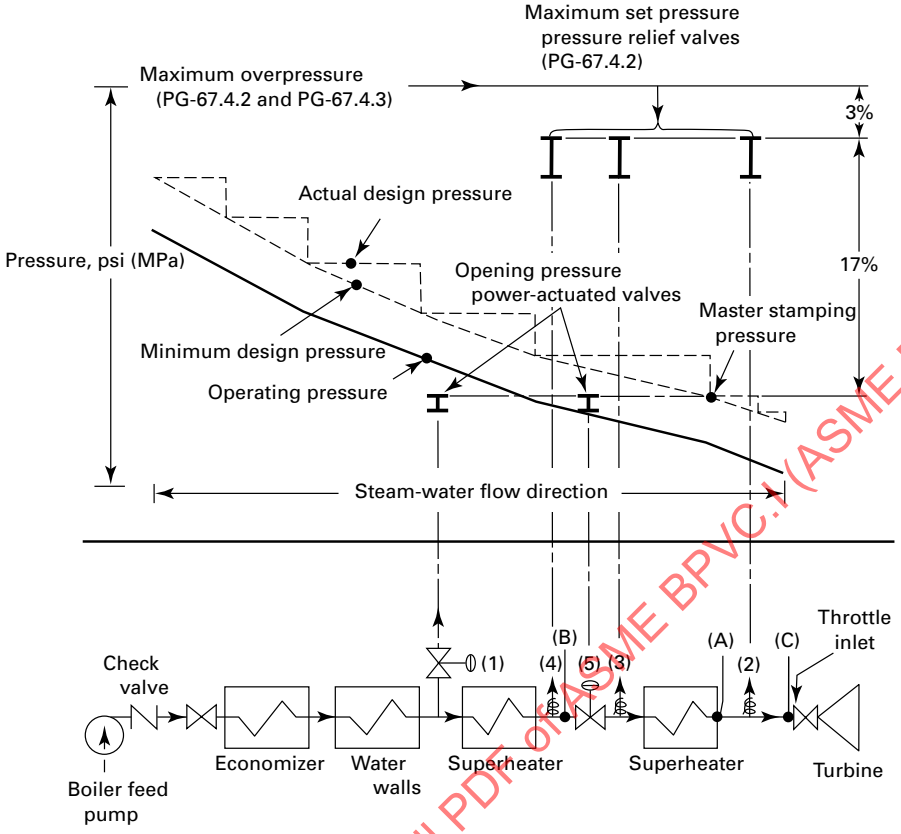
PG-67.3 One or more pressure relief valves on the boiler proper shall be set at or below the maximum allowable working pressure (except as noted in PG-67.4). If additional valves are used the highest pressure setting shall not exceed the maximum allowable working pressure by more than 3%. The complete range of pressure settings of all the saturated-steam pressure relief valves on a boiler shall not exceed 10% of the highest pressure to which any valve is set. Pressure setting of pressure relief valves on high-temperature water boilers[15] may exceed this 10% range. Economizer pressure relief devices required by PG-67.2.1.6 shall be set as above using the MAWP of the economizer.

PG-67.4 For a forced-flow steam generator with no fixed steam and waterline (Figure PG-67.4), equipped with automatic controls and protective interlocks responsive to steam pressure, pressure relief valves may be provided in accordance with the above paragraphs or the following protection against overpressure shall be provided:

PG-67.4.1 One or more power-actuated pressure-relieving valves[16] shall be provided in direct communication with the boiler when the boiler is under pressure and shall receive a control impulse to open when the maximum allowable working pressure at the superheater outlet, as shown in the master stamping (PG-106.3), is exceeded. The total combined relieving capacity of the power-actuated relieving valves shall be not less than 10% of the maximum design steaming capacity of the boiler under any operating condition as determined by the Manufacturer. The valve or valves shall be located in the pressure part system where they will relieve the overpressure.

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Figure PG-67.4
Requirements for Overpressure Protection Forced-Flow Steam Generator



Pressure
(A) = master stamping (PG-106.3)
(B) = component design at inlet to stop valve (5) (PG-67.4.4.1)
(C) = turbine throttle inlet [ASME B31.1, para. 122.1.2(d)]

Pressure Relief and Power-Actuated Valves
(1) = power actuated (PG-67.4.1)
(2), (3), and (4) = pressure relief valve (PG-67.4.2)
(5) = superheater stop (PG-67.4.4)

Pressure Relief Valve Flow Capacity (minimum, based on rated capacity of boiler)
(1) = 10% – 30% (PG-67.4.1)
(2) = minimum of one valve (PG-68.1)
(2) + (3) when downstream to stop valve (5) = that required for independently fired superheaters (PG-68.3)
(2) + (3) + (4) = 100% – (1) (PG-67.4.2)

Pressure Relief Valve Opening Pressure (maximum)
(1) = (A), and (B) when there is stop valve (5) (PG-67.4.1)
(2), (3), and (4) = (A) + 17% (PG-67.4.2)
(5) = (A) (PG-67.4.1)

Alternate Requirements for Pressure Relief Valves

Pressure Relief Valve Flow Capacity (minimum, based on rated capacity of boiler)
(1) = 10% – 30% (PG-67.4.1)
(2) = one valve minimum (PG-68.1)
(2) + (3) when downstream to stop valve (5) = that required for independently fired superheaters (PG-68.3)
(4) = 10% total with minimum of two valves when there is a stop valve (5) (PG-67.4.3.3)
(2) + (4) = 10% with minimum of two valves when there is no stop valve (5) (PG-67.4.3.3)

Pressure Relief Valve Opening Pressure (maximum)
(1) = (A), and (B) when there is stop valve (5) (PG-67.4.1)
(2), (3), and (4) = (A) + 20% (PG-67.4.3.3)
(5) = (A) (PG-67.4.1)

Automatic Pressure Controls (PG-67.4.3)
(a) at (C) for normal operation under load (PG-67.4.3.2.1)
(b) at (A) + 10% to overide control (a) (PG-67.4.3.2.2)
(c) at (A) + 20% to shut off flow of fuel and feedwater (PG-67.4.3.2.3)
(d) pressure relief valves at (4) to shut off flow of fuel and feedwater by "fail-safe" power circuit (PG-67.4.3.4)

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An isolating stop valve of the outside-screw-and-yoke or ball type may be installed between the power-actuated pressure-relieving valve and the boiler to permit repairs provided an alternate power-actuated pressure-relieving valve of the same capacity is so installed as to be in direct communication with the boiler in accordance with the requirements of this paragraph.

The isolating stop valve port area shall at least equal the area of the inlet of the power-actuated pressure-relieving valve. If the isolating stop valve is of the ball type, the valve shall include a means to clearly identify whether the valve is in the open or closed position. If the isolating stop valve is power actuated (air, motor, hydraulic, etc.), a manual override mechanism shall be provided.

Power-actuated pressure-relieving valves discharging to intermediate pressure and incorporated into bypass and/or startup circuits by the boiler Manufacturer need not be capacity certified. Instead, they shall be marked by the valve manufacturer with a capacity rating at a set of specified inlet pressure and temperature conditions. Power-actuated pressure-relieving valves discharging directly to atmosphere shall be capacity certified. This capacity certification shall be conducted in accordance with the provisions of PG-69.3. The valves shall be marked in accordance with the provisions of PG-69.4.

PG-67.4.2 Pressure relief valves shall be provided, having a total combined relieving capacity, including that of the power-actuated pressure-relieving capacity installed under PG-67.4.1, of not less than 100% of the maximum designed steaming capacity of the boiler, as determined by the Manufacturer, except the alternate provisions of PG-67.4.3 are satisfied. In this total, no credit in excess of 30% of the total required relieving capacity shall be allowed for the power-actuated pressure-relieving valves actually installed. Any or all of the pressure relief valves may be set above the maximum allowable working pressure of the parts to which they are connected, but the set pressures shall be such that when all of these valves (together with the power-actuated pressure-relieving valves) are in operation the pressure will not rise more than 20% above the maximum allowable working pressure of any part of the boiler, except for the steam piping between the boiler and the prime mover.

PG-67.4.3 The total installed capacity of pressure relief valves may be less than the requirements of PG-67.4.2 provided all of the following conditions are met.

(23) **PG-67.4.3.1** The boiler shall be of no less steaming capacity than 1,000,000 lbm/hr (450 000 kg/h) and installed in a unit system for power generation (i.e., a single boiler supplying a single turbine-generator unit).

PG-67.4.3.2 The boiler shall be provided with automatic devices, responsive to variations in steam pressure, which include not less than all the following:

PG-67.4.3.2.1 A control capable of maintaining steam pressure at the desired operating level and of modulating firing rates and feedwater flow in proportion to a variable steam output.

PG-67.4.3.2.2 A control that overrides PG-67.4.3.2.1 by reducing the fuel rate and feedwater flow when the steam pressure exceeds the maximum allowable working pressure as shown in the master stamping (PG-106.3) by 10%, and

PG-67.4.3.2.3 A direct-acting overpressure-trip-actuating mechanism, using an independent pressure-sensing device, that will stop the flow of fuel and feedwater to the boiler, at a pressure higher than the set pressure of PG-67.4.3.2.2, but less than 20% above the maximum allowable working pressure as shown in the master stamping (PG-106.3).

PG-67.4.3.3 There shall be not less than two pressure relief valves and the total rated relieving capacity of the pressure relief valves shall be not less than 10% of the maximum designed steaming capacity of the boiler as determined by the Manufacturer. These pressure relief valves may be set above the maximum allowable working pressure of the parts to which they are connected but shall be set such that the valves will lift at a pressure no higher than 20% above the maximum allowable working pressure as shown in the master stamping (PG-106.3).

PG-67.4.3.4 At least two of these pressure relief valves shall be equipped with a device that directly transmits the valve stem lift action to controls that will stop the flow of fuel and feedwater to the boiler. The control circuitry to accomplish this shall be arranged in a "fail-safe" manner (see Note).

NOTE: "Fail-safe" shall mean a circuitry arranged as either of the following:

(a) *Energize to Trip.* There shall be at least two separate and independent trip circuits served by two power sources, to initiate and perform the trip action. One power source shall be a continuously charged DC battery. The second source shall be an AC-to-DC converter connected to the DC system to charge the battery and capable of performing the trip action. The trip circuits shall be continuously monitored for availability.
It is not mandatory to duplicate the mechanism that actually stops the flow of fuel and feedwater.

(b) *De-energize to Trip.* If the circuits are arranged in such a way that a continuous supply of power is required to keep the circuits closed and operating and such that any interruption of power supply will actuate the trip mechanism, then a single trip circuit and single power supply will be enough to meet the requirements of this subparagraph.

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PG-67.4.3.5 The power supply for all controls and devices required by PG-67.4.3 shall include at least one source contained within the same plant as the boiler and which is arranged to actuate the controls and devices continuously in the event of failure or interruption of any other power sources.

PG-67.4.4 When stop valves are installed in the water-steam flow path between any two sections of a forced-flow steam generator with no fixed steam and waterline,

PG-67.4.4.1 The power-actuated pressure-relieving valve(s) required by PG-67.4.1 shall also receive a control impulse to open when the maximum allowable working pressure of the component, having the lowest pressure level upstream to the stop valve, is exceeded, and

PG-67.4.4.2 The pressure relief valves shall be located to provide the pressure protection requirements in PG-67.4.2 or PG-67.4.3.

PG-67.4.5 A reliable pressure-recording device shall always be in service and records kept to provide evidence of conformity to the above requirements.

(23) **PG-67.5** Pressure relief valves or power-actuated pressure-relieving valves shall be tested in accordance with the requirements of PG-69, and shall be credited with capacities as determined by the provisions of PG-69. For pressures over 3,200 psig (22.1 MPa), the rated relieving capacity, W, shall be multiplied by the appropriate supercritical correction factor, K_{sc}, from Nonmandatory Appendix A, Table A-400 (Table A-400M).

Pressure relief valves may be used that give any opening up to the full discharge capacity of the area of the opening of the inlet of the valve, provided the movement of a steam pressure relief valve is such as not to induce lifting of water in the boiler.

For high-temperature water boilers pressure relief valves shall be used. Such valves shall have a closed bonnet. In addition the pressure relief valves shall be capable of satisfactory operation when relieving water at the saturation temperature corresponding to the pressure at which the valve is set to blow.

(23) PG-68 SUPERHEATER AND REHEATER

PG-68.1 Except as permitted in PG-58.3.2, every attached superheater shall have one or more pressure relief valves in the steam flow path between the superheater outlet and the first stop valve.

(a) The location shall be suitable for the service intended and shall provide the overpressure protection required.

(b) The pressure drop upstream of each pressure relief valve shall be considered in the determination of set pressure and relieving capacity of that valve.

(c) The pressure relief valve, or valves, may be located anywhere in the length of the superheater outlet header, provided

(1) the header has a full, free steam passage from end to end

(2) the header is so constructed that steam is supplied to it at practically equal intervals throughout its length so that there is a uniform flow of steam through the superheater tubes and the header

PG-68.2 The discharge capacity of the pressure relief valve, or valves, on an attached superheater may be included in determining the number and size of the pressure relief valves for the boiler, provided

(a) there are no intervening valves between the superheater pressure relief valve and the boiler

(b) the discharge capacity of the pressure relief valve, or valves, on the boiler, as distinct from the superheater is at least 75% of the aggregate valve capacity required.

PG-68.3 Every isolable superheater that may be shut off from the boiler and permit the superheater to become a fired pressure vessel and all nonintegral separately fired superheaters shall have one or more pressure relief valves having a discharge capacity equal to 6 lbm/ft^2 (29 kg/m^2) of steam per hour, using the superheater surface measured on the side exposed to the hot gases. As an alternative the Manufacturer may also calculate the minimum pressure relief valve discharge capacity in lbm (kg) of steam per hour from the maximum expected heat absorption (as determined by the Manufacturer) in Btu/hr (W), divided by 1,000 (646). In the case of electrically heated superheaters, the pressure relief valve capacity shall be based upon 3½ lbm/hr/kW (1.6 kg/h/kW) input. The number of pressure relief valves installed shall be such that the total capacity is at least equal to that required. Pressure relief valves for separately fired superheaters shall be located in accordance with the rules of PG-68.1 and the mounting rules of PG-71.

PG-68.4 Every reheater shall have one or more pressure relief valves, such that the total relieving capacity is at least equal to the maximum steam flow for which the heater is designed. The capacity of the reheater pressure relief valves shall not be included in the required relieving capacity for the boiler and superheater.

One or more pressure relief valves with a combined relieving capacity not less than 15% of the required total shall be located along the steam flow path between the reheater outlet and the first stop valve. The pressure drop upstream of the pressure relief valves on the outlet side of the reheater shall be considered in determining their set pressure.

PG-68.5 A soot blower connection may be attached to the same outlet from the superheater or reheater that is used for the pressure relief valve connection.

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PG-68.6 Every pressure relief valve used on a superheater or reheater discharging superheated steam at a temperature over 450°F (230°C) shall have a casing, including the base, body, and, if applicable, bonnet and spindle, of steel, steel alloy, or equivalent heat-resisting material.

The pressure relief valve shall have a flanged inlet connection, or a weld-end inlet connection. Power-actuated pressure-relieving valves may have other inlet connection types that conform to PG-11 standard pressure part pressure–temperature ratings and PG-71.2 pressure relief inlet area sizing requirements. It shall have the seat and disk of suitable heat erosive and corrosive resisting material, and the spring of direct spring-loaded safety valves shall be fully exposed outside of the valve casing so that it shall be protected from contact with the escaping steam.

PG-68.7 The capacity of a pressure relief valve on superheated steam shall be calculated by multiplying the capacity determined in accordance with PG-69.2 by the appropriate superheat correction factor K_{sh}, from Nonmandatory Appendix A, Table A-401 (Table A-401M).

(23) PG-69 CERTIFICATION OF CAPACITY OF PRESSURE RELIEF VALVES

PG-69.1 Before the Certification Mark is applied to any pressure relief valve or power-actuated pressure-relieving valve, the valve manufacturer (see Note below) shall have the relieving capacity of their pressure relief valves certified in accordance with the provisions of this paragraph.

NOTE: Within the requirements of PG-69 through PG-73.7.3, a *manufacturer* (with lowercase "m") is defined as a person or organization that is completely responsible for the design, material selection, capacity certification, manufacture of all component parts, assembly, testing, sealing, and shipping of pressure relief valves certified under this Section.

An *assembler* (with lowercase "a") is defined as a person or organization that purchases or receives from a manufacturer the necessary component parts or valves and assembles, adjusts, tests, seals, and ships pressure relief valves certified under this Section at a geographical location other than and using the facilities other than those used by the manufacturer.

PG-69.1.1 For steam service, capacity certification tests shall be conducted using dry saturated steam. The limits for test purposes shall be 98% minimum quality and 20°F (10°C) maximum superheat. Correction from within these limits may be made to the dry saturated condition.

For liquid service, capacity certification tests shall be conducted using water at a temperature between 40°F to 125°F (5°C to 50°C).

PG-69.1.4 For steam service, capacity certification tests shall be conducted at a pressure that does not exceed the set pressure by 3% or 2 psi (15 kPa), whichever is greater. Pressure relief valves shall be adjusted so that the blowdown does not exceed 4% of the set pressure. For pressure relief valves set at or below 100 psi (700 kPa), the blowdown shall be adjusted so as not to exceed 4 psi (30 kPa). Pressure relief valves used on forced-flow steam generators with no fixed steam and waterline, and pressure relief valves used on high-temperature water boilers shall be adjusted so that the blowdown does not exceed 10% of the set pressure. The reseating pressure shall be noted and recorded.

For liquid service, capacity certification tests shall be conducted at a pressure that does not exceed the set pressure by 10% or 3 psi (20 kPa), whichever is greater. There are no maximum blowdown requirements for liquid service valves; however, the reseating pressure shall be noted and recorded.

PG-69.2 Relieving capacities shall be determined using one of the methods in Section XIII, 9.7.4 through 9.7.6. PG-69.2.1 through PG-69.2.6 have been transferred to Section XIII.

PG-69.3 If a manufacturer wishes to apply the Certification Mark to a power-actuated pressure-relieving valve under PG-67.4.1, the power-actuated pressure-relieving valve or valves shall be certified in accordance with Section XIII, 9.7.5 or 9.7.6.

PG-69.4 Power-actuated pressure-relieving valves, having capacities certified in accordance with the provision of PG-69.3, shall be marked as required by PG-110 with the computed capacity, corresponding to 3% above the full load operating pressure and temperature conditions at the valve inlet when the valve is operated by the controller, and they shall also be stamped with the set pressure of the controller. When the valve is marked as required by this paragraph, it shall be the guarantee by the manufacturer that the valve also conforms to the details of construction herein specified.

PG-70 CAPACITY OF PRESSURE RELIEF VALVES

PG-70.1 Subject to the minimum number required by PG-67.1, the number of pressure relief valves required shall be determined on the basis of the maximum designed steaming capacity, as determined by the boiler Manufacturer, and the relieving capacity marked on the valves by the manufacturer.

PG-71 MOUNTING OF PRESSURE RELIEF VALVES

PG-71.1 When two or more pressure relief valves are used on a boiler, they may be mounted either separately or as twin valves made by placing individual valves on Y-bases, or duplex valves having two valves in the same body casing. Twin valves made by placing individual valves on Y-bases, or duplex valves having two valves in the same body, shall be of approximately equal capacity.

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When not more than two valves of different sizes are mounted singly on the same component (e.g., drum, economizer, superheater, etc.) the relieving capacity of the smaller valve shall be not less than 50% of that of the larger valve.

PG-71.2 The pressure relief valve or valves shall be connected to the boiler independent of any other connection, and attached as close as possible to the boiler or the normal steam flow path, without any unnecessary intervening pipe or fitting. Such intervening pipe or fitting shall be not longer than the face-to-face dimension of the corresponding tee fitting of the same diameter and pressure under ASME B16.5 and shall also comply with PG-8 and PG-39. Every pressure relief valve shall be connected so as to stand in an upright position, with spindle vertical. On high-temperature water boilers of the watertube forced-circulation type, the valve shall be located at the boiler outlet.

(23) **PG-71.3** The opening or connection between the boiler and the pressure relief valve shall have at least the area of the valve inlet. No valve of any description, except as allowed by PG-71.3.1, shall be placed between the required pressure relief valve or valves and the boiler, nor on the discharge pipe between the pressure relief valve and the atmosphere. When a discharge pipe is used, the cross-sectional area shall be not less than the full area of the valve outlet or of the total of the areas of the valve outlets, discharging thereinto. It shall be as short and straight as possible and so arranged as to avoid undue stresses on the valve or valves.

All pressure relief valve discharges shall be so located or piped as to be carried clear from running boards or platforms. Ample provision for gravity drain shall be made in the discharge pipe at or near each pressure relief valve, and where water of condensation may collect. Each valve shall have an open gravity drain through the casing below the level of the valve seat. For iron- and steel-bodied valves exceeding NPS 2½ (DN 65), the drain hole shall be tapped not less than NPS ⅜ (DN 10).

Discharge piping from pressure relief valves on high-temperature water boilers shall be provided with adequate provisions for water drainage as well as the steam venting.

The installation of cast iron bodied pressure relief valves for high-temperature water boilers is prohibited.

PG-71.3.1 A changeover valve may be installed between pressure relief valves and the boiler or piping to be protected [excluding organic fluid vaporizers (Part PVG), thermal fluid heaters (Part PTFH), and PRVs in liquid service] when the following conditions are met:

(a) The two pressure relief valves connected to the changeover valve shall be of the same inlet and outlet size and of approximately equal capacity. Only the capacity of the smaller pressure relief valve shall be counted towards the total required relieving capacity.

(b) The changeover valve shall be designed such that there is no position where the moving internal components will isolate or block both pressure relief valves simultaneously.

(c) The changeover valve shall have an indicator that shows which pressure relief valve is in service.

(d) The changeover valve shall have a positive locking device that permits it to be locked only when one of the outlet ports is fully open and the other outlet port is fully closed. Also, a warning tag shall be affixed to the changeover valve stating that the changeover valve is to be locked or sealed at all times except when being operated by a competent person who shall remain stationed at the changeover valve until it is again locked or sealed.

(e) The changeover valve shall be equipped with external valves to safely bleed off the pressure between the isolated pressure relief valve and the fully closed port of the changeover valve. Also, a warning tag shall be affixed to the changeover valve stating that the bleed valve shall be fully opened prior to servicing the isolated pressure relief valve.

(f) The changeover valve shall comply with the requirements of ASME B16.34.

(g) Calculations demonstrating that the changeover valve, mounting nozzle, and its supporting vessel or pipe are capable of sustaining reaction forces from the pressure relief valve discharge shall be made available to the Authorized Inspector.

(h) The changeover valve inlet shall be permanently and clearly marked with the word “inlet.”

(i) The changeover valve shall have a permanently affixed nameplate with the following information:

(1) the actual orifice area of the pressure relief valve and coefficient of discharge K_d

(2) C_v (K_v) value of changeover valve

(3) the name of the changeover valve manufacturer

(j) The changeover valve flow path length may exceed the limit imposed by PG-71.2, provided the piping and changeover valve coefficient C_v (K_v) meets the requirement of (k). The use of the *Y*-bases and intervening pipe or fittings as provided for in PG-71.1 and PG-71.2, respectively, shall not be permitted when applying this paragraph.

(k) The changeover valve shall have a valve coefficient, C_v (K_v), equal to or greater than the following:

(U.S. Customary Units)

$$C_v = 5.69AK_dK_nK_{sh}\sqrt{\frac{P_r}{\delta}}$$

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(SI Units)

$$K_v = 0.36778AK_dK_nK_{sh}\sqrt{\frac{P_r}{\delta}}$$

where

A = actual orifice area of the pressure relief valve, in.^{2} (mm^2)
K_d = actual coefficient of discharge of the safety or safety relief valve
K_N = steam correction factor as per Section XIII, 9.7.6.4 for dry saturated steam pressures over 1,580 psia (10.9 MPa) and up to 3,200 psia (22.1 MPa)
K_{Sh} = superheat correction factor for the safety or safety relief valve [see Nonmandatory Appendix A, Table A-401 (Table A-401M)]
P_r = absolute relieving pressure, psia (MPa)
δ = density of steam at P_r, (lbm/ft^3) (kg/m^3)

The opening area of all piping, fittings, and boiler openings between the boiler and the changeover valve shall have at least the area of the inlet of the pressure relief valves attached.

(l) The boiler Manufacturer shall provide to the AI a certified test report determining the rated C_v (K_v) for the valve model, type, and size when requested.

The tests shall be made under the supervision of and certified by the manufacturer. The testing facilities, methods, and procedures shall be in accordance with the applicable requirements of ANSI/ISA-S75.02-1988.

(m) The changeover valve nameplate information shall be shown on the Manufacturer's Data Report.

PG-71.3.2 Definition

changover valve: a three-way stop or diverter valve with one inlet port and two outlet ports designed to isolate either one of the two outlet ports from the inlet port, but not both simultaneously during any mode of operation.

PG-71.4 If a muffler is used on a pressure relief valve, it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid a possibility of restriction of the steam passages due to deposit. Mufflers shall not be used on high-temperature water boiler pressure relief valves.

When a pressure relief valve is exposed to outdoor elements that may affect operation of the valve, it is permissible to shield the valve with a satisfactory cover. The shield or cover shall be properly vented and arranged to permit servicing and normal operation of the valve.

PG-71.5 When a boiler is fitted with two or more pressure relief valves on one connection, this connection to the boiler shall have a cross-sectional area not less than the combined areas of inlet connections of all the pressure relief valves with which it connects and shall also meet the requirements of PG-71.3.

PG-71.6 Pressure relief valves may be attached to drums or headers by welding provided the welding is done in accordance with Code requirements.

PG-71.7 Every boiler shall have proper outlet connections for the required pressure relief valve, or valves, independent of any other outside steam connection, the area of opening to be at least equal to the aggregate areas of inlet connections of all of the pressure relief valves to be attached thereto. An internal collecting pipe, splash plate, or pan may be used, provided the total area for inlet of steam thereto is not less than twice the aggregate areas of the inlet connections of the attached pressure relief valves. The holes in such collecting pipes shall be at least ¼ in. (6 mm) in diameter and the least dimension in any other form of opening for inlet of steam shall be ¼ in. (6 mm).

Such dimensional limitations to operation for steam need not apply to steam scrubbers or driers provided the net free steam inlet area of the scrubber or drier is at least 10 times the total area of the boiler outlets for the pressure relief valves.

PG-71.8 If pressure relief valves are attached to a separate steam drum or dome, the opening between the boiler proper and the steam drum or dome shall be not less than required by PG-71.7.

PG-72 OPERATION OF PRESSURE RELIEF VALVES

PG-72.1 Pressure relief valves shall be designed and constructed to operate without chattering, with a minimum blowdown of 2 psi (15 kPa) or 2% of the set pressure, whichever is greater, and to attain full lift at a pressure not greater than 3% above their set pressure.

Pressure relief valves used on forced-flow steam generators with no fixed steam and waterline, and pressure relief valves used on high-temperature water boilers must be marked for these special services by the valve manufacturer or assembler.

PG-72.2 The set pressure tolerance plus or minus shall not exceed that specified in the following table:

Set Pressure, psi (MPa)	Tolerance, Plus or Minus From Set Pressure
≤70 (0.5)	2 psi (15 kPa)
>70 (0.5) and ≤300 (2.1)	3% of set pressure
>300 (2.1) and ≤1,000 (7.0)	10 psi (70 kPa)
>1,000 (7.0)	1% of set pressure

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PG-73 MINIMUM REQUIREMENTS FOR PRESSURE RELIEF VALVES

PG-73.1 Permissible Pressure Relief Valves.

PG-73.1.1 Pressure relief valves shall be either direct spring-loaded safety valves, direct spring-loaded safety relief valves, or pilot-operated pressure relief valves.

PG-73.1.2 Power-actuated pressure-relieving valves shall only be used for applications specified in PG-67.4.1.

PG-73.1.3 Deadweight or weighted lever safety valves or safety relief valves shall not be used.

PG-73.1.4 Unless otherwise defined, the definitions relating to pressure relief devices in ASME PTC 25 shall apply.

PG-73.2 Minimum Requirements.

PG-73.2.1 All pressure relief valves shall be so constructed that the failure of any part cannot obstruct the free and full discharge of steam and water from the valve. Pressure relief valves shall have the seat inclined at any angle between 45 deg and 90 deg, inclusive, to the centerline of the disk.

PG-73.2.2 The design shall incorporate guiding arrangements necessary to insure consistent operation and tightness.

PG-73.2.3 The spring shall be designed so that the full lift spring compression shall be no greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the free height and height measured 10 min after the spring has been compressed solid three additional times after presetting at room temperature) shall not exceed 0.5% of the free height.

PG-73.2.4 To provide a means for verifying whether it is free, each safety valve or safety relief valve shall have a substantial lifting device, which when activated will release the seating force on the disk when the valve is subjected to pressure of at least 75% of the set pressure. The lifting device shall be such that it cannot lock or hold the valve disk in lifted position when the exterior lifting force is released. Disks of pressure relief valves used on high-temperature water boilers shall not be lifted while the temperature of the water exceeds 200°F (93°C). If it is desired to lift the valve disk to assure that it is free, this shall be done when the valve is subjected to a pressure of at least 75% of the set pressure. Pilot-operated pressure relief valves shall be provided with either a lifting device as described above or means for connecting and applying pressure to the pilot adequate to verify that the moving parts critical to proper operations are free to move. For high-temperature water boilers, the lifting mechanism shall be sealed against leakage.

PG-73.2.5 The seat of a pressure relief valve shall be fastened to the body of the valve in such a way that there is no possibility of the seat lifting.

PG-73.2.6 A body drain below seat level shall be provided in the valve and this drain shall not be plugged during or after field installation. For valves exceeding NPS 2½ (DN 65), the drain hole or holes shall be tapped not less than NPS ⅜ (DN 10). For valves of NPS 2½ (DN 65) or smaller, the drain hole shall not be less than ¼ in. (6 mm) in diameter.

PG-73.2.7 In the design of the body of the valve, consideration shall be given to minimizing the effects of water deposits.

PG-73.2.8 Valves having screwed inlet or outlet connections shall be provided with wrenching surfaces to allow for normal installation without damaging operating parts.

PG-73.2.9 Means shall be provided in the design of all valves for use under this Section, for sealing all external adjustments. Seals shall be installed by the manufacturer, the manufacturer's authorized representative, or an assembler at the time of the initial adjustment. After spring replacement and/or subsequent adjustment, the valve shall be resealed. Seals shall be installed in such a manner as to prevent changing the adjustment without breaking the seal and, in addition, shall serve as a means of identifying the manufacturer, the manufacturer's authorized representative, or the assembler making the adjustment.

PG-73.2.10 Valve capacity may be restricted by restricting the lift of a valve provided the following requirements are met:

(a) The valve size shall be NPS ¾ (DN 20) or larger.

(b) No changes shall be made in the design of the valve except to change the valve lift by use of a lift restraining device described in (c) below.

(c) The restriction of valve capacity shall be permitted only by the use of a lift restraining device which shall limit valve lift and shall not otherwise interfere with flow through the valve. The design of the lift restraining device shall be subject to review by an ASME designee.

(d) The lift restraining device shall be designed so that, if adjustable, the adjustable feature can be sealed. Seals shall be installed by the valve manufacturer or assembler at the time of initial adjustment.

(e) Valves shall not have their lifts restricted to a value less than 30% of full rated lift, or 0.080 in. (2 mm).

(f) When sizing and selecting valves, the restricted lift nameplate capacity shall be determined by multiplying the capacity at full rated lift by the ratio of the restricted lift to the full rated lift.

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PG-73.2.11 A pressure relief valve over NPS 3 (DN 80), used for pressure greater than 15 psig (100 kPa), shall have a flanged inlet connection or a welded inlet connection. Power-actuated pressure-relieving valve inlet connection requirements are provided in PG-68.6. The dimensions of the flanges subjected to boiler pressure shall conform to the applicable ASME standards as given in PG-42. The facing shall be similar to those illustrated in the standard.

PG-73.2.12 The pilot sensing line of pilot-operated pressure relief valves shall be adequately protected from freezing.

PG-73.3 Material Selections.

PG-73.3.1 Cast iron seats and disks are not permitted.

PG-73.3.2 Adjacent sliding surfaces such as guides and disks or disk holders shall both be of corrosion-resistant material. Springs of corrosion-resistant material or having a corrosion-resistant coating are required. The seats and disks of pressure relief valves shall be of suitable material to resist corrosion by the lading fluid.

NOTE: The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the manufacturer and the purchaser.

PG-73.3.3 Materials used in bodies and bonnets or yokes shall be listed in Section II, Parts A and B, and identified in Tables 1A and 1B of Section II Part D, as permitted for Section I construction. Materials used in body to bonnet or body to yoke bolting shall be listed in ASME B16.34. Materials used in all other parts required for the pressure-relieving or pressure-retaining function shall be

(a) listed in ASME Section II

(b) listed in ASTM Specifications (see Note below) or

(c) controlled by the manufacturer of the pressure relief valve by a specification ensuring control of chemical and physical properties and quality at least equivalent to ASTM Standards (see Note in PG-73.3.4)

PG-73.3.4 Pressure relief valves may have bronze parts complying with either SB-61, SB-62, or SB-148, provided the maximum allowable stresses and temperatures do not exceed the values given in Section II, Part D, Subpart 1, Table 1B, and shall be marked to indicate the class of material used. Such valves shall not be used on superheaters delivering steam at a temperature over 450°F (230°C) for SB-61 and SB-148, and 306°F (150°C) for SB-62, and shall not be used for high-temperature water boilers.

NOTE: It shall be the manufacturer's responsibility to ensure that the allowable stresses at temperature meet the requirements of Section II, Part D, Mandatory Appendix 1, Basis for Establishing Stress Values in Tables 1A and 1B.

PG-73.4 Inspection of Manufacturing and/or Assembly.

PG-73.4.1 A manufacturer shall demonstrate to the satisfaction of an ASME designee that the manufacturer's manufacturing, production, and test facilities and quality control procedures will ensure close agreement between the performance of random production samples and the performance of those valves submitted for capacity certification.

PG-73.4.2 Manufacturing, assembly, inspection, and test operations including capacity, are subject to inspections at any time by an ASME designee.

PG-73.4.3 A manufacturer or assembler may be granted permission to apply the Certification Mark with "V" Designator to production pressure relief valves capacity-certified in accordance with PG-69, provided the following tests are successfully completed. This permission shall expire on the sixth anniversary of the date it is initially granted. This permission may be extended for 6-yr periods if the following tests are successfully repeated within the 6-month period before expiration.

(a) Two sample production pressure relief valves of a size and capacity within the capability of an ASME-accredited laboratory shall be selected by an ASME designee. The maximum blowdown for these samples shall not exceed the value specified in the following table:

Set Pressure, psi (kPa)	Maximum Blowdown
<67 (500)	4 psi (30 kPa)
≥67 (500) and ≤250 (1 700)	6% of set pressure
>250 (1 700) and <375 (2 500)	15 psi (100 kPa)
≥375 (2 500)	4% of set pressure

The blowdown for sample valves designed for use on forced flow steam generators with no fixed steam and waterline or high-temperature water boilers shall not exceed 10% of the set pressure. For liquid service valves, there are no specific blowdown requirements.

(1) Operational and capacity tests shall be conducted in the presence of an ASME designee at an ASME-accredited laboratory. The valve manufacturer or assembler shall be notified of the time of the test and may have representatives present to witness the test.

(2) Should any valve fail to relieve at or above its certified capacity or should it fail to meet performance requirements in PG-72, the test shall be repeated at the rate of two replacement valves, selected in accordance with (a), for each valve that failed.

(3) Should any of the replacement valves fail to meet the capacity or performance requirements of this Section, the manufacturer or assembler shall determine the cause of failure and take corrective action to guard against future occurrence. The cause of failure and corrective action shall be documented and submitted to the ASME Designated

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Organization within 60 days of the failure or be cause for revocation of the authorization to use the Certification Mark on that particular type of valve. Upon acceptance of the submitted corrective action by the ASME Designated Organization, the requirements of PG-73.4.3 shall apply.

(b) For valve designs that exceed the size, capacity, or pressure capability of an ASME-accepted testing facility, the following alternative methods shall be used in lieu of (a).

(1) If the valve lift at rated overpressure can be measured, the following shall apply:

(-a) Two production valves that are representative of the design shall be tested per ASME PTC 25, Part III to demonstrate to the satisfaction of the representative of the ASME Designated Organization that the following requirements are met. If only one valve of the design will be produced within the 6-yr period that the permission is granted, only that valve need be tested.

(-1) The measured set pressure shall be consistent with the stamped set pressure within the tolerances required by PG-72.2.

(-2) The valve shall achieve the minimum lift for its certified capacity.

(-3) The valve shall operate without chatter or flutter.

(-b) The testing shall be performed at a facility that is mutually agreeable to the manufacturer, the representative of the ASME Designated Organization, and the facility owner. The facility shall be capable of demonstrating this.

(-c) In the event of failure of the tests, (a)(3) shall apply.

(2) If the valve lift at rated overpressure cannot be measured, the following shall apply:

(-a) For initial certification, two functional models that are representative of the design shall be used, provided the test requirements of (a) are followed and the following additional tests are completed satisfactorily:

(-1) Two production valves that are representative of the design shall be tested per ASME PTC 25, Part III to demonstrate to the satisfaction of the representative of the ASME Designated Organization that the following requirements are met. If only one valve of the design will be produced within the six-year period that the permission is granted, only that valve need be tested.

(+a) The measured set pressure shall be consistent with the stamped set pressure within the tolerances required by PG-72.2.

(+b) Seat tightness and a secondary pressure zone leakage test shall be demonstrated in accordance with PG-73.5.3.

(-2) The testing shall be performed at a facility that is mutually agreeable to the manufacturer, the representative of the ASME Designated Organization, and the facility owner. The facility shall be capable of demonstrating this.

(-3) In the event of failure of the tests, (a)(3) shall apply.

(-b) For 6-yr renewal of capacity certification, (-a) shall apply.

PG-73.4.4 Use of the Certification Mark by an assembler indicates the use of original unmodified parts in strict accordance with the instructions of the manufacturer of the valve.

(a) An assembler may transfer original and unmodified pressure relief parts produced by the manufacturer to other assemblers, provided the following conditions are met:

(1) both assemblers have been granted permission to apply the Certification Mark with the "V" or "UV" Designator to the specific valve type in which the parts are to be used

(2) the Quality Control System of the assembler receiving the pressure relief valve parts shall define the controls for the procurement and acceptance of those parts

(3) the pressure relief valve parts are appropriately packaged, marked, or sealed by the manufacturer to ensure that the parts are

(-a) produced by the manufacturer

(-b) the parts are original and unmodified

(b) However, an assembler may convert original finished parts by either machining to another finished part or applying a corrosion-resistant coating to valve springs for a specific application under the following conditions:

(1) Conversions shall be specified by the manufacturer. Drawings and/or written instructions used for part conversion shall be obtained from the manufacturer and shall include a drawing or description of the converted part before and after the conversion.

(2) The assembler's quality control system, as accepted by a representative from an ASME Designated Organization, must describe in detail the conversion of original parts, provisions for inspection and acceptance, personnel training, and control of current manufacturer's drawings and/or written instructions.

(3) The assembler must document each use of a converted part.

(4) The assembler must demonstrate to the manufacturer the ability to perform each type of conversion. The manufacturer shall document all authorizations granted to perform part conversions. The manufacturer and assembler shall maintain a file of such authorizations.

(5) For an assembler to offer restricted lift valves, the assembler must demonstrate to the satisfaction of the manufacturer the ability to perform valve lift restrictions. The manufacturer shall document all authorizations granted to restrict the lift of the valves, and shall maintain

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records of the lift restrictions made by the assembler. The assembler shall maintain a file of such authorizations.

(6) At least annually a review shall be performed by the manufacturer of an assembler's system and conversion capabilities. The manufacturer shall document the results of these reviews. A copy of this documentation shall be kept on file by the assembler. The review results shall be made available to a representative from an ASME Designated Organization.

PG-73.5 Testing by Manufacturers or Assemblers.

PG-73.5.1 Pressure Testing. Each pressure relief valve to which the Certification Mark is to be applied shall be subjected to the following tests by the manufacturer or assembler:

(a) The pressure-containing parts of each valve shall be hydrostatically tested at a pressure at least 1.5 times the design pressure of the parts. Parts meeting the following criteria shall be exempt from pressure testing:

(1) the applied stress under hydrostatic test conditions does not exceed 50% of the allowable stress; and

(2) the part is not cast or welded.

(b) Alternatively, testing may be performed pneumatically at a pressure 1.25 times the design pressure of the part. Pneumatic testing can be hazardous; it is therefore recommended that special precautions be taken when conducting a pneumatic test.

(c) Testing may be done in the component or assembled condition.

(d) When the valve is designed for discharging directly to atmosphere, the valve components downstream of the valve disk are exempt from pressure testing.

(e) Valve components are exempt from pressure testing when fully contained within pressure-containing parts that have been either pressure tested or exempted from pressure testing by (a)(1) and (a)(2).

(f) These tests shall be conducted after all machining and welding operations on the parts have been completed.

(g) There shall be no sign of leakage.

PG-73.5.2 Every valve shall be tested by the manufacturer or assembler to demonstrate its set point and pressure-containing integrity.

(a) Pressure relief valves for steam service shall be tested with steam. The blowdown control elements of the pressure relief valve shall be set to the manufacturer's specifications.

(b) Pressure relief valves for liquid service shall be tested with water. When adjusted to correct for service temperature conditions, the actual test pressure (cold differential test pressure) shall be marked on the valve per PG-110.

PG-73.5.2.1 For pressure relief valves for steam service, tests shall be conducted either on equipment that meets the requirements of PG-73.5.6, or on the boiler, by raising the pressure to demonstrate the set pressure.

PG-73.5.2.2 When the valve is beyond the production test equipment capabilities, an alternative test method presented in PG-73.5.2.2.1 or PG-73.5.2.2.2 may be used, provided all of the following conditions are met:

(a) testing the valve at full pressure may cause damage to the valve, or testing of the valve is impractical due to boiler system operational safety considerations

(b) the valve lift has been mechanically verified to meet or exceed the required lift

(c) the blowdown control elements of the safety valve are set to the valve manufacturer's specification

(d) the valve design is compatible with the alternative test method selected

PG-73.5.2.2.1 The valve, with its lift temporarily restricted during the test, if required to prevent valve damage, shall be tested on steam to demonstrate set pressure.

PG-73.5.2.2.2 The valve may be fitted with an auxiliary lift assist device and tested on steam at a pressure less than the valve set pressure. The lift assist device and test procedure shall be calibrated to provide the set pressure setting within the tolerance of PG-72.2.

PG-73.5.3 Leak Test. (23)

(a) After completion of the tests required by PG-73.5.2, a seat tightness test shall be conducted.

(1) For steam service pressure relief valves, the seat tightness test shall be conducted using steam at the maximum expected operating pressure but at a pressure not exceeding the reseating pressure of the valve. When being tested, a valve exhibiting no sign of leakage shall be considered adequately tight.

(2) For liquid service pressure relief valves, the seat tightness test shall be conducted using water. The seat tightness test and acceptance criteria shall be as designated by the valve manufacturer's published specifications or other specification agreed to by the boiler manufacturer.

(3) When the maximum expected operating pressure is beyond the production test equipment capabilities, the seat tightness test and acceptance criteria shall be as designated by the valve manufacturer's published specifications or other specification agreed to by the boiler Manufacturer.

(b) Closed bonnet pressure relief valves designed for discharge to a closed system shall be tested with a minimum of 30 psig (200 kPa) air or other gas in the secondary pressure zone. There shall be no sign of leakage.[17]

PG-73.5.4 A manufacturer or assembler shall have a documented program for the application, calibration, and maintenance of test gages.

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PG-73.5.5 Testing time on steam valves shall be sufficient to assure that test results are repeatable and representative of field performance.

PG-73.5.6 Test fixtures and test drums, where applicable, shall be of adequate size and capacity to assure that the observed set pressure is consistent with the stamped set pressure within the tolerance required by PG-72.2.

PG-73.6 Design Requirements. At the time of submission of valves for capacity certification or testing in accordance with PG-69, the ASME designee has the authority to review design for conformity with the requirements of this Section and to reject or require modification of designs that do not conform, prior to capacity testing.

PG-73.7 Certification Mark With the "V" Designator. Each pressure relief valve to which the Certification Mark with the "V" Designator will be applied shall have been fabricated or assembled by a manufacturer or assembler holding a valid Certificate of Authorization[18] (PG-105.2) and capacity certified in accordance with the requirements of this Section.[19] A Certified Individual (CI) shall provide oversight to assure that each use of the Certification Mark with the "V" Designator on a pressure relief valve is in accordance with the requirements of this Section, and that each use of the Certification Mark with the "V" Designator is documented on a Certificate of Conformance, Form P-8.

PG-73.7.1 Requirements for the Certified Individual (CI). The CI shall

(a) be an employee of the manufacturer or assembler

(b) be qualified and certified by the manufacturer or assembler. Qualifications shall include as a minimum

(1) knowledge of the requirements of this Section for the application of the Certification Mark with the "V" Designator

(2) knowledge of the manufacturer's or assembler's quality program

(3) training commensurate with the scope, complexity, or special nature of the activities to which oversight is to be provided

(c) have a record, maintained and certified by the manufacturer or assembler, containing objective evidence of the qualifications of the CI and the training program provided

PG-73.7.2 Duties of the Certified Individual (CI). The CI shall

(a) verify that each item to which the Certification Mark with the "V" Designator is applied has a current capacity certification and meets all applicable requirements of this Section

(b) review documentation for each lot of items to be stamped to verify, for the lot, that requirements of this Section have been completed

(c) sign the Certificate of Conformance, Form P-8, prior to release of control of the pressure relief valves

PG-73.7.3 Certificate of Conformance, Form P-8.

(a) The Certificate of Conformance, Form P-8, shall be filled out by the manufacturer or assembler and signed by the Certified Individual. Multiple duplicate pressure relief valves may be recorded as a single entry, provided the valves are identical and are produced in the same lot.

(b) The manufacturer's or assembler's written quality control program shall include requirements for completion of Certificates of Conformance, Form P-8, and retention, by the manufacturer or assembler, for a minimum of 5 years.

PG-73.8 Set Pressure Change. The set pressure of a valve may be changed after completion of Form P-8 but prior to the signing of the Master Data Report, provided all of the following requirements are met:

(a) All parts conversions, valve adjustments, and testing shall be performed by the manufacturer or an assembler that has been granted permission to apply the Certification Mark with "V" Designator to the specific valve type.

(b) Updating or creating a new Form P-8 shall be performed by the valve manufacturer or assembler that performs the set pressure change.

(c) Updating or creating a new Form P-7, if required, shall be performed by the boiler manufacturer.

(d) The change to the set pressure shall be validated per PG-73.5.2.

(e) Markings on the valve related to the set pressure change (i.e., set pressure, capacity) shall be updated and shall comply with PG-110. Superseded markings on the valve shall be obliterated, and the original nameplate shall be removed and replaced.

(f) All other requirements of this Section for the use of the Certification Mark with the "V" Designator shall apply, in particular leak testing per PG-73.5.3 and resealing external adjustments per PG-73.2.9.

FABRICATION

PG-75 GENERAL (23)

The fabrication of boiler pressure parts shall conform to the general fabrication requirements in the following paragraphs. Additional requirements for fabrication are found in the Parts of this Section that pertain to the methods of construction used.

PG-75.1 Visual examination shall be performed to verify requirements for dimensions, joint preparation, and alignment prior to welding or joining, and finished weld conditions, as follows:

(a) Visual examination shall be confined to the portions of the assembly that are exposed to unobstructed observation with the unaided eye (or with corrective lenses).

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This is normally performed when access is sufficient to place the eye within approximately 24 in. (600 mm) and at an angle not less than approximately 30 deg to the surface to be examined. Mirrors may be used to achieve a view of the component to be examined.

(b) Lighting of the area being examined must be adequate to provide clear observation, with no shadows and essentially free of glare. Supplementary lighting may be used where natural lighting is inadequate for proper examination.

(c) The area under observation shall be clean and free of all "loose" foreign materials such as scale, sand, weld spatter and slag, cutting chips, etc.

(d) At the discretion of the Manufacturer or the Inspector, supplemental visual examination methods may be used to verify acceptability of suspect areas.

(e) At the option of the Manufacturer, visual examination may be performed in accordance with Section V, Article 9.

PG-76 CUTTING PLATES AND OTHER STOCK

(23) **PG-76.1** Plates may be cut by machining, punching, shearing, electric arc or gas process, laser, thermal or plasma processes, or high pressure water jet (with or without abrasives or other additives). Any unfinished edge shall retain sufficient metal to meet the requirements of PG-79.

PG-76.2 End faces of nozzle or manhole necks may remain unwelded in the completed vessel. When these end faces are cut by shearing, at least $\frac{1}{8}$ in. (3 mm) of additional metal shall be removed by any method that will produce a smooth finish.

PG-77 MATERIAL IDENTIFICATION

The Manufacturer shall describe, in their written Quality Control System, the process for maintaining identification of the pressure part materials as to the type of material. Material identification shall be maintained until the data report (Partial Data Report or Master Data Report) for the item containing the materials is complete.

PG-77.1 When the boiler is completed, there shall remain visible on shell plates, furnace sheets, and heads, one group of the plate manufacturer's stamps, consisting of the manufacturer's name, plate identification number, material specification number with grade, class, and type as appropriate, except that heads containing tube holes and buttstraps shall have visible at least a sufficient portion of such stamps for identification.

PG-77.2 It is permissible for an authorized representative of the boiler Manufacturer to transfer the markings on the plate provided a record is made of such transfer. In lieu of the above and PG-77.1, identification may be by applying a coded marking traceable to the original required markings or by recording the required markings using methods such as material tabulations or as built illustration which ensure identification of each piece of material during fabrication and subsequent identification in the completed boiler. Such transfers of markings shall be made prior to cutting, except that the Manufacturer may transfer markings immediately after cutting, provided the control of these transfers is described in the Manufacturer's written Quality Control System (A-301 and A-302). The procedure for making such transfer shall be acceptable to the Authorized Inspector.

PG-77.3 An authorized representative of the plate manufacturer may duplicate the required stamping on any material wherever located.

PG-77.4 When plate specification heat treatments are not performed by the plate manufacturer, they shall be performed by or under the control of the fabricator, who shall then place the letters "MT" following the letter "G" in the mill plate marking (see SA-20) to indicate that the material specification heat treatments have been performed. The fabricator shall also show by a supplement to the appropriate Mill Test Report that the specified heat treatment has been performed.

PG-77.5 For other than plate material, the maintenance of identification shall be at least to the type of material. This can be achieved through any suitable method found acceptable to the Inspector, such as color coding, abbreviated marking, written record, etc.

PG-78 REPAIRS OF DEFECTS IN MATERIALS

Defects in material may be repaired by the boiler Manufacturer provided acceptance by the Inspector is first obtained for the method and extent of repairs. Material that cannot be satisfactorily repaired shall be rejected.

PG-79 TUBE HOLES AND ENDS

Tube holes shall be made by any of the following methods:

(a) drilled full size.

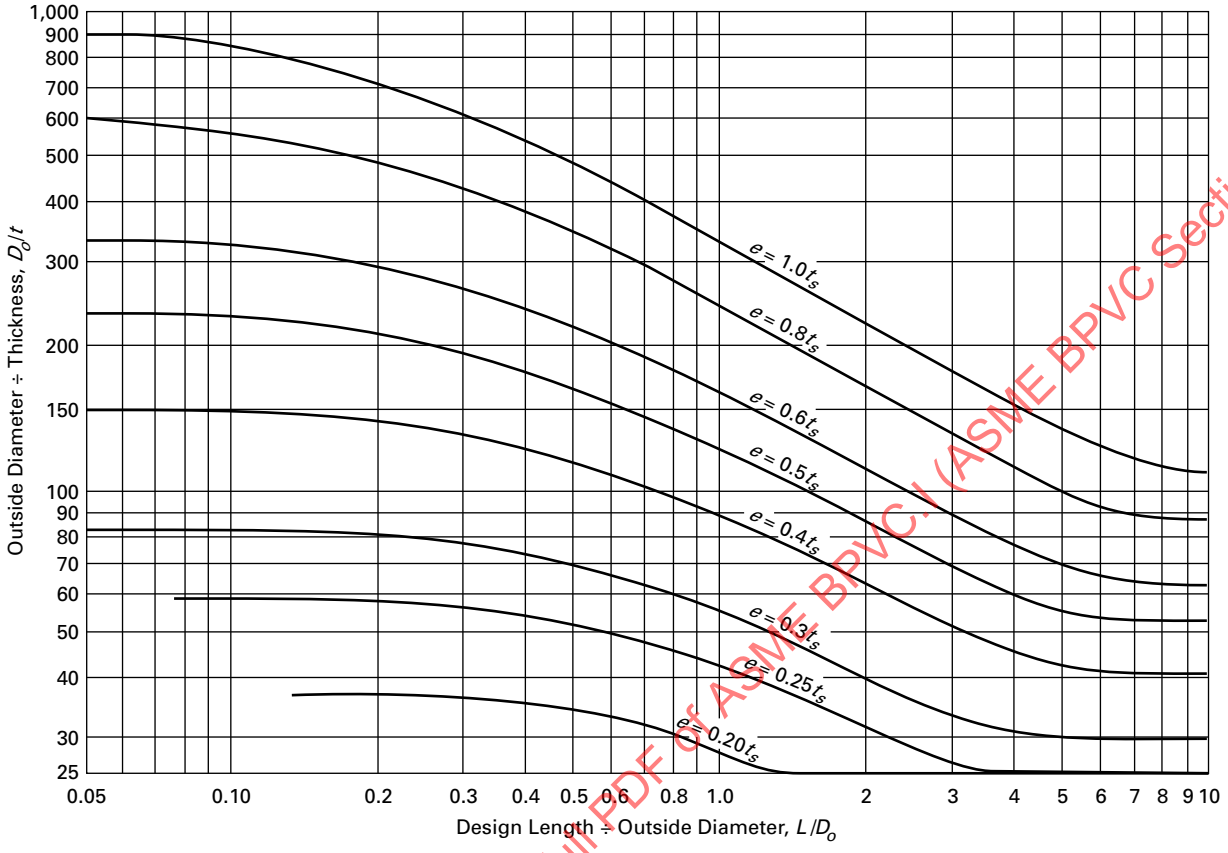
(b) punched at least $\frac{1}{2}$ in. (13 mm) smaller in diameter than full size, and then drilled, reamed, or finished full size with a rotating cutter.

(c) cut smaller in diameter than full size by laser beam or by thermal- or plasma-arc method, and then machined to full size. The smaller diameter shall be such that the subsequent machining of the holes to full size shall completely remove all metal whose mechanical and metallurgical properties have been affected as a result of the cutting process.

(d) cut full size with a high-pressure water jet (with or without abrasives or other additives), or cut smaller in diameter than full size, then drilled, reamed, or finished full size with a rotating cutter.

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Figure PG-80
Maximum Permissible Deviation From a Circular Form, *e*, for Cylindrical Parts Under External Pressure



GENERAL NOTES:
(a) The above chart applies to cylinders over 24 in. (600 mm) O.D.
(b) Use the curves $e = 1.0t_s$ or $e = 0.2t_s$, respectively, for points falling above or below those curves.

Tube holes may be counterbored where the metal is thicker than that required to get a proper bearing by expanding, so as to form narrow seats into which the tube ends can be properly expanded, provided there is space available to permit a proper amount of flare of the tube end.

The sharp edges of tube holes shall be taken off on both sides of the component with a file or other tool.

PG-80 PERMISSIBLE OUT-OF-ROUNDNESS OF CYLINDRICAL SHELLS

PG-80.1 Internal Pressure. Finished cylindrical sections of headers, shells, drums, and similar components shall be circular at any section within a limit of 1% of the mean diameter, based on the differences between the maximum and minimum mean diameters at any section. To determine the difference in diameters, measurements may be made on the inside or the outside, and when the component is made of plates of unequal thicknesses, the measurements shall be corrected for the plate thicknesses as they may apply, to determine the diameters at the middle line of the plate thickness.

PG-80.2 External Pressure. Welded cylindrical furnaces and other cylindrical parts subjected to external pressure shall be rolled to practically a true circle with a maximum plus or minus deviation not to exceed the following:

(a) For components greater than 24 in. (600 mm) O.D., the maximum permissible deviation, *e*, shall be obtained from Figure PG-80. The symbols *L*, D_O, and t_S are as defined in PG-28.3.1.1. Where the component at any cross section is made of plates having different thicknesses, t_S is the nominal thickness of the thinnest plate.

(b) For components equal to or less than 24 in. (600 mm) O.D., the maximum deviation shall not exceed 1% of the O.D.

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PG-81 TOLERANCE FOR FORMED HEADS

When heads are made to an approximate ellipsoidal shape, the inner surface of such heads must lie outside and not inside of a true ellipse drawn with the major axis equal to the inside diameter of the head and one-half the minor axis equal to the depth of the head. The maximum variation from this true ellipse shall not exceed 0.0125 times the inside diameter of the head.

PG-82 HOLES FOR STAYS

PG-82.1 Holes for threaded stays shall be drilled full size or punched and subsequently drilled or reamed. Punched holes shall not exceed $^{1}/_{4}$ in. (6 mm) less than full diameter for plates over $^{5}/_{16}$ in. (8 mm) or $^{1}/_{8}$ in. (3.2 mm) less than full diameter for plates not exceeding $^{5}/_{16}$ in. (8 mm) thickness prior to finished drilling or reaming. Threaded holes shall be tapped fair and true with a full thread.

PG-82.2 Holes for welded stays shall be cut and prepared in accordance with PW-29.

INSPECTION AND TESTS

PG-90 GENERAL

PG-90.1 Each boiler, superheater, waterwall, or economizer shall be inspected during construction and after completion by an Authorized Inspector (AI). The AI may perform inspections at other stages of the work as the AI may designate (PW-46.2). Each Manufacturer or Assembler is required to arrange for the services of Authorized Inspectors (see Foreword and PG-91) to perform inspections on all of the Manufacturer's work within the scope of this Section, whether performed in the shop or in the field. Duties of the AI are described elsewhere in this Section and include the following:

PG-90.1.1 Verifying that the Manufacturer or Assembler has a valid ASME Certificate of Authorization covering the scope of Code activities (PG-104.2.1, PG-105.5).

PG-90.1.2 Monitoring compliance with the accepted Quality Control Program and verifying that any changes meet the requirements of this Section (PG-105.4, PEB-18, A-301, A-302).

PG-90.1.3 Verifying that the Certificate Holder has the necessary Code books, Addenda, and Code Cases to cover the work being performed.

PG-90.1.4 Reviewing a selected number of the Manufacturer's design calculations to verify compliance with Section I (PG-90.3).

PG-90.1.5 Witnessing and approving proof tests to establish Maximum Allowable Working Pressure (MAWP) (A-22).

PG-90.1.6 Verifying that the Certificate Holder has sufficient material control to assure that material used for construction complies with the applicable requirements of this Section (PG-10, PG-11, PG-105.4, A-302.4).

PG-90.1.7 When cutting plate material into two or more pieces is necessary, verifying that the Certificate Holder's controls provide a positive means of identification to maintain traceability of materials (PG-77.2, A-302.4).

PG-90.1.8 Verifying that the Certificate Holder's personnel are examining cut edges before welding (PW-29.3).

PG-90.1.9 Verifying that all welding procedure specifications, procedure qualification records, welder and welding operator qualification records conform to the requirements of this Section (PW-1.2, PW-28, PW-40.2, PW-44.3, PW-47, PW-48, PW-53, PB-47, PB-48).

PG-90.1.10 If welded repairs are necessary, accepting the method and extent of repairs and verifying that only qualified welding procedures, welders, and welding operators are used (PG-78, PG-93.2, PW-40, PW-44.9, PW-54.2, PB-33).

PG-90.1.11 Verifying that all required heat treatments have been performed and are properly documented (PG-19, PG-20, PG-11.3.4, PW-39, PW-44.4, PW-44.6, PW-49, Mandatory Appendix VIII).

PG-90.1.12 Verifying that required nondestructive examinations and tests have been performed by qualified personnel and that the results are properly documented (PG-20.1.2, PG-25.2, PG-93.1, PW-11, PW-44.7, PW-44.8, PW-51, PW-52).

PG-90.1.13 Performing the required inspections and witnessing hydrostatic tests (PG-99, PW-54, PB-49, PMB-21, PEB-17, PEB-18).

PG-90.1.14 Verifying that the responsible representative of the Certificate Holder has signed the Data Report and that it is correct before being signed (PG-104, PG-112, PG-113, PW-1.2.5, PB-1.4.5).

PG-90.1.15 Prior to stamping, verifying that the item is in compliance with the requirements of this Section. After stamping, verifying that the stamping is correct and that the nameplate, if used, has been properly attached (PG-106, PG-108, PG-109, PW-1.2.5, PB-1.4.5).

PG-90.3 The Manufacturer is responsible for the preparation of design calculations to show compliance with the rules of Section I and their signature on the Manufacturers' Data Report Form shall be considered to include certification that has been done. The Manufacturer shall make available such design calculations as the Authorized Inspector may request. The Authorized Inspector has the

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duty to review a selected number of the Manufacturer's design calculations to verify compliance with Section I.

PG-91 QUALIFICATION OF INSPECTORS

The inspection required by this Section shall be by an Inspector employed by an ASME accredited Authorized Inspection Agency.[20] These Inspectors shall have been qualified in accordance with ASME QAI-1.

PG-93 EXAMINATION AND REPAIR OF FLAT PLATE IN CORNER JOINTS

PG-93.1 When flat plate greater than ½ in. (13 mm) thickness is welded to other pressure parts to form a corner joint, such as in flat heads [Figure PG-31, illustrations (g-1), (g-2), (i-1), and (i-2)], waterlegs of firebox boilers or combustion chambers of wetback boilers [Figure A-8, illustrations (l) through (n) and (p)], and the exposed edges of the plate are closer to the edge of the weld than a distance equal to the thickness of the plate, the peripheral plate edges and any remaining exposed surface of the weld joint preparation shall be examined after welding by either the magnetic particle or liquid penetrant method. When the plate is nonferromagnetic, only the liquid penetrant method shall be used. The requirements of this paragraph shall not apply to those joints when 80% or more of the pressure load is carried by tubes, stays, or braces, or when the exposed edges of the plate are farther from the edge of the weld than a distance equal to the thickness of the plate.

PG-93.2 Laminations, cracks, or other imperfections found during the examination required by PG-93.1 that would affect the safety of the vessel shall be repaired in accordance with PG-78. The imperfection(s) may be pursued by any suitable method (grinding, chipping, etc.). The repaired area shall be subjected to the same examination that first revealed the imperfection.

PG-93.3 Methods and acceptance criteria for magnetic particle and liquid penetrant examination shall be in accordance with A-260 or A-270, respectively.

PG-99 HYDROSTATIC TEST

Hydrostatic testing of the completed boiler unit shall be conducted in accordance with the following requirements:

After a boiler has been completed (see PG-104), it shall be subjected to pressure tests using water at not less than ambient temperature, but in no case less than 70°F (20°C). Where required test pressures are specified in this paragraph, whether minimum or maximum pressures, they apply to the highest point of the boiler system. When the boiler is completed in the Manufacturer's shop without boiler external piping, subsequent hydrostatic testing of the boiler external piping shall be the responsibility of any holder of a valid Certification Mark with the "S," "A," or "PP" Designator. The pressure relief valves need not be included in the hydrostatic test. The tests shall be made in two stages in the following sequence:

PG-99.1 Hydrostatic pressure tests shall be applied by raising the pressure gradually to not less than 1½ times the maximum allowable working pressure as shown on the data report to be stamped on the boiler. No part of the boiler shall be subjected to a general membrane stress greater than 90% of its yield strength (0.2% offset) at test temperature. The primary membrane stress to which boiler components are subjected during hydrostatic test shall be taken into account when designing the components. Close visual examination for leakage is not required during this stage.

PG-99.2 The hydrostatic test pressure may then be reduced to the maximum allowable working pressure, as shown on the Data Report, to be stamped on the boiler and maintained at this pressure while the boiler is carefully examined. The metal temperature shall not exceed 120°F (50°C) during the close visual examination.

PG-99.3 A completed forced-flow steam generator with no fixed steam and waterline, having pressure parts designed for different pressure levels along the path of water-steam flow, shall be subjected to a hydrostatic pressure test by the above procedure (PG-99.1 and PG-99.2) based upon

PG-99.3.1 For the first stage test (PG-99.1) a hydrostatic test pressure of not less than 1½ times the maximum allowable working pressure at the superheater outlet as shown in the master stamping (PG-106.3) but no less than 1¼ times the maximum allowable working pressure of any part of the boiler, excluding the boiler external piping.

PG-99.3.2 For the second stage test (PG-99.2) the hydrostatic test pressure may be reduced to not less than the maximum allowable working pressure at the superheater outlet.

PG-99.4 Test Gages.

PG-99.4.1 An indicating gage, visible to the operator controlling the pressure applied, shall be connected to the pressure parts. Hydrostatic head on the gage shall be considered such that the required test pressure is achieved at the top of the boiler.

PG-99.4.2 Dial pressure gages used in testing shall have dials graduated over the entire range of the intended maximum test pressure. It is preferred that the range of the gage be double the intended maximum test pressure, but in no case shall the range be less than 1½ nor more than 4 times that pressure. The spacing between graduations shall be such that the inspector and the operator controlling the test shall be able to determine when the required test pressure has been applied. Digital pressure gages having a wider range of pressure readings may

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be used provided the readings give the same or greater degree of accuracy as obtained with dial pressure gages.

CERTIFICATION BY STAMPING AND DATA REPORTS

PG-101 HEATING SURFACE COMPUTATION

PG-101.1 For the stamping required by PG-106, the heating surface shall be computed as specified in PG-101.1.1 through PG-101.1.3.

PG-101.1.1 Heating surface, as part of a circulating system in contact on one side with water or wet steam being heated and on the other side with gas or refractory being cooled, shall be measured on the side receiving heat.

PG-101.1.2 Boiler heating surface and other equivalent surface outside the furnace shall be measured circumferentially plus any extended surface.

PG-101.1.3 Waterwall heating surface and other equivalent surface within the furnace shall be measured as the projected tube area (diameter × length) plus any extended surface on the furnace side. In computing the heating surface for this purpose, only the tubes, fireboxes, shells, tubesheets, and the projected area of headers need to be considered, except that for vertical firetube steam boilers only that portion of the tube surface up to the middle of the gage glass is to be computed.

PG-104 GENERAL

(23) **PG-104.1** The completed boiler unit includes all piping and piping components as defined in the Preamble.

The Manufacturer [see Note (1) below] of any complete boiler unit to be stamped with the Certification Mark has the responsibility of assuring through proper Code certification that all work performed by them or others responsible to them complies with all requirements of the Code, including design, construction, materials, and workmanship. With the exception of field installed boiler external piping, when some portions of a complete boiler unit are supplied by, or Code work is performed by others not responsible to the Manufacturer, the Manufacturer has the duty of obtaining from these other organizations their proper Code certification, covering such portions of work.

When the Manufacturer furnishes a shop assembled boiler that is complete except for boiler external piping, and the boiler has been hydrostatically tested in the shop and properly stamped with the Certification Mark with the "S" Designator, the subsequent installation in the field of the external piping within the scope of Section I is not by itself considered "field assembly of the boiler" [see Note (2) below].

No Manufacturer or assembler may accept Code responsibility for welding that falls within the scope of the Code, that is performed by employees of any other organization, except through proper Code certification as provided in PG-11.5 or PW-1.2. Subcontracted work other than welding that is performed by employees of any other organization shall follow the Manufacturer's written quality control system. The responsibilities set forth herein relate only to Code compliance and are not to be construed as involving contractual relations or legal liabilities.

NOTE:

(1) Boiler Manufacturer or Manufacturer as used in PG-104 or other paragraphs referenced to this Note may also be an Engineering-Contractor organization with or without fabricating facilities, but having the capability of providing a design specification that establishes the pressure and temperature conditions for each component of a complete boiler unit and of assembling the fabricated parts in the field with authorization from the Society to use the Certification Mark with the "S" Designator in accordance with the Code provisions in PG-105.3.

(2) When boiler external piping within the scope of Section I is furnished by other than the boiler Manufacturer, the boiler Manufacturer is not responsible for the Code certification of such piping. The organizations that furnish and that install such external piping by either welding or mechanical assembly shall furnish proper Code certification (PG-104.2) for such piping including Manufacturers' Data Report Form P-4A as required by PG-112.2.5 and PG-112.3. The hydrostatic test of the completed boiler shall be documented on Form P-4A.

PG-104.2 Proper Code certification refers to the furnishing of stamping and Data Reports as evidence to establish the following:

PG-104.2.1 The organization that performed that portion of the work held an appropriate Certificate of Authorization.

PG-104.2.2 By signing and furnishing the appropriate data report, that organization certified compliance with Code rules for that portion of the work.

PG-104.2.3 By proper use of the Certification Mark, that organization identified the portions of the work covered by its Data Report Form.

PG-104.2.4 By countersignature on the same Data Report a qualified Inspector confirmed that portion of the work complied with applicable Code rules.

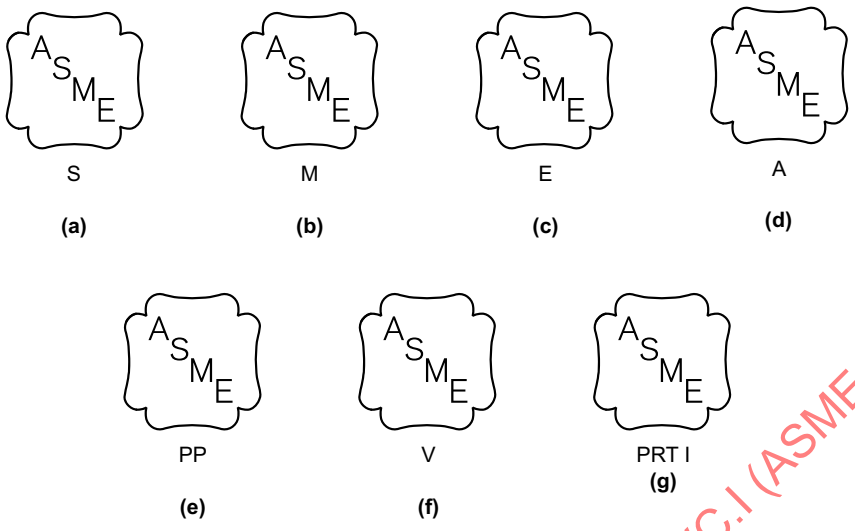
PG-105 CERTIFICATION MARKS (23)

PG-105.1 Authorization. Except as permitted in PG-105.5, no organization may assume responsibility for Code construction without having first received from the ASME a Certificate of Authorization to use the Certification Mark (see Figure PG-105.1) and Designators. The Designators used with the Certification Mark are defined as follows:

(a) S — power boiler Designator
(b) M — miniature boiler Designator
(c) E — electric boiler Designator

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Figure PG-105.1
(23) **Official Certification Mark to Denote the American Society of Mechanical Engineers' Standard for Boilers**



(d) A — boiler assembly Designator
(e) PP — pressure piping Designator
(f) V — boiler pressure relief valve Designator
(g) PRT I — fabricated parts Designator

Each boiler, superheater, waterwall, economizer, or boiler part to which a Certification Mark is to be applied shall be fabricated by a Manufacturer who is in possession of a Certificate of Authorization to use the Certification Mark with appropriate Designator.

PG-105.2 Application for Certificate of Authorization. Any organization desiring a Certificate of Authorization shall apply to the ASME in accordance with the certification process of ASME CA-1. Authorization to use Certification Marks may be granted, renewed, suspended, or withdrawn as specified in ASME CA-1.

PG-105.3 Designated Oversight. The Manufacturer or Assembler shall comply with the requirements of ASME CA-1 for Designated Oversight by use of an Authorized Inspection Agency or Certified Individual, as applicable.

PG-105.4 Quality Control System. Any Manufacturer or Assembler holding or applying for a Certificate of Authorization shall demonstrate a quality program that meets the requirements of ASME CA-1 and establishes that all Code requirements including material, design, fabrication, examination (by the Manufacturer), and inspection for boilers and boiler parts (by the Authorized Inspector) will be met. The quality control system shall be in accordance with the requirements of A-301 and A-302.

Certificates of Authorization will be endorsed to indicate the scope of activity authorized.

The Manufacturer may at any time make changes in the quality program concerning the methods of achieving results subject to acceptance by the Authorized Inspector. For manufacturers or assemblers of pressure relief valves bearing the "V" Designator, such acceptance shall be by the ASME designee.

PG-105.5 Code Construction Before Receipt of Certificate of Authorization. When used to demonstrate their quality control system, a Manufacturer may start fabricating Code items before receipt of a Certificate of Authorization to use a Certification Mark under the conditions specified in ASME CA-1.

PG-105.6 Regulations on Use of Certification Marks. ASME may at any time revise the requirements concerning the issuance and use of Certification Marks as it deems appropriate, and all such regulations shall become binding upon the holders of any valid Certificates of Authorization.

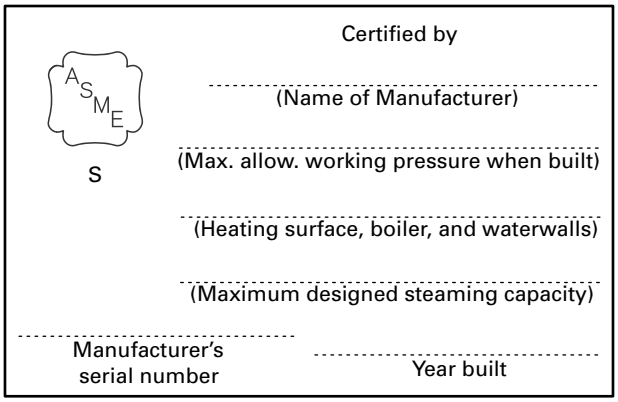
PG-105.7 "PP" Designator. A Manufacturer in possession of a valid Certificate of Authorization to use the Certification Mark with the "PP" Designator may

(a) design and fabricate welded boiler external piping. Such piping shall be stamped or marked and recorded as required by PG-109.

(b) fabricate other parts of boilers, such as superheater, waterwall, or economizer headers, where the complete design requirements are provided by others. Such parts shall be stamped or marked as required by PG-106.8 and documented on Form P-4, Manufacturer's Partial Data Report, as called for in PG-112.2.4.

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Figure PG-106
Form of Stamping



PG-106 STAMPING OF BOILERS

PG-106.1 The Manufacturer shall stamp each boiler, superheater, waterwall, or economizer constructed in compliance with this Section in the presence of the Authorized Inspector, after the hydrostatic test, in the shop of the Manufacturer, except that in cases where boilers, superheaters, waterwalls, or economizers are not completed and hydrostatically tested before shipment, proper stamping shall be applied at the shop and the data reports required in PG-112 and PG-113 shall be signed by the same or different Inspectors who shall indicate the portions of the inspections made at the shop and the field. The stamping shall consist of the appropriate Certification Mark shown in Figure PG-105.1, which shall be put on each piece of equipment listed above in the locations specified in PG-111, except as provided in PG-106.2. Application of the ASME Certification Mark and Designator may be by stamping or by alternate methods that comply with Mandatory Appendix VII.

PG-106.2 When the watertube boiler is arranged integrally with its economizer, superheater and/or waterwalls, the stamping required in PG-106.1 for such parts as are fabricated by the Manufacturer of the boiler may be combined into a *single* stamping located as specified in PG-111.5. Identifying marks shall be placed on all headers as required in PG-111.10, PG-111.11, and PG-111.12.

PG-106.3 For forced-flow steam generators with no fixed steam and waterline, consisting of groups of pressure parts or components designed at several different levels of maximum allowable working pressures (PG-21), the stamping, required in PG-106.1 for such parts as are fabricated by the Manufacturer of the boiler, shall be combined into a single stamping. In addition, whichever Manufacturer [see PG-104.1, Note (1)] has the responsibility for assurance of Code certification for a completed boiler unit, that Manufacturer shall provide a master stamping for the complete unit which shall show the maximum allowable working (minimum design) pressure at the superheater outlet as determined by the Manufacturer as item PG-106.4.1(c). In no case shall the master stamping pressure be more than the maximum allowable working pressure of any part of the unit, excluding the steam piping between the boiler and the prime mover. The master stamping shall be located as required in PG-111.5.2.

PG-106.4 In addition to the Certification Mark, the following items shall also be stamped with letters and figures at least $^{5}/_{16}$ in. (8 mm) high [$^{5}/_{32}$ in. (4 mm) on miniature boilers if necessary], arranged as shown in Figure PG-106 Marking of the required items may be by stamping or by alternate methods that comply with Mandatory Appendix VII.

PG-106.4.1 Items on Boilers.

(a) Manufacturer's serial number
(b) certified by (name of Manufacturer)
(c) maximum allowable working pressure when built
(d) heating surface (or power input for electric boilers)
(e) year built
(f) maximum designed steaming capacity (or, for high-temperature water boilers, maximum designed output; or, for thermal fluid heaters, the maximum designed flow rate)

PG-106.4.2 Items on Waterwalls, Superheaters, or Economizers.

(a) Manufacturer's serial number
(b) certified by (name of Manufacturer)
(c) maximum allowable working pressure when built
(d) heating surface (not required for integral superheaters) (rated absorption for an isolable economizer)
(e) for isolable or nonintegral separately fired superheaters, heating surface or the minimum pressure relief valve discharge capacity calculated from the maximum expected heat absorption (as determined by the Manufacturer)

PG-106.5 For boilers with no pressure-retaining part larger than 16 in. (400 mm) O.D., or for equipment operating at temperatures above 800°F (425°C), a cast, etched, or stamped metallic nameplate may be used to provide the data required by PG-106 instead of stamping directly on the pressure-retaining material. This plate shall be securely attached to the item it describes. If the attachment is by welding, the welding shall meet the requirements of this Section. The Authorized Inspector shall witness the stamping of the Certification Mark and verify that the nameplate has been attached. If the original marking becomes indistinct or illegible, see Mandatory

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Appendix III for documentation requirements and additional guidance.

PG-106.6 Each Manufacturer shall furnish, in addition, a metallic plate or plates on which the above data are reproduced for all the items manufactured by them, except when the original stampings are so located on the completed (or assembled) boiler unit that all will be readily visible from one place on the operating floor or platform. These plates, if used, shall be located as specified in PG-111.13. All data on such additional plates, including the Certification Mark, shall be added to the plate by a method that results in markings that are permanent and clearly legible. Acceptable methods of application include but are not limited to casting, etching, and stamping. This marking need not be witnessed by an Authorized Inspector. The letters and figures on these nameplates shall be not less than $^{5}/_{32}$ in. (4 mm) high.

(23) **PG-106.7** When the Manufacturer is an Engineering-Contractor [see PG-104.1, Note (1)], either of the sequences specified in PG-106.7.1 and PG-106.7.2 may be selected by the Manufacturer for the certification and stamping of the completed boiler.

PG-106.7.1 Certification of Field Assembly Prior to Certification of Engineering-Contractor.

(a) The Engineering-Contractor shall prepare a Form P-3A Master Data Report with the Certification of Engineering-Contractor portion remaining blank. This Master Data Report, including all associated Partial Data Reports shall be forwarded to the Assembler.

(b) After the required inspections and the hydrostatic test have been performed, the Assembler and Assembler's Authorized Inspector shall certify the field assembly portion of Form P-3A. The Assembler shall then forward the completed Form P-3A, including all associated Partial Data Reports, to the Engineering-Contractor.

(c) The Engineering-Contractor shall provide a metallic master stamping plate or plates. The letters and figures on this plate shall be not less than $^{5}/_{32}$ in. (4 mm) high. This plate shall include, in addition to the Certification Mark, all the data required by PG-106.4. Such data, except the Certification Mark, may be cast, etched, or stamped on this plate. The Certification Mark shall be stamped. The stamping of the master stamping plate shall be in the presence of the Engineering-Contractor's Authorized Inspector after the Inspector has examined the Design Specification for the complete boiler unit, verified the plate data, and is satisfied that the Engineering-Contractor has provided for the construction of the complete boiler unit. The Engineering-Contractor and Engineering-Contractor's Authorized Inspector shall then sign the Certification of Engineering-Contractor portion of Form P-3A.

(d) The Engineering-Contractor shall provide the Assembler with the master stamping plate who shall affix it to a location on the boiler as specified in PG-111.13.

PG-106.7.2 Certification of Engineering-Contractor Prior to Certification of Field Assembly.

(a) The Engineering-Contractor shall provide a metallic master stamping plate or plates. The letters and figures on this plate shall be not less than $^{5}/_{32}$ in. (4 mm) high. This plate shall include, in addition to the Certification Mark, all the data required by PG-106.4. Such data, except the Certification Mark, may be cast, etched, or stamped on this plate. The Certification Mark shall be stamped. The stamping of the master stamping plate shall be in the presence of the Engineering-Contractor's Authorized Inspector after the inspector has examined the Design Specification for the complete boiler unit, verified the plate data, and is satisfied that the Engineering-Contractor has provided for the construction of the complete boiler unit. The Engineering-Contractor and Engineering-Contractor's Authorized Inspector shall then sign the Certification of Engineering-Contractor portion of Form P-3A in the presence of and when authorized by the Authorized Inspector.

(b) The Engineering-Contractor shall provide the Assembler with the master stamping plate and Form P-3A Master Data Report, including all associated Partial Data Reports.

(c) After the required inspections and the hydrostatic test have been performed, the Assembler shall affix the master stamping plate to the boiler at a location as specified in PG-111.13 in the presence of and when authorized by the Assembler's Authorized Inspector.

(d) The Assembler and the Assembler's Authorized Inspector shall then sign the Certificate of Field Assembly portion of Form P-3A. The Assembler shall then forward the completed Form P-3A, including all associated Partial Data Reports, to the Engineering-Contractor.

PG-106.8 Stamping and Marking of Parts.

(23) **PG-106.8.1** When only a part of the boiler is supplied and the data are recorded on Form P-4, Manufacturer's Partial Data Report (see PG-112.2.4), the part shall be stamped with

(a) Certification Mark and appropriate Designator above the word "part"

(b) certified by (name of Manufacturer)

(c) Manufacturer's serial number of the part

(d) year built

When stamping with the Certification Mark with the "PRT I" Designator, the word "part" may be eliminated from the stamping.

Parts may be stamped with the Certification Mark without being pressure tested prior to shipment (see PG-112 for requirements for documentation and stamping

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of pressure parts that do not contain pressure-retaining welds).

PG-106.8.2 In lieu of such stamping, small parts [5 in. (125 mm) O.D. and under] may be marked with an identification acceptable to the Inspector (e.g., bar coding, etching, paint stencil, etc.) and traceable to the Form P-4, Manufacturer's Partial Data Report. Such marking shall be of a type that will remain visible until the part is installed. The Certification Mark is not required.

PG-106.8.3 Manufacturers of parts who do not perform or assume any design responsibility for the parts they manufacture shall identify on Form P-4, Manufacturer's Partial Data Report (see PG-112.2.4), the Certificate Holder assuming responsibility for the design of the part. The Manufacturer shall document the Edition and Addenda used to manufacture the part in the "Remarks" section of Form P-4.

PG-106.8.4 Manufacturers with multiple locations, each with its own Certificate of Authorization, may transfer boiler parts from one location to another without Partial Data Reports, provided the Quality Control System describes the method of identification, transfer, and receipt of the parts.

PG-106.9 No accessory or part of a boiler may be marked "ASME" or "ASME Std." unless so specified in the Code.

PG-106.10 Shell plates, furnace sheets, and heads shall have identification stamping in conformance with PG-77.

PG-106.11 The American Society of Mechanical Engineers' Certification Marks and the boiler builder's stamps shall not be covered permanently by insulating or other material.

PG-106.12 Multiple Pressure Steam Generators consisting of several sections of heat exchange surface designed for different pressure levels may be considered as a single boiler and the Manufacturer's stamping required by PG-106.1 combined into a single stamping provided

PG-106.12.1 The different circuits of the boiler are not intended to be operated separately or independently.

PG-106.12.2 The extent and design of the boiler external piping for each circuit shall be established in accordance with PG-58.2.

PG-106.12.3 The various circuits shall be separated from each other by providing a stop valve and a check valve in the feedwater piping leading to each circuit, in accordance with PG-58.4.

PG-106.12.4 Each circuit shall be given a hydrostatic test corresponding to its MAWP, as required by PG-99.

PG-106.12.5 Each circuit shall be stamped with the information required by PG-106.4. The stamping shall be located in accordance with PG-111.

PG-106.12.6 The Manufacturer shall furnish, in addition, a single metallic plate on which the above data are reproduced for all of the circuits. This plate shall be located in accordance with PG-111.13. All data on such plates shall be cast, etched or stamped. The Certification Mark shall be stamped on this plate and shall be witnessed by an Authorized Inspector. The letter and figures on these nameplates shall be not less than $^{5}/_{32}$ in. (4 mm) high.

PG-107 FIELD ASSEMBLY

Code responsibility for a completed boiler unit that is field assembled [excluding the shop assembled boiler with field installed piping, see PG-104.1, Note (2)] may be assumed only under the following conditions.

PG-107.1 By the boiler Manufacturer [see PG-104.1, Note (1)], provided

PG-107.1.1 Assembly work is performed by workmen employed by the boiler Manufacturer.

PG-107.1.2 Any work performed by others, such as erection of piping, that falls within the scope of the Code, is handled by proper Code certification.

PG-107.1.3 The completed boiler unit is properly stamped with the Manufacturer's Certification Mark with the "S" Designator in accordance with PG-108.1.

PG-107.1.4 Data Reports are prepared in accordance with PG-113.1.

PG-107.2 Jointly by the boiler Manufacturer and the assembler responsible for performing the hydrostatic test of the completed boiler, signing of the Certificate of Field Assembly Compliance on the Master Data Report, and for providing the supplemental stamping in accordance with PG-108.2, provided

PG-107.2.1 Assembly work is performed by workmen employed by the assembler.

PG-107.2.2 The assembler uses their own properly qualified welding procedures, welders and/or welding operators.

PG-107.2.3 Any work performed in the field by others, such as erection of boiler external piping or partial assembly of the boiler proper, that falls within the scope of the Code, is handled by proper Code certification.

(a) Code certification of boiler external piping installed by an organization other than the boiler Manufacturer or assembler shall be provided in accordance with PG-109.

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(b) Code certification of work performed by an organization responsible for partial field assembly of a boiler shall be provided as follows:

(1) The work performed shall be described on a Form P-3. The form shall be marked as not being the Master Data Report. Lines 1 through 5 of the form shall be completed by the assembler responsible for partial field assembly of the boiler, except that the words "partial field assembly" are to be inserted on Line 4 instead of the unit identification and ID numbers. The portion of partial field assembly completed by the assembler and the location of the stamping required by (3) shall be described on Line 15, Remarks.

(2) The Certificate of Field Assembly Compliance on the form shall be completed and signed by the assembler. The Certificate of Field Assembly Inspection on the form shall be completed and signed by the assembler's Authorized Inspector.

(3) When authorized by the Authorized Inspector, the assembler's Certification Mark together with the assembler's name, or an acceptable abbreviation, and the words "partial field assembly" shall be stamped by the assembler on a major pressure part assembled as part of the work covered by the Code certification. If limited space prevents this, the stamping shall be applied near the Manufacturer's stamping required by PG-106.

PG-107.2.4 The completed boiler unit is properly stamped with the Manufacturer's Certification Mark with the "S" Designator and the assembler's Certification Mark in accordance with PG-108.2.

PG-107.2.5 Data Reports are prepared in accordance with PG-113.2 and such Data Reports clearly define the work completed by the Manufacturer and the assembler.

PG-108 STAMPING FOR FIELD-ASSEMBLED BOILERS

Field assembly of a completed boiler unit may be made by anyone possessing a valid Certificate of Authorization for a power boiler stamp or an assembly stamp provided responsibility is assumed in accordance with the requirements of PG-107. Stamping for field assembled boiler units shall be completed as specified in PG-108.1 and PG-108.2.

PG-108.1 When responsibility for the completed boiler unit is assumed under PG-107.1, no additional stamping beyond that required by PG-106 is necessary.

PG-108.2 When responsibility for the completed boiler unit is assumed under PG-107.2, the Manufacturer's [see PG-104.1, Note (1)] stamping shall be supplemented with the assembler's stamp, together with the name of the assembler or an acceptable abbreviation. This supplementary stamping shall be applied in the field on the boiler near the stamping called for by PG-106 when authorized by the field Inspector after the required inspections and the hydrostatic test of the completed boiler unit. This supplementary stamping shall also be reproduced on a nameplate as required by PG-106.6 or PG-106.7 and attached in a location immediately adjacent to the master stamping plate, as required in PG-111.13.

PG-109 STAMPING OF PRESSURE PIPING

PG-109.1 Boiler external piping, as defined in the Preamble, may be fabricated by a manufacturer other than the Manufacturer of the boiler, provided that the manufacturer has been issued a Certificate of Authorization to use the Certification Mark with the "S" or "PP" Designator. Boiler external piping may be installed by welding by a manufacturer or contractor other than the Manufacturer of the boiler, provided such an organization has been issued a Certificate of Authorization to use the Certification Mark with the "S," "PP," or "A" Designator. When boiler external piping is installed by welding, the welding, including the qualification of welding procedures, welders, and welding operators, shall be done in accordance with the applicable rules of ASME B31.1. The welding shall be inspected by an Authorized Inspector at such stages of the work as the Inspector may elect. The organizations that fabricate or install such piping shall furnish proper code certification (PG-104.2).

PG-109.1.1 When contracted for by the boiler Manufacturer, that piping shall be documented on Form P-4, Manufacturer's Partial Data Report, in accordance with PG-112.2.4.

PG-109.1.2 When contracted for by other than the boiler Manufacturer, that piping shall be documented on Form P-4A, Manufacturer's Data Report for Fabricated Piping, in accordance with PG-112.2.5.

PG-109.2 Welded boiler external piping included within the scope of this Code, over NPS 2 (DN 50), shall be stamped with a Certification Mark with "S" or "PP" Designator, together with the manufacturer's or contractor's name and serial number. Such stamping shall be on the pipe, valve, or fitting adjacent to the welded joint farthest from the boiler. For piping operating at temperatures above 800°F (425°C) the Certification Mark may be stamped on a nameplate that is irremovably attached by welding, provided such welding is postweld heat treated, or on a circular metal band at least $\frac{1}{4}$ in. (6 mm) thick. This band around the pipe shall be secured in such a manner as to prevent it from slipping off during handling and installation.

Welded piping NPS 2 (DN 50) or less included within the scope of this Code shall be marked with an identification acceptable to the Inspector and traceable to the required Data Report. Such marking shall be of a type that will remain visible until the piping has been installed.

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PG-109.3 Mechanically assembled boiler external piping which contains no pressure boundary welds does not require stamping, and as such may be assembled by a nonstamp holder. Note that the responsibility for documentation and hydrostatic testing of a mechanically assembled boiler external piping must be assumed by a holder of a valid Certification Mark with the "S," "A," or "PP" Designator (see PG-112.2.5).

(23) ## PG-110 STAMPING OF BOILER PRESSURE RELIEF VALVES

Each pressure relief valve shall be plainly marked with the required data by the Manufacturer or Assembler (see PG-73.4.4) in such a way that the marking will not be obliterated in service. The marking shall be placed on the valve or on a metal nameplate securely fastened to the valve. The other required data may be stamped, etched, impressed, cast, or applied by other means acceptable to the ASME Designated Organization on the valve or nameplate. For units other than those included below, see PG-4. The marking shall include the following:

(a) the name (or an acceptable abbreviation) of the Manufacturer and Assembler, as applicable

(b) Manufacturer's design or type number

(c) NPS (DN) (the nominal pipe size of the valve inlet)

(d) set pressure _____ psi (MPa), and if applicable per PG-73.5.2, cold differential test pressure _____ psi (MPa)

(e) *Capacity*

(1) capacity _____ lbm/hr (kg/h) (for saturated steam service in accordance with PG-69.2) or

(2) capacity _____ lbm/hr (kg/h) at _____ °F (°C) (for power-actuated pressure-relieving valves in accordance with PG-69.4, or for pressure relief valves for superheated steam service in accordance with PG-68.7 or supercritical steam service in accordance with PG-67.5) or

(3) capacity _____ gal/min (l/min) at 70°F (20°C) at an overpressure of 10% or 3 psi (20 kPa), whichever is greater, for valves certified on water or

(4) capacity _____ lbm/hr (kg/h) at _____ °F (°C) _____ (fluid identification) (for organic fluid vaporizers in accordance with PVG-12.4)

(f) year built, or alternatively, a coding may be marked on the valve such that the valve Manufacturer or Assembler can identify the year the valve was assembled and tested

(g) Certification Mark as shown in Figure PG-105.1 with a "V" Designator placed under the Certification Mark. A marking method other than the stamp issued by the Society may be used, provided that it is acceptable to the ASME Designated Organization.

(h) The pilot of a pilot-operated pressure relief valve shall be plainly marked by the Manufacturer or Assembler showing the name of the Manufacturer, the Manufacturer's design or type number, the set pressure in psi (MPa), and the year built, or alternatively, a coding that the Manufacturer can use to identify the year built. The pilot and main valve of a pilot-operated pressure relief valve shall each be marked with the same unique identifier to establish association of both components.

PG-111 LOCATION OF STAMPINGS

The location of the required stampings shall be as listed below. These stampings shall be left uncovered or an easily removable marked cover may be provided over the stamping when a boiler is covered with insulation, or jacketed. No piping, boiler appliance, or other obstructions shall interfere with reading of the stamping.

PG-111.1 Horizontal-return tubular boilers — on the front head above the central rows of tubes.

PG-111.2 Horizontal-flue boilers — on the front head above the flues.

PG-111.3 Traction, portable, or stationary boilers of the locomotive type or Star watertube boilers — on the furnace end above the handhole. Or on traction boilers of the locomotive type — on the left wrapper sheet forward of the driving wheel.

PG-111.4 Vertical firetube and vertical submerged tube boilers — on the shell above the firedoor and handhole opening.

PG-111.5 Watertube Boilers.

PG-111.5.1 Drum type — on a head of the steam outlet drum near and above the manhole.

PG-111.5.2 Forced-flow steam generator with no fixed steam and waterline — the master stamping (PG-106.3) shall be located on a major pressure part, located near the main operating floor where readily visible. The Data Report Form shall record the location of the master stamping.

PG-111.6 Scotch marine boilers — on either side of the shell near the normal water level line and as near as practical to the front tubesheet.

PG-111.7 Economic boilers — on the front head, above the center row of tubes.

PG-111.8 Miniature and electric boilers — on some conspicuous and accessible place on the boiler proper, or on a stamping plate at least $^{3}/_{64}$ in. (1.2 mm) thick, permanently fastened (adhesives prohibited) to the boiler.

PG-111.9 On any of the above types where there is not sufficient space in the place designated, and for other types and new designs — in a conspicuous place on the boiler proper. The Data Report Form shall record the location of the required stamping.

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PG-111.10 Superheaters — on superheater header near the outlet. Other headers shall carry identifying marks.

PG-111.11 Economizers — at a handy location on water inlet header or drums. Other headers shall carry identifying marks.

PG-111.12 Waterwalls — on one end of a lower header. Other headers shall carry identifying marks.

PG-111.13 When required by PG-106.6 and PG-106.7, the Manufacturer [see PG-104.1, Note (1)] shall furnish a nameplate or plates on which the appropriate Certification Mark and design data for the scope of the Manufacturer's responsibility are permanently imprinted. The nameplate shall be securely attached to the front of the boiler, its setting or casing, at a place readily visible from the operating floor or platform.

PG-112 MANUFACTURER'S DATA REPORT FORMS

PG-112.1 Twelve types of Manufacturer's Data Report Forms are shown in A-350 under the heading "Data Report Forms and Guides" at the end of this Section. These forms shall be used by the Manufacturer [see PG-104.1, Note (1)] to record all the items constructed in accordance with this Section, as defined in the provisions of PG-112.2. When the certification of the complete boiler unit is accomplished by more than one Data Report, the principal Data Report (Form P-2, P-2A, P-3, P-3A, or PL-1) shall be designated as the Master Data Report (see PG-113).

Supporting Data Reports, such as Form P-4 and, when used as a Partial Data Report, Form P-3, shall be attached to and referenced in the Master Data Report. Requirements for completing multiple pages of Data Report Forms are shown in A-350.1.

For forced-flow steam generators with no fixed steam and waterline consisting of groups of pressure parts or components designed at several different pressure levels, a separate Manufacturer's Data Report, Form P-3 or Form P-4, shall clearly identify the pressure parts at each pressure level and show the maximum allowable working pressure. These several Data Reports shall be attached to and referenced in a Master Data Report (PG-113) that shall clearly identify each component as part of the complete unit.

PG-112.2 Types of Data Report Forms. The types of Data Report Forms and the purposes for which they are to be used are specified in PG-112.2.1 through PG-112.2.9.

PG-112.2.1 Form P-2, Manufacturer's Data Report for All Types of Boilers Except Watertube and Electric, shall be used to record all types of boilers that are not watertube, electric, or locomotive.

PG-112.2.1.1 Form P-2A, Manufacturer's Data Report for All Types of Electric Boilers, shall be used to record all types of electric boilers.

PG-112.2.1.2 Form P-2B, Manufacturer's Data Report for Electric Superheaters and Reheaters, shall be used to record electric superheaters and reheaters installed external to the boiler setting.

PG-112.2.2 See below.

(a) Form P-3, Manufacturer's Data Report for Watertube Boilers, Superheaters (except electric), Waterwalls, and Economizers, shall be used to record all of the items comprising a complete watertube boiler. When Form P-3 is used as a Master Data Report, the box at the top of the first page of the form shall be checked to indicate it is the Master Data Report.

Item 10 on Form P-3 shall be used to record other parts connected at the openings listed in Item 11 if such parts are fabricated of materials or by processes that require Code inspection. If such parts have not been connected prior to the hydrostatic test, a notation shall be made under Item 10 reading: "No parts connected to the openings listed in Item 11 except as noted."

(b) When Form P-3 is used as a Partial Data Report, it shall be used to record boiler parts requiring inspection and stamping under this Section that are furnished by other than the Manufacturer responsible for the completed boiler.

(1) Form P-3, when used as a Partial Data Report, shall be used only to provide supporting data for the information given on the Master Data Report for the completed boiler.

(2) When used to record parts furnished to the user of an existing boiler as replacement or repair parts, Form P-3, Partial Data Report, is sufficient and need not support a Master Data Report. A copy of the parts Manufacturer's Form P-3, Partial Data Report, shall be forwarded to the purchaser.

(3) The parts Manufacturer shall indicate under "Remarks" the extent to which the Manufacturer has performed the design functions. When the parts Manufacturer performed only a portion of the design, the Manufacturer shall state which portion of the design the Manufacturer has performed.

PG-112.2.3 Form P-3A, Engineering-Contractor Data Report for a Complete Boiler Unit, shall be used when such an organization assumes the Manufacturer's Code responsibility as provided for by PG-104.1, Note (1). This form shall be used to certify Code responsibility for the design specification of the complete boiler unit, of which the components are individually certified by their individual manufacturers in accordance with the Code rules. This form also provides for field assembly certification.

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Form P-3A shall not be used by a Manufacturer to provide Code certification for only a portion of the complete boiler unit.

PG-112.2.4 See below.

(a) Form P-4, Manufacturer's Partial Data Report, shall be used to

(1) record boiler parts requiring inspection and stamping under this Section that are furnished by other than the Manufacturer responsible for the completed boiler, superheater, waterwall, or economizer

(2) record boiler external piping when required by PG-109.1

(b) Except as provided in (c), Form P-4 shall be used only to provide supporting data for the information given on the Master Data Report (see PG-113) or on a Form P-3 that is used to record a superheater, waterwall, or economizer.

(c) Form P-4 shall be used to record boiler parts requiring inspection and stamping under this Section that are furnished by other than the Manufacturer responsible for the completed boiler.

(1) Form P-4 shall be used only to provide supporting data for the information given on the Master Data Report for the completed boiler.

(2) When used to record parts furnished to the user of an existing boiler as replacement or repair parts, Form P-4 is sufficient and need not support a Master Data Report Form. A copy of the parts Manufacturer's Form P-4 shall be forwarded to the purchaser.

(3) The parts Manufacturer shall indicate under "Remarks" the extent to which the Manufacturer has performed the design functions. When the parts Manufacturer performed only a portion of the design, the Manufacturer shall state which portion of the design the Manufacturer has performed.

(23) **PG-112.2.5** Form P-4A shall be used to record boiler external piping when required by PG-109.1.2. Form P-4A shall be used when the fabricated piping, either welded or mechanically assembled, is not furnished by the boiler Manufacturer but is furnished by an organization not contractually responsible to the Manufacturer [see PG-104.1, Note (1)]. The organization responsible for the fabrication and installation of this piping shall have the responsibility for distributing copies of Form P-4A to the inspection agency and proper authorities. The organization certifying Form P-4A retains the responsibility for the Code design and shall retain the Form P-4A for a minimum of 5 yr.

PG-112.2.6 Form P-5, Summary Data Report for Process Steam Generators, may be used by the Manufacturer [see PG-104.1, Note (1)] to record all items of field-assembled process steam generators of the waste heat or heat recovery type, comprising one or more drums and one or more arrays of heat exchange surface designed for different pressure levels. All such component items shall be constructed to the applicable rules of the Code and shall be certified by individual Data Report Forms executed by the component manufacturer and the Authorized Inspector. When used, the Summary Data Report Form P-5 shall list all the properly executed data report forms for components comprising the complete process steam generator and shall be attached to the Manufacturer's Data Report.

PG-112.2.7 When using a print version of a Data Report Form, Form P-6, Manufacturer's Data Report Supplementary Sheet, shall be used to record additional data where space was insufficient on a Data Report Form. This Manufacturer's Data Report Supplementary Sheet will be attached to the Manufacturer's Data Report Form where used. When using an electronic version of a Data Report Form, it may be expanded to include all additional data, or Form P-6 may be used in accordance with PG-112.5.2.

PG-112.2.8 Form P-7, Manufacturer's Data Report for Pressure Relief Valves, shall be used to record required pressure relief valves. Form P-7 shall be used as supporting data for Form P-2, P-3, P-3A, or PL-1. Form P-7 is not required for boilers certified on Form P-2A, or for boilers with a single pressure relief valve when the pressure relief valve size, set pressure, and capacity [lbm/hr (kg/h)] are included in the remarks section of Form P-2 or P-3. (23)

PG-112.2.9 See below.

(a) Form PL-1, Manufacturer's Data Report for Locomotive Boilers, shall be used to record all of the items comprising a complete locomotive boiler. The box at the top of the form shall be checked to indicate it is a Master Data Report.

(b) When Form PL-1 is used as a Partial Data Report, it shall be used to record locomotive boiler parts requiring inspection and stamping under this Section that are furnished by other than the Manufacturer responsible for the completed locomotive boiler.

(1) Form PL-1, when checked as a Partial Data Report, shall be used only to provide supporting data for the information given on the Master Data Report Form PL-1 for the completed locomotive boiler.

(2) When used to record parts furnished to the user of an existing boiler as replacement or repair parts, Form PL-1, Partial Data Report, is sufficient and need not support a Master Data Report Form PL-1. A copy of the parts Manufacturer's Form PL-1 shall be forwarded to the purchaser.

(3) The parts Manufacturer shall indicate under "Remarks" the extent to which the Manufacturer has performed the design functions. When the parts Manufacturer performed only a portion of the design, the Manufacturer shall state which portion of the design the Manufacturer has performed.

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PG-112.3 Manufacturer's Data Reports and all associated Partial Data Reports shall be furnished to the purchaser, the inspection agency, and the state, municipal, or provincial authority at the place of installation. Partial Data Reports for pressure parts requiring inspection under this Section, and which are furnished by other than the Manufacturer having Code responsibility for the boiler or the superheater, waterwall, or economizer, shall be executed by the parts Manufacturer and the Inspector in accordance with the requirements of this Section.

Except as provided in PG-112.2.2(b), PG-112.2.4(b), or PG-112.2.9(b), the Partial Data Reports shall be forwarded, in duplicate, to the Manufacturer of the boiler or the superheater, waterwall, or economizer. These Partial Data Reports, together with the Inspector's own inspection, shall be the final Inspector's authority to witness the application of the Certification Mark to the boiler or the superheater, waterwall, or economizer. The Partial Data Reports shall be attached to the associated Form P-2, P-2A, P-3, P-3A, P-5, or PL-1 by the Manufacturer having Code responsibility for the boiler or the superheater, waterwall, or economizer.

PG-112.4 A-350 includes nonmandatory guides to aid in the completion and certification of the Manufacturer's Data Report Forms.

PG-112.5 When a multiple pressure steam generator is considered a single boiler (see PG-106.12), it shall be documented as indicated in PG-112.5.1 and PG-112.5.2.

PG-112.5.1 Data Report Form P-3 or P-3A shall be used by the Manufacturer as the Master Data Report to record all items comprising a multiple pressure steam generator of the waste heat or heat recovery type. The Master Data Report shall list all of the properly executed data report forms for the items comprising the complete steam generator unit.

PG-112.5.2 Other forms such as Forms P-3, P-4, P-5, P-6, and P-7 shall be used as necessary to provide and summarize supporting information for the Master Data Report.

PG-112.6 Manufacturer's Partial Data Report Form P-3, P-4, or PL-1 and stamping in accordance with PG-106 are neither required nor prohibited for pressure parts that do not contain pressure-retaining welds (e.g., boiler furnace walls, floor panel assemblies, tubes with support or hanger lugs). However, the Manufacturer shall certify that the material and construction are in accordance with the requirements of this Section.

PG-112.6.1 Certification may be supplied in the form of bills of material and drawings with a statement of compliance or Certificate of Compliance from the Manufacturer.

PG-112.6.2 The Certification shall state what materials were used including size (O.D. and wall thickness) and which edition and addenda of the Code were used to construct the parts.

PG-112.6.3 The parts shall be clearly identified with markings traceable to the certification. The markings may be in the form of labels, tags, stamping, paint, or coded identification.

PG-113 MASTER DATA REPORT FORM

PG-113.1 The Master Data Report (using Manufacturer's Data Report Form P-2, P-2A, P-3, P-3A, or PL-1, as applicable) shall be used by the boiler Manufacturer [see PG-104.1, Note (1)] to fully document all parts of a complete boiler unit [excluding boiler external piping; see PG-104.1, Note (2)] as having Code certification in accordance with the Code requirements for design, construction, and workmanship.

PG-113.2 When a field-assembled boiler unit is documented by Data Forms from manufacturers other than the Manufacturer [see PG-104.1, Note (1)] responsible for the complete boiler unit, the boiler Manufacturer shall complete the applicable Master Data Report Form by recording the required data from all supporting Data Report Forms that are required for the complete boiler unit. All Data Forms shall be securely attached to the Master Data Report. The Data Reports shall clearly separate shop fabrication from field assembly and in the case of large units, supplemental sheets may be used to record the information. The certificate of shop inspection block and the certificate of field assembly block shall clearly designate the items to be certified by the Inspector in the shop and those to be certified by the Inspector in the field. The certified Data Reports furnished by the several manufacturers shall be the shop or field Inspector's authority to accept the components fabricated by the other manufacturers and included in the construction of the complete boiler unit.

PG-113.3 The boiler Manufacturer [see PG-104.1, Note (1)] shall have the responsibility for distributing copies of the complete Master Data Report Form (Form P-2, P-2A, P-3, P-3A, or PL-1, as applicable) to the inspection agency and the required number of proper authorities. The Manufacturer's written quality control system shall include requirements for completion of Manufacturer's Data Reports. The Manufacturer shall retain the Manufacturer's Data Reports for a minimum of 5 years.

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PART PW
REQUIREMENTS FOR BOILERS FABRICATED BY WELDING

GENERAL

PW-1 GENERAL

PW-1.1 Scope. The rules in Part PW are applicable to boilers and component parts thereof, including piping constructed under the provisions of this Section, that are fabricated by welding and shall be used in conjunction with the general requirements in Part PG as well as with the specific requirements in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PW-1.2 Responsibility. Each Manufacturer[21] (Certificate of Authorization holder) is responsible for the welding done by their organization and shall establish the procedures and conduct the tests required in Section IX to qualify the welding procedures they use in the construction of the weldments built under Section I and the performance tests of welders[22] who apply these procedures. Alternatively, AWS Standard Welding Procedure Specifications that have been accepted by Section IX may be used for Section I construction, provided the welding meets the requirements of this Section. A particular AWS Standard Welding Procedure may contain a range for a welding variable where only part of the range meets the requirements of this Section. This could apply to one or more welding variables. The Section I requirements always take precedence. Manufacturers intending to use AWS Standard Welding Procedures shall describe in their Quality Control System (A-302.7) control measures used to assure that the welding meets the requirements of this Section and Section IX. Other occurrences of the phrase qualified in accordance with Section IX in this Part shall be construed to permit use of AWS Standard Welding Procedures accepted by Section IX and controlled as described above. Such welding will ordinarily be done by employees of the Manufacturer who accepts the responsibility for Code construction of the boiler or part being welded. Alternatively, the Manufacturer may perform Code welding using the services of individual welders who are not employed by the Manufacturer provided all the following conditions are met.

PW-1.2.1 All Code construction shall be the responsibility of the Manufacturer.

PW-1.2.2 All welding shall be performed in accordance with Manufacturer's Welding Procedure Specifications that have been qualified by the Manufacturer in accordance with the requirements of Section IX.

PW-1.2.3 All welders shall be qualified by the Manufacturer in accordance with the requirements of Section IX.

PW-1.2.4 The Manufacturer's quality control system shall include as a minimum

PW-1.2.4.1 A requirement for complete and exclusive administrative and technical supervision of all welders by the Manufacturer.

PW-1.2.4.2 Evidence of the Manufacturer's authority to assign and remove welders at their discretion without involvement of any other organization.

PW-1.2.4.3 A requirement for Assignment of Welder identification symbols.

PW-1.2.4.4 Evidence that this program has been accepted by the Manufacturer's Authorized Inspection Agency which provides the inspection service.

PW-1.2.5 The Manufacturer shall be responsible for Code compliance of the weldment including stamping the Certification Mark with appropriate Designator and providing Data Report Forms properly executed and countersigned by the Authorized Inspector.

PW-1.3 Welding Definitions. For some of the more common terms related to welding, refer to Section IX, QG-109.2.

MATERIALS

PW-5 GENERAL

PW-5.1 Materials used in welded construction of pressure parts shall conform to one of the specifications given in Section II and shall be limited to those specifically permitted in Parts PG, PWT, and PFT and for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B, for Section I construction and for which weld Group P-Numbers are assigned in Section IX.

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PW-5.2 Carbon or alloy steel having a carbon content of more than 0.35% shall not be used in welded construction or be shaped by oxygen cutting or other thermal cutting processes.

PW-5.3 Austenitic stainless steel materials joined by electroslag welding shall be limited to SA-240 Grades 304 and 316, SA-182 Grades F304 and F316, and SA-351 Grade CF 8.

PW-5.4 Welding electrodes and filler metal shall be selected to provide deposited weld metal of chemical composition and mechanical properties compatible with the materials to be joined and the service conditions anticipated.

When Grade 91 filler metal (e.g., AWS B9 or B91, ISO CrMo91, etc.) is used to make pressure-retaining welds in P-No. 15E Gr. 1 materials, the nickel plus manganese (Ni + Mn) content of the filler metal shall not exceed 1.2%.

PW-5.5 Rimmed and semi-killed steels shall not be joined by the inertia and continuous drive friction welding processes.

PW-5.6 For pressure-retaining welds in 2¼Cr–1Mo materials, other than circumferential buttwelds less than or equal to 3½ in. (89 mm) in outside diameter, when design metal temperatures exceed 850°F (455°C), the weld metal shall have a carbon content greater than 0.05%.

DESIGN

PW-8 GENERAL

The rules in the following paragraphs apply specifically to the design of boilers and parts thereof that are fabricated by welding and shall be used in conjunction with the general requirements for design in Part PG, as well as with the specific requirements for design in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PW-9 DESIGN OF WELDED JOINTS

PW-9.1 Longitudinal, circumferential, and other joints, uniting the material used for drums, shells, or other pressure parts, except as otherwise provided in PG-31, PG-39, PW-41, PWT-11, and Part PFT shall be full penetration butt welds. The welds should preferably be of the double-welded butt type, but may also be of the single-welded butt type with the filler metal added from one side only when made to be the equivalent of the double-welded butt joint by providing means for accomplishing complete penetration.

PW-9.2 Welding Grooves. The dimensions and shape of the edges to be joined by butt welds shall be such as to permit complete fusion and complete joint penetration.

PW-9.3 Transitions at Butt Joints Between Materials of Unequal Thickness. This paragraph is not intended to apply to joint designs specifically provided for elsewhere in this Code.

The requirements of PW-9.3.1 through PW-9.3.3, as applicable to the specific type of pressure part, shall be met.

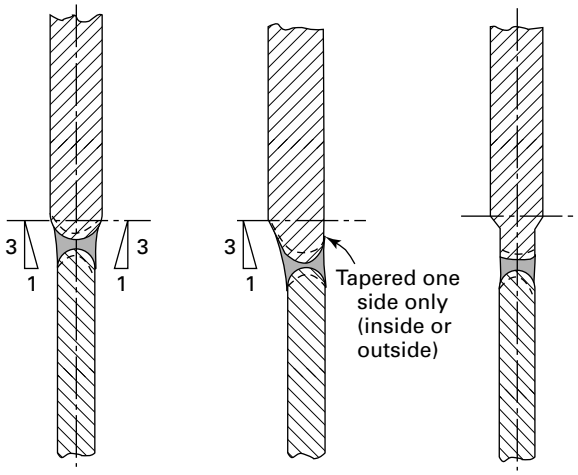
PW-9.3.1 Shells, Drums, and Vessels (Including Those Fabricated From Materials Complying With Piping or Tubing Material Specifications). When materials of unequal thickness are joined via a butt joint, a tapered transition shall be provided if the difference in thickness is greater than one-fourth the thickness of the thinner material or ⅛ in. (3 mm), whichever is less. Any process that will provide a uniform taper may be used to form the transition section. The weld may be partly or entirely in the tapered section or adjacent to it as indicated in Figure PW-9.3.1. The tapered transition shall have a length not less than 3 times the offset between the adjoining surfaces, as shown in Figure PW-9.3.1. Provisions for tapers at circumferential butt-welded joints connecting formed heads to main shells are contained in PW-9.3.3.

For longitudinal joints, the middle lines of the adjoining materials shall be in alignment with the fabricating tolerances specified in PW-33. Alternatively, the middle lines of the adjoining materials may be offset so that the inside or outside diameters form a continuous surface, provided the following conditions are met:

(a) The ratio of plate thicknesses shall not exceed 2:1.

(b) The maximum design temperature shall not exceed 750°F (400°C).

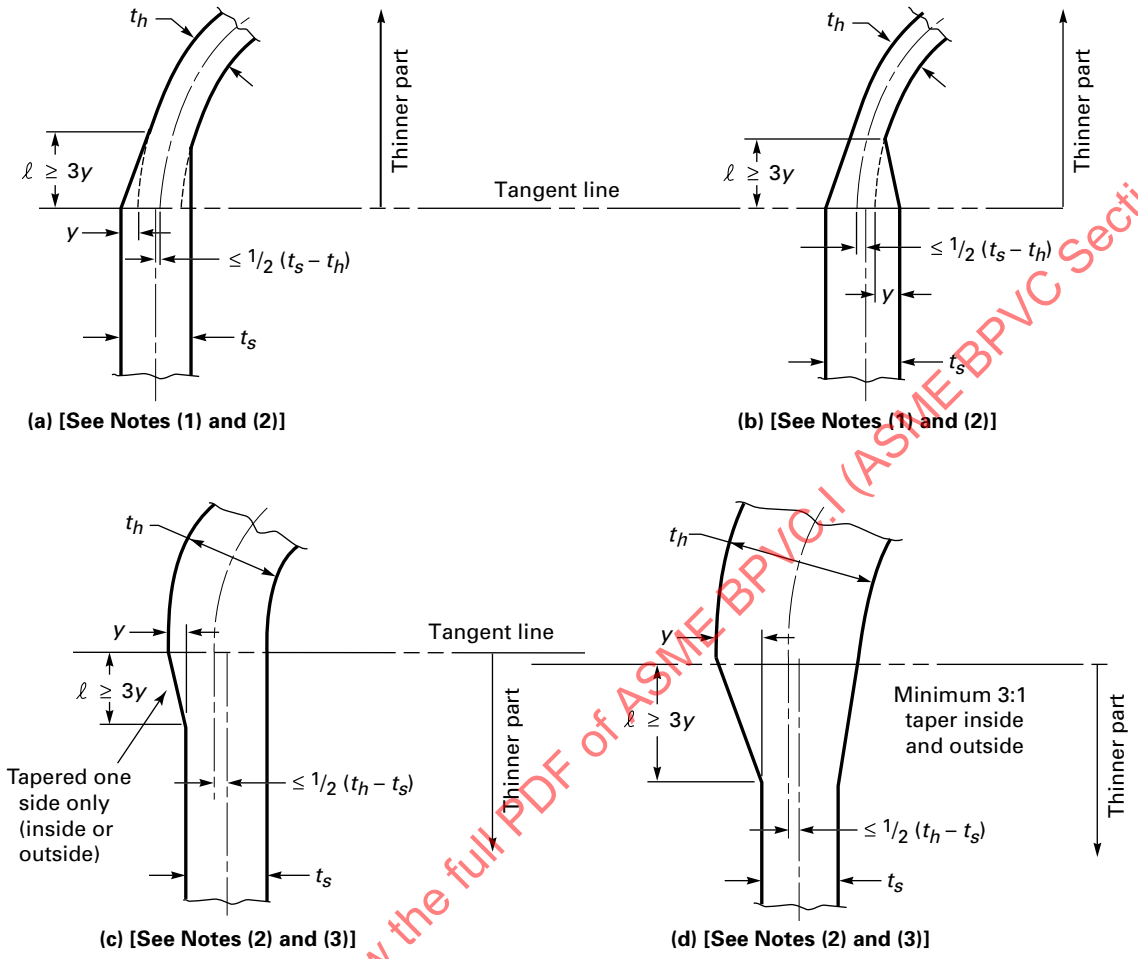
Figure PW-9.3.1
Butt Welding of Plates of Unequal Thickness



(a) Preferred Method (Centerlines Coincide) (b) Permissible (Circumferential Joints Only) (c) Not Permissible

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Figure PW-9.3.3
Heads Attached to Shells



GENERAL NOTE:
t_h = nominal thickness of head
t_s = nominal thickness of shell

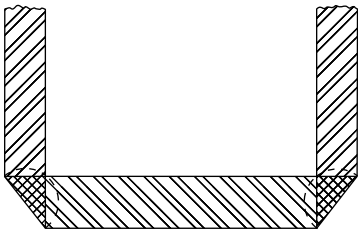
NOTES:
(1) In all cases, the projected length of taper, ℓ, shall be not less than $3y$.
(2) Length of required taper, ℓ, may include the width of the weld. The shell plate centerline may be on either side of the head plate centerline.
(3) In all cases, ℓ shall be not less than $3y$ when t_h exceeds t_s. Minimum length of skirt is $3t_h$ but need not exceed $1\frac{1}{2}$ in. (38 mm) except when necessary to provide required length of taper. When t_h is equal to or less than $1.25t_s$, length of skirt shall be sufficient for any required taper.

PW-9.3.2 Pipes and Tubes. When tube and pipe components of different diameters or thicknesses are welded circumferentially, the transition shall not exceed a slope of 30 deg from the smaller to the larger diameter. Any process that will provide a uniform taper may be used to form the transition section. The weld may be partly or entirely in the tapered section or adjacent. Alignment shall meet the provisions of PW-34.

PW-9.3.3 Heads Attached to Shells. A tapered transition having a length not less than 3 times the offset between the adjacent surfaces of abutting sections as shown in Figure PW-9.3.3, illustrations (a) and (b) shall be provided at joints between formed heads and shells that differ in thickness by more than one-fourth the thickness of the thinner section or by more than $\frac{1}{8}$ in. (3 mm), whichever is less. When a taper is required on any formed head thicker than the shell and intended for butt-welded attachment [see Figure PW-9.3.3, illustrations (c) and (d)], the length of the skirt as measured from the tangent line shall meet the requirements in Figure PW-9.3.3 and the taper shall be entirely within the skirt. When the transition is formed by removing material from the thicker section, the minimum thickness of that

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Figure PW-9.4
Prohibited Welded Joint



section, after the material is removed, shall not be less than that required by Part PG. The centerline misalignment between shell and head shall be no greater than one-half the difference between the actual shell and head thickness, as illustrated in Figure PW-9.3.3, illustrations (a) through (d).

PW-9.4 Prohibited Welded Joints. Corner joints as depicted in Figure PW-9.4 are prohibited.

PW-10 HEAT TREATMENT

Boiler pressure parts joined by welding shall be preheated and postweld heat treated in accordance with the requirements in PW-38 and PW-39.

CAUTION: Creep strength enhanced ferritic (CSEF) steels are a family of ferritic alloys whose high temperature creep strength is enhanced by the creation of a precise condition of microstructure, specifically martensite or bainite, which is stabilized during tempering by controlled precipitation of temper-resistant carbides, carbonitrides, or other stable and/or meta-stable phases. Careful consideration should be given to the preheating, welding, and heat treatment of pressure-retaining items that are fabricated from CSEF steels. The tensile and creep strength properties of these materials may be significantly degraded if the appropriate welding and heat treatment requirements are not followed.

PW-11 VOLUMETRIC EXAMINATION OF WELDED BUTT JOINTS

PW-11.1 Welded butt joints requiring volumetric examination are specified in Table PW-11. Unless Table PW-11 restricts volumetric examination to one method, either the radiographic or the ultrasonic method may be used. Acceptance of the weld shall be determined by the method selected for the initial examination of the completed weld. If repairs are required, the repairs shall be examined using the same method by which the unacceptable imperfections were detected. Subsequent examination of the weld following acceptance is beyond the requirements of this Section and shall be a matter of agreement between the Manufacturer and the User.

Experience has demonstrated that welded butt joints not requiring volumetric examination by these rules have given safe and reliable service even if they contain imperfections that may be disclosed upon further examination. Any examination and acceptance standards beyond the requirements of this Section are beyond the scope of this Code and shall be a matter of agreement between the Manufacturer and the User.

PW-11.2 Definitions. For use with Table PW-11 and elsewhere in this Section, the following definitions apply:

butt joint: a joint between two members aligned approximately in the same plane.

circumferential butt weld: includes circumferential welded butt joints in drums, headers, pipes, and tubes, and welded butt joints attaching formed heads to drums, shells, and headers.

longitudinal butt weld: includes longitudinal and spiral welded butt joints in drums, shells, headers, pipes, and tubes; any welded butt joint within a sphere or within a formed or flat head or tubesheet; and welded butt joints attaching insert-nozzles of the type shown in Figure PW-16.1, illustrations (q-1) through (q-4).

nondestructive examination (NDE): examination methods used to verify the integrity of materials and welds in a component without damaging its structure or altering its mechanical properties. NDE may involve surface, subsurface, and volumetric examination.

NPS: nominal pipe size.

volumetric NDE: a method capable of detecting imperfections that may be located anywhere within the examined volume. For Section I construction, volumetric NDE is limited to radiographic (RT) and ultrasonic (UT) examination methods.

PW-11.3 For use with Table PW-11, the size and thickness of welded butt joints is defined as the larger and thicker of the two abutting edges after edge preparation.

The geometric unsharpness U_g is defined by the equation

$$U_g = Fd/D$$

where

D = distance from source of radiation to the weld
d = distance from the source side of the weld to the film
F = source size; the maximum projected dimension of the radiating source (or effective focal spot) in the plane perpendicular to the distance D from the weld
U_g = geometric unsharpness

PW-11.4 Volumetric examination of creep strength enhanced ferritic (CSEF) material welds shall be performed after postweld heat treatment.

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(23)

Table PW-11
Required Volumetric Examination of Welded Butt Joints

Butt Weld Type	Pressure Part Service Conditions [Note (1)]		
	Subject to Furnace Radiant Heat [Note (2)]	Not Subject to Furnace Radiant Heat [Note (2)]	
	Contains Steam and/or Water	Contains Water	Contains Steam
Longitudinal	All sizes and thicknesses	All sizes and thicknesses	All sizes and thicknesses
Circumferential welds in drums and shells	>NPS 10 (DN 250) or >1⅛ in. (29 mm) thick	>NPS 10 (DN 250) or >1⅛ in. (29 mm) thick	>NPS 10 (DN 250) or >1⅛ in. (29 mm) thick
Circumferential welds in pipes, tubes, and headers	>NPS 4 (DN 100) or >½ in. (13 mm) thick	>NPS 10 (DN 250) or >1⅛ in. (29 mm) thick	>NPS 16 (DN 400) or >1⅝ in. (41 mm) thick

GENERAL NOTES:
(a) Unless exempted by this table, all longitudinal and circumferential welded butt joints are to be volumetrically examined throughout their entire length.
(b) Volumetric examination is required when either the size or wall thickness limit is exceeded (i.e., the diameter and thickness limitations apply independently).
(c) Radiographic examination shall be performed in accordance with PW-51.
(d) Ultrasonic examination shall be carried out in accordance with PW-52.
(e) Personnel performing the volumetric examination required by this table shall be qualified and certified in accordance with PW-50.
(f) When any combination of radiographic parameters produces a geometric unsharpness exceeding 0.07 in. (1.8 mm) then UT shall be used.
(g) When volumetric examination is required and the thickness is below ½ in. (13 mm), RT shall be used.
(h) Both RT and UT examination are required for welds in ferritic materials using the electroslag process. If a grain refining (austenizing) heat treatment is used, the UT examination shall be performed after the heat treatment is completed. If an austenizing heat treatment is not used, the UT examination shall be done after an intermediate postweld heat treatment or after the final postweld heat treatment is completed.
(i) Both RT and UT examination are required for welds in any material using the inertia or continuous drive friction welding process.
(j) For electric boilers volumetric examination is not required when the maximum allowable working pressure is ≤100 psig (700 kPa) and the shell I.D. is ≤16 in. (400 mm) (see PEB-9).
(k) For firetube boilers, volumetric examination is not required for
(1) longitudinal welded butt joints in furnaces made with the addition of filler metal, provided a bend test of a sample of the welded joint for each section of the furnace meets the requirements of PW-53
(2) circumferential welded butt joints in furnaces (see PFT-14)
(3) butt welds and corner joints meeting the requirements of PFT-21.1 through PFT-21.3 for waterlegs, furnaces, and fireboxes
(l) For miniature boilers, volumetric examination is not required (see PMB-9).
(m) Volumetric examination is not required for the longitudinal weld in ERW products that comply with an acceptable material specification when used for construction within the limitations of PG-9.5.
(n) For watertube boilers, volumetric examination is not required for butt welds and corner joints meeting the requirements of PWT-12 and PFT-21.

NOTES:
(1) Service conditions and pressure part contents are as determined by the designer.
(2) A weld will not be considered subject to radiant heat from the furnace when in a portion of a pressure part that has five or more rows of tubes between it and the furnace.

PW-13 HEAD-TO-FLANGE REQUIREMENTS

Dished heads, other than hemispherical, concave to pressure to be attached by butt welding, and flanged heads or flanged furnace connections to be fillet welded, shall have a length of flange not less than 1 in. (25 mm) for heads or furnace openings not over 24 in. (600 mm) in external diameter and not less than 1½ in. (38 mm) for heads or furnace openings over 24 in. (600 mm) in diameter.

PW-14 OPENINGS IN OR ADJACENT TO WELDS

Any type of opening that meets the requirements for compensation given in PG-32 through PG-44 may be located in a welded joint.

PW-15 WELDED CONNECTIONS

PW-15.1 Nozzles, other connections, and their compensation may be attached to vessels by welding. Sufficient weld and compensation shall be provided on either side of the plane through the center of the opening, parallel to the longitudinal axis of the vessel, to develop the required strength, as prescribed in PG-37, in shear or tension, whichever is applicable

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(see Figure PW-15 for example calculations, where, if a fillet weld has unequal legs, the value of WL_1 or WL_2 shall be taken as the length of the shorter leg).

PW-15.1.1 The stress correction factors in PW-15.2 shall apply to all welds.

PW-15.1.2 The strength of fillet welds shall be based on one-half the area subjected to shear, computed on the average diameter of the weld.

PW-15.1.3 The strength of groove welds shall be based on one-half the area subjected to shear or tension, as applicable, computed using the minimum weld depth dimension in the direction under consideration.

PW-15.1.6 The strength calculations for nozzle attachment welds are not required for the weld configurations shown in Figure PW-16.1, illustrations (a) through (c), (g), (h), (o), (q-1) through (q-4), (u-1), (v-1), (w-1), (y), and (z).

PW-15.2 Stress Values for Weld Metal. The allowable stress values for groove and fillet welds in percentages of stress values for the vessel material are as follows:

Material	Percentage
Groove-weld tension	74%
Groove-weld shear	60%
Fillet-weld shear	49%

NOTE: These values are obtained by combining the following factors: 87½% for combined end and side loading, 80% for shear strength, and the applicable joint efficiency factors.

PW-15.3 Compensation plates and saddles of nozzles attached to the outside of a vessel shall be provided with at least one telltale hole [maximum size ¼ in. (6 mm) pipe tap] that may be tapped for a preliminary compressed-air and soapsuds test for tightness of welds that seal off the inside of the vessel. These telltale holes shall be left open when the vessel is in service.

PW-15.4 Figure PW-16.1 illustrates some types of fusion welded connections which are acceptable.

When end faces of nozzle or manhole necks are to remain unwelded in the completed vessel, these end faces shall not be cut by shearing unless at least ⅛ in. (3 mm) of additional metal is removed by any method that will produce a smooth finish.

PW-16 MINIMUM REQUIREMENTS FOR ATTACHMENT WELDS

PW-16.1 General. Except as permitted in PW-16.5, PW-16.6, and PW-16.7 nozzles and other connections to shells, drums, and headers shall be attached by full penetration welds applied from one or both sides, partial penetration welds applied from both sides, fillet welds applied from both sides, or fillet and partial penetration welds on opposite sides. In addition to the strength calculations required in PG-37, the location and minimum size of attachment welds for nozzles and other connections shall conform to the requirements in this paragraph.

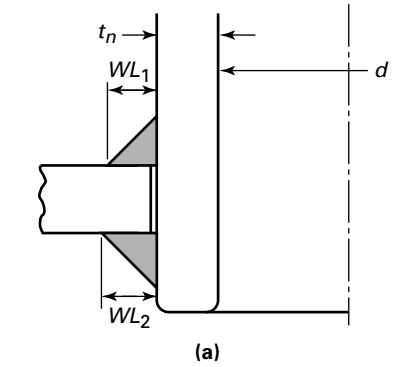
PW-16.2 Nomenclature. The symbols used in this paragraph and in Figures PW-16.1 and PW-16.2 are defined as follows:

t = thickness of vessel shell or head
t_c = not less than the smaller of ¼ in. (6 mm) or $0.7t_{min}$ (inside corner welds may be further limited by a lesser length of projection of the nozzle wall beyond the inside face of the vessel wall)
t_l = thickness of lug, hanger, or bracket, as shown in Figure PW-16.2
t_{min} = the smaller of ¾ in. (19 mm) or the thickness of either of the weld parts joined by a fillet, single bevel, or single J-weld
t_n = thickness of nozzle wall
t_w = dimension of partial penetration attachment welds (fillet, single bevel, or single J), measured as shown in Figure PW-16.1

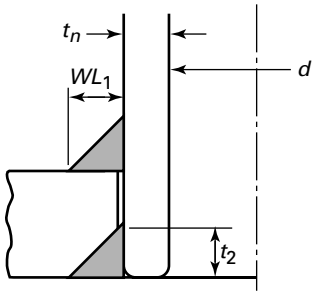
$t_1 + t_2 \geq 1\frac{1}{4}t_{min}$ measured as shown in Figure PW-16.1, in., both t_1 and t_2 shall each be not less than the smaller of ¼ in. (6 mm) or $0.7t_{min}$

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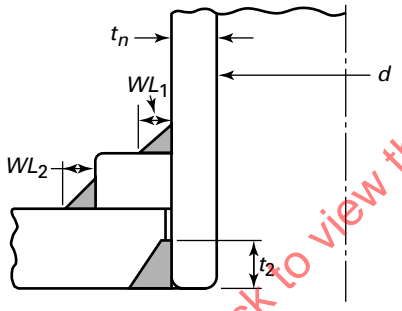
Figure PW-15
Examples of Weld Strength Calculations



(a)



(b)



(c)

For illustration (a):

Required weld strength (PG-37.2):

$$W = (A - A_1)S_v$$

Weld strength = WL_1 in shear + WL_2 in shear

$$= 0.49\ (1/2)\ WL_1\ \pi\ (d + 2t_n + WL_1)\ S_v\ f_{r1} +$$
$$0.49\ (1/2)\ WL_2\ \pi\ (d + 2t_n + WL_2)\ S_v\ f_{r1}$$

For illustration (b):

Required weld strength (PG-37.2):

$$W = (A - A_1)S_v$$

Weld strength = WL_1 in shear + t_2 in tension

$$= 0.49\ (1/2)\ WL_1\ \pi\ (d + 2t_n + WL_1)\ S_v\ f_{r1} +$$
$$0.74\ (1/2)\ t_2\ \pi\ (d + 2t_n)\ S_v\ f_{r1}$$

For illustration (c):

(1) Required weld strength (PG-37.2):

$$W = (A - A_1)S_v$$

Weld strength = WL_2 in shear + t_2 in tension

$$= 0.49\ (1/2)\ WL_2\ \pi\ (D_p + WL_2)\ S_v\ f_{r3} +$$
$$0.74\ (1/2)\ t_2\ \pi\ (d + 2t_n)\ S_v\ f_{r1}$$

(2) Check nozzle to pad and shell (PG-37.3):

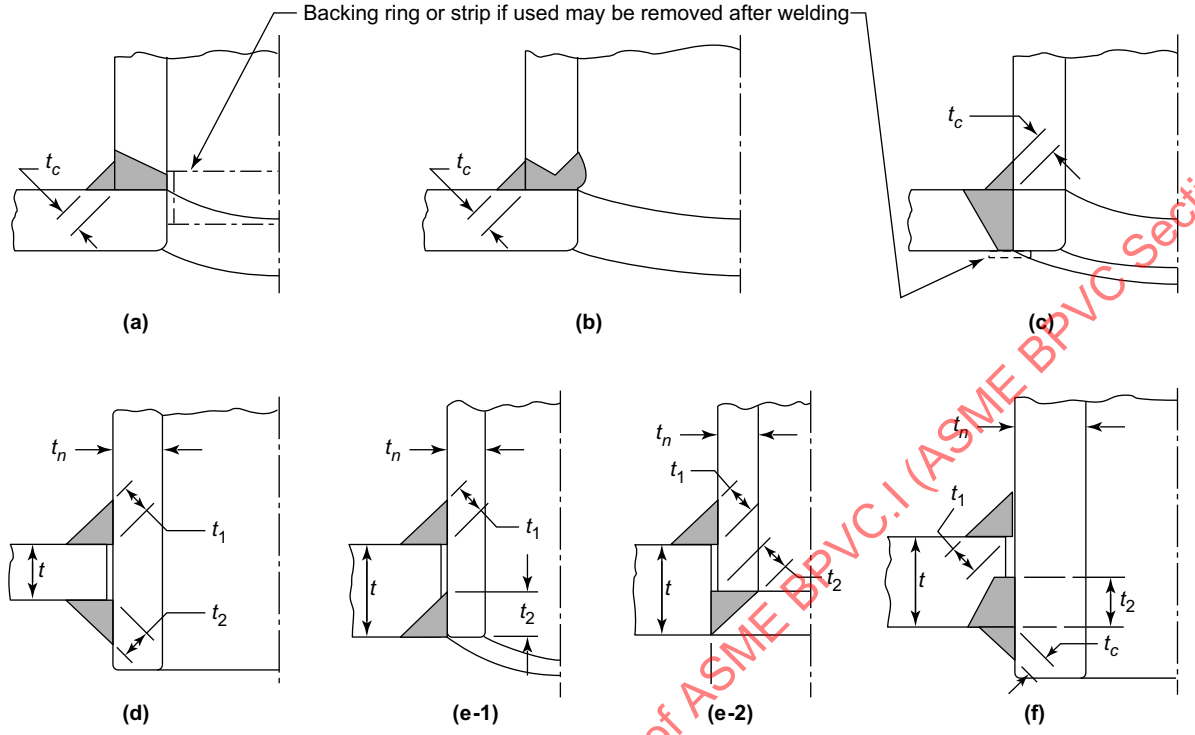
$$W = (A - A_1 - A_{42} - A_5)S_v$$

Weld strength = WL_1 in shear + t_2 in tension

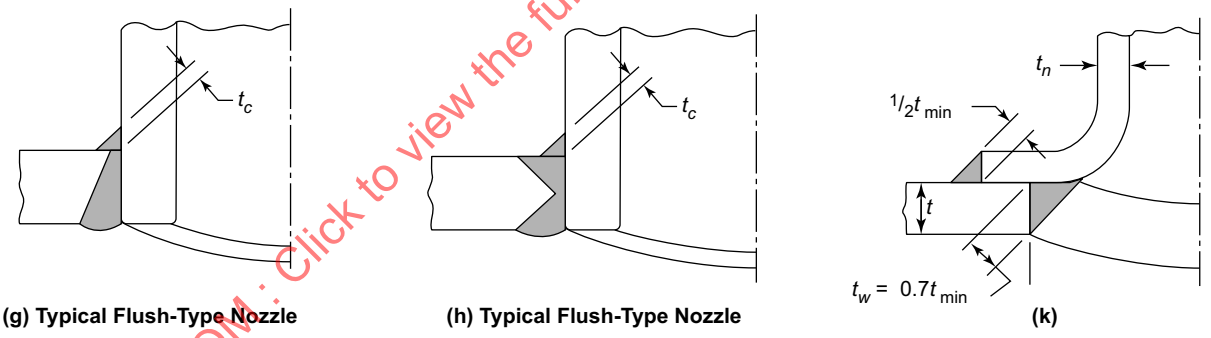
$$= 0.49\ (1/2)\ WL_1\ \pi\ (d + 2t_n + WL_1)\ S_v\ f_{r1} +$$
$$0.74\ (1/2)\ t_2\ \pi\ (d + 2t_n)\ S_v\ f_{r1}$$

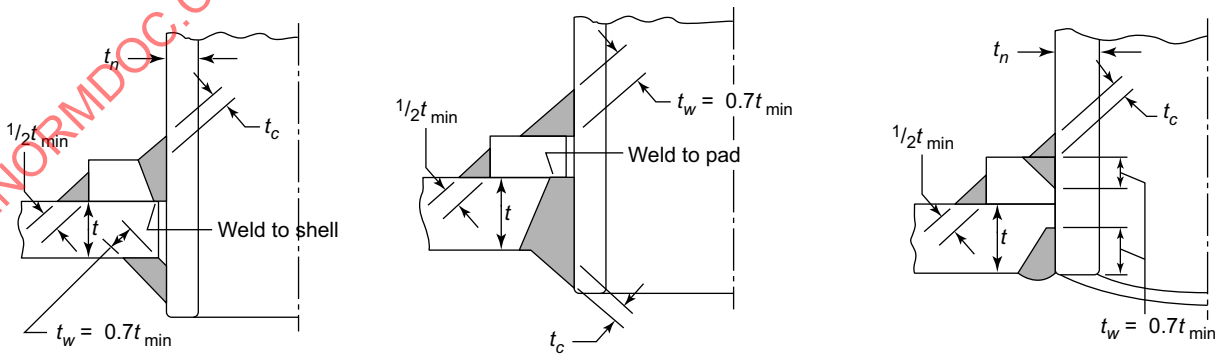
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Figure PW-16.1
(23) **Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Drums, and Headers**



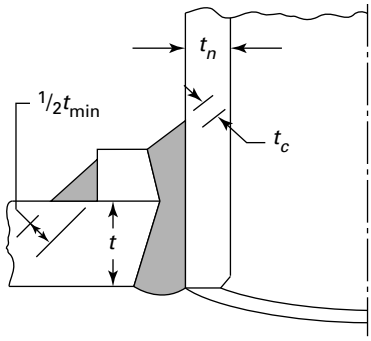
For illustrations (d) through (f):
$t_1 + t_2 \geq 1\,^1/_4 t_{min}$
t_1 and t_2 shall each be not less than the smaller of $^1/_4$ in. (6 mm) or $0.7t_{min}$



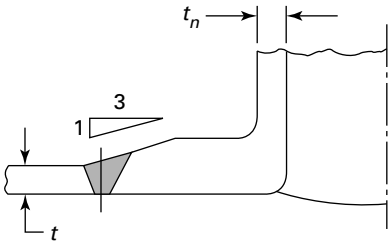


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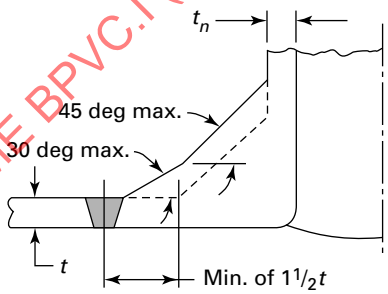
Figure PW-16.1
Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Drums, and Headers (Cont'd)



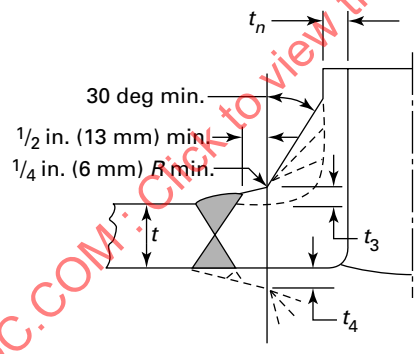
(o)



(q-1)

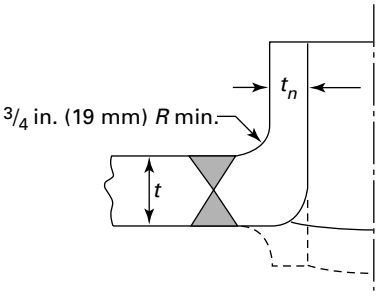


(q-2)



$t_1 + t_4 \leq 0.2t$ but not greater than $1/4$ in. (6 mm)

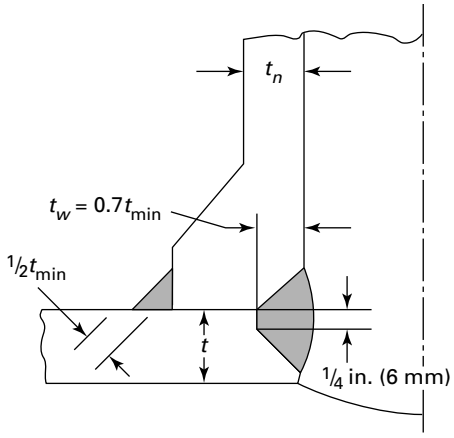
(q-3)



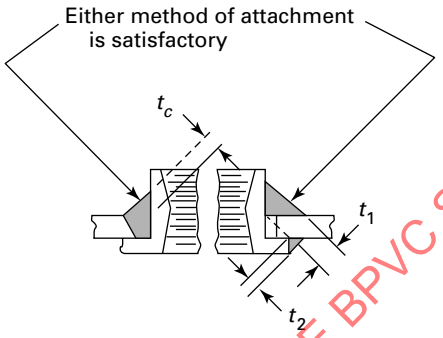
(q-4)

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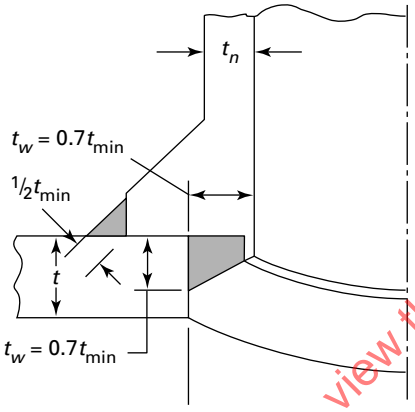
Figure PW-16.1
Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Drums, and Headers (Cont'd)



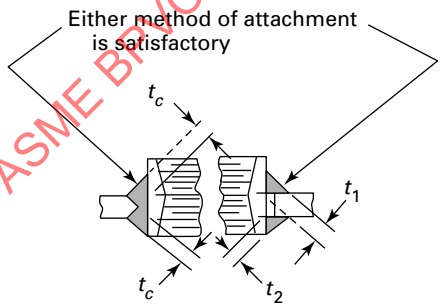
(r)



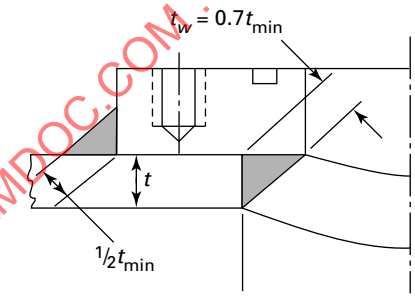
(u-1) (u-2)



(s)



(v-1) (v-2)



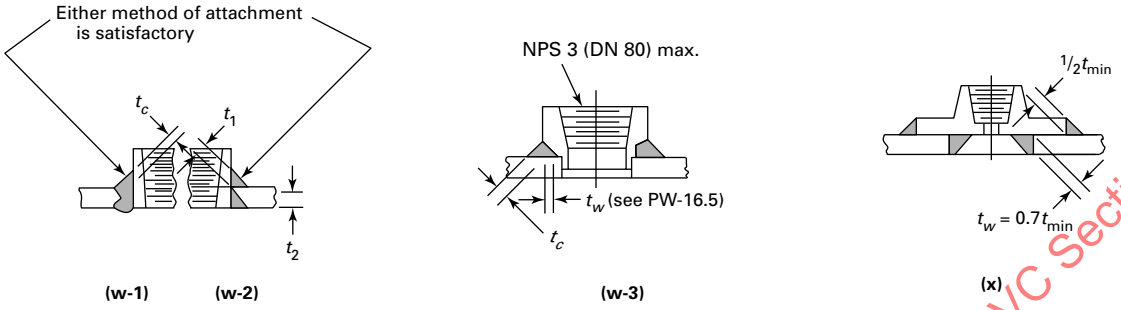
(t)

For illustrations (u) and (v):
$t_1 + t_2 \geq 1\,1/4t_{min}$
t_1 and t_2 shall each be not less than the smaller of $1/4$ in. (6 mm) or $0.7t_{min}$

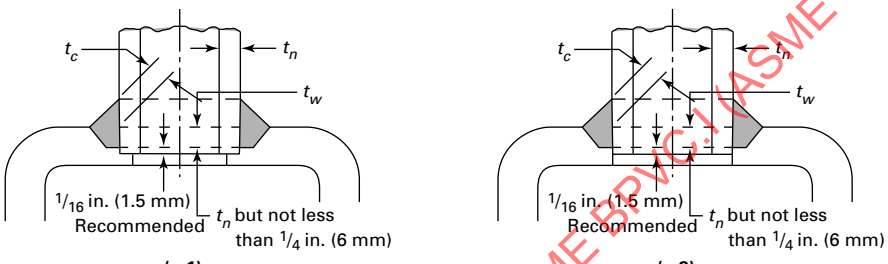
For illustrations (u-2) and (v-2):
For NPS 3 (DN 80) and smaller, see exemption in PW-16.4.

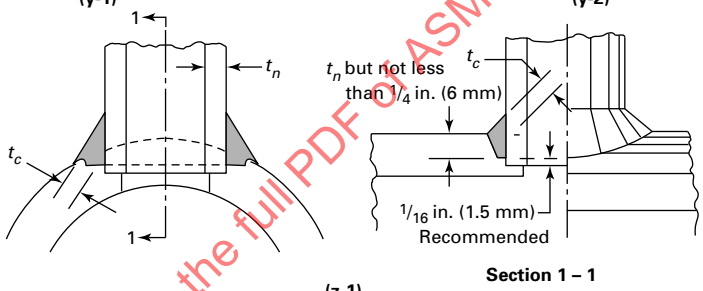
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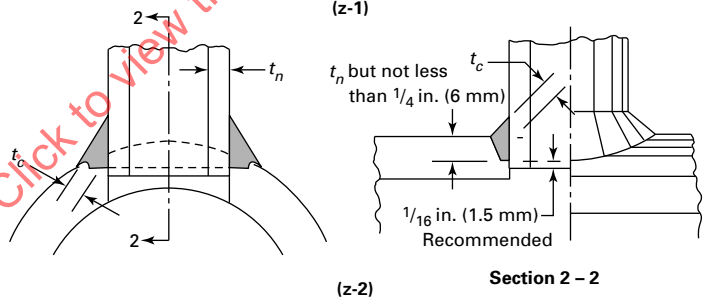
Figure PW-16.1
Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Drums, and Headers (Cont'd)



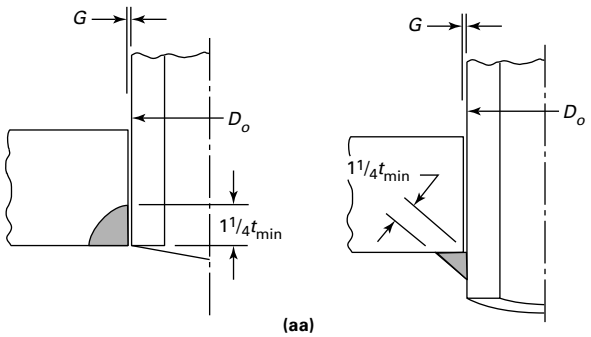
For illustrations (w-2) and (x):
For NPS 3 (DN 80) and smaller, see exemption in PW-16.4.





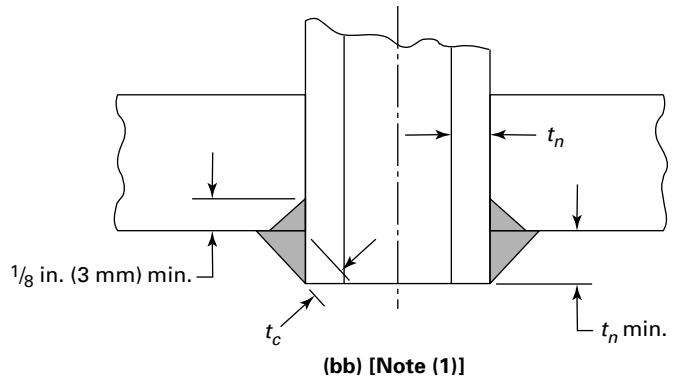


For illustration (aa):
(a) For applications where there are no external loads: $G = 1/8$ in. (3 mm) max.
(b) With external loads:
$G = 0.005$ for $D_o < 1$ in. (25 mm)
$G = 0.010$ for 1 in. $< D_o < 4$ in. (100 mm)
$G = 0.015$ for 4 in. $< D_o < 6\,5/8$ in. (170 mm)



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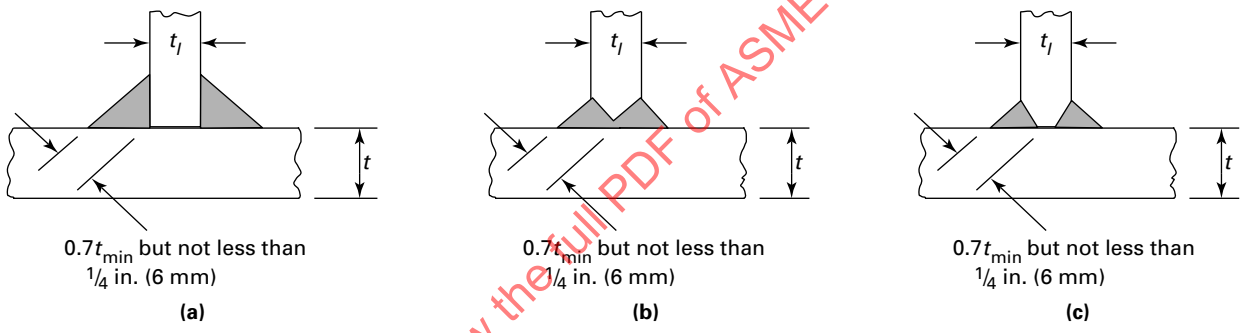
Figure PW-16.1
Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Drums, and Headers (Cont'd)



(bb) [Note (1)]

NOTE: (1) NPS 2 (DN 50) max., $t_n \le 1/4$ in. (6 mm)

Figure PW-16.2
Some Acceptable Forms of Welds for Lugs, Hangers, and Brackets on Shells, Drums, and Headers
(See PG-55)



PW-16.3 All welding shall be equivalent to that required under the rules within this Section. Volumetric examination of attachment welds may be omitted except as specifically required in other paragraphs of this Code, and except for inserted-type nozzles similar to those illustrated in Figure PW-16.1, illustrations (q-1) through (q-4).

PW-16.4 Fittings shown in Figure PW-16.1, illustrations (u-2), (v-2), (w-2), and (x) not exceeding NPS 3 (DN 80) may be attached by welds that are exempt from size requirements other than those specified in PW-15.1.

PW-16.5 Internally threaded fittings not exceeding NPS 3 (DN 80) may be attached by a fillet groove weld from the outside only as shown in Figure PW-16.1, illustration (w-3). The groove weld t_w shall be not less than the thickness of Schedule 160 pipe (ASME B36.10M). The external fillet weld throat shall be not less than t_c. For fittings smaller than NPS 1/2 (DN 15), use Schedule 160 from ASME B16.11, Table 8.

PW-16.6 Necks and Tubes Up to and Including NPS 6 (DN 150) Attached From One Side Only. Necks and tubes not exceeding NPS 6 (DN 150) may be attached by partial penetration or fillet welds from one side only on either the outside or inside of the vessel in accordance with the provisions given below

(a) When the neck or tube is attached from the outside only, a welding groove shall be cut into the surface to a depth of not less than t_n on the longitudinal axis of the opening. It is recommended that the neck or tube extend a minimum of 1/16 in. (1.5 mm) past the bottom of the weld groove to aid in centering the neck or tube. The dimension t_w of the attachment weld shall be not less than t_n and not less than 1/4 in. (6 mm). See Figure PW-16.1, illustrations (y-1), (y-2), (z-1), and (z-2).

(b) When the neck or tube is attached from the inside only, the depth of welding groove or throat of fillet weld shall be at least equal to $1\frac{1}{4}t_{min}$. Radial clearance between the vessel hole and nozzle outside diameter at the unwelded side shall not exceed tolerances given in

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Figure PW-16.1, illustration (aa). Such attachments shall satisfy the rules for reinforcement of opening except that no material in the nozzle neck shall be counted as reinforcement.

(c) Watertubes may be welded into a tubesheet or header in accordance with the following provisions, where t_w, t_c, and t_{min} are as defined in PW-16.2 and illustrated in Figure PW-16.1, illustration (bb):

(1) The size shall not exceed NPS 2 (DN 50).

(2) The thickness shall not exceed $^1/_4$ in. (6 mm).

(3) The groove depth t_w shall be not less than $^1/_8$ in. (3 mm) and t_c shall be not less than $^1/_4$ in. (6 mm) or $0.7t_{min}$, whichever is smaller.

(4) The tube shall be welded from the waterside of the boiler.

(5) The application shall be limited to 650°F (345°C) maximum.

PW-16.7 The minimum throat dimensions of fillet welds defined in PW-16.2 shall be maintained around the circumference of the attachment, except as provided below:

(a) For a radial nozzle attachment on a cylindrical shell (or header) as shown in Figure PW-16.1 where the nozzle meets the size limitations in PG-32.3.2, the fillet weld leg dimensions that meet the minimum throat dimensions shall be determined at the plane through the longitudinal axis of the cylindrical shell (other planes need not be considered), and these fillet weld leg dimensions shall be used around the circumference of the attachment.

(b) For a radial nozzle attachment on a cylindrical shell (or header) as shown in Figure PW-16.1, illustrations (a) through (c), (g), (h), and (o), where the nozzle exceeds the size limitations in PG-32.3.2, the fillet weld leg dimensions that meet the minimum throat dimensions shall be determined at the plane through the longitudinal axis of the cylindrical shell (other planes need not be considered), and these fillet weld leg dimensions shall be used around the circumference of the attachment.

(c) For a radial nozzle attachment on a cylindrical shell (or header) as shown in Figure PW-16.1, illustrations (a) through (c), (g), and (h), where the outside diameter of the nozzle is the same as the outside diameter of the cylindrical shell or when the outside diameter of the nozzle is too large to make a fillet weld, the fillet weld leg dimensions that meet the minimum throat dimensions shall be determined at the plane through the longitudinal axis of the cylindrical shell (other planes need not be considered), and these fillet weld leg dimensions shall be used around the circumference of the attachment to the maximum extent possible, and from that point, the fillet weld may be transitioned into a butt weld or full-penetration weld, developing the required strength.

PW-16.8 Partial-penetration-weld-type tube-to-header nozzles and other connections such as shown in Figure PW-16.1, illustrations (y-1) and (z-1), constructed with ferritic materials and designed for 900°F (480°C) or higher service, shall be designed to avoid an accumulation of oxide between the nozzle end and the seat. Designs that could satisfy this include, but are not limited to, a weld joint design establishing a $^1/_{16}$ in. (1.5 mm) minimum gap between the nozzle end and the seat, or a design that tapers either the nozzle end or seat such that any oxide formed between the tube and shell, drum, or header can spall from the gap, as shown in Figure PW-16.8.

PW-17 FORGED FLAT HEADS WITH INTEGRAL HUBBED FLANGE

The hub shall be integrally forged with the flat head by direct forging action, or machined from a forging. Plate, bar, or rod shall not be used in lieu of a forging. The hub shall have minimum dimensions in accordance with Figure PW-17-1. The hub shall have the minimum tensile strength and elongation specified for the material, measured in the direction parallel to the axis of the vessel. Proof of this shall be furnished by a tension test specimen (subsize if necessary) taken in this direction and as close to the hub as practical. One test specimen may represent a group of forgings that are of the same design, from the same heat of material, and forged in the same manner.

PW-19 WELDED-IN STAYS

Welded-in stays may be used in lieu of threading and shall meet the requirements of PW-19.1 through PW-19.8.

PW-19.1 The stays shall be inserted into countersunk holes through the sheet, except as provided in PW-19.4, and attached by full penetration welds. The area of the weld in shear measured parallel to that portion of the stay extending through the sheet shall be not less than 1.25 times the required cross-sectional area of the stay, but in no case shall the size of the weld be less than $^3/_8$ in. (10 mm).

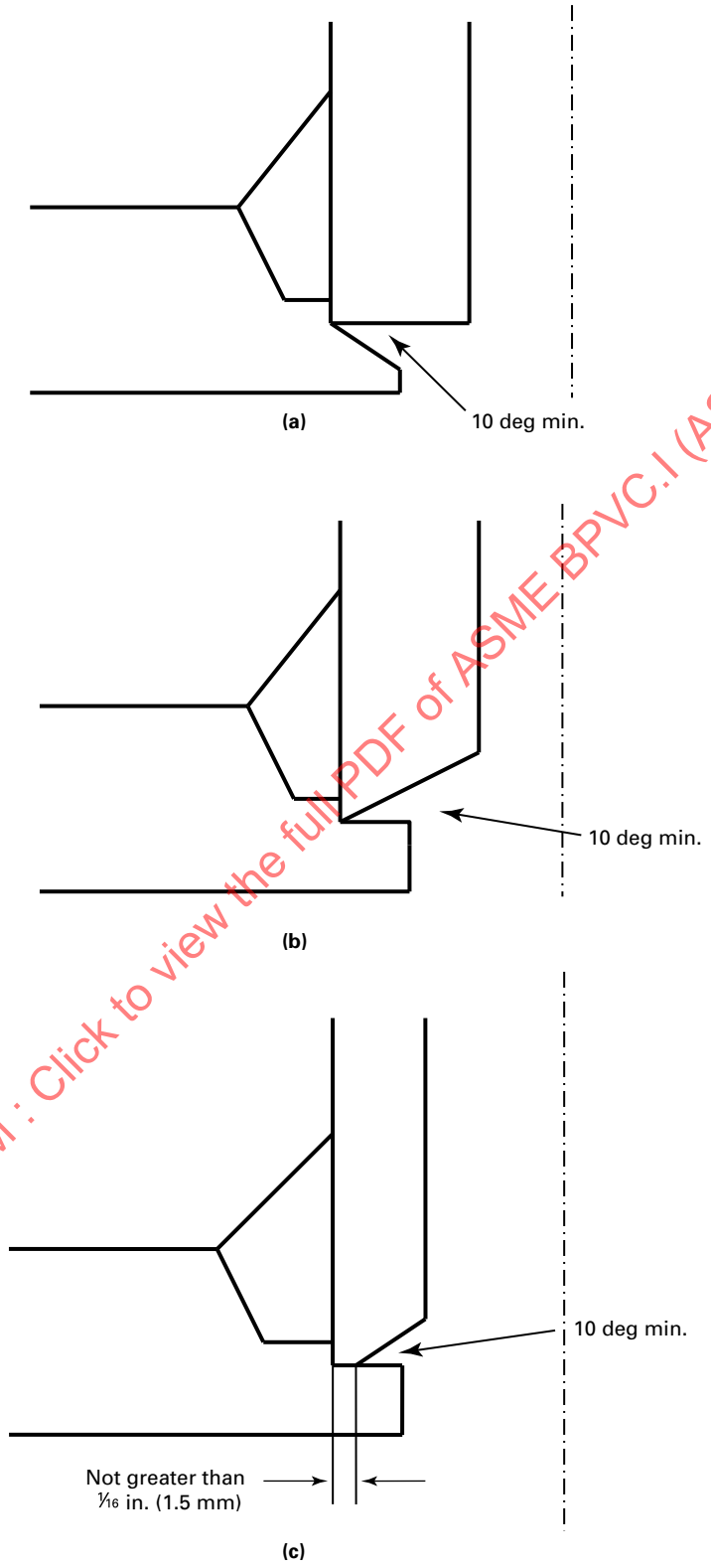
PW-19.2 The ends of the stays shall not be covered by weld metal and the face of the welds shall not be below the outside surface of the plates.

PW-19.3 The ends of stays inserted through the sheet shall not project more than $^3/_8$ in. (10 mm) beyond surfaces of the plate exposed to primary furnace gases.[23]

PW-19.4 Diagonal stays shall be attached to the inner surface of the shell, but not the head, by fillet welds only, as described in PW-19.4.1 and PW-19.4.3. [See Figures PW-19.4(a) and PW-19.4(b).]

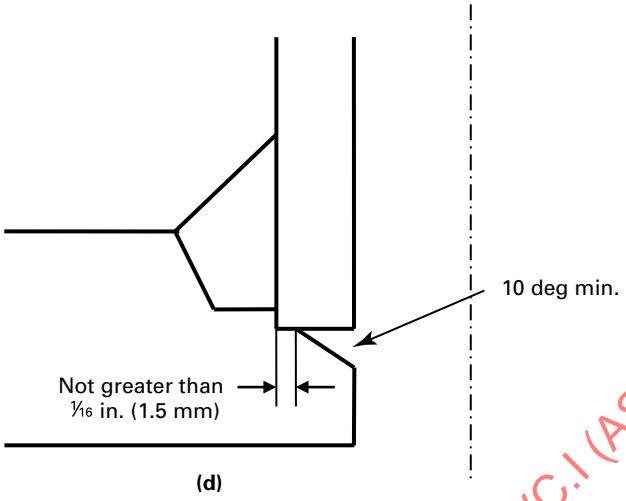
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Figure PW-16.8
Some Acceptable Designs for Partial-Penetration-Weld-Type Nozzles and Other Connections Designed for 900°F (480°C) or Higher Service

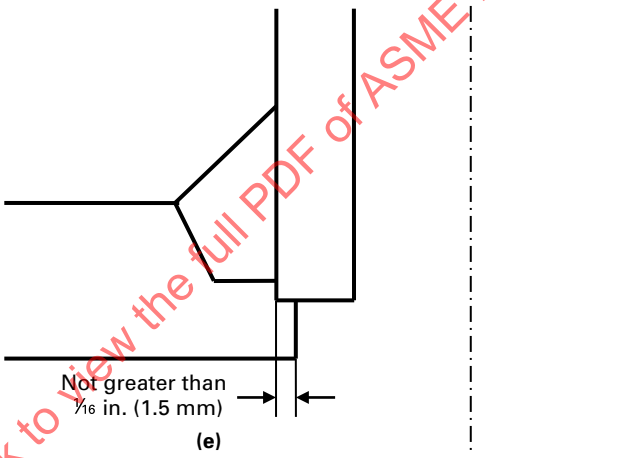


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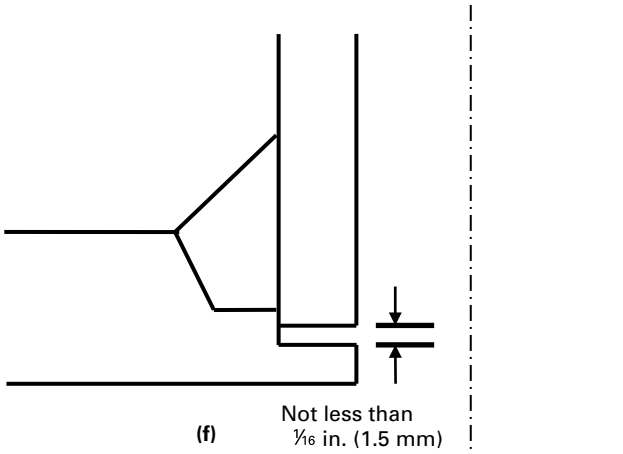
Figure PW-16.8
Some Acceptable Designs for Partial-Penetration-Weld-Type Nozzles and Other Connections Designed for 900°F (480°C) or Higher Service (Cont'd)



(d)



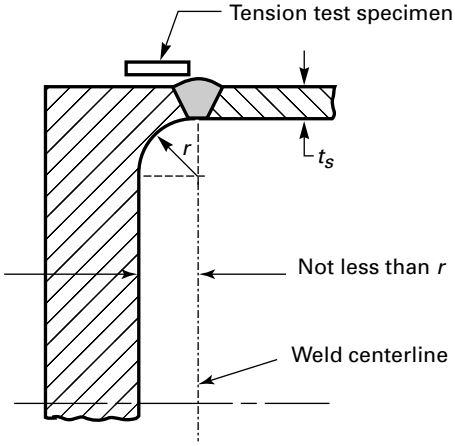
(e)



(f)

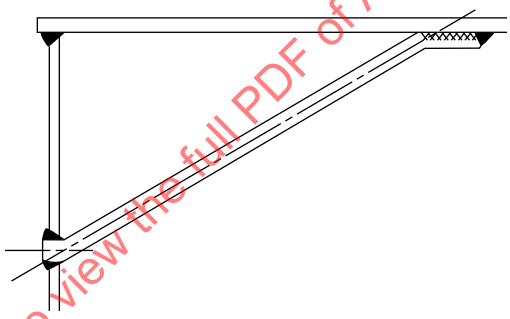
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Figure PW-17-1
Forged Flat Head With Integral Butt-Welded Hubbed Flange



GENERAL NOTES:
(a) Refer to Figure PG-31, illustration (a), (b-1), or (b-2) for dimensional requirements.
(b) Tension test specimen may be located on the inside or outside of the hub.

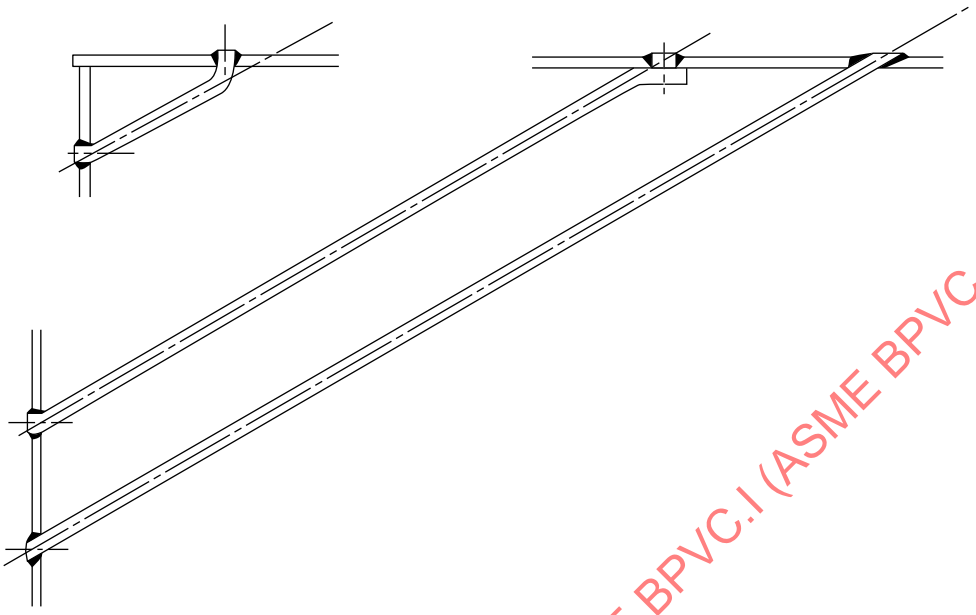
Figure PW-19.4(a)
Some Acceptable Types of Diagonal Braces for Installation by Welding



GENERAL NOTE: A round bar or a round bar with a forged palm.

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Figure PW-19.4(b)
Unacceptable Types of Diagonal Braces for Installation by Welding



PW-19.4.1 The fillet welds shall be not less than $^{3}/_{8}$ in. (10 mm) size and shall continue the full length of each side of the portion of the stay in contact with the shell. The product of the aggregate length of these fillet welds times their throat shall be not less than 1.25 times the required cross-sectional area of the stay. A fillet weld across the end of the stay is optional but shall not be credited in calculating the required area of fillet welds.

PW-19.4.3 The longitudinal center line of the stay, projected if necessary, shall intersect the inner surface of the plate to which the stay is attached within the outer boundaries of the attaching welds, also projected if necessary.

PW-19.5 The pitch of stays attached by welding to flat surfaces shall comply with the requirements of PFT-27.

PW-19.6 The welding shall be done in such a manner that excessive weld deposits do not project through the surface of the plate at the root of the weld.

PW-19.7 The welding shall be postweld heat treated in accordance with PW-39.

PW-19.8 Telltale holes are not required in staybolts attached by welding.

FABRICATION

PW-26 GENERAL (23)

The rules in the following paragraphs apply to the manufacture of boilers and boiler parts fabricated by welding. They shall be used with the fabrication requirements in Part PG and other Parts of this Section for the specific boiler types under consideration.

PW-27 WELDING PROCESSES (23)

The welding processes that may be used under this Part shall meet all the test requirements of Section IX and are restricted to PW-27.1 through PW-27.4.

PW-27.1 The following welding processes may be used for any Section I construction: shielded metal arc, submerged arc, gas metal arc, hybrid plasma-gas metal arc, flux cored arc, gas tungsten arc, plasma arc, atomic hydrogen arc, oxyhydrogen, oxyacetylene, laser beam, electron beam, flash, induction, pressure thermit, pressure gas, and inertia and continuous drive friction welding.

Resistance welding is permitted within the thickness and diameter limitations given in PG-9.5, except that circumferential butt welds and pressure-bearing attachment welds are not restricted. Resistance welding of nonpressure-bearing attachments is not restricted, except as provided in PW-27.2.

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PW-27.2 Arc stud welding and resistance stud welding may be used for nonpressure-bearing attachments having a load- or nonload-carrying function. Stud size shall be limited to 1 in. (25 mm) diameter maximum for round studs or an equivalent cross-sectional area for studs with other shapes. For load-carrying attachments, the requirements of PW-28.6 shall be met prior to the start of production welding, and the postweld heat treatment requirements of PW-39 shall also be complied with.

PW-27.3 The electroslag welding process may be used for butt welds only in austenitic stainless steels of types listed in PW-5.3 and ferritic steels. Electroslag welds in ferritic steels require special NDE [Table PW-11, General Notes (a) and (b)] and special heat treatment (PW-39.7).

PW-27.4 Capacitor discharge welding may be used for attaching bare wire thermocouples to pressure-containing parts within the limitations given in PW-39.8.

PW-27.5 Definitions are given in Section IX, which include variations of these processes.

PW-27.6 When welding UNS N06230 with filler metal of the same nominal composition as the base metal, only GMAW or GTAW processes are allowed.

(23) ## PW-28 WELDING QUALIFICATION AND WELD RECORDS

PW-28.1 Requirements for Qualification of Welding Procedures, Welders, and Welding Operators.

PW-28.1.1 Except as permitted in PW-28.1.2, the Welding Procedure Specifications, welders, and welding operators shall be qualified in accordance with Section IX.

PW-28.1.1.1 For welds joining two different P-No. materials, if the required transverse tension test fails in the weld metal and does not satisfy the criteria in Section IX, QW-153.1, an alternate test may be performed in accordance with the following requirements:

(a) The alternate welding procedure qualification tensile testing shall be performed at the lowest temperature at which the allowable stress values of either base metal is based on time dependent material properties, per Section II, Part D, Tables 1A and 1B, Notes T1 through T12, ±50°F (±28°C). In lieu of Section IX, QW-153, the tensile strength shall not be less than the value specified for the lower-strength base metal at the test temperature in Section II, Part D, Table U.

(b) The test temperature shall be documented on the WPS and the procedure qualification record (PQR).

(c) The design temperature shall be equal to or greater than the test temperature.

(d) The welding filler metal used in production is limited to the same classification or nominal manufacturing composition range used for the procedure qualification.

(e) During hydrostatic testing, the stress on the welded joint may not exceed 90% of the minimum specified yield strength of the filler metal specified in Section II, Part C. If the filler metal yield strength is not reported on the filler metal certified material test report (CMTR) or in the filler metal classification in Section II, Part C, the yield strength shall be determined using an all-weld-metal tension test specimen that has been removed from either the center of the weld metal of the procedure qualification test assembly or from a separate weld deposit buildup.

PW-28.1.2 For welding of nonpressure bearing attachments that have no load-carrying function (e.g., extended heat transfer surfaces, insulation support pins) to pressure parts, the following apply:

(a) Possession of a Certificate of Authorization by the organization performing such welding is neither required nor prohibited.

(b) Qualification of Welding Procedures and performance qualification is not required when the welding process is automatic.

(c) When the material used for the nonpressure part makes the mechanical test requirements for procedure qualification and performance qualifications impracticable (i.e., insufficient material ductility), a weld test coupon may be evaluated using the macro-examination method for both groove and fillet welds as follows:

(1) The test coupon may be of production configuration and shall be of sufficient length to contain a specimen for macro-examination.

(2) One face of the cross-section shall be smoothed and etched with a suitable etchant (see Section IX, QW-470) to give a clear definition to the weld metal and heat-affected zone.

(3) When heat treatment is a requirement of the WPS, it shall be considered a nonessential variable. All other Section IX variables remain.

(4) The weldable quality of the nonpressure part materials shall be verified by the macro-examination of a single cross-section of either the groove or fillet weld as in the production configuration.

(5) The groove weld may qualify a fillet weld.

(6) Macro-examination of the cross-sections of the weld metal and heat-affected zone of both the pressure part and nonpressure part material shall show complete fusion and freedom from cracks.

PW-28.1.3 Butt joints welded from one side (single-welded butt joints), including welds made to PW-41.2, where complete penetration at the root is required, shall conform to the following:

(a) Single-welded butt joint design shall be considered an essential variable.

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(b) No additional testing is required beyond that required by Section IX.

Welding procedures may be simultaneously qualified by more than one organization as permitted in Section IX, QG-106.4, provided that each organization accepts full responsibility for any such qualification and complies with other requirements of Section IX for documentation of welding records. The Manufacturer's or Assembler's written quality control program shall include requirements for addressing the requirements of Section IX, QG-106.4.

PW-28.2 Production welding shall not begin until the procedures, welders, and welding operators have been qualified. Performance qualification by volumetric NDE, in conformance with Section IX, QW-304 for welders or QW-305 for welding operators, may be performed. The weld used for the performance qualification shall be contained within the first 3 ft (1 m) of the first production weld.

PW-28.3 The Manufacturer shall maintain qualification records of the welding procedures, welders, and welding operators employed in accordance with Section IX. These records shall be controlled in accordance with the Manufacturer's Quality Control System and be accessible to the Authorized Inspector. Continuity records for welders and welding operators need not be retained for more than 5 yr.

PW-28.3.1 The Manufacturer shall establish a procedure, except as permitted in PW-28.3.2 and PW-28.3.3, that identifies the welders or welding operators who made each welded joint. One or more of the following methods acceptable to the Authorized Inspector may be used:

(a) The welders or welding operators may stamp their identification mark on or adjacent to all welded joints made by them, or adjacent to a continuous weld or a series of similar joints they made at intervals of not greater than 3 ft (1 m).

(b) In lieu of stamping, the Manufacturer may keep a record of welded joints and the welders or welding operators used in making the joints.

PW-28.3.2 When making multiple load-carrying or nonload-carrying structural attachment welds on pressure parts, the Manufacturer need not identify the welder or welding operator that welded each individual joint, provided

(a) The Manufacturer's Quality Control System includes a procedure whereby the identity of the welders or welding operators that made such welds on each pressure part will be maintained so that the Inspector can verify that the welders or welding operators were all properly qualified.

(b) the welds are all the same type and configuration and are welded with the same welding procedure specification.

PW-28.3.3 For pressure-retaining or load-bearing attachment welds, tack welds that become part of the final weld are not required to be traceable to a welder or welding operator. The Quality Control System of the Manufacturer shall include a procedure to permit the Inspector to verify that such tack welds were made by qualified welders or welding operators.

PW-28.4 Prior to the start of production welding, where stud welding is used to attach load-carrying studs, a production test weld of the procedure and welding operator shall be performed on a separate test plate or tube. This weld test shall consist of five studs, welded and subjected to either the bend or torque stud weld testing described in Section IX.

PW-28.5 If tube butt welds are made using the flash welding process, production testing shall be performed in accordance with Section IX, QW-199.1.3 as follows:

(a) one sample shall be tested at the start of production

(b) one sample shall be tested at the beginning, midpoint, and end of each work shift

(c) when production shifts are consecutive, a test at the end of the shift may serve as the test for the beginning of the next shift

(d) when a welding operator is replaced during production

(e) if any machine settings are changed

When any production run weld fails to pass the required tests, the following actions shall be taken:

(1) Welding parameters shall be adjusted until two consecutive welds pass the bend test.

(2) All welds that were made after the previous successful test shall be either

(-a) cut out and rewelded, or

(-b) cut out and tested in reverse sequence of welding until two successive welds pass the tests.

PW-29 BASE METAL PREPARATION

PW-29.1 The preparation of joints prior to welding may involve any of the conventional methods in use such as machining, thermal cutting, chipping, grinding, or combinations of these.

PW-29.2 Where thermal cutting is used, the effect on the mechanical and metallurgical properties of the base metal shall be taken into consideration.

PW-29.3 The method of base metal preparation used shall leave the welding groove with reasonably smooth surfaces and free from deep notches, striations, or irregularities. The surfaces for welding shall be free of all scale, rust, oil, grease, or other foreign materials.

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Table PW-33
Alignment Tolerance of Sections to Be Butt Welded

Section Thickness, in. (mm)	Direction of Joints in Cylindrical Shells	
	Longitudinal, in. (mm)	Circumferential, in. (mm)
Up to 1/2 (13), incl.	1/4t	1/4t
Over 1/2 (13) to 3/4 (19), incl.	1/8 (3.0)	1/4t
Over 3/4 (19) to 1 1/2 (38), incl.	1/8 (3.0)	3/16 (5)
Over 1 1/2 (38) to 2 (50), incl.	1/8 (3.0)	1/8t
Over 2 (50)	Lesser of 1/16t or 3/8 (10)	Lesser of 1/8t or 3/4 (19)

PW-29.4 Cast surfaces to be welded shall be machined, chipped, or ground where necessary to remove foundry scale and to expose sound metal.

PW-31 ASSEMBLY

PW-31.1 Parts that are being welded shall be fitted, aligned, and retained in position during the welding operation within the tolerance specified in PW-33.

PW-31.2 Bars, jacks, clamps, tack welds, or other appropriate means may be used to hold the edges of the parts to be welded in alignment.

PW-31.3 Tack welds used to secure alignment shall either be removed completely when they have served their purpose or their stopping and starting ends shall be properly prepared by grinding or other suitable means so that they may be satisfactorily incorporated into the final weld. Tack welds, whether removed or left in place, shall be made using a fillet weld or butt weld procedure qualified in accordance with Section IX. Tack welds to be left in place shall be made by welders qualified in accordance with Section IX and shall be examined visually for defects and, if found to be defective, shall be removed.

PW-31.4 When joining two parts by the inertia and continuous drive friction welding processes, one of the two parts must be held in a fixed position and the other part rotated. The two faces to be joined must be essentially symmetrical with respect to the axis of rotation. Some of the basic types of applicable joints are solid round-to-solid round, tube-to-tube, solid round-to-tube, solid round-to-plate, and tube-to-plate.

PW-33 ALIGNMENT TOLERANCE, SHELLS AND VESSELS (INCLUDING PIPE OR TUBE USED AS A SHELL)

PW-33.1 Alignment of sections at edges to be butt welded shall be such that the maximum offset is not greater than the applicable amount as listed in Table PW-33, where t is the nominal thickness of the thinner section at the joint.

PW-33.2 Joints in spherical vessels and within heads and joints between cylindrical shells and hemispherical heads shall meet the requirements in PW-33.1 above for longitudinal joints in cylindrical shells.

PW-33.3 Any offset within the allowable tolerance provided above shall be faired at a 3 to 1 taper over the width of the finished weld, or if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld.

PW-34 ALIGNMENT, TUBE AND PIPE

PW-34.1 When tubes or pipes are welded together, the alignment shall be such that the inside surfaces provide for complete weld penetration. The weld shall meet the reinforcement requirements of PW-35.

PW-35 FINISHED LONGITUDINAL AND CIRCUMFERENTIAL JOINTS (23)

PW-35.1 Butt welds shall have complete joint penetration. Weld metal may be added as reinforcement on each face of the weld to ensure that the weld grooves are completely filled and that the surface of the weld metal at any point is not below the surface of the adjoining base materials. The thickness of the weld reinforcement on each face shall not exceed the following:

Nominal Thickness, in. (mm)	Maximum Reinforcement, in. (mm)	
	Circumferential Joints in Pipe and Tubing	Other Welds
Up to 1/8 (3), incl.	3/32 (2.5)	3/32 (2.5)
Over 1/8 (3) to 3/16 (5), incl.	1/8 (3.0)	3/32 (2.5)
Over 3/16 (5) to 1/2 (13), incl.	5/32 (4.0)	3/32 (2.5)
Over 1/2 (13) to 1 (25), incl.	3/16 (5.0)	3/32 (2.5)
Over 1 (25) to 2 (50), incl.	1/4 (6.0)	1/8 (3.0)
Over 2 (50) to 3 (75), incl.	[Note (1)]	5/32 (4.0)
Over 3 (75) to 4 (100), incl.	[Note (1)]	7/32 (5.5)
Over 4 (100) to 5 (125), incl.	[Note (1)]	1/4 (6.0)
Over 5 (125)	[Note (1)]	5/16 (8.0)

NOTE: (1) The greater of 1/4 in. (6 mm) or 1/8 times the width of the weld in inches (mm).

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As-welded surfaces are permitted; however, the following apply:

(a) The surface of the welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to avoid stress raisers.

(b) Undercuts shall not exceed $^1/_{32}$ in. (0.8 mm) or 10% of the wall thickness, whichever is less, and shall not encroach on the required section thickness.

(c) The surfaces of the finished weld shall be suitable to permit proper interpretation of the nondestructive examinations.

If there is a question regarding the surface condition of the weld when interpreting a radiographic image, the radiographic image shall be compared to the actual weld surface for determination of acceptability.

PW-35.2 The weld reinforcement need not be removed except to the extent necessary to meet the thickness requirements in PW-35.1.

PW-35.3 Backing strips used at longitudinal welded joints shall be removed and the weld surface prepared for volumetric examination as required. Inside backing rings may remain at circumferential joints of cylinders, provided they meet the requirements of PW-41.

PW-35.4 The welded joint between two members joined by the inertia or continuous drive friction welding processes shall be full penetration weld. Visual examination of the as-welded flash roll of each weld shall be made as an in-process check. The weld upset shall meet the specified amount with ±10%. The flash shall be removed to sound metal.

PW-36 MISCELLANEOUS WELDING REQUIREMENTS

PW-36.1 Before applying weld metal on the second side to be welded, the root of double-welded butt joints shall be prepared by suitable methods such as chipping, grinding, or thermal gouging, so as to secure sound metal at the base of weld metal deposited on the face side, except for those processes of welding by which proper fusion and penetration are otherwise obtained and by which the root of the weld remains free from impurities.

PW-36.2 Fillet Welds. In making fillet welds, the weld metal shall be deposited in such a way as to secure adequate penetration into the base metal at the root of the weld. Undercuts on pressure-retaining boundaries shall not exceed the lesser of $^1/_{32}$ in. (0.8 mm) or 10% of the nominal thickness of the adjoining surface and shall not encroach upon the required section thickness. The surface of the welds shall be free from coarse ripples or grooves, and shall merge smoothly with the surfaces being joined. Concavity of the face of the weld is permissible, provided it does not encroach on the required weld thickness.

PW-36.3 When attachment welds are made to the clad portion of pressure parts constructed from P-No. 5B, P-No. 6, or P-No. 15E and other creep-strength-enhanced ferritic steels having weld metal buildup or corrosion-resistant weld metal overlay, the rules of PW-44.2(a) and PW-44.2(b) shall be followed.

PW-38 PREHEATING AND INTERPASS TEMPERATURES

PW-38.1 The Welding Procedure Specification for the material being welded shall specify the minimum preheating and maximum interpass requirements in accordance with the rules of this Section and Section IX.

The temperatures in Table PW-38-1 are recommended unless otherwise mandated by this Part.

For P-No. 1 materials, the rules for preheating only apply when mandated by PW-39 for exemption of postweld heat treatment.

PW-38.2 Preheat for welding or thermal cutting may be applied by any method that does not harm the base material or any weld metal already applied, or that does not introduce into the welding area foreign material that is harmful to the weld. If preheating is performed using electric resistance heating pads, it is recommended that it be performed in accordance with the requirements of Mandatory Appendix VIII, VIII-6.1 except that these requirements are mandatory for P-No.15E materials.

PW-38.3 No welding or thermal cutting operations shall be carried out on boiler components when the temperature of the base metal in the welding or cutting zone is below 50°F (10°C).

PW-38.4 The base metal temperature for the parts to be welded or thermally cut shall be at or above the minimum required temperature as specified in the Welding Procedure Specification.

For tubes and pipes with an outside diameter and wall thickness not exceeding 10 in. (250 mm) and 1 in. (25 mm) respectively, minimum preheat is to be established for a distance not less than 3 times the thickness of the weld on either side of the weld. For all other welds, preheat temperature is to be established in all directions from the point of welding for a distance of 3 in. (75 mm) or 1.5 times the larger thickness of the pressure parts being joined, whichever is greater. Shorter distances than these are acceptable if preheat temperature is achieved for the full depth of the weld. Recommended minimum temperatures are given in Table PW-38-1. Higher preheat temperatures shall be applied as required by Tables PW-39-1 through PW-39-14 when rules for exemption from postweld heat treatment are applied.

It is cautioned that the preheating temperatures listed in Table PW-38-1 do not necessarily ensure satisfactory completion of the welded joint. In order to produce a successful welded joint in certain individual materials

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Table PW-38-1
Recommended Preheat Temperatures for Welding of Pressure Parts and Attachments

Material [Note (1)]	Greater Material Thickness, in. (mm)	Additional Limits	Recommended Minimum Temperature, °F (°C) [Note (2)]
P-No. 1, Groups 1, 2, and 3	...	Refer to Table PW-39-1	...
P-No. 3, Groups 1, 2, and 3	≤5/8 (≤16)	None	50 (10)
		Specified minimum tensile strength is ≥70,000 psi (≥480 MPa)	200 (95)
	>5/8 (>16)	None	200 (95)
P-No. 4, Groups 1 and 2 [Note (3)]	All	None	250 (120)
P-No. 5A, Group 1 [Note (3)]	All	None	300 (150)
	All	Specified minimum tensile strength is >60,000 psi (>410 MPa)	400 (205)
P-No. 5B, Group 1	All	None	300 (150)
	All	Specified minimum tensile strength is ≥60,000 psi (≥410 MPa) or thickness is >1/2 in. (>13 mm) or % Cr > 6.0 [Note (4)]	400 (205)
P-No. 6, Groups 1, 2, and 3	All	None	400 (205)
P-No. 10A, Group 1	All	None	175 (80)
P-No 10I, Group 1	All	None	300 (150)
P-No. 15 E, Group 1	All	≤1/2 in. (≤13 mm)	300 (150)
	All	>1/2 in. (>13 mm)	400 (205)
All other materials, see [Note (5)]			

NOTES:
(1) P-No. and Group Number are in accordance with Section IX, Table QW/QB-422.
(2) For tubular butt welds made using machine or automatic weld processes, preheat may be considered as self-preheating when the weld is completed without interruption, subject to the following:
(a) Tube size is restricted to a wall thickness ≤1/4 in. (≤6 mm) and outside diameter ≤4 in. (≤100 mm).
(b) The entire weld and base metal heat-affected zone remains above the specified minimum preheat level throughout the weld cycle, with the exception of the first pass.

The use of a self-preheating technique shall be documented on the Welding Procedure Specification. The achievement of preheat temperature shall be verified once in the production environment where it is to be used.

(3) For P-Numbers 4 and 5A with a base material thickness ≤5/8 in. (≤16 mm) at the weld, except as required to meet PW-38.3, welds that are subject to a subsequent postweld heat treatment are not required to be preheated.
(4) Composition may be based on ladle or product analysis or per specification limits.
(5) For materials not covered by P-Numbers listed in this Table or are unassigned, the manufacturer should evaluate the need for preheat and specify the minimum temperature if required.

within a given P-Number listing, it may be necessary to preheat the materials to temperatures higher than indicated by these recommendations.

PW-38.5 For tack welds the base metal temperature shall be at or above the minimum temperature specified in the Welding Procedure Specification for a distance not less than 1 in. (25 mm) in all directions from the point of welding.

(23) **PW-38.6** When welding two different ferritic P-Number materials, the minimum preheat temperature shall be the higher temperature for the materials to be welded.

When different P-Number materials are joined by welding where one requires preheat above 50°F (10°C), and the other does not, the preheat need only be maintained on the side of the welded joint requiring the higher preheat. The thickness of the base metal shall not exceed 5/8 in. (16 mm) on either side of the weld.

PW-38.7 When heat is required to achieve the specified preheat temperature, the temperature shall be verified by use of temperature-indicating crayons, thermocouple pyrometers, or other suitable methods to ensure that the preheat temperature is obtained prior to and uniformly maintained during the welding operation.

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When thermocouples are used, they may be temporarily attached directly to pressure-containing parts using the low-energy capacitor discharge method of welding in accordance with the requirements of PW-39.8. Preheat is not required for attachment of thermocouples in accordance with this paragraph.

PW-38.8 Interruption of welding is permitted as follows:

(a) The minimum preheat temperature shall be maintained until welding is complete, except interruption of welding is permitted when the following conditions as appropriate are satisfied:

(1) A minimum of $^{3}/_{8}$ in. (10 mm) thickness of weld is deposited or 25% of the welding groove is filled, whichever is less. It is recommended that the surface of the welds prior to cooling should be free of sharp discontinuities.

(2) For P-No. 1, 3, 4, and 5A materials (with a chromium content of 3.0% maximum for P-No. 5A), the weld shall be cooled to room temperature.

(3) For P-No. 5B with a chromium content greater than 3.0%, P-No. 6, and P-No. 15E materials, the weld is subjected to an intermediate heat treatment to be determined by the manufacturer. The preheat temperature may be reduced to, but not below, 200°F (95°C) for the purpose of root examination without performing an intermediate heat treatment.

Intermediate heat treatment for P-No. 5B or 15E materials may be omitted entirely when using low-hydrogen electrodes and filler metals classified by the filler metal specification with supplemental diffusible-hydrogen designator of H4 or lower and suitably controlled by maintenance procedures to avoid contamination by hydrogen-producing sources.

(4) After cooling and before welding is resumed, visual examination of the weld shall be performed to assure that no cracks have formed.

(5) Preheat shall be reestablished before welding is resumed.

(b) Preheat may be interrupted between tack welding and its reestablishment as required for completion of welding of the joint.

PW-38.9 Except as detailed in the following or otherwise demonstrated by qualification of the Welding Procedure Specification in accordance with the rules of Section IX, interpass temperature shall be controlled to a maximum of 800°F (425°C).

For the following P-Numbers, the maximum interpass temperature shall be controlled as specified:

(a) P-No. 6: 600°F (315°C)
(b) P-No. 8: 350°F (175°C)
(c) P-No. 10H: 200°F (95°C)
(d) P-No. 10I: 450°F (230°C)
(e) P-No. 43: 300°F (150°C)
(f) P-No. 45: 300°F (150°C)

For welds between different P-Numbers where the required preheat temperature for one P-Number exceeds the allowable interpass temperature for the second P-Number to be welded, the allowable interpass temperature may be exceeded by a maximum of 150°F (85°C).

PW-39 REQUIREMENTS FOR POSTWELD HEAT TREATMENT

The rules in the following paragraphs apply specifically to the fabrication of the boiler proper and parts thereof and do not apply to the external piping as defined in the Preamble.

PW-39.1 Before applying the detailed requirements and exemptions in these paragraphs, satisfactory weld procedure qualifications of the procedures to be used shall be performed in accordance with all the essential variables of Section IX including conditions of postweld heat treatment or lack of postweld heat treatment and including other restrictions listed below. Except as otherwise specifically provided in PFT-29, PMB-9, PW-39.8, PW-40.2, PW-40.3, and in the notes within Tables PW-39-1 through PW-39-14, all welded pressure parts of power boilers shall be given a postweld heat treatment at a temperature not less than that specified in Tables PW-39-1 through PW-39-14 and Table PW-39.2. The materials in Tables PW-39-1 through PW-39-14 and Table PW-39.2 are listed in accordance with the materials P-Number grouping of Section IX, QW-420.

In Tables PW-39-1 through PW-39-14 and Table PW-39.2, where an upper limit for holding temperature is specified, and that limit is exceeded during postweld heat treatment, then one of the following shall occur:

(a)) For P-No. 15E material, the rules of Table PW-39-5 shall be followed.

(b) For P-No. 1 materials, if the upper critical temperature was not exceeded, and the part was slow cooled, then no further action is required.

(c) For all other P-Numbers, the Manufacturer shall determine if the lower critical temperature (LCT) was exceeded and shall take either of the following actions as necessary:

(1) If it is determined that the LCT was not exceeded, then the part may be accepted as-is with the agreement of the Inspector.

(2) If the LCT was exceeded, then one of the following shall be performed:

(-a) The affected material shall be removed and replaced with new material.

(-b) The affected material shall be removed and reheat-treated in accordance with the material specification and then reinstalled.

(-c) Provide a WPS qualified in accordance with Section IX for postweld heat treatment temperatures that exceed LCT.

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(23) **PW-39.2** When pressure parts of two different P-Number groups are joined by welding, the following applies:

(a) Postweld heat treatment for combinations of P-No. 1, 3, 4, 5A, 5B, 6, 7, 8, and 15E shall be within the temperature range specified in Table PW-39.2. The Notes in Tables PW-39-1 through PW-39-14 shall be applied for the material requiring the higher postweld heat treatment temperature except as noted in PW-39.2.1.

(b) For all other combinations, the postweld heat treatment shall be that specified in Tables PW-39-1 through PW-39-14 and applicable notes for the material requiring the higher postweld heat treatment temperature except as noted in PW-39.2.1.

When nonpressure parts are welded to pressure parts, the postweld heat treatment temperature of the pressure parts shall control.

When joining two different materials, the following shall apply:

(1) When only one of the materials is exempt from postweld heat treatment, postweld heat treatment shall be performed to the parameters of the nonexempt material.

(2) Postweld heat treatment may be omitted from the final weld when the part that is not exempt is buttered and heat treated in accordance with the rules of Section I.

(-a) The welding procedure specification shall be qualified in accordance with Section IX, QW-283 for welds with buttering.

(-b) The weld consumable used for the buttering and the final fill shall either

(-1) have a chemistry nominally matching the P-Number that is exempted from postweld heat treatment within the rules of Tables PW-39-1 through PW-39-14, or

(-2) be an austenitic or nickel-based weld consumable.

(3) Postweld heat treatment may be omitted when both materials meet the exemption requirements in Tables PW-39-1 through PW-39-14.

Pressure part welds and attachment welds using ferritic filler metals that have a specified chromium content of more than 3% shall receive a postweld heat treatment. The postweld heat treatment time and temperature used shall be not less than that shown in Tables PW-39-1 through PW-39-14 and Table PW-39.2 for a base metal or equivalent analysis.

PW-39.2.1 Fillet welds, partial penetration welds, and full penetration welds through the tube or pipe thickness, attaching P-No. 4 or P-No. 5A tubes and pipe to headers of lower P-Number material, may be postweld heat treated at the temperature specified in Tables PW-39-1 through PW-39-3 for the lower P-Number material provided the tubes or pipe comply with all the following conditions:

(a) a maximum specified chromium content of 3.0%

(b) a maximum size of NPS 4 (DN 100)

(c) a maximum thickness of ½ in. (13 mm)

(d) a maximum specified carbon content of not more than 0.15%

The exceptions to postweld heat treatment described in the General Notes of the lower P-Number tables do not apply.

PW-39.3 In the procedures that follow, the volume of metal required to be heated, to meet or exceed the minimum postweld heat treatment temperatures listed in Tables PW-39-1 through PW-39-14 and Table PW-39.2, is defined as the soak band. As a minimum, the soak band shall contain the weld and a portion of the base metal on each side of the weld being heat treated, including the weld heat-affected zones. The width of each portion of base metal to be included in the soak band shall be equal to the lesser of the vessel or shell thickness, or 2 in. (50 mm). A greater amount of base material, on either or both sides of the weld, may also be heated to permit temperature gradient control.

The weldment shall be heated slowly to the temperature specified in Tables PW-39-1 through PW-39-14 and Table PW-39.2 and held for the specified time, and shall be allowed to cool slowly in a still atmosphere to a temperature not exceeding 800°F (425°C). Suggested heating and cooling rates for postweld heat treatment are shown in A-101. The heating and cooling rates for postweld heat treatment described in A-101 are provided as a general guide; the requirements for individual materials within the P-Number listing may have rates more or less restrictive than this general guide. Several weldments of varied thickness may be postweld heat treated in the same furnace at the same time.

If heating of P-No. 15E materials is performed using electric resistance heating pads, it shall be performed in accordance with the requirements of Mandatory Appendix VIII. While not mandatory for other materials, the Appendix may be used as a guide for the heat treatment of those other materials.

The term "nominal thickness" as used in Tables PW-39-1 through PW-39-14 is defined as follows:

(a) For full penetration butt welds, the nominal thickness is the thinner of the parts being joined.

(b) For full penetration corner welds, the nominal thickness is the depth of the weld.

(c) For partial penetration groove and material repair welds, the nominal thickness is the depth of the weld. The total depth of partial or full penetration groove welds made from both sides shall be taken as the sum of the depth of both sides at a given location.

(d) For fillet welds, the nominal thickness is the weld throat. When a fillet weld is used in conjunction with a groove weld, the nominal thickness is either the depth of the groove weld or the fillet throat dimension, whichever is greater.

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Table PW-39-1
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 1 (23)

Material	Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 1 Group No. 1, 2, 3	1,100–1,300 (595–705)	1 hr/in. (1 h/25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

GENERAL NOTES:

(a) Postweld heat treatment is not mandatory for P-No. 1 Group 1 materials under the following conditions:

(1) when the nominal thickness as defined in PW-39.3 is 1 in. (25 mm) or less.

(2) when the nominal thickness as defined in PW-39.3 exceeds 1 in. (25 mm), postweld heat treatment is not required when the calculated carbon equivalent, CE, of each base metal in the weld joint is less than or equal to 0.45 using the following formula, and a minimum preheat of 200°F (95°C) is applied.

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

NOTE: The maximum chemical composition limit from the material specification or the actual values from a chemical analysis or material test report shall be used in computing the CE. If the chemistry values required for the last two terms are not available, 0.15% shall be substituted for those two terms as follows:

$$CE = C + \frac{Mn}{6} + 0.15$$

(3) electroslag welds shall follow the postweld heat treatment requirements in PW-27.3 and PW-39.7.

(4) for stays welded in accordance with PW-19, the diameter of the stay is not used to determine the preheat requirement.

(b) Postweld heat treatment is not mandatory for P-No. 1 Groups 2 and 3 materials under the following conditions:

(1) when the nominal thickness of a weld as defined in PW-39.3 is ¾ in. (19 mm) or less.

(2) when the nominal thickness of the weld as defined in PW-39.3 exceeds ¾ in. (19 mm) but does not exceed 1 in. (25 mm) and the calculated CE of each of the base metals in the weld joint is less than or equal to 0.45 using the formula in General Note (a)(2).

(3) For stays welded in accordance with PW-19, the diameter of the stay is not used to determine preheat requirements.

(4) when the nominal thickness of a weld as defined in PW-39.3 is greater than 1 in. (25 mm) but does not exceed 1½ in. (38 mm), and:

(a) the calculated carbon equivalent, CE, of each of the base metals in the weld joint is less than or equal to 0.45, using the formula in General Note (a)(2)

(b) a minimum preheat of 250°F (120°C) is applied

(c) no individual weld pass thickness exceeds ¼ in. (6 mm)

(5) for welds used to attach extended heat-absorbing surface to tubes and insulation attachment pins to pressure parts

(6) for studs welded to pressure parts, provided preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of the pressure part exceeds 1 in. (25 mm)

(c) Postweld heat treatment is not mandatory for P-No. 1 Groups 1, 2, or 3 under the following conditions:

(1) for corrosion-resistant weld metal overlay cladding of pipe or tube materials, provided that all of the following conditions are met:

(a) the thickness of the overlay cladding is ¼ in. (6 mm) or less

(b) preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of the pressure part exceeds ¾ in. (19 mm)

(c) the pipe or tube material

(-1) does not exceed NPS 5 (DN 125) outside diameter

(-2) is not used as a drum or shell

(2) for welds attaching nonload-carrying studs not exceeding ½ in. (13 mm) in diameter when using an automatic arc stud welding or automatic resistance stud welding process

(3) for attaching bare wire thermocouples by capacitor discharge welding or electric resistance welding, provided the following requirements are met:

(a) the requirements of PW-39.8

(b) the minimum wall thickness shall be 0.200 in. (5.0 mm) or greater

(4) electroslag welds shall follow the postweld heat treatment requirements of PW-27.3 and PW-39.7

(d) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table PW-39.1.

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Table PW-39-2
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 3

Material	Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 3 Group No. 1, 2, 3	1,100–1,300 (595–705)	1 hr/in. (1 h/25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

GENERAL NOTES:

(a) Except for P-No. 3 Group No. 3, postweld heat treatment of P-No. 3 materials is not mandatory under the following conditions (postweld heat treatment is mandatory for P-No. 3 Group No. 3 materials for all thicknesses):

(1) for circumferential butt welds in pressure parts with both a nominal wall thickness of $\frac{5}{8}$ in. (16 mm) or less, and a specified maximum carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.25%

(2) for fillet welds used on socket welding fittings conforming to the rules of PW-41, when the following conditions are met:

(a) a fillet weld throat thickness of $\frac{1}{2}$ in. (13 mm) or less, regardless of base metal thickness

(b) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.25%

(c) a minimum preheat of 200°F (95°C) when the thickness of a pressure part at the weld exceeds $\frac{5}{8}$ in. (16 mm)

(3) for fillet welds with a throat thickness of $\frac{1}{2}$ in. (13 mm) or less and combination groove and fillet welds with a weld thickness of $\frac{1}{2}$ in. (13 mm) or less attaching nonpressure parts to pressure parts that have a specified maximum carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.25% provided preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of the pressure part at the weld exceeds $\frac{5}{8}$ in. (16 mm)

(4) for welds used to attach extended heat-absorbing surface to tubes and insulation attachment pins to pressure parts

(5) for tubes or pressure-retaining handhole and inspection plugs or fittings that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of $\frac{3}{8}$ in. (10 mm) or less, and preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of either part exceeds $\frac{5}{8}$ in. (16 mm)

(6) postweld heat treatment is not mandatory for studs welded to pressure parts for purposes not included in (4) above and which have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by Purchaser to a value within the specification limits), provided a preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of the pressure part exceeds $\frac{5}{8}$ in. (16 mm)

(7) for fillet welds attaching connections to a vessel, provided that all of the following conditions are met:

(a) the diameter of the finished opening (diameter d in Figures PG-33.1, PG-33.2, and PW-15) does not exceed that allowed in PG-32.1.2 or 2 in. (50 mm), whichever is less

(b) the throat thickness does not exceed $\frac{3}{8}$ in. (10 mm)

(c) preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of either part exceeds $\frac{5}{8}$ in. (16 mm)

(d) the connections are not placed in the vessel such as to form ligaments, the efficiency of which would affect the vessel thickness

(e) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.25%

(8) for corrosion-resistant weld metal overlay cladding of pipe or tube materials, provided that all of the following conditions are met:

(a) the thickness of the overlay cladding is $\frac{1}{4}$ in. (6 mm) or less

(b) preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of the pressure part exceeds $\frac{5}{8}$ in. (16 mm)

(c) the pipe or tube material

(-1) does not exceed NPS 5 (DN 125) outside diameter

(-2) is not used as a drum or shell

(9) for welds attaching nonload-carrying studs not exceeding $\frac{1}{2}$ in. (13 mm) in diameter when using an automatic arc stud welding or automatic resistance stud welding process

(10) for attaching bare wire thermocouples by capacitor discharge welding or electric resistance welding, provided the following requirements are met:

(a) the requirements of PW-39.8

(b) the minimum wall thickness shall be 0.200 in. (5.0 mm) or greater

(b) When it is impractical to postweld heat treat at the temperature specified in this table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table PW-39.1.

(c) General Note (a) does not apply to welds using the inertia and continuous drive friction welding processes. Postweld heat treatment is mandatory for all thicknesses of materials welded using inertia and continuous drive friction welding.

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Table PW-39-3
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 4

Material	Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 4 Group No. 1, 2	1,200–1,350 (650–730)	1 hr/in. (1 h/25 mm), 15 min minimum	1 hr/in. (1 h/25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

GENERAL NOTES:

(a) Postweld heat treatment is not mandatory for P-No. 4 materials under the following conditions:

(1) for circumferential butt welds in pressure parts with all the following conditions:

(a) a nominal base metal thickness of $^{5}/_{8}$ in. (16 mm) or less at the weld

(b) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%

(c) a minimum preheat of 250°F (120°C). This minimum preheat is not required for SA-213 Grade T11 tube materials with a maximum outside diameter of 1.5 in. (38 mm) and a maximum thickness of 0.165 in. (4.2 mm) when buttwelded using a multipass GTAW process

(2) for fillet welds used on socket welding fittings conforming to the rules of PW-41, when the following conditions are met:

(a) a fillet weld throat thickness of $^{1}/_{2}$ in. (13 mm) or less, regardless of base metal thickness

(b) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%

(c) a minimum preheat of 250°F (120°C)

(3) for pipe and tube materials meeting the requirements of (1)(a) and (1)(b) above and having fillet welds attaching nonpressure parts to them, provided the fillet weld has a throat thickness of $^{1}/_{2}$ in. (13 mm) or less and the material is preheated to 250°F (120°C) minimum; or combination groove and fillet welds attaching nonpressure parts to pressure parts, with a weld thickness of $^{1}/_{2}$ in. (13 mm) or less, provided the material is preheated to a minimum of 250°F (120°C); or heat-absorbing surfaces and non-load-carrying studs attached to them, provided the material is preheated to 250°F (120°C) minimum. A lower preheating temperature may be used, provided specifically controlled procedures necessary to produce sound joints are used. Such procedures shall include but shall not be limited to the following:

(a) the throat thickness of fillet welds shall be $^{1}/_{2}$ in. (13 mm) or less

(b) the maximum continuous length of fillet welds shall be not over 4 in. (100 mm)

(c) electrodes or filler metal shall be dry and shall provide a low-hydrogen weld deposit. Chromium-molybdenum filler metals shall have a maximum specified chromium content of not more than 2.50% and a maximum specified carbon content of not more than 0.05%

(d) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded

(4) for tubes or pressure-retaining handhole and inspection plugs or fittings that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of $^{3}/_{8}$ in. (10 mm) or less, and preheat to a minimum temperature of 250°F (120°C) is applied when the thickness of either part exceeds $^{5}/_{8}$ in. (16 mm)

(5) for corrosion-resistant weld metal overlay cladding of pipe or tube materials, provided that all of the following conditions are met:

(a) the thickness of the overlay cladding is $^{1}/_{4}$ in. (6 mm) or less

(b) preheat to a minimum temperature of 250°F (120°C) is applied when the thickness of the pressure part exceeds $^{1}/_{2}$ in. (13 mm)

(c) the pipe or tube material

(-1) does not exceed NPS 5 (DN 125) outside diameter

(-2) is not used as a drum or shell

(6) for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:

(a) a maximum pipe or tube size of NPS 4 (DN 100)

(b) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within specification limits) of not more than 0.15%.

(c) a maximum fin thickness of $^{1}/_{8}$ in. (3 mm)

(d) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat-affected zone does not encroach upon the required minimum wall thickness

(7) for welds attaching nonload-carrying studs or insulation attachment pins not exceeding $^{1}/_{2}$ in. (13 mm) in diameter when using an automatic arc stud welding or automatic resistance stud welding process

(8) postweld heat treatment is not mandatory for attaching bare wire thermocouples by capacitor discharge welding or electric resistance welding, provided the following requirements are met:

(a) The requirements of PW-39.8.

(b) The maximum carbon content of the base material is restricted to 0.15%.

(c) The minimum wall thickness shall be 0.20 in. (5.0 mm) or greater.

(b) General Note (a) does not apply to welds using the inertia and continuous drive friction welding processes. Postweld heat treatment is mandatory for all thicknesses of materials welded using inertia and continuous drive friction welding.

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Table PW-39-4

(23) **Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 5A and P-No. 5B**

Material	Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 5A Group No. 1 and P-No. 5B Group No. 1	1,250–1,425 (675–775)	1 hr/in. (1 h/25 mm), 15 min minimum	1 hr/in. (1 h/25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

GENERAL NOTES:

(a) Postweld heat treatment is not mandatory under the following conditions:

(1) for circumferential butt welds in pressure parts with all of the following conditions:

(a) a maximum specified chromium content of 3.0%

(b) a nominal base metal thickness of $\frac{5}{8}$ in. (16 mm) or less at the weld

(c) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%

(d) a minimum preheat of 300°F (150°C)

(2) for fillet welds used on socket welding fittings conforming to the rules of PW-41, when the following conditions are met:

(a) a maximum specified chromium content of 3.0%

(b) a fillet weld throat thickness of $\frac{1}{2}$ in. (13 mm) or less, regardless of base metal thickness

(c) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%

(d) a minimum preheat of 300°F (150°C)

(3) for pipe and tube materials meeting the requirements of (1)(a) through (1)(c) above having fillet welds attaching nonpressure parts to them, provided the fillet weld has a throat thickness of $\frac{1}{2}$ in. (13 mm) or less and the material is preheated to 300°F (150°C) minimum; or combination groove and fillet welds attaching nonpressure parts to pressure parts with a weld thickness of $\frac{1}{2}$ in. (13 mm) or less, and the material is preheated to a minimum of 300°F (150°C); or heat-absorbing surfaces and non-load-carrying studs attached to them, provided the material is preheated to 300°F (150°C) minimum. A lower preheating temperature may be used, provided specifically controlled procedures necessary to produce sound joints are used. Such procedures shall include but shall not be limited to the following:

(a) the maximum throat thickness of fillet welds shall be $\frac{1}{2}$ in. (13 mm)

(b) the maximum continuous length of fillet welds shall be not over 4 in. (100 mm)

(c) electrodes or filler metal shall be dry and shall provide a low-hydrogen weld deposit. Chromium-molybdenum filler metals shall have a maximum specified chromium content of not more than 2.50% and a maximum specified carbon content of not more than 0.05%

(d) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded

(4) for tubes or pressure-retaining handhole and inspection plugs or fittings with a specified maximum chromium content of 6% that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of $\frac{3}{8}$ in. (10 mm) or less, and preheat to a minimum temperature of 300°F (150°C) is applied when the thickness of either part exceeds $\frac{5}{8}$ in. (16 mm)

(5) for welds attaching nonload-carrying studs or insulation attachment pins not exceeding $\frac{1}{2}$ in. (13 mm) in diameter when using an automatic arc stud welding or automatic resistance stud welding process

(6) for corrosion-resistant weld metal overlay of P-No. 5A pipe or tube, provided the following conditions are met:

(a) a minimum preheat of 300°F (150°C) is applied when the thickness exceeds $\frac{1}{2}$ in. (13 mm)

(b) overlay is applied using GTAW or GMAW with a 360 deg spiral deposition technique

(c) overlay cladding thickness does not exceed $\frac{1}{8}$ in. (3 mm)

(d) the tube or pipe material

(1) does not exceed NPS 5 (DN 125) outside diameter

(2) is not used as a drum or shell

(b) Postweld heat treatment is not mandatory for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:

(1) a maximum pipe or tube size of NPS 4 (DN 100)

(2) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%

(3) a maximum fin thickness of $\frac{1}{8}$ in. (3 mm)

(4) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat-affected zone does not encroach upon the required minimum wall thickness

(c) General Note (a) does not apply to welds using the inertia and continuous drive friction welding processes. Postweld heat treatment is mandatory for all thicknesses of materials welded using inertia and continuous drive friction welding.

(d) Postweld heat treatment is not mandatory for attaching bare wire thermocouples by capacitor discharge welding or electric resistance welding provided the following requirements are met:

(1) The requirements of PW-39.8.

(2) The maximum carbon content of the base material is restricted to 0.15%.

(3) The minimum wall thickness shall be 0.20 in. (5.0 mm).

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Table PW-39-5
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 15E (23)

Material	Holding Temperature, °F (°C) [Notes (1)-(4)]	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)	
		Up to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 15E Group No. 1	1,300–1,445 (705–785)	1 hr/in. (1 h/25 mm), 30 min minimum	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

GENERAL NOTES:

(a) Postweld heat treatment is not mandatory for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:

(1) a maximum pipe or tube size of NPS 4 (DN 100)

(2) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%

(3) a maximum fin thickness of $\frac{1}{8}$ in. (3 mm)

(4) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat-affected zone does not encroach upon the required minimum wall thickness

(b) Postweld heat treatment is not mandatory for attaching bare wire thermocouples by capacitor discharge welding or electric resistance welding, provided the following requirements are met:

(1) The requirements of PW-39.8.

(2) The maximum carbon content of the base material is restricted to 0.15%.

(3) The minimum wall thickness shall be 0.20 in. (5.0 mm)

NOTES:

(1) If the nominal weld thickness is ≤0.5 in. (13 mm), the minimum holding temperature is 1,250°F (675°C).

(2) For welds made with nickel-based filler metals, or with Grade 91 filler metal (e.g., AWS B9 or B91, ISO CrMo91, etc.) that has Ni + Mn content less than or equal to 1.0%, the maximum holding temperature can be increased to 1,470°F (800°C). However, if the PWHT encompasses multiple welds and any one of those welds was made with Grade 91 filler metal that has a Ni + Mn content greater than 1.0%, but not greater than 1.2%, or if the Ni + Mn content of the filler metal is unknown, the maximum PWHT temperature shall be 1,445°F (785°C). *Explanatory Note to (2) Above:* The lower transformation temperature for matching filler material is affected by alloy content, primarily the total of Ni + Mn. The maximum holding temperature has been set to avoid heat treatment in the intercritical zone.

(3) If a portion of the component is heated above the heat treatment temperature allowed above, one of the following actions shall be performed:

(a) The component in its entirety must be renormalized and tempered.

(b) If the maximum holding temperature in the table or [Note (2)] above is exceeded, but does not exceed 1,470°F (800°C), the weld metal shall be removed and replaced.

(c) The portion of the component heated above 1,470°F (800°C) and at least 3 in. (75 mm) on either side of the overheated zone must be removed and be renormalized and tempered or replaced.

(d) The allowable stress shall be that for Grade 9 material (i.e., SA-213-T9, SA-335-P9, or equivalent product specification) at the design temperature, provided that the portion of the component that was heated to a temperature exceeding the maximum holding temperature is subjected to a final heat treatment within the temperature range and for the time required above. In order to apply the provisions of this paragraph, the Manufacturer must have qualified a WPS with representative test specimens that accurately simulate the thermal history of the production part. Specifically, the qualification specimens first must be heat treated at a similar temperature for a similar time that violated the maximum holding temperature limit and then must receive a final heat treatment for the required time within the temperature range specified by this table. The use of this provision shall be noted in the Manufacturer's Data Report in accordance with PG-5.6.1(c)(1).

(4) For welds made with weld consumables of nominally matching chemistry to the base metal (e.g., AWS B9, B91, B92, ISO CrMo91), after the completion of welding and prior to any postweld heat treatment the weld metal shall be cooled to below 400°F (205°C). Measurement and documentation of temperature are required during this cooling step.

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Table PW-39-6
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 6

Material	Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 6 Group No. 1, 2, 3	1,400–1,475 (760–800)	1 hr/in. (1 h/25 mm), 15 min minimum	1 hr/in. (1 h/25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

GENERAL NOTES:
(a) Postweld heat treatment is not mandatory for P-No. 6 materials under the following conditions:
(1) for Type 410 material where the material and construction shall comply with the following conditions:
(a) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.08%
(b) the electrodes used shall produce an austenitic chromium-nickel weld deposit, or a non-air-hardening nickel-chromium-iron weld deposit, and provided the following additional requirements are met:
(-1) the material thickness at the welded joint does not exceed $\frac{3}{8}$ in. (10 mm)
(-2) or material thickness over $\frac{3}{8}$ in. (10 mm) through $1\frac{1}{2}$ in. (38 mm), the following additional conditions shall be required:
(2) for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:
(a) a maximum pipe or tube size of NPS 4 (DN 100)
(b) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within specification limits) of not more than 0.15%
(c) a maximum fin thickness of $\frac{1}{8}$ in. (3 mm)
(d) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat-affected zone does not encroach upon the required minimum wall thickness
(b) General [Note (a)] does not apply to welds using the inertia and continuous drive friction welding processes. Postweld heat treatment is mandatory for all thicknesses of materials welded using inertia and continuous drive friction welding.

Table PW-39-7
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 7

Material	Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 7 Group No. 1, 2	1,350–1,425 (730–775)	1 hr/in. (1 h/25 mm), 15 min minimum	1 hr/in. (1 h/25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

GENERAL NOTES:
(a) Postweld heat treatment for P-No. 7 material shall be performed as described in PW-39.3, except that the cooling rate shall be a maximum of 100°F/hr (55°C/h) in the range above 1,200°F (650°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
(b) Postweld heat treatment is not mandatory for P-No. 7 materials under the following conditions:
(1) for Type 405 material where the material and construction shall comply with the following conditions:
(a) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification) of not more than 0.08%
(b) the electrodes used shall produce an austenitic chromium-nickel weld deposit, or a non-air-hardening nickel-chromium-iron weld deposit, and provided the following additional requirements are met:
(-1) the material thickness at the welded joint does not exceed $\frac{3}{8}$ in. (10 mm)
(-2) for material thickness over $\frac{3}{8}$ in. (10 mm) through $1\frac{1}{2}$ in. (38 mm), the following additional requirements are met:
(2) for electric resistance welds used to attach extended heat-absorbing fins to pipe and tube materials, provided the following requirements are met:
(a) a maximum pipe or tube size of NPS 4 (DN 100)
(b) a maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%
(c) a maximum fin thickness of $\frac{1}{8}$ in. (3 mm)
(d) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat-affected zone does not encroach upon the required minimum wall thickness

(e) For Figure PW-16.1, except as stipulated in (f) below, the nominal thickness is the depth of the groove, if present, through the shell or nozzle or reinforcing pad, or the throat of any fillet weld, whichever is greater.

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Table PW-39-8
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 8

Material	Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 8	For dissimilar metal welds, see Table PW-39.2, Note (2)	None	None	None

GENERAL NOTES:

(a) Postweld heat treatment is neither required nor prohibited for joints between austenitic stainless steels of the P-No. 8 group.

(b) Cautionary Note: Relaxation cracking (see Section II, Part D, Nonmandatory Appendix A, A-206) can occur in not only cold-formed areas but also in welds where high-level residual tensile stress exists. Unless one or more of the following conditions is satisfied, PWHT at the temperature listed in Table PG-19 for the specific material grade may be advisable to avoid relaxation cracking:

(1) The design temperature does not exceed 1,000°F (540°C).

(2) The welding is limited to the following (singular or in combination):

(a) circumferential butt welds in pressure parts with a nominal base metal thickness of ½ in. (13 mm) or less at the weld

(b) circumferential fillet welds with a throat thickness of ½ in. (13 mm) or less and combination groove and fillet welds with a weld thickness of ½ in. (13 mm) or less

(c) attaching extended heat-absorbing fins to pipe and tube materials by electric resistance welding, provided the following requirements are met

(-1) a maximum pipe or tube size of NPS 4 (DN 100)

(-2) maximum specified carbon content (SA material specification carbon content, except when further limited by the Purchaser to a value within the specification limits) of not more than 0.15%

(-3) a maximum fin thickness of ⅛ in. (3 mm)

(-4) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat-affected zone does not encroach on the required minimum wall thickness

(d) attaching nonload-carrying studs not exceeding ½ in. (13 mm) in diameter when using an automatic arc stud welding or automatic resistance stud welding process

(e) attaching bare wire thermocouples by capacitor discharge welding or electric resistance welding under the requirements of PW-39.8 with a nominal base metal thickness not less than 0.2 in. (5 mm)

Table PW-39-9
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 10H

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 10H Group No. 1	None	None	None	None

GENERAL NOTE: For the austenitic-ferritic wrought duplex stainless steels listed below, postweld heat treatment is neither required nor prohibited, but any heat treatment applied shall be performed as listed below and followed by liquid quenching or rapid cooling by other means.

Alloy	Postweld Heat Treatment, Temperature, °F (°C)
S31803	1,870–2,010 (1 020–1 100)

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Table PW-39-10
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 10I

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperaturefor Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 10I Group No. 1	1,250 (675)	1 hr/in. (1 hr/25 mm), 15 min minimum	1 hr/in. (1 hr/25 mm)	1 hr/in. (1 hr/25 mm)

GENERAL NOTE: Postweld heat treatment for P-No. 10I (SA-268 TP446 material only) shall be performed as described in PW-39.3, except that the cooling rate shall be a maximum of 100°F/hr (55°C/h) above 1,200°F (650°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.

Table PW-39-11
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 31

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 31	None	None	None	None

GENERAL NOTE: Postweld heat treatment is neither required nor prohibited for joints between materials of the P-No. 31 group.

Table PW-39-12
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 43

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)	
		Up to 1 in. (25 mm)	Over 1 in. (25 mm)
UNS No. N06617	1,740 (950)	1 hr	1 hr plus 1 hr/in. (1 hr/25 mm)
All other P-No. 43 Alloys	None	None	None

GENERAL NOTES:

(a) Postweld heat treatment is not mandatory for UNS No. N06617 (Alloy 617) materials under any one of the following conditions:
- *(1)* or design temperatures less than 1,000°F (540°C)
- *(2)* for circumferential butt welds in pressure parts with a nominal base metal thickness of ½ in. (13 mm) or less at the weld
- *(3)* for attaching bare wire thermocouples by capacitor discharge welding or electric resistance welding, provided all the following requirements are met:
  - *(-a)* the requirements of PW-39.8
  - *(-b)* the minimum wall thickness shall be 0.2 in. (5.0 mm)

(b) As an alternative, solution annealing Alloy 617 in accordance with its material specification is acceptable.

(c) Except for Alloy 617, postweld heat treatment is neither required nor prohibited for joints between all other materials of the P-No. 43 group.

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Table PW-39-13
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 45

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)	
		Up to 1 in. (25 mm)	Over 1 in. (25 mm)
UNS Nos. N08800, N08810, and N08811	1,625 (885)	1½ hr	1½ hr plus 1 hr/in. (1 h/25 mm)
All other P-No. 45 Alloys	None	None	None

GENERAL NOTES:
(a) For UNS Nos. N08800 (Alloy 800), N08810 (Alloy 800H), and N08811 materials, the minimum holding temperature above is to be used if the filler metal other than SFA-5.14 ERNiCrCoMo-1 is used. When SFA-5.14 ERNiCrCoMo-1 filler metal is used, the minimum holding temperature shall be 1,740°F (950°C).
(b) Postweld heat treatment is not mandatory for UNS Nos. N08800 (Alloy 800), N08810 (Alloy 800H), and N08811 materials under any one of the following conditions:
(1) for design temperatures less than 1,000°F (540°C)
(2) for circumferential butt welds in pressure parts with a nominal base metal thickness of ½ in. (13 mm) or less at the weld
(3) for attaching bare wire thermocouples by capacitor discharge welding or electric resistance welding, provided all the following requirements are met:
(-a) the requirements of PW-39.8
(-b) the minimum wall thickness shall be 0.20 in. (5.0 mm)
(c) As an alternative, solution annealing for UNS Nos. N08800 (Alloy 800), N08810 (Alloy 800H), and N08811 materials in accordance with their material specification is acceptable.
(d) Except for UNS Nos. N08800 (Alloy 800), N08810 (Alloy 800H), and N08811 materials, postweld heat treatment is neither required nor prohibited for joints between all other materials of the P-No. 45 group.

Table PW-39-14
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 51

Material	Minimum Holding Temperature, °F (°C)	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)		
		Up to 2 in. (50 mm)	Over 2 in. (50 mm) to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 51	None	None	None	None

GENERAL NOTE: Postweld heat treatment is neither required nor prohibited for joints between materials of the P-No. 51 group.

Table PW-39.1
Alternate Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels

Decrease in Temperature Below Minimum Specified Temperature, °F (°C)	Minimum Holding Time [Note (1)] at Decreased Temperature, hr	Notes
0 (0)	1	(2)
50 (28)	2	...
100 (56)	4	...
150 (83)	10	(3)
200 (111)	20	(3)

GENERAL NOTES:
(a) Applicable only when permitted in Tables PW-39-1 through PW-39-14.
(b) Interpolation may be used between temperature limits listed in this table to arrive at minimum holding time at the decreased temperature.

NOTES:
(1) Minimum holding time per inch (25 mm) for thickness up to and including 2 in. (50 mm). Add 15 min per inch (25 mm) of thickness for thickness greater than 2 in. (50 mm).
(2) For interpolation only.
(3) These lower postweld heat treatment temperatures permitted only for P-No. 1, Group 1 and 2 materials.

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(23)

Table PW-39.2
Mandatory Requirements for Postweld Heat Treatment Temperature Ranges for Welds Between P-No. 1, 3, 4, 5A, 5B Group 1, 6, 7, 8, and 15E Group 1

P-No.									
1	3	4	5A	5B Group 1	6	7	8 [Note (2)]	15E Group 1	
PWHT Temperature Range, °F (°C)									P-No.
See Table PW-39-1	1,100–1,300 (595–705)	1,200–1,300 (650–705)	1,250–1,300 (675–705)	1,250–1,300 (675–705)	[Note (1)]	[Note (1)]	1,100–1,300 (595–705)	[Note (1)]	1
...	See Table PW-39-2	1,200–1,300 (650–705)	1,250–1,300 (675–705)	1,250–1,300 (675–705) [Note (1)]	[Note (1)]	1,100–1,300 (595–705)	[Note (1)]	3	
...	...	See Table PW-39-3	1,250–1,350 (675–730)	1,250–1,350 (675–730)	[Note (1)]	[Note (1)]	1,200–1,350 (650–730)	1,300–1,350 (705–730)	4
...	...	...	See Table PW-39-4	1,250–1,425 (675–775)	[Note (1)]	1,350–1,425 (730–775)	1,250–1,425 (675–775)	1,300–1,425 (705–775)	5A
...	...	...	...	See Table PW-39-4	[Note (1)]	1,350–1,425 (730–775)	1,250–1,425 (675–775)	1,300–1,425 (705–775)	5B Group 1
...	...	...	...	...	See Table PW-39-6	[Note (1)]	[Note (1)]	[Note (1)]	6
...	...	...	...	...	...	See Table PW-39-7	1,350–1,425 (730–775)	1,350–1,425 (730–775)	7
...	...	...	...	...	...	...	See Table PW-39-8	1,300–1,445 (705– 85)	8 [Note (2)]
...	...	...	...	...	...	...	...	See Table PW-39-5	15E Group 1

GENERAL NOTE: This Table provides PWHT temperature ranges for materials of different P-Numbers welded together. For P-Numbers not listed, exemptions and other requirements for mandatory postweld heat treatment requirements, see Tables PW-39-1 through PW-39-14.

NOTES:

(1) For these welds, the lower minimum PWHT of the higher P-No. may exceed the lower critical temperature of the lower P-No. Consideration should be given to separate welding procedure qualifications for these material combinations per the rules of Section IX, QW-407.1.

(2) Sensitization of certain 300 series stainless steels may occur when they are exposed for periods of time in the temperature range of about 1,000°F to 1,550°F (540°C to 845°C). Sensitization involves the precipitation of chromium carbides along the grain boundaries potentially leading to intergranular corrosion during service. Refer to Section II, Part D, Nonmandatory Appendix A for further information. Consideration should be given to reducing sensitization by such means as the use of low carbon or stabilized grades of stainless steel or buttering the nonstainless portion of the weld with a Ni-base weld metal and postweld heat treating prior to completing the dissimilar metal weld without subsequent postweld heat treatment (see Section IX, QW-283 for rules regarding the qualification of such welds).

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(f) When multiple openings depicted in Figure PW-16.1 form a ligament where the spacing between centers is less than twice the average diameter, the nominal thickness of a combination groove and fillet weld shall be the sum of the groove depth and fillet weld throat.

The holding time at temperature as specified in Tables PW-39-1 through PW-39-14 and Table PW-39.2, need not be continuous. It may be an accumulation of time of multiple postweld heat treat cycles.

PW-39.4 The weldments shall be postweld heat treated by any of the following methods.

PW-39.4.1 Heating the complete assembly as a unit.

PW-39.4.2 Heating sections of assemblies.

PW-39.4.3 In cases where the vessel is postweld heat treated in sections, the heat treatment of the final joints may be performed by one of the following methods.

PW-39.4.3.1 By uniformly heating a circumferential band around the vessel, to the temperature and for the time specified in Tables PW-39-1 through PW-39-14 and Table PW-39.2, for postweld heat treatment.

PW-39.4.3.2 Alternatively, the postweld heat treatment of the final joints may be performed by heating in the furnace, provided the overlap of the heated sections of the vessel is at least 5 ft (1.5 m). When this procedure is used, the portion outside of the furnace shall be thermally shielded (using blankets, brick, etc.) so that the temperature gradient is not harmful.

PW-39.4.3.2.1 Where the cross section of the vessel that projects from the furnace contains a nozzle, consideration shall be given to controlling the temperature in the nozzle, so that the temperature gradient is not harmful.

PW-39.5 Nozzles or other welded attachments for which postweld heat treatment is required may be locally postweld heat treated by one of the following methods.

PW-39.5.1 By heating a circumferential band around the entire vessel with the welded connection located at the middle of the band. Except as modified below, the soak band shall extend around the entire vessel, and shall include the nozzle of welded attachment.

PW-39.5.1.1 By heating a circumferential band around the entire vessel with the welded connection located at the middle of the band. Provided the required soak band around the nozzle or attachment weld, as defined in PW-39.3, is heated to the required temperature and held for the required time, as specified in Tables PW-39-1 through PW-39-14 and Table PW-39.2, the remainder of the circumferentially-heated band may be varied in width around the circumference of the vessel. The temperature within the heated band shall be controlled to prevent harmful gradients.

PW-39.5.1.2 By heating a circumferential band around the entire vessel with the welded connection located at the middle of the band. Provided the required soak band around the nozzle or attachment weld, as defined in PW-39.3, is heated to the required temperature and held for the required time, as specified in Tables PW-39-1 through PW-39-14 and Table PW-39.2, the remainder of the circumferentially-heated band need not reach the required postweld heat treatment temperature. The temperature within the heated band shall be controlled to prevent harmful gradients.

PW-39.5.2 Local areas around nozzles or welded attachments in the larger radius sections of double curvature heads, or spherical shells or heads, may be postweld heat treated by heating a circular region around the nozzle. This region, or soak band, shall include the nozzle or welded attachment and shall be measured from the center of the nozzle or attachment. The soak band shall be a circle whose radius is equal to the radius at the widest width of the width of the weld attaching the nozzle or attachment to the shell, plus the thickness of the shell or head, or 2 in. (50 mm), whichever is less. The portion of the vessel outside of the circular region shall be thermally shielded using blankets, brick, or other suitable insulation material so that the temperature gradient is not harmful. A greater amount of base material may also be heated to permit temperature gradient control.

PW-39.5.3 Nozzles that contain circumferential welds in close proximity to a vessel or shell have additional thermal restraint imposed by this close proximity. Adequate length between the weld on the nozzle and the shell shall be provided so that the postweld heat treatment does not introduce harmful stresses at the nozzle attachment weld. Alternatively, the weld may be postweld heat treated by heating a full circumferential band around the entire vessel or shell, which shall include the nozzle in the center of the band.

PW-39.6 In the case of local postweld heat treatment of welded joints in pipes, tubes, and headers, the soak band shall extend around the entire pipe tube or header.

PW-39.7 Electroslag welds in ferritic materials over 1½ in. (38 mm). in thickness at the joint shall be given a grain refining (austenitizing) heat treatment.

PW-39.8 Capacitor discharge or electric resistance welding may be used for attaching bare wire thermocouples, without subsequent postweld heat treatment, provided the energy output for welding is limited to a maximum 125 W-sec and any requirements specified in the applicable notes as found in Tables PW-39-1 through PW-39-14 shall apply. A welding procedure

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specification shall be prepared and the content shall describe as a minimum the capacitor discharge equipment, the combination of materials to be joined, and the technique of application. Qualification of the welding procedure is not required.

PW-40 REPAIR OF DEFECTS

PW-40.1 Weld imperfections, such as cracks, pinholes, and incomplete fusion, detected visually or by leakage tests or by the examinations described in PW-11 and found to be rejectable, shall be removed by mechanical means or by thermal grooving processes, after which the joint shall be rewelded and reexamined.

PW-40.2 When tube-to-header or tube-to-drum welded joints have already received the postweld heat treatment required by PWT-11 and PW-39, minor local additional welding for rework of the joint or to improve the fillet weld contour may be performed on the materials listed in (b) without repeating the postweld heat treatment, subject to all the following limitations:

(a) The depth of any rework welding below the surface shall not exceed the smaller of 10% of the thickness of the drum or header, or 50% of the wall thickness of the tube.

(b) The area to be rework welded shall be preheated to at least the minimum temperatures as indicated below for the material.

Material Welding P-Number Group	Minimum Preheat, °F (°C), for Rework Welding
P-No. 3, Groups 1 and 2	200 (95)
P-No. 4	250 (120)
P-No. 5A	300 (150)

(c) The tubes shall not exceed 4 in. (100 mm) O.D.

(d) The welding procedure used for the rework welding shall have been qualified to the requirements of Section IX for the thickness of rework welding to be performed and for the omission of postweld heat treatment.

(e) For P-No. 1, all groups, see Table PW-39-1 for PWHT exemptions.

PW-40.3 Defects in P-No. 1, all groups (if not otherwise exempted by Table PW-39-1), and P-No. 3 Group Nos. 1 and 2 materials, and in the welds joining these materials, may be weld repaired after the final PWHT but prior to the final hydrostatic test using half bead or temper bead welding methods. The welded repairs may be performed without repeating the postweld heat treatment, provided that all of the requirements below are met.

PW-40.3.1 Defect Removal for Base Materials. The defect shall be removed or reduced to an acceptable size. Before repair welding, the groove shall be examined to verify that the defect has been reduced to an acceptable size, using either the magnetic particle or the liquid penetrant examination methods. When the material is nonferromagnetic, only the liquid penetrant method shall be used. Methods for magnetic particle examination and liquid penetrant examination shall be in accordance with A-260 and A-270, respectively; however, the acceptance standards for the examination shall be in accordance with the requirements of the original base material specification.

PW-40.3.2 Defect Removal for Welds and Welded Repairs. The defect shall be removed, and the groove examined to verify defect removal, using either the magnetic particle or the liquid penetrant examination methods. When the material is nonferromagnetic, only the liquid penetrant method shall be used. Methods and acceptance standards for magnetic particle examination and liquid penetrant examination shall be in accordance with A-260 or A-270, respectively.

PW-40.3.3 The total repair depth shall not exceed 10% of the base material thickness. The total depth of a weld repair shall be taken as the sum of the depths for repairs made from both sides of a weld at a given location. The total area of such repairs shall not exceed 100 in.^{2} (0.065 m^2).

PW-40.3.4 In addition to the requirements of Section IX for qualification of welding procedure specifications for groove welds, the following requirements shall apply:

(a) The weld procedure qualification shall have been made using material of the same P-No. and Group No. as the material to be repaired. The specific welding technique or combination of welding techniques used shall have been developed and tested to assure adequate tempering of the underlying weld bead heat-affected zones.

(b) The weld metal shall be deposited by the manual shielded metal-arc process. Only low hydrogen welding electrodes shall be used. The electrodes shall be properly conditioned in accordance with Section II, Part C, SFA-5.5, Annex A, A6.12.

(c) The maximum heat input for each weld layer shall not exceed that used in the procedure qualification test.

(d) The maximum deposited weld bead width for any electrode shall be four times the electrode core diameter.

(e) The repair area, including a band equal in width to 4 in. (100 mm) or four times the thickness of the weld repair, whichever is greater, on either side of the groove, shall be preheated and maintained at a minimum temperature of 350°F (175°C) during welding. The maximum interpass temperature shall be 450°F (230°C).

(f) The repair weld method shall be limited to either the half bead or temper bead weld repair technique as follows:

(1) For the half bead technique, the initial layer of weld metal shall be deposited over the entire area using $\frac{1}{8}$ in. (3.2 mm) max. diameter electrodes. Approximately one-half of the thickness of this layer shall then be removed by grinding before depositing subsequent layers.

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Subsequent weld metal layers shall be deposited using either $\frac{1}{8}$ in. (3.2 mm) or $\frac{5}{32}$ in. (4 mm) max. diameter electrodes.

(2) For the temper bead technique, the initial layer of weld metal shall be deposited over the entire area using either $\frac{3}{32}$ in. (2.4 mm) or $\frac{1}{8}$ in. (3.2 mm) diameter electrodes.

The subsequent weld layers for either weld repair method shall be deposited in such a manner as to ensure tempering of the prior weld beads.

Surface temper beads for either weld repair method shall be applied to a level above the surface being repaired without contacting the base material, but close enough to the edge of the underlying weld metal to ensure tempering of the base material heat-affected zone (suggested temper bead layer placement is shown in Section IX, Figure QW-462.12). The half bead or temper bead weld procedure specification shall be qualified in accordance with the requirements given in Section IX, QW-290, using welding electrodes or filler metals that are identified with a supplemental diffusible hydrogen designator of H-4.

(g) Hardness testing for qualification of either the half bead or temper bead repair weld procedure specifications shall be in accordance with Section IX, QW-290.5(c). The acceptance criteria for hardness testing for either weld repair method shall be as follows:

(1) For P-No. 1 material, all groups, the maximum peak hardness of the weld and base metal heat-affected zone shall not exceed 300HV10.

(2) For P-No. 3 Groups 1 and 2 materials, the maximum peak hardness of the weld and base metal heat-affected zone shall not exceed 315HV10.

PW-40.3.5 For materials greater than 1 in. (25 mm) thick, after completing all welding, the repair area shall be heated to and maintained at a temperature of 450°F to 550°F (230°C to 290°C) for a minimum period of 4 hr.

PW-40.3.6 Any final temper bead reinforcement shall then be removed substantially flush with the surface of the base material.

PW-40.3.7 After the finished half bead or temper bead repair weld has reached ambient temperature, it shall be examined to the requirements of PW-40.3.2, using the same nondestructive examination technique that was used to examine the weld groove.

PW-40.3.8 The vessel shall be hydrostatically tested in accordance with PW-54.

PW-40.3.9 The Manufacturer shall obtain the approval of the Authorized Inspector, prior to making the repair.

PW-41 CIRCUMFERENTIAL JOINTS IN PIPES, TUBES, AND HEADERS

The rules in the following paragraphs apply specifically to the boiler proper and parts thereof.

PW-41.1 Circumferential welded butt joints in pipe, tubes, and headers shall meet the radiographic and ultrasonic examination requirements of Table PW-11.

PW-41.2 All circumferential welded joints of parts covered by this paragraph and welded in accordance therewith shall have a double-welded butt joint or a single-welded butt joint made the equivalent of a double-welded butt joint, except as otherwise provided in PW-41.4 and PW-41.5.

PW-41.2.1 The strength of the weld shall be sufficient to develop the full strength of the part in the longitudinal direction. There shall be no valley or groove along the edge or in the center of the weld except as permitted by PW-35.1. Weld reinforcement may be removed if so desired. The design of the joint and the method of welding shall be such that there will be no appreciable projection of weld metal past the inside surface.

PW-41.2.2 The welding of butt joints from one side (single-welded butt joints) requires complete penetration at the root of the weld. (23)

(a) Complete penetration at the root of the weld shall be demonstrated by the qualification of the procedure being used to make the weld and shall be qualified per PW-28.1.4.

(b) When complete penetration at the root of the weld cannot be demonstrated, the welding procedure shall include a backing ring or equivalent.

(c) The depth of weld measured shall not be less than the thinner of the two parts being joined.

(d) Welds performed without a backing ring shall have a maximum concavity depth equal to the lesser of $\frac{3}{32}$ in. (2.5 mm) or 20% of the minimum required thickness (based on the thinner pipe or tube being joined).

(e) The contour of the concavity shall be smooth and the resulting thickness of the weld, including reinforcement, shall be at least equal to the minimum required thickness of the thinner pipe or tube. The depth of the weld concavity allowed under the rules of this paragraph shall be reduced by an amount equal to any net thickness replacement used, as permitted in PW-41.2.3.

PW-41.2.3 When the wall is recessed for a backing ring or to assure a uniform inside diameter of the weld preparation, the depth of such recess shall be so limited that the remaining net section of the wall is not less than the minimum required thickness. For boiler and superheater tubes where the diameter does not exceed 4 in. (100 mm), the recess may reduce the required thickness by not more than $\frac{1}{32}$ in. (0.8 mm), provided the

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reduced net section is replaced by weld metal in the outside reinforcement such that the resulting thickness of the weld, including reinforcement, is at least equal to the minimum required thickness.

PW-41.2.4 Backing rings may be of any size or shape suitable for the welding process and may be left in place or removed as desired. Materials for backing rings shall be compatible with the weld metal and base material and shall not cause harmful alloying or contamination. If left in place they must be properly secured to prevent dislodgment and shall have a contour on the inside to minimize the restriction to flow, if needed, and be of such inside diameter as to permit the passage of a tube cleaner where such cleaner is to be used.

PW-41.2.5 When welded joints in tubes or pipes are not postweld heat treated, the procedure qualification test shall be made under the same conditions, but the performance qualification test may be made on either postweld heat treated or nonpostweld heat-treated samples.

PW-41.3 Pipe connections not exceeding NPS ½ (DN 15) may be welded to pipe or headers under the provisions of this paragraph without the inspection required by this Section.

PW-41.4 For attachment of nozzles to boiler drums or headers see PW-15.

PW-41.5 Welded socket-type joints or sleeve type joints may be used to connect pipe or tubes to valves or fittings, or to each other, provided the conditions specified in PW-41.5.1 through PW-41.5.6 are met.

PW-41.5.1 Pipe shall not exceed NPS 3 (DN 80) and tubing shall not exceed 3½ in. (89 mm) nominal outside diameter (see PG-42, for ASME socket welding components).

PW-41.5.2 The depth of insertion of a pipe or tube into a socket shall be at least ¼ in. (6 mm). There shall be at least 1/16 in. (1.5 mm) clearance between the end of the pipe or tube and the internal shoulder of the socket, before welding.

PW-41.5.3 The fit between the socket or sleeve and the pipe or tube shall conform to applicable standards for socket weld fittings, and in no case shall the inside diameter of the socket or sleeve exceed the outside diameter of the pipe or tube by more than 0.080 in. (2.03 mm).

PW-41.5.4 The average outside diameter of the hub or sleeve (collar or end portion of socket welding fittings) shall be sufficient to make the average hub or sleeve thickness not less than 1.09 times the nominal thickness of the pipe or tube.

PW-41.5.5 The throat dimension of the fillet weld shall be not less than 0.77 times the nominal thickness of the pipe or tube.

PW-41.5.6 The depth of the insertion of a pipe or tube into a sleeve shall be at least ¼ in. (6 mm). There shall be at least 1/16 in. (1.5 mm) clearance between the butting ends of the pipe or tube, before welding.

PW-42 JOINTS IN VALVES AND OTHER BOILER APPURTENANCES

Valves, other boiler appurtenances such as water columns, and casings of pumps that are part of a boiler circulation system, may have fusion-welded joints other than longitudinal, complying with the requirements of this Part except that inspection of these joints is not required. The Manufacturer shall furnish, if requested, a statement certifying that these requirements have been met.

PW-44 FABRICATION RULES FOR BIMETALLIC TUBES WHEN THE CLAD STRENGTH IS INCLUDED

PW-44.1 The strengths for annealed wrought products are listed in Section II, Part D, Subpart 1, Tables 1A and 1B. Values applicable to either Section I or Section VIII, Division 1 may be used. The strength of deposited clad metal (welded or laser fused) shall be inferred from an annealed wrought material with nominally equivalent strength and composition as the clad (see PG-27.2.1.5 and PG-27.4.10). The in-text table below contains wrought alloys and weld wires that may be considered as nominally equivalent for this purpose. For powders used in laser-fused cladding, the deposit chemistry shall nominally conform to that for weld wire for welded cladding. For clad alloys that are not included in the table below, the strength may be established by performing tests in conformance with Section II, Part D, Mandatory Appendix 5 and submitting the data to ASME for analysis.

Generic Identity Wrought/Weld	Wrought UNS No.	AWS Classifications
309 or 309S/309	S30908	ER309
None/309L	None — use S30403	ER309L
None/312	None — use S30403	ER312
33/33	R20033	None — matches wrought chemistry
600/82	N06600	ERNiCr-3
622/622	N06022	ERNiCrMo-10
625/625	N06625	ERNiCrMo-3
690/52	N06690	ERNiCrFe-7
671/72	None — use N06600	ERNiCr-4
825/None	N08825	None

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Some of the clad alloys are subject to embrittlement during long-term service over specific temperature ranges. In particular, Alloy 625 embrittles in the temperature range of 1,000°F to 1,400°F (540°C to 760°C), and the ferrite phase of 312 stainless steels embrittles above 500°F (260°C) with the shortest embrittlement time occurring at 885°F (475°C) (see Section II, Part D, Nonmandatory Appendix A, A-207).

PW-44.2 Rules governing the P-No. of the bimetallic tube to which an attachment is welded are as follows:

(a) If the attachment is welded to the clad portion, the P-No. shall be that associated with the clad except when the combination of heat input and clad thickness create a new heat-affected zone in the core tube, in which case the P-No. having the more conservative rules shall be applicable. Macroetching and microhardness measured from a representative sample may be used to determine whether a new heat-affected zone is created in the core tube by the attachment welding.

(b) If the attachment is welded to the core, the P-No. shall be that associated with the core tube.

PW-44.3 The rules of Section IX applicable to corrosion-resistant weld metal overlays (CRO) shall apply for welding procedure qualifications and for welding performance qualifications. In addition, qualification as a groove weld in accordance with Section IX shall be satisfied to demonstrate strength and ductility of the weldment.

PW-44.4 Exemptions to postweld heat treatment (PWHT) in PW-39 that are specific to corrosion-resistant weld metal overlay cladding of pipe or tube materials shall apply. When there are no such exemptions, PWHT is mandatory and shall be based on the core material in accordance with PW-39.

PW-44.5 A stress relief to relax residual stresses and improve ductility may be desirable before making cold bends on bimetallic tubing.

PW-44.6 Bimetallic tubes that are cold formed after cladding may require post-forming heat treatments.

PW-44.6.1 For bimetallic tubes in which the core tube and clad are both austenitic materials (either steel or nickel-based alloy), the cold forming rules of PG-19 shall apply with the minimum heat treatment temperature being the highest applicable to the two alloys. For weld- or laser-fused cladding, the nominal wrought equivalents in PW-44.1 may be used.

PW-44.6.2 For bimetallic tubes in which the core is ferritic and the clad austenitic (either steel- or nickel-based alloy), the forming limits in Table PG-19 that would initiate a required solution heat treatment shall not be exceeded. For weld- or laser-fused cladding, the nominal wrought equivalents in PW-44.1 may be used.

PW-44.7 Demonstration of the cladding process to achieve a metallurgical bond and a clad that is free from rejectable defects shall be by examination of a workmanship bimetallic tube sample using cladding parameters that are to be used in production. The bimetallic tube sample shall have a minimum length of 7 in. (175 mm). This sample shall be evaluated prior to the start of fabrication and repeated for a new sample anytime an essential variable is changed, using the methods described in paras. PW-44.7.1 through PW-44.7.4.

PW-44.7.1 Two 0.5 in. (13 mm)-long rings shall be removed, one from each end, and the four available cross sections (the ends of the two rings) shall be examined using the liquid penetrant technique in accordance with A-270 except for revisions to the acceptance criteria in (a) through (c) below. The basis for rejection of indications on any of the examined surfaces shall be as follows:

(a) Any linear indication (length more than or equal to three times the width) with a length of $^{1}/_{16}$ in. (1.6 mm) or greater. Rejectable linear indications on two or more surfaces shall constitute rejection of the cladding process.

(b) More than two isolated rounded indications on any single examined surface with a size of ≥ 50% of clad thickness or $^{1}/_{16}$ in. (1.6 mm), whichever is less. Rounded indications that are initially classified as nonrejectable shall be further explored by either incremental sectioning or supplemental NDE. Any such rounded indication that is determined to extend $^{1}/_{8}$ in. (3.2 mm) or more below the ring surface shall be reclassified as a rejectable indication. Rejectable indications on more than two of the four examined surfaces shall constitute rejection of the cladding process.

(c) Four or more rounded indications with a size of ≥ 75% of clad thickness or $^{1}/_{16}$ in. (1.6 mm), whichever is less, in a line separated by $^{1}/_{16}$ in. (1.6 mm) or less, edge to edge. Rejectable indications on two or more of the four examined surfaces shall constitute rejection of the cladding process.

PW-44.7.2 After removal of the two rings, the remaining portion of the tube shall be split longitudinally, and the four available cross sections shall be examined using the liquid penetrant technique in accordance with A-270, except for revisions to the acceptance criteria in (a) through (c) below. The basis for rejection of indications on any of the four examined surfaces shall be as follows:

(a) Any linear indication (length more than or equal to three times the width) with a length of $^{1}/_{16}$ in. (1.6 mm) or greater. Rejectable linear indications on two or more surfaces shall constitute rejection of the cladding process.

(b) More than two isolated rounded indications on any single examined surface with a size of ≥ 50% of clad thickness or $^{1}/_{16}$ in. (1.6 mm), whichever is less. Rounded indications that are initially classified as nonrejectable shall be further explored by either incremental sectioning or

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supplemental NDE. Any such rounded indication that is determined to extend $\frac{1}{8}$ in. (3.2 mm) or more below the surface shall be reclassified as a rejectable indication. Rejectable indications on two or more of the four examined surfaces shall constitute rejection of the cladding process.

(c) Four or more rounded indications with a size of ≥ 75% of clad thickness or $\frac{1}{16}$ in. (1.6 mm), whichever is less, in a line separated by $\frac{1}{16}$ in. (1.6 mm) or less, edge to edge. Rejectable indications on one or more of the four examined surfaces shall constitute rejection of the cladding process.

PW-44.7.3 Ultrasonic examination (UT) may be substituted for the examinations described in PW-44.7.1 and PW-44.7.2, provided the following conditions are satisfied:

(a) The examination shall be done in accordance with Section V, Article 4, with specific emphasis on the portions relating to cladding (T-432.2, T-434.1.4, T-434.4, and T-473).

(b) The procedures shall have sensitivity to identify and size rejectable defects of the sizes identified in PW-44.7.1(a) through PW-44.7.1(c) and PW-44.7.2(a) through PW-44.7.2(c).

(c) Four areas shall be selected, each containing a 7 in. (175 mm) length of bimetallic tubing. These four lengths shall be given a full clad volumetric and core-to-clad bond-line examination, and the acceptance or rejection of a single length or the group of four lengths collectively shall be based on the criteria in PW-44.7.2(a) through PW-44.7.2(c).

PW-44.7.4 In the event the cladding process is rejected based on PW-44.7.1, PW-44.7.2, or PW-44.7.3, two recovery paths are available as follows:

(a) The amount of sampling shall be doubled from the previous examination and a retest performed using the same methods. Rejection of any grouping shall constitute rejection of the process. In the event of a rejection of the process on the second attempt, the retest protocol may be repeated a third and final time.

(b) The cladding process parameters shall be changed to produce a new workmanship sample and the examination process repeated from the beginning.

PW-44.8 The rules in this paragraph and its subparagraphs are applicable to laser-fused cladding and welded cladding but not to coextruded tubing. During production of bimetallic tubes, the Manufacturer responsible for certifying the boiler unit shall establish a nondestructive examination program, to be implemented by the cladding organization, consisting of the elements described in PW-44.8.1 through PW-44.8.4 as a minimum.

PW-44.8.1 Visual examination (VT) shall be performed on 100% of the clad surface in accordance with Section V, Article 9. Any indication open to the surface shall additionally be subjected to liquid penetrant examination (PT) in accordance with A-270 and acceptance or rejection based on A-270.4. The portion of bimetallic tubing containing rejectable defects shall either be removed or the defects repaired in accordance with PW-44.9.

PW-44.8.2 A minimum of 5% of the clad portion of bimetallic tubing shall be subjected to liquid penetrant examination (PT) in accordance with A-270 and acceptance or rejection based on A-270.4. The portion of bimetallic tubing containing rejectable defects shall either be removed or the defects repaired in accordance with PW-44.9.

PW-44.8.3 In the vicinity of all the areas identified for PT in PW-44.8.2, clad thickness shall be measured at a location (or locations) identified by the Manufacturer responsible for certifying the boiler unit. The means for measuring the clad thickness shall be established by the Manufacturer responsible for certifying the boiler unit using calibration standards typical of the clad process. All violations of minimum clad thickness shall initiate a more extensive thickness survey to establish the extent of the affected area, and an engineering evaluation for disposition shall be performed by the Manufacturer responsible for certifying the boiler unit.

PW-44.8.4 Other elements that may be considered for inclusions in the production examination program include the following:

(a) validation of chemical composition of the clad, particularly chromium

(b) documentation of dimensional characteristics of the completed component

(c) records of clad areas for each weld consumable used

(d) hardness testing

(e) examining the clad surface with copper sulfate to identify bare areas

(f) macroscopic and microscopic metallographic sampling

PW-44.9 Defects confined to the clad, revealed by the examinations in PW-44.8 or found otherwise, that do not encroach on the minimum clad thickness or the minimum total wall thickness shall be removed locally by mechanical means and the area smoothly blended to the adjacent contour. Defects that encroach on the minimum clad thickness or the minimum total wall thickness shall be weld repaired in accordance with the applicable portions of PW-41. All repaired areas shall subsequently be examined to the requirements of PW-44.8 and subparagraphs and shown to conform to the acceptance standards in A-270.

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INSPECTION AND TESTS

PW-46 GENERAL

PW-46.1 The rules in the following paragraphs apply specifically to the inspection and testing of power boilers and power boiler parts that are fabricated by welding and shall be used in conjunction with the general requirements for inspection and tests in Part PG as well as the specific requirements for inspection and tests in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PW-46.2 Inspection During Fabrication. The Manufacturer shall submit the vessel or other pressure part for inspection at such stages of the work as may be designated by the Inspector.

PW-47 CHECK OF WELDING PROCEDURE

PW-47.1 It is the duty of the Inspectors to assure themselves that the welding procedures employed in construction have been qualified under the provisions of Section IX. The Manufacturer shall submit evidence to the Inspector that those requirements have been met.

PW-47.2 The Inspector has the right at any time to call for and witness the test welding and testing although it is not mandatory that the Inspector witness the test welding and the testing unless the Inspector so desires.

PW-48 CHECK OF WELDER AND WELDING OPERATOR PERFORMANCE QUALIFICATIONS

PW-48.1 It is the duty of the Inspectors to assure themselves that all welding is done by welders or welding operators qualified under the provisions of Section IX. The Manufacturer shall make available to the Inspector a certified copy of the record of performance qualification tests of each welder and welding operator as evidence that these requirements have been met.

PW-48.2 The Inspector has the right at any time to call for and witness the test welding and testing although it is not mandatory that the Inspector witness the test welding and the testing unless the Inspector so desires.

PW-49 CHECK OF HEAT TREATMENT PRACTICE

The Inspectors shall satisfy themselves that all heat treating operations required by the Code have been correctly performed.

(23) PW-50 QUALIFICATION OF NONDESTRUCTIVE EXAMINATION PERSONNEL

PW-50.1 The Manufacturer shall be responsible for assuring that nondestructive examination (NDE) personnel have been qualified and certified in accordance with their employer's written practice prior to performing or evaluating radiographic or ultrasonic examinations required by this Section. SNT-TC-1A[4] or CP-189 shall be used as a guideline for employers to establish their written practice. When the following techniques are used, the training, experience, and examination requirements in Section V, Article 1, Mandatory Appendix II shall also be included in the employer's written practice, as applicable:

(a) computed radiography (CR)
(b) digital radiography (DR)
(c) phased array ultrasonic testing (PAUT)
(d) ultrasonic time-of-flight diffraction (TOFD)

National or international Central Certification Programs will satisfy the examination and demonstration requirements of the employer's written practice. Provisions for training, experience, qualification, and certification of NDE personnel shall be described in the Manufacturer's quality control system (see PG-105.4).

PW-50.2 NDE personnel shall be qualified by examination. Qualification of NDE Level III personnel certified prior to the 2004 Edition of Section I may be based on demonstrated ability, achievement, education, and experience. Such qualification shall be specifically addressed in the written practice.

If the NDE Level III personnel are certified in either the RT or UT methods and use the techniques of computed radiography (CR), digital radiography (DR), phased array ultrasonic testing (PAUT), or ultrasonic time-of-flight diffraction (TOFD), the requirements in Section V, Article 1, Mandatory Appendix II for Level III personnel shall be satisfied prior to their next recertification period.

When NDE personnel have been certified in accordance with a written practice based on an edition of SNT-TC-1A or CP-189 dated earlier than that referenced in A-360, their certification shall be valid until their next scheduled recertification.

PW-50.3 Recertification shall be in accordance with the employer's written practice based on the edition of SNT-TC-1A or CP-189 referenced in A-360. Recertification may be based on evidence of continued satisfactory performance or by reexamination(s) deemed necessary by the employer.

In addition, if the techniques of computed radiography (CR), digital radiography (DR), phased array ultrasonic testing (PAUT), or ultrasonic time-of-flight diffraction (TOFD) are used, the NDE personnel shall satisfy the training, experience, and examination requirements in Section V, Article 1, Mandatory Appendix II.

PW-51 RADIOGRAPHIC EXAMINATION (23)

PW-51.1 When the radiographic examination method is used to examine a weld requiring volumetric examination by PW-11, the weld shall be examined throughout its entire length by the X-ray or gamma-ray method in

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accordance with Section V, Article 2. The requirements of T-274 are to be used as a guide but not for the rejection of radiographs unless the geometrical unsharpness exceeds 0.07 in. (1.8 mm).

PW-51.2 A single-welded circumferential butt joint with backing (ring or strip) may be radiographed without removing the backing, if

(a) that backing is to remain in place

(b) the image of the backing does not interfere with the evaluation of the weld

PW-51.3 Indications visible on the radiographs of welds and characterized as imperfections are unacceptable under the conditions listed in PW-51.3.1 through PW-51.3.4. The unacceptable imperfections shall be repaired as provided in PW-40 and the repair reexamined by radiography in accordance with PW-51.

PW-51.3.1 Any indication characterized as a crack, or zone of incomplete fusion or penetration.

PW-51.3.2 Any other elongated indication on the radiograph that has a length greater than

(a) 1/4 in. (6 mm) for t up to 3/4 in. (19 mm), incl.

(b) 1/3t for t from 3/4 in. (19 mm) to 2 1/4 in. (57 mm), incl.

(c) 3/4 in. (19 mm) for t over 2 1/4 in. (57 mm)

where t is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, t is the thinner of the two parts being joined.

PW-51.3.3 Any group of aligned indications that have an aggregate length greater than t in a length of 12t, except when the distance between the successive imperfections exceeds 6L where L is the length of the longest imperfection in the group.

PW-51.3.4 Rounded indications that exceed the acceptance criteria in A-250.

PW-51.4 For the purposes of the Manufacturer's Quality Program, the Code Document is the radiograph review form as required by Section V, Article 2, T-292.

PW-51.5 A complete set of radiographic images (either in film or digital form) for each job shall be kept on file until the Data Report is signed. If film radiographs are digitized, the digitization shall be in accordance with Section V, Article 2, Mandatory Appendix III. The radiograph review form shall be retained by the Manufacturer until the Data Report is signed and kept on file for a period of at least 5 additional years.

(23) PW-52 ULTRASONIC EXAMINATION

PW-52.1 When the ultrasonic examination method is used to examine a weld requiring volumetric examination by PW-11, the weld shall be examined throughout its entire length using the techniques and standards for ultrasonic examination as defined in Section V, Article 4, Mandatory Appendix VII, Ultrasonic Examination Requirements for a Workmanship Based Acceptance Criteria. As an alternative, Nonmandatory Appendix E may be used for the ultrasonic examination of welds requiring volumetric examination by PW-11.

PW-52.2 For the purposes of the Manufacturer's Quality Program, the Code Document is the report, as required by Section V, Article 4, T-493.

The report for each job shall be retained by the Manufacturer until the Data Report is signed and kept on file for a period of at least 5 additional years.

PW-52.3 Acceptance–Rejection Standards. Imperfections that create a response that exceeds the reference levels specified in Section V shall be investigated by the ultrasonic examination personnel to determine their shape, identity, and location. Those imperfections shall be evaluated against the following criteria.

PW-52.3.1 Cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

PW-52.3.2 Other imperfections are unacceptable if the indication exceeds the reference level and their length exceeds the following:

(a) 1/4 in. (6 mm) for t up to 3/4 in. (19 mm), incl.

(b) 1/3t for t from 3/4 in. (19 mm) to 2 1/4 in. (57 mm), incl.

(c) 3/4 in. (19 mm) for t over 2 1/4 in. (57 mm)

where t is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, t is the thinner of these two thicknesses.

PW-53 TEST PLATES

PW-53.1 Vessel Test Plates. Cylindrical pressure parts such as drums and shells and all noncylindrical pressure parts that are subject to internal pressure and are fabricated by fusion welding, shall meet the test requirements in PW-53.2 through PW-53.9. The following are exempt from these requirements:

(a) cylindrical pipe, tubes, and headers subject to internal pressure, including heads attached by welding to these pressure parts

(b) all pressure parts constructed of P-No. 1 materials

(c) all attachment welds

PW-53.2 Welded Test Plates. A welded test plate having the dimensions shown in Figure PW-53.1 shall be prepared from plate of the same material specification, the same or greater thickness as the weld at the joint and using the same welding procedure as used for the parts that it represents. To be considered the same specification as the steel being welded, the chemical composition must be within the specification limits, and the steel making practice, i.e., killed, semikilled, or rimmed, must be the same.

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The weld consumables used to weld the test plate shall be from the same manufacturer and lot(s), control or heat number(s) as that to be used for each weld process in production.

If weld consumables are purchased with a Certified Material Test Report based on Schedule 4 or I level of testing as defined in Section II, Part C, SFA-5.01/SFA-5.01M, then the requirement to make a test plate is exempted.

The plate shall be welded by one of the following methods.

PW-53.2.1 Attach the test plate as shown in Figure PW-53.2 to one end of one longitudinal joint of each vessel so that the edges to be welded are a continuation of the corresponding edges of the longitudinal joint. In this case the weld metal shall be deposited in the weld joint of the test plate continuously with that deposited in the shell joint.

PW-53.2.2 For circumferential and other welded joint configurations not described in PW-53.2.1, for which attachment of a test plate as shown in Figure PW-53.2 is not possible, weld the joint in the test plate without attaching it as a continuation of a joint in the vessel plate. If the essential variables of the welding procedure specification used to weld all joint configurations in the vessel plate remain unchanged, one test plate may be used to satisfy the requirements for all welded joint configurations in the same vessel plate.

PW-53.3 Where there are several pressure parts of any one design being welded in succession, and in which the plates are of the same material that is covered by the welding procedure, a test plate shall be furnished for each 200 ft (60 m), or fraction thereof, of the main welded joints. The thickness of the thinnest plate and of the thickest plate shall not differ by more than $\frac{1}{4}$ in. (6 mm).

PW-53.4 Where more than one welder or welding operator is used on a vessel, the inspector may designate the welder or welding operator who shall make the required test plate.

PW-53.5 The test plate shall be so supported that the welding does not warp the plate out of line by an angle greater than 5 deg. The plate shall be straightened before postweld heat treatment to remove any warping that has occurred. The test plate shall be given the same preheat treatment and the same postweld heat treatment as the vessel that it represents. In no case shall the temperature of preheat or postweld heat treatment be higher than that used for the vessel.

PW-53.6 Test Specimens. The coupons for tension and bend test shall be removed as shown in Figure PW-53.1 and shall be of the dimensions shown in Figures PW-53.3(a) and PW-53.3(b). If the dimensions of the weld groove are such that a full size tension specimen cannot be obtained, then a small size specimen as shown in Figure 4 of SA-370 may be used. The specimen removed shall be the largest specimen that contains only all-weld metal in the reduced section.

PW-53.7 Tension Tests.

PW-53.7.1 Except as provided in PW-53.7.5 two types of tension test specimen are required, one of the joint and the other of the weld metal.

PW-53.7.2 The tension specimen of the joint shall be transverse to the welded joint and shall be the full thickness of the welded plate after the outer and inner surfaces of the weld have been machined to a plane surface flush with the surface of the plate. When the capacity of the available testing machine does not permit testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall be tested and shall meet the requirements.

PW-53.7.3 If the transverse tension test specimen breaks in the weld, its tensile strength shall be not less than the minimum of the specified tensile range of the base material (The tension test of the joint specimen as specified herein is intended as test of the welded joint and not of the plate.). When the specimen breaks outside the weld at not less than 95% of the minimum of the specified tensile range of the base material and the weld shows no sign of weakness, the test shall be accepted as meeting the requirements. When the specimen or a portion thereof breaks in the base material below this strength tolerance because of a local defect, one additional specimen shall be tested and shall meet the requirements.

PW-53.7.4 The tension test specimen of the weld metal shall be taken such that the reduced portion of the specimen shall consist entirely of deposited weld metal and shall meet the following requirements:

Tensile strength = at least that of the minimum of the range of the plate which is welded

Elongation, minimum, %, in 2 in. (50 mm) = 20,

$$\text{or} = 700 / U + 10 \text{ (U.S. customary units), whichever is less}$$
$$= 4820 / U + 10 \text{ (SI units), whichever is less}$$

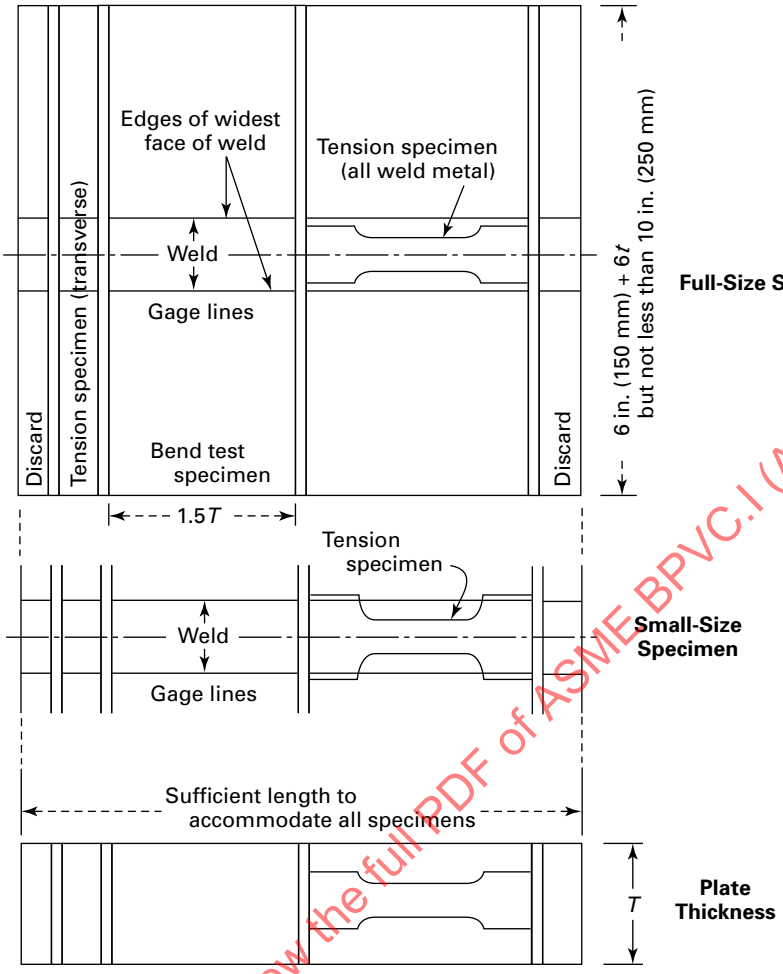
where

U = minimum specified tensile strength of the material to be welded, ksi (MPa), as given in the applicable stress table.

If small size tensile specimens are used, measurement of elongation may be omitted.

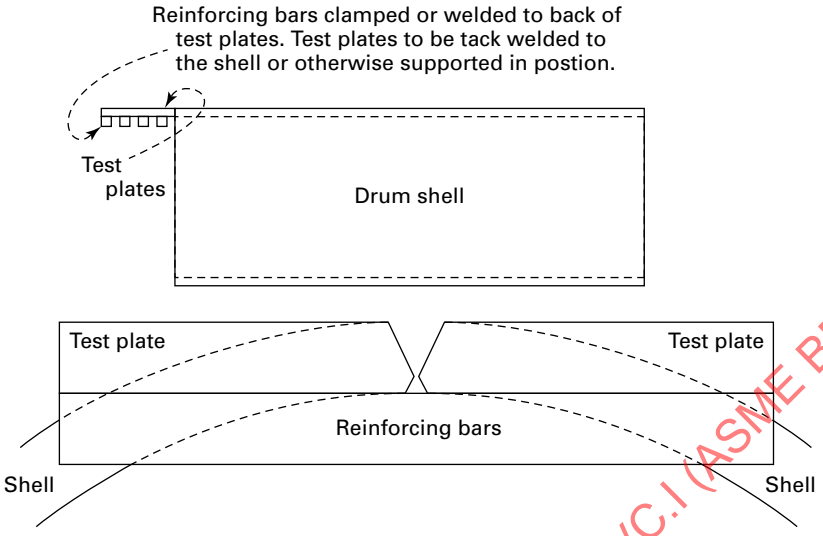
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Figure PW-53.1
Test Specimens From Longitudinal Welded Test Plates



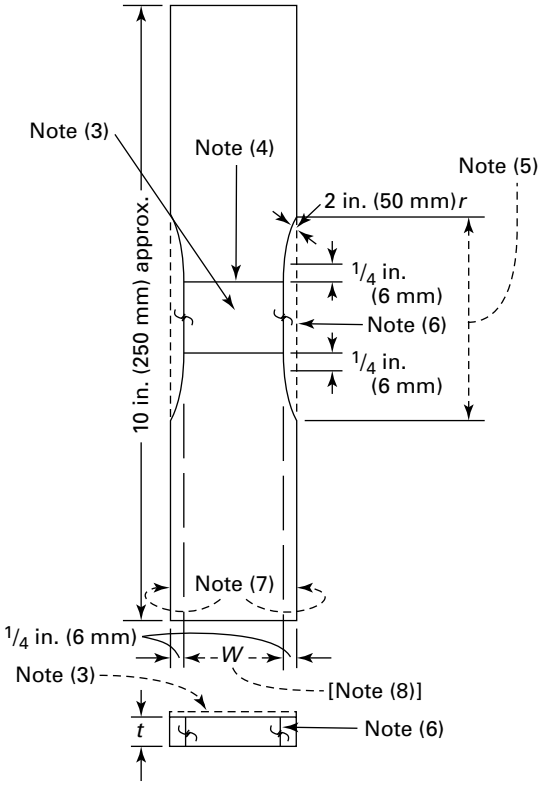
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Figure PW-53.2
Method of Forming Longitudinal Test Plates

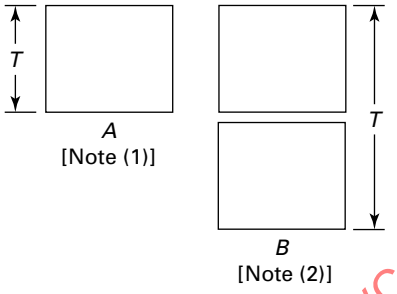


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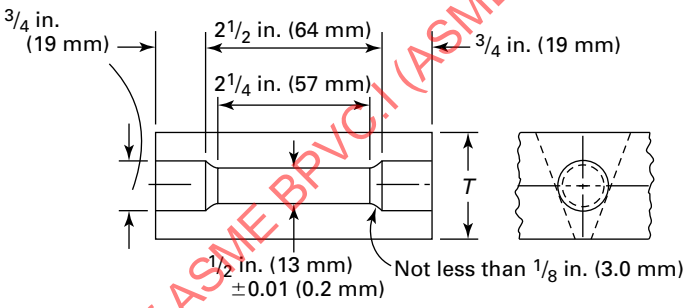
Figure PW-53.3(a)
Details of Tension Test Specimens



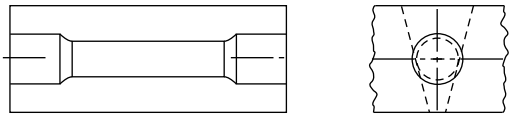
Transverse Tension Specimen



Transverse Tension Specimen



Full Size All Weld Metal Tension Specimen

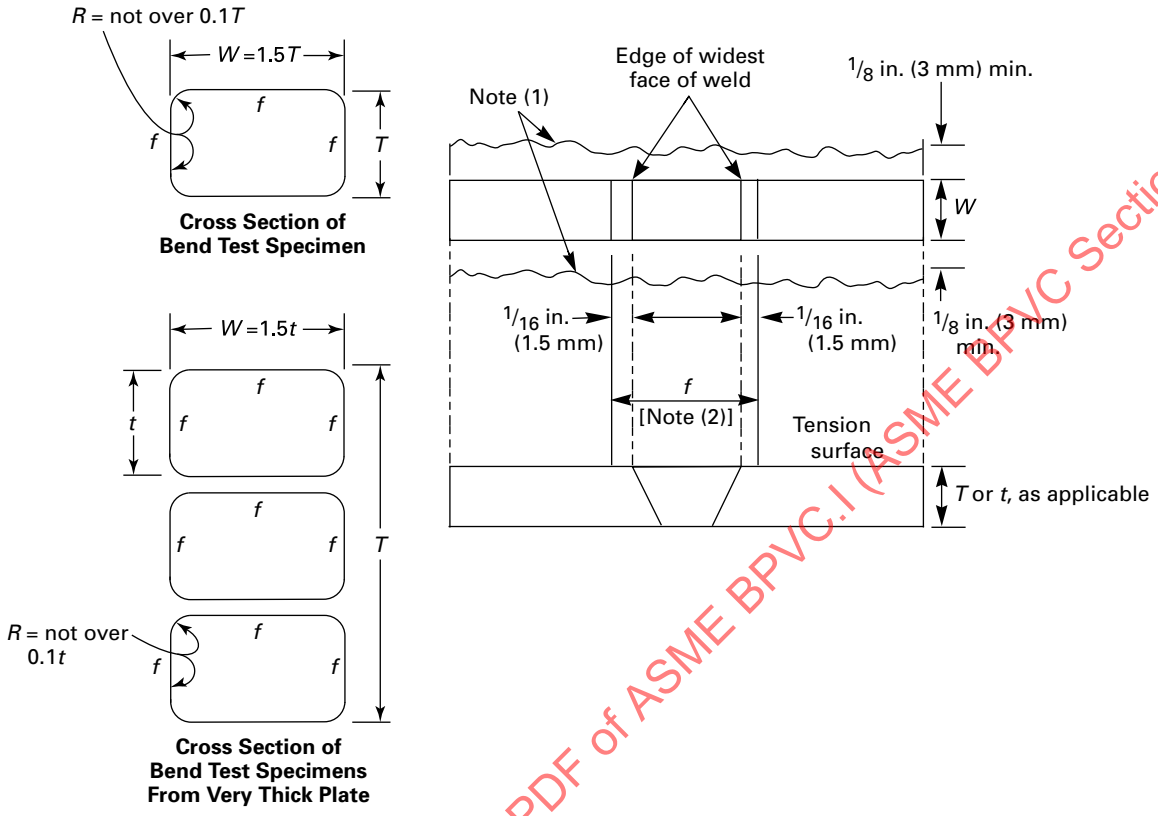


Small Size All Weld Metal Tension Specimen [Note (9)]

NOTES:
(1) *A* — Cross section through tension specimen.
(2) *B* — Cross section through tension specimens on very thick plate.
(3) Weld reinforcement shall be machined flush with base metal.
(4) Edge of widest face of weld.
(5) This section machined preferably by milling.
(6) "*f*" indicates light finish cut.
(7) These edges may be flame cut.
(8) $W = 1\frac{1}{2}$ in. (38 mm) ±0.01 in. (0.2 mm) if t does not exceed 1 in. (25 mm); $W = 1$ in. (25 mm) ±0.01 in. (0.2 mm) if t exceeds 1 in. (25 mm).
(9) Specimen sizes in accordance with Figure 4 of SA-370.

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Figure PW-53.3(b)
Details of Bend Test Specimens



NOTES:
(1) If coupons have been cut apart by a fusion process, the flame cut surfaces are to be machined off as indicated.
(2) This surface to be reasonably smooth. Any tool marks remaining must be lengthwise of specimen. "*f*" indicates light finish cut. Weld reinforcement to be removed.

PW-53.7.5 For plate thicknesses less than $^{5}/_{8}$ in. (16 mm), the all-weld metal tension test may be omitted.

PW-53.8 Bend Tests.

PW-53.8.1 The bend test specimen shall be transverse to the welded joint of the full thickness of the plate and shall be of rectangular cross section with a width $1^{1}/_{2}$ times the thickness of the specimen. When the capacity of the available testing machines does not permit testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall be tested and shall meet the requirements. The inside and outside surfaces of the weld shall be machined to a plane surface flush with the surface of the specimen. The edges of this surface shall be rounded to a radius not over 10% of the thickness of the test specimen. The specimen shall be bent cold under free bending conditions until the least elongation measured within or across approximately the entire weld on the outside fibers of the bend test specimen is 30%, or $700/U$ ($4\,820/U$) + 20%, whichever is less where

U = minimum specified tensile strength of the material to be welded, ksi (MPa), as given in the applicable stress table.

PW-53.8.2 When a crack is observed in the tensile strained surface of the specimen between the edges before the elongation required in PW-53.8.1 is attained, the specimen shall be considered to have failed and the test shall be stopped. Cracks at the corners of the specimen shall not be considered as a failure. The appearance of small imperfections in the convex surface shall not be considered as a failure if the greatest dimension does not exceed $^{1}/_{8}$ in. (3 mm).

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PW-53.9 Retests.

PW-53.9.1 Should any of the specimens fail to meet the requirements by more than 10%, no retest shall be allowed except that in the case of failure of the free-bend test specimen due to permissible types of imperfections, free-bend specimen retests may be allowed at the discretion of the Inspector.

PW-53.9.2 Should any of the specimens fail to meet the requirements by 10% or less, retests shall be allowed. A second test plate shall be welded by the same operator who welded the plate which did not meet the test requirements. The retest shall be made on specimens cut from the second plate.

PW-53.9.3 The retests shall comply with the requirements. For either of the tension retests, two specimens shall be cut from the second test plate, and both of these shall meet the requirements.

PW-53.9.4 When there is more than one specimen of the same type and one or more of the specimens fail to meet the requirements by 10% or less, a retest may be made for each specimen required for the weld under consideration. Each such specimen shall meet the requirements.

PW-53.9.5 If the percentage of elongation of all-weld metal tension specimen is less than that specified and any part of the fracture is more than $^{3}/_{4}$ in. (19 mm) from the center of the 2 in. (50 mm) gage length of the specimen, a retest shall be allowed.

PW-54 HYDROSTATIC TEST

PW-54.1 Welded pressure parts shall be subjected to a hydrostatic test with the completed boiler in accordance with PG-99. The hydrostatic test may be made either in the Manufacturer's shop or in the field.

PW-54.2 Except as described in PW-54.3, when repairs are made, the part shall again be tested in the regular way, and if it passes the test the Inspector shall accept it. If it does not pass the test the Inspector may permit supplementary repairs, or if in the Inspector's judgment the pressure part is not suitable for service, the Inspector may permanently reject it.

PW-54.3 Welding of nonpressure parts to pressure parts and seal welding of pressure-retaining handhole and inspection plugs or fittings secured by physical means may be performed after the hydrostatic test without requiring another hydrostatic test provided the following criteria are met.

PW-54.3.1 Welding is done in conformance with this Part and the completed weld is inspected by the Authorized Inspector. The Manufacturers' Data Report Form shall be signed only after completion of the welding.

PW-54.3.2 For nonpressure parts welded to pressure parts, the following additional conditions shall be met:

(a) The pressure part material is limited to P-No. 1 materials.

(b) The nonpressure attachment material is limited to carbon steel with a carbon content not exceeding 0.2% or any P-No. 1 material.

(c) The welding is done by stud welding or by fillet welding having a throat not exceeding the lesser of 0.70 times the thickness of the pressure part or $^{1}/_{4}$ in. (6 mm).

(d) A minimum 200°F (95°C) preheat shall be applied when the pressure part thickness exceeds $^{3}/_{4}$ in. (19 mm).

PW-54.3.3 For seal welding of pressure-retaining handhole and inspection plugs or fittings secured by physical means, the following additional conditions shall be met:

(a) The seal welds must be exempted from postweld heat treatment by rules elsewhere in this section.

(b) The completed weld is examined using either the magnetic particle or liquid penetrant examination method in accordance with A-260 or A-270, respectively. When the base materials or welds are nonferromagnetic, only the liquid penetrant method shall be used.

PW-54.4 Refer to A-64 as guidance for welded pressure parts supplied to the user of an existing boiler as replacement or repair parts.

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PART PR
REQUIREMENTS FOR BOILERS FABRICATED BY RIVETING

GENERAL

PR-1 SCOPE

The rules in this Part are applicable to boilers and component parts thereof that are fabricated by riveting. These rules shall be used in conjunction with the general requirements in the applicable Parts of this Section and Mandatory Appendix V that pertain to the type of boiler under consideration.

PR-2 RESPONSIBILITY

PR-2.1 Each Manufacturer (Certificate of Authorization holder) is responsible for the riveting done by its organization. Such riveting will ordinarily be done by employees of the Manufacturer, who accepts the responsibility for Code construction of the boiler or part being riveted. Alternatively, the Manufacturer may perform Code riveting using the services of individual riveters who are not in its employ provided all the conditions in PR-2.1.1 through PR-2.1.3 are met.

PR-2.1.1 All Code construction shall be the responsibility of the Manufacturer.

PR-2.1.2 The Manufacturer shall include in its quality control system, as a minimum, the following:

(a) a requirement for complete and exclusive administrative and technical supervision of all riveters by the Manufacturer

(b) evidence that the addition to the Manufacturer's quality control system required in (a) has been accepted by the Manufacturer's Authorized Inspection Agency, which provides inspection services

PR-2.1.3 The Manufacturer shall be responsible for Code compliance of the riveted boiler or component part, including stamping the Certification Mark with the appropriate designator and providing Data Report Forms properly executed and countersigned by the Authorized Inspector.

MATERIALS

PR-3 GENERAL

Materials used in riveted construction of pressure parts shall conform to one of the specifications given in Section II. Such materials shall be limited to those specifically permitted in Parts PG, PWT, and PFT and for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B, for Section I construction.

DESIGN

PR-4 GENERAL

The rules in PR-5 through PR-18 apply specifically to the design of boilers and parts thereof that are fabricated by riveting. These rules shall be used in conjunction with the general requirements for design in Part PG and with the specific requirements for design in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PR-5 STRENGTH OF PLATES

In determining the efficiency of a riveted joint, the nominal tensile strength of the material under consideration shall be used.

PR-6 STRENGTH OF RIVETS

In computing the ultimate strength of rivets in shear, the values given in PG-14 shall be used.

PR-7 CRUSHING/COMPRESSIVE STRENGTH OF PLATES (23)

The resistance to crushing (compressive strength) of material may be determined by testing in accordance with ASTM E9 of the actual material under consideration. Alternatively, the following values in psi (MPa) may be used:

(a) SA-204 all grades: 95,000 (655)

(b) SA-285, SA-515 all grades: 95,000 (655)

(c) SA-516 all grades: 95,000 (655)

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Table PR-9-1
Minimum Thickness of Buttstraps

Required Thickness of Shell Plate, in. (mm)	Minimum Thickness of Buttstraps, in. (mm)
1/4 (6)	1/4 (6)
9/32 (7)	1/4 (6)
5/16 (8)	1/4 (6)
11/32 (9)	1/4 (6)
3/8 (10)	5/16 (8)
13/32 (10.5)	5/16 (8)
7/16 (11)	3/8 (10)
15/32 (12)	3/8 (10)
1/2 (13)	7/16 (11)
17/32 (13.5)	7/16 (11)
9/16 (14)	7/16 (11)
5/8 (16)	1/2 (13)
3/4 (19)	1/2 (13)
7/8 (22)	5/8 (16)
1 (25)	11/16 (17)
1 1/8 (29)	3/4 (19)
1 1/4 (32)	7/8 (22)
1 1/2 (38)	1 (25)

PR-8 JOINT EFFICIENCY AND THE THICKNESS OF SHELLS AND DRUMS

PR-8.1 The efficiency of a joint is the ratio of the strength of the joint to the strength of the solid plate. For a riveted joint, this is determined by calculating the breaking strength of a unit section of the joint considering each possible mode of failure separately, and dividing the lowest result by the breaking strength of the solid plate of equal length of the unit section of the joint. The efficiency of the joint shall be calculated by the general method described in A-1 through A-6.

PR-8.2 The minimum thickness or maximum allowable working pressure of cylindrical shells and drums of riveted construction shall be the greater thickness or lesser pressure considering both longitudinal and circumferential stress.

PR-8.2.1 Circumferential Stress (Longitudinal Joints). The minimum thickness or maximum allowable working pressure of shells and drums shall be determined using the rules given in PG-27 or A-317 using a value of E that equals the lesser of the efficiency of the buttstrap longitudinal joint or the ligament efficiency per PG-52 or PG-53. The value of S shall be multiplied by 0.7.

PR-8.2.2 Longitudinal Stress (Circumferential Joints). The minimum thickness or maximum allowable working pressure shall be determined using the following equations:

$$t = \frac{PR}{2(0.7SE) + 0.4P}$$

$$P = \frac{2(0.7SEt)}{R - 0.4t}$$

where

E = joint efficiency (see A-1 through A-6)
P = maximum allowable working pressure, psi (MPa)
R = inside radius of the shell at the point of connection to the adjacent shell course or head, in. (mm)
S = maximum allowable stress value at the design temperature of the metal, as listed in the tables specified in PG-23, psi (MPa)
t = minimum required thickness of shell, in. (mm)

PR-9 THICKNESS OF BUTTSTRAPS

The minimum thickness of buttstraps for double-strap joints are shown in Table PR-9-1. Intermediate values shall be determined by interpolation.

PR-10 LONGITUDINAL JOINTS

The riveted longitudinal joints of a shell or drum shall be of butt- and double-strap construction. PR-10 does not apply to domes [see V-6(b)] or the portion of a boiler shell that is staybolted to the firebox sheet.

PR-11 CIRCUMFERENTIAL JOINTS

PR-11.1 The riveted circumferential joints of a shell or drum may be single- or double-riveted lap construction or butt- and double-strap construction.

PR-11.2 The total force on a circumferential joint is the cross-sectional area of the inside diameter of the shell or drum multiplied by the maximum allowable working pressure. When 50% or more of the total force is supported by the affect of tubes or through stays, the strength of the circumferential joints shall be at least 70% of that required by PR-8.2.2.

PR-12 TRANSVERSE PITCH (BACK PITCH) OF ROWS OF RIVETS

PR-12.1 For longitudinal joints, the distance between the centerlines of any two adjacent rows of rivets, or the "back pitch" measured at right angles to the direction of the joint shall have the following minimum values:

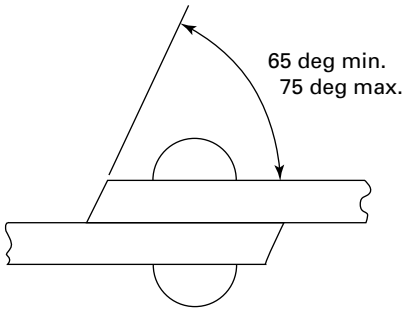
PR-12.1.1 If $p/d \le 4$, the minimum value shall be $2d$.

PR-12.1.2 If $p/d > 4$, the minimum value shall be

$$2d + 0.1(p - 4d)$$

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Figure PR-13-1
Typical Plate Edge Beveled for Sealing by Calking in a Riveted Joint



where

d = diameter of the rivet holes, in. (mm)
p = pitch of rivets in outer row where a rivet in the inner row comes midway between two rivets in the outer row, in. (mm)
= pitch of rivets in the outer row less pitch of rivets in the inner row where two rivets in the inner row come between two rivets in the outer row, in. (mm) (It is here assumed that the joints are the usual construction where rivets are symmetrically spaced.)

PR-12.2 The back pitch of rivets in circumferential joints may be less than that required in PR-12.1 provided the ligaments between the rivet holes in the direction of the joint and those rivets in the diagonal direction, as determined by the rules in PG-52 and PG-53, are sufficient to withstand all of the following:

(a) the stress due to pressure

(b) any stress due to the weight of components in support of the boiler structure

PR-12.3 The back pitch of rivets shall be measured either on the flat plate before rolling or on the median line after rolling. The location of rivet holes in the plate shall govern the locations of rivet holes in the butt-straps.

PR-12.4 The distance between any two rows of rivets in a circumferential joint or back pitch shall be not less than 1.75d.

PR-13 PREPARATION OF PLATE EDGES FOR CALKING

The plate edges to be sealed by calking shall be beveled to an angle not less than 65 deg and not more than 75 deg to the plane of the plate. Refer to Figure PR-13-1.

PR-14 EDGE DISTANCE

PR-14.1 Edge distance shall be measured from the center of the rivet holes (a line that passes through and perpendicular to the axis of the rivet holes) to the calking edge of the plate before calking.

PR-14.2 On longitudinal joints of all types and on circumferential joints of drums having heads that are not supported by tubes or through-stays, the distance from the center of a row of rivet holes to the calking edges of the plates, except rivet holes in the ends of butt-straps, shall be not less than 1.5 times and not more than 1.75 times the diameter of the rivet holes.

PR-14.3 The distance from centers of rivet holes of circumferential joints to the edges of the plate in shells or drums having heads that are supported by tubes or through-stays shall be not less than 1.25 times the diameter of the rivet holes.

PR-15 RIVETED CONNECTIONS

Attachment by riveting shall be in accordance with the requirements in PR-15.1 through PR-15.5.

PR-15.1 Openings for nozzles and other connections shall be far enough away from any riveted shell or drum joint so that the joint and the opening connection flange and/or reinforcement plates do not interfere with one another.

PR-15.2 For nozzle fittings having a bolting flange and an integral flange for riveting, the thickness of the flange attached to the boiler shall not be less than the thickness of the neck of the fitting.

PR-15.3 The allowable stress on a rivet in tension used to attach a flanged frame or ring to the outside of a shell or drum shall be as shown in Table PR-15.3-1.

PR-15.4 The total load in tension on the rivets used to attach a flanged frame or ring to a shell or drum shall be determined by the following: (23)

$$L_R = A_{CI} \text{ or } A_{CO} \times P$$

The total cross-sectional area of rivets required for the load on the rivets shall be determined by the following:

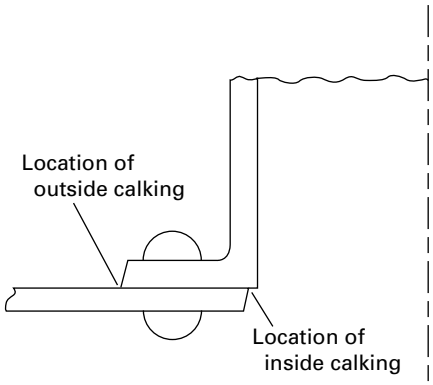
$$A = \frac{L_R}{S_R}$$

Table PR-15.3-1
Allowable Stress on Rivets in Tension

Material Specification and Grade	Allowable Stress
SA-31 Grade A	9,000 psi (62 MPa)
SA-31 Grade B	11,600 psi (80 MPa)

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Figure PR-15.4-1
Location of Seams in Inside and Outside Calking Boundaries



where

A = required cross-sectional area, in.^{2} (mm^2)
A_{CI} = area bounded by inside calking, in.^{2} (mm^2) (see Figure PR-15.4-1)
A_{CO} = area bounded by outside calking, in.^{2} (mm^2) (see Figure PR-15.4-1)
L_R = load on rivets, lbf (N)
P = maximum allowable working pressure, psi (MPa)
S_R = allowable stress from Table PR-15.3-1, psi (MPa)

PR-15.5 The rivets attaching nozzles shall be so spaced as to avoid the possibility of the shell plate or the nozzle flange failing by tearing around through the rivet holes. An example illustrating the method of calculating is given in A-75.

PR-16 REINFORCEMENT OF OPENINGS

The area of reinforcement shall be designed in accordance with the requirements of PG-32 through PG-39.

PR-17 REINFORCING SHELLS OF WATERTUBE BOILERS

Plates used to reinforce the tube openings in the shells of water tube boilers shall meet the requirements of PR-17.1 through PR-17.4. Reinforcing plates shall be protected from the fire and products of combustion.

PR-17.1 Reinforcement plates may be attached to the inside, outside, or both sides of the shell. In all cases, the tubes shall be rolled into the shell and the reinforcing plate or plates so the tubes act as a staybolt.

(23) **PR-17.2** For the purpose of calculating the total load on stay tubes and rivets and laying out attachment rivets relative to the tubes, the boundary of plates used to reinforce tube openings in drums shall be defined as follows:

(a) For reinforcing plates attached to the outside or both sides of a shell [see Figure PR-17.2-1, illustration (a)], the load on rivets and tubes shall be determined by multiplying the area of the outside reinforcing plate less the area of rivet and tube holes, in square inches (square millimeters), by the maximum allowable working pressure in psi (MPa) (see PR-15.4).

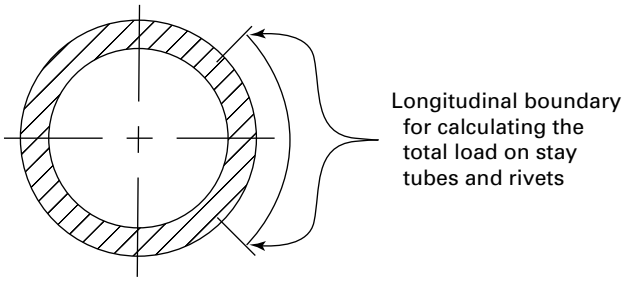
(b) For reinforcing plates attached to the inside of a shell, the load on rivets and tubes shall be determined as in Figure PR-17.2-1, illustration (b), except the boundary of the area under consideration that runs parallel to the axis of the shell shall be lines drawn radially from the longitudinal edge of the reinforcing plate to the outside surface of the shell.

PR-17.3 Reinforcing Plates and Rivets.

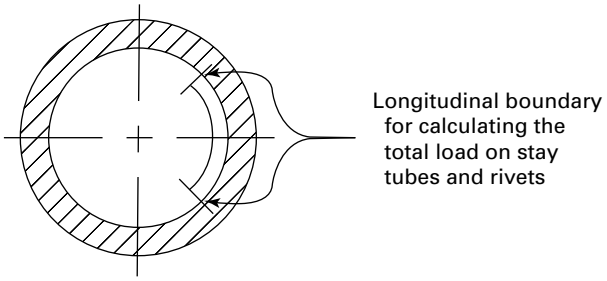
PR-17.3.1 Sections of plates used to reinforce tube openings and stayed by rivets shall meet the requirements of PG-46 using a value of 2.5 for C. The value of S shall be multiplied by 0.7.

PR-17.3.2 The minimum cross-sectional area of the rivet shall be calculated using the method in PR-15.4 using the maximum area supported by a single rivet less the area of the rivet hole for the value of A_{CI} or A_{CO}.

Figure PR-17.2-1
Boundary of Reinforcing Plate on Outside and Inside of Drum



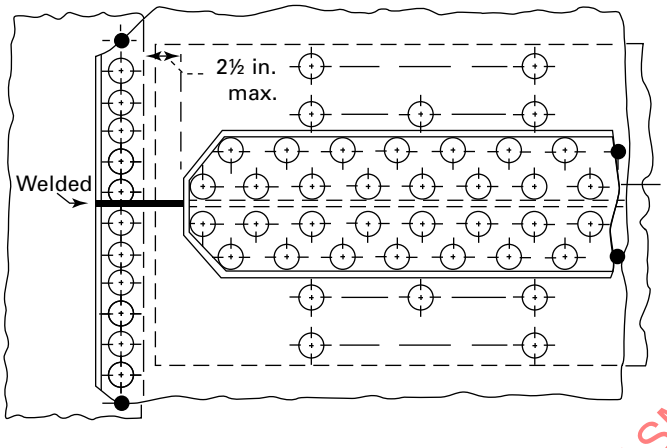
(a) Reinforcing Plate on Outside of Drum



(b) Reinforcing Plate on Inside of Drum

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Figure PR-20.2-1
Allowable Welding of Plate Edges at Ends of Buttstraps



PR-17.3.3 The maximum spacing of rivets with respect to the tubes shall meet the requirements in PFT-27.

PR-17.4 Reinforcing Plates and Tubes.

PR-17.4.1 The minimum thickness or maximum allowable working pressure of sections of plates used to reinforce tube openings and stayed by tubes shall be determined in accordance with PFT-31. The value of S shall be multiplied by 0.7.

PR-17.4.2 The minimum required cross-sectional area of the tube shall be determined in accordance with PG-49 and multiplying the allowable stress by 0.7.

FABRICATION

PR-18 GENERAL

The rules in PR-19 through PR-24 apply specifically to the fabrication of boilers and parts thereof that are fabricated by riveting. These rules shall be used in conjunction with the general requirements for fabrication in Part PG and with the specific requirements for fabrication in the applicable Parts of this Section that pertain to the type of boiler under construction.

PR-19 WELDED CONNECTIONS IN RIVETED BOILERS

PR-19.1 For boilers and components fabricated with a combination of welding and riveting, all welding requiring postweld heat treatment shall be completed and heat treated before assembly by riveting.

PR-19.2 For welds that do not require postweld heat treatment, care shall be taken so riveted joints and attachments are protected from welding, thermal cutting, and any process that generates heat that will cause a change to the physical characteristics of the riveted joint.

PR-20 BUTTSTRAPS

PR-20.1 Buttstraps shall be formed to the curvature of the shell with which they are to be used. This forming shall be accomplished by applying pressure or by rolling. Forming methods that involve strikes or blows shall not be used.

PR-20.2 The ends of inner buttstraps of riveted buttstrap longitudinal joints may be welded to the edges of heads or of the adjoining shell plate or to circumferential buttstraps for tightness in accordance with the requirements of Part PW. When a buttstrap of a longitudinal joint does not extend the full length of the shell plate, as shown in Figure PR-20.2-1, the abutting edges of the shell plate may be welded provided the distance from the end of the buttstrap to the edge of the flange or head or adjacent shell plate is not greater than 2.5 in. (65 mm).

PR-21 RIVET HOLES

PR-21.1 Finished rivet holes shall not exceed 1.065 times the actual diameter of the rivet shank at ambient temperature.

PR-21.2 All holes for rivets in plates, buttstraps, heads, stays, and lugs shall be drilled. Alternatively, they may be punched at least $\frac{1}{8}$ in. (3 mm) less than full diameter for material not over $\frac{5}{16}$ in. (8 mm) in thickness and at least $\frac{1}{4}$ in. (6 mm) less than full diameter for material over $\frac{5}{16}$ in. (8 mm). Such holes shall not be punched in material more than $\frac{5}{8}$ in. (16 mm) in thickness.

PR-21.3 For final drilling or reaming of the rivet hole to full diameter, the parts shall be firmly bolted in position by tack bolts.

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PR-21.4 The finished holes shall be true, cleaned of burrs, and concentric.

PR-22 ASSEMBLY OF JOINTS

After drilling or reaming rivet holes, the plates and butt-straps of longitudinal joints shall be separated, the burrs and chips shall be removed, and the plates reassembled metal-to-metal with barrel pins fitting the holes and with tack bolts.

PR-23 RIVETING

PR-23.1 Rivets shall be of sufficient length to fill the rivet holes completely and form heads at least equal in strength to the bodies of the rivets. Some forms of finished rivet heads that are acceptable are shown in ASME B18.1.2.

PR-23.2 Rivet snaps used on the factory head of the rivet shall have less volume than the head. They shall first make contact with the center of the head and then form outward.

PR-23.3 Before driving, rivets shall be heated to a temperature between 1,800°F (980°C) and 2,250°F (1,230°C). Forming of the rivet shall be completed above 1,350°F (730°C). Complete filling of the hole and forming of the head shall be achieved in a single operation.

PR-23.4 Barrel pins shall be used to align finished rivet holes. Tack bolts shall be used in all rivet holes to hold the plates firmly together. A single tack bolt shall be removed at a time and replaced with a rivet.

PR-23.5 To maintain even temperature throughout the joint during riveting, rivets shall be driven in an order that prevents uneven heating of the material in the rivet zone.

PR-23.6 No riveting shall be done when the temperature of the base metal is less than 70°F (20°C). The surface of all areas within 6 in. (150 mm) of the point where a rivet is to be driven should be heated to a temperature at least hot enough to prevent the rivet from cooling too rapidly during the upsetting process. No riveting shall be done when surfaces are wet or covered with ice, when snow is falling on the surfaces to be riveted, or during periods of high wind, unless the workers performing the riveting and the work are properly protected.

PR-23.7 To prevent the rivet from cooling too rapidly during the upsetting process, the tooling that comes in direct contact with the rivet should be heated before use.

PR-24 JOINT TIGHTNESS

PR-24.1 The calking edges of plates, buttstraps, and vessel heads shall have the heat-affected zone created by thermal cutting or other processes removed. Calking shall be done with a tool of such form that there is no danger of scoring or damaging the plate underneath the calking edge, or splitting the calked sheet.

PR-24.2 Prior to the hydrostatic test, a two-pass seal weld having a throat thickness not to exceed $^{3}/_{16}$ in. (5 mm) may be used on calking edges of plates, buttstraps, and vessel heads provided all the requirements of Part PW and (a) through (d) below are met. The heat from welding shall not distort the plate or loosen the rivets in such a manner as to break the initial bond affected in the riveted joint.

(a) Shell plates in circumferential-riveted lap joints may be seal welded provided the shell plates are a minimum of 1.2 times thicker than a seamless shell of the same size and material.

(b) Nozzle attachment flanges may be seal welded provided the shell plates are a minimum of 1.2 times thicker than a seamless shell of the same size and material. The nozzle attachment flange thickness must be 1.2 times greater than that required when seal welding is not applied.

(c) Unstayed dished heads may be seal welded with no increase in head thickness. Seal welding shall not be applied closer than $^{1}/_{2}$ in. (13 mm) to the point of tangency of the knuckle of the flange.

(d) The inner buttstraps in locomotive-type boilers may be seal welded with no increase in the shell or butt-strap thickness.

INSPECTION, TESTS, AND DATA REPORTS

PR-25 GENERAL

In addition to the inspections required per PG-90, an inspection shall be made of the fit up of plates in riveted joints prior to reaming the rivet holes and of the finished rivet heads that will not be visible during the hydrostatic test.

PR-26 HAMMER TEST

After the rivets in a joint have cooled to ambient temperature, a hammer test shall be conducted of each rivet by tapping one end of each rivet with a hammer. An unbroken and tensioned rivet should give a ringing sound, whereas a broken or loose rivet will give a hollow or nonresponsive sound. Broken or loose rivets shall be replaced.

PR-27 HYDROSTATIC TEST

A hydrostatic test of the completed boiler or part shall be conducted per the requirements of PG-99.

PR-28 DATA REPORTS

Boilers or parts fabricated by riveting or partially fabricated by riveting shall be documented on the appropriate type of Data Report Form as required in PG-112. The

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following information shall be recorded on a Form P-6 Data Report Supplementary Sheet and referenced in "Remarks" on the master data report:

(a) For longitudinal joints

(1) type of riveted joint (see A-2 through A-6)

(2) efficiency of joint (see PR-8)

(3) material specification, grade, and thickness of buttstraps (if used)

(4) material specification, grade, and diameter of rivets

(5) diameter and pitch of rivet holes

(b) For circumferential joints, the attachment of heads and tube sheets, and mud rings

(1) type of riveted joint, lap, butt, or mud ring

(2) efficiency of joint (see PR-8)

(3) material specification, grade, and diameter of rivets

(4) diameter, number of rows, and pitch of rivet holes

(c) For all other types of riveted joints, including, but not limited to, nozzle attachment, steam dome attachment, corner joints, and lap joints in stayed wrappers

(1) pattern of the rivets in the joint

(2) material specification, grade, and diameter of rivets

(3) diameter, number of rows, and pitch of rivet holes

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PART PB
REQUIREMENTS FOR BOILERS FABRICATED BY BRAZING

GENERAL

PB-1 GENERAL

PB-1.1 Scope. The rules in Part PB are applicable to pressure parts of boilers, including piping constructed under the provisions of this Section, that are fabricated by brazing. These rules shall be used in conjunction with the general requirements in Part PG and the specific requirements in the applicable Parts of this Section that pertain to the type of boiler under consideration. The rules in Part PB are not applicable to nonpressure bearing attachments to pressure parts that have essentially no load-carrying function (such as extended heat transfer surface, insulation support pins, etc.).

PB-1.1.1 Definition of Brazing. A group of welding processes that produces coalescence of materials by heating them to the brazing temperature in the presence of a filler metal having liquidus above 840°F (450°C) and below the solidus of the base metal. The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action.

PB-1.1.2 Brazing processes that are permitted for use under this Part are classified by method of heating as follows:

(a) torch brazing
(b) furnace brazing
(c) induction brazing
(d) resistance brazing
(e) dip brazing — salt and flux bath

PB-1.2 Elevated Temperature. Maximum design temperature is dependent on the brazing filler metal and on the base metals being joined. The maximum design temperatures for some brazing filler metals are shown in Table PB-1.

PB-1.3 Service Restrictions. Brazed components may be used for service up to the temperatures as shown in Table PB-1, provided acceptable qualification tests are performed.

PB-1.4 Responsibility. Each Manufacturer[24] (Certificate of Authorization Holder) is responsible for the brazing done by their organization and shall establish the procedures and conduct the tests required by Section IX, and when necessary those required by this Section to qualify the brazing procedures used in the construction of brazed assemblies and the performance tests of brazers[25] who apply these procedures. Such brazing will ordinarily be done by employees of the Manufacturer who accepts the responsibility for Code construction of the boiler or part being brazed. Alternatively, the Manufacturer may perform Code brazing using the services of individual brazers who are not employed by the Manufacturer provided all the following conditions are met.

PB-1.4.1 All Code construction shall be the responsibility of the Manufacturer.

PB-1.4.2 All brazing shall be performed in accordance with Manufacturer's brazing procedure specifications that have been qualified by the Manufacturer in accordance with the requirements of Section IX and when necessary, based on design temperature, with the additional requirements of this Section.

PB-1.4.3 All brazers shall be qualified by the Manufacturer in accordance with the requirements of Section IX.

PB-1.4.4 The Manufacturer's quality control system shall include the following as a minimum.

PB-1.4.4.1 A requirement for complete and exclusive administrative and technical supervision of all brazers by the Manufacturer.

PB-1.4.4.2 Evidence of the Manufacturer's authority to assign and remove brazers without involvement of any other organization.

PB-1.4.4.3 A requirement for assignment of brazer identification symbols.

PB-1.4.4.4 Evidence that this program has been accepted by the Manufacturer's Authorized Inspection Agency.

PB-1.4.5 The Manufacturer shall be responsible for Code compliance of the brazement including Code symbol stamping and providing Data Report Forms properly executed and countersigned by the Authorized Inspector.

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Table PB-1
Maximum Design Temperatures for Brazing Filler Metal

Filler Metal Classification	Temperature Below Which Section IX Tests Only Are Required, °F (°C)	Temperature Range Requiring Section IX and Additional Tests, °F (°C)
BCuP	300 (150)	300–350 (150–175)
BAg	400 (205)	400–500 (205–260)
BCuZn	400 (205)	400–500 (205–260)
BCu	400 (205)	400–650 (205–345)
BAlSi	300 (150)	300–350 (150–175)

GENERAL NOTE: Temperatures based on AWS recommendations.

MATERIALS

PB-5 GENERAL

PB-5.1 Materials used in brazed construction of pressure parts shall conform to one of the specifications given in Section II and shall be limited to those specifically permitted in Parts PG, PWT, and PFT for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B for Section I Construction, and for which brazing group P-Numbers are assigned in Section IX.

PB-5.2 Combinations of Dissimilar Metals. Combinations of dissimilar metals may be joined by brazing provided they meet the qualification requirements of Section IX and this Section.

PB-6 BRAZING FILLER METALS

The selection of the brazing filler metal for a specific application shall depend upon its suitability for the base metals being joined and the intended service. Satisfactory qualification of the brazing procedure under Section IX and when necessary based on design temperature, with the additional requirements of this Section, is considered proof of the suitability of the filler metal. Brazing with brazing filler metals other than those listed in Section II, Part C, SFA-5.8 shall be separately qualified for both procedure and performance qualification in accordance with Section IX and when necessary with the additional requirements of this Section.

PB-7 FLUXES AND ATMOSPHERES

Suitable fluxes or atmospheres or combinations of fluxes and atmospheres shall be used to prevent oxidation of the brazing filler metal and the surfaces to be joined. Satisfactory qualification of the brazing procedure under Section IX and when necessary, based on design temperature, with the additional requirements of this Section, is considered proof of the suitability of the flux and/or atmosphere.

DESIGN

PB-8 GENERAL

The rules in the following paragraphs apply to boilers and parts thereof that are fabricated by brazing and shall be used in conjunction with the general requirements for design in Part PG, as well as with the specific requirements for design in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PB-9 STRENGTH OF BRAZED JOINTS

It is the responsibility of the Manufacturer to determine from suitable tests or from experience that the specific brazing filler metal selected can produce a joint which will have adequate strength at design temperature. The strength of the brazed joint shall not be less than the strength of the base metal, or the weaker of the two base metals in the case of dissimilar metal joints.

PB-9.1 Qualification of Brazed Joints for Design Temperatures Up to the Maximum Shown in Column 1 of Table PB-1. Satisfactory qualification of the brazing procedure in accordance with Section IX is considered evidence of the adequacy of the base materials, the brazing filler metal, the flux and/or atmosphere, and other variables of the procedure.

PB-9.2 Qualification of Brazed Joints for Design Temperatures in the Range Shown in Column 2 of Table PB-1. For design temperatures in the range shown in Column 2 of Table PB-1, tests in addition to those in PB-9.1 are required. These tests shall be considered a part of the qualification procedure. For such design temperatures, two tension tests on production type joints are required, one at the design temperature and one at $1.05T$ [where T is the design temperature in degrees Fahrenheit (or degrees Celsius)]. Neither of these production-type joints shall fail in the braze metal.

PB-10 BRAZED JOINT EFFICIENCY

The joint efficiency factor to be used in design of boilers with brazed joints shall be 1 for all joints.

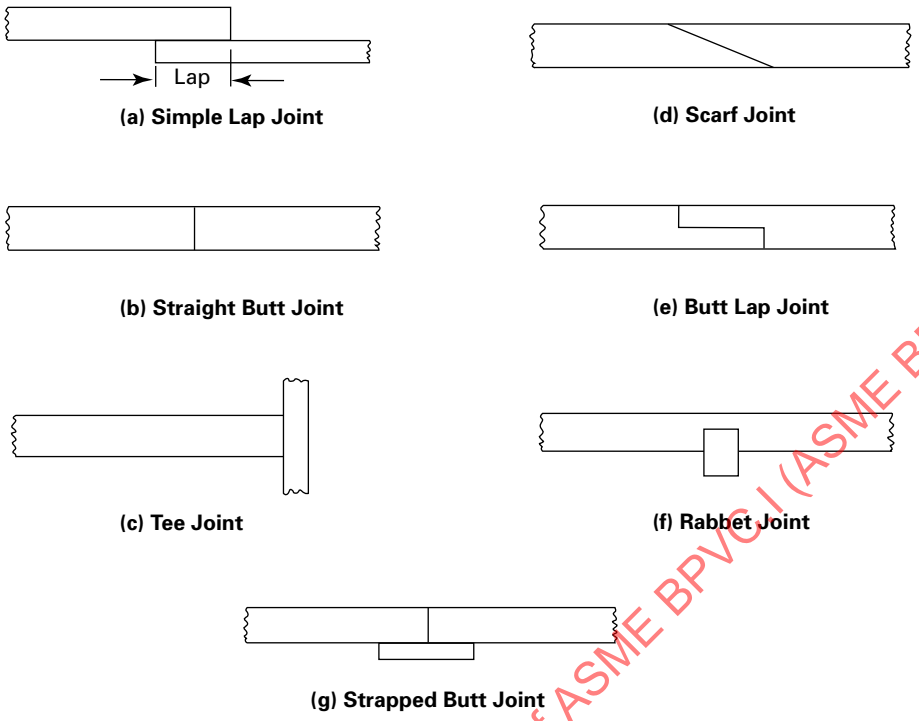
PB-14 APPLICATION OF BRAZING FILLER METAL

The design of the joint shall provide for the application of the brazing filler metal. Where practicable, the brazing filler metal shall be applied in such a manner that it will flow into the joint or be distributed across the joint and produce visible evidence that it has penetrated the joint.

PB-14.1 Manual Application. The manual application of the brazing filler metal by face-feeding to a joint should be from one side only. Visual observation of the other side of the joint will then show if the required penetration of the joint by the filler metal has been obtained.

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Figure PB-15
Some Acceptable Types of Brazed Joints



PB-14.2 Preplaced Brazing Filler Metal. The brazing filler metal may be preplaced in the form of slugs, powder, rings, strip, cladding, spraying, or other means. After brazing, the brazing filler metal should be visible on both sides of the joint.

PB-15 PERMISSIBLE TYPES OF JOINTS

Some permissible types of brazed joints are shown in Figure PB-15. Lap joints shall have a sufficient overlap to provide a higher strength in the brazed joint than in the base metal.

The nominal thickness of base material used with lap joints tested using the test fixture shown in Section IX, Figure QB-462.1(e) shall not exceed ½ in. (13 mm). There is no thickness limitation when specimens are tested without the test fixture shown in Section IX, Figure QB-462.1(e).

PB-16 JOINT CLEARANCE

The joint clearance shall be kept sufficiently small so that the filler metal will be distributed by capillary action. Since the strength of a brazed joint tends to decrease as the joint clearance is increased, the clearance for the assembly of joints in pressure vessels or parts thereof shall be within the tolerances set up by the joint design and used for the corresponding qualification specimens made in accordance with Section IX.

NOTE: For guidance, see Table PB-16, which gives recommended joint clearances at brazing temperature for varying types of brazing filler metal. Brazing alloys will exhibit maximum strength if clearances are maintained within these limits.

PB-17 JOINT BRAZING PROCEDURE

A joint brazing procedure shall be developed for each different type of joint of a brazed assembly. A recommended form for recording the brazing procedure is shown in Section IX, Form QB-482. If more than one joint occurs in a brazed assembly, the brazing sequence shall be specified on the drawing or in instructions accompanying the drawing. If welding and brazing are to be done on the same assembly, the welding shall precede the brazing unless it is determined that the heat of welding will not adversely affect the braze previously made.

PB-18 OPENINGS

PB-18.1 Openings for nozzles and other connections shall be far enough away from any main brazed joint so that the joint and the opening reinforcement plates do not interfere with one another.

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Table PB-16
Recommended Joint Clearance at Brazing Temperature

Brazing Filler Metal	Clearance [Note (1)]	
	in.	mm
BAlSi	0.006–0.010 for laps less than or equal to $\frac{1}{4}$ in.	0.15–0.25 for laps less than or equal to 6 mm
	0.010–0.025 for laps greater than $\frac{1}{4}$ in.	0.25–0.64 for laps greater than 6 mm
BCuP	0.001–0.005	0.02–0.13
BAg	0.002–0.005	0.05–0.13
BCuZn	0.002–0.005	0.05–0.13
BCu	0.000–0.002 [Note (2)]	0.000–0.05 [Note (2)]
BNi	0.001–0.005	0.02–0.13

NOTES:
(1) In the case of round or tubular members clearance on the radius is intended.
(2) For maximum strength, use the smallest possible clearance.

PB-18.2 Openings for pipe connections in boilers having brazed joints may be made by inserting pipe couplings, or similar devices not exceeding NPS 3 (DN 80) in the shell or heads and securing them by welding provided the welding is performed by welders who have been qualified under the provisions of Section IX for the welding position and type of joint used. Such attachments shall conform to the rules for welded connections PW-15 and PW-16.

PB-19 BRAZED CONNECTIONS

PB-19.1 Connections such as saddle type fittings and fittings inserted into openings formed by outward flanging of the vessel wall, in sizes not exceeding NPS 3 (DN 80), may be attached to boilers by lap joints of brazed construction. Sufficient brazing shall be provided on either side of the line through the center of the opening parallel to the longitudinal axis of the shell to develop the strength of the reinforcement through shear in the brazing.

PB-19.2 For nozzle fittings having a bolting flange and an integral flange for brazing, the thickness of the flange attached to the boiler shall not be less than the thickness of the neck of the fitting.

FABRICATION

PB-26 GENERAL

The rules in the following paragraphs apply specifically to the fabrication of boilers and parts thereof that are fabricated by brazing and shall be used in conjunction with the general requirements for fabrication in Part PG, as well as the specific requirements for fabrication in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PB-28 QUALIFICATION OF BRAZING PROCEDURE

PB-28.1 Each brazing procedure shall be recorded in detail by the Manufacturer. Each brazing procedure shall be qualified in accordance with Section IX and when necessary determined by design temperature with the additional requirements of this Section.

PB-28.2 Brazing of all test coupons shall be conducted by the Manufacturer. Testing of all test coupons shall be the responsibility of the Manufacturer. Qualification of a brazing procedure by one Manufacturer shall not qualify that procedure for any other Manufacturer, except as provided in Section IX, QG-106.1(c).

PB-29 QUALIFICATION OF BRAZERS AND BRAZING OPERATORS

PB-29.1 The brazers and brazing operators used in brazing pressure parts shall be qualified in accordance with Section IX.

The qualification test for brazing operators of machine or furnace brazing equipment shall be performed on a separate test plate prior to the start of brazing or on the first work piece.

PB-29.2 Each brazer or brazing operator shall be assigned an identifying number, letter, or symbol by the Manufacturer that shall be used to identify the work of that brazer or brazing operator.

PB-29.3 The Manufacturer shall maintain qualification records of the brazers and brazing operators showing the date and result of tests and the identification mark assigned to each. These records shall be certified by the Manufacturer by signature or some other method of control in accordance with the Manufacturer's Quality Control System and be accessible to the Inspector. Continuity records showing that the qualifications of brazers

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and brazing operators have been maintained need not be retained for more than 5 yr.

PB-29.4 Brazing of all test coupons shall be conducted by the Manufacturer. Testing of all test coupons shall be the responsibility of the Manufacturer. A performance qualification test conducted by one Manufacturer shall not qualify a brazer or brazing operator to do work for any other Manufacturer, except as provided in Section IX, QG-106.2(g).

PB-30 CLEANING OF SURFACES TO BE BRAZED

The surfaces to be brazed shall be clean and free from grease, paint, oxides, scale, and foreign matter of any kind. Any chemical or mechanical cleaning method may be used that will provide a surface suitable for brazing.

PB-31 CLEARANCE BETWEEN SURFACES TO BE BRAZED

The clearances between surfaces to be brazed shall be maintained within the tolerances provided for by the joint design and used in the qualifying procedure. If greater tolerances are to be used in production, the joint must be requalified for those greater tolerances. The control of tolerances required may be obtained by using spot welding, crimping, or other means that will not interfere with the quality of the braze. If such means are employed in production, they must also be employed in qualification of procedure, brazer, and operator.

PB-32 POSTBRAZING OPERATIONS

Brazed joints shall be thoroughly cleaned of flux residue by any suitable means after brazing and prior to visual examination.[26] Other postbrazing operations such as thermal treatments shall be performed in accordance with the qualified procedure.

PB-33 REPAIR OF DEFECTIVE BRAZING

Brazed joints that have been found to be defective may be rebrazed, where feasible, after thorough cleaning, by employing the same brazing procedure used for the original braze. If a different brazing procedure is employed, i.e., torch repair of furnace brazed parts, a repair brazing procedure shall be established and qualified.

When a repair brazing procedure is established it shall meet Section IX and other conditions set forth in this Section.

INSPECTION AND TESTS

PB-46 GENERAL

PB-46.1 The rules in the following paragraphs apply specifically to the inspection and testing of power boiler parts that are fabricated by brazing and shall be used in conjunction with the general requirements for inspection and tests in Part PG as well as the specific requirements for inspection and tests in the applicable Parts of this Section that pertain to the type of boiler under consideration.

PB-46.2 Inspection During Fabrication. The Manufacturer shall submit the boiler or other pressure part for inspection at such stages of the work as may be designated by the Inspector.

PB-47 CHECK OF BRAZING PROCEDURE

PB-47.1 Inspectors shall assure themselves that the brazing procedure for each type of joint being produced is qualified in accordance with the requirements of Section IX and when necessary the additional requirements of this Section. Inspectors shall satisfy themselves that each joint has been fabricated in accordance with the procedure. Where there is evidence of consistent poor quality, the Inspector shall have the right at any time to call for and witness tests of the brazing procedure.

PB-48 BRAZER AND BRAZING OPERATOR

PB-48.1 The Manufacturer shall certify that the brazing on a boiler or part thereof has been done by brazers or brazing operators who are qualified under the requirements of Section IX. Inspectors shall assure themselves that only qualified brazers or brazing operators have been used.

PB-48.2 The Manufacturer shall make available to the Inspector a certified copy of the record of the qualification tests of each brazer and brazing operator. The Inspector shall have the right at any time to call for and witness tests of the ability of a brazer or brazing operator.

PB-49 VISUAL EXAMINATION

PB-49.1 When possible, both sides of each brazed joint shall be visually examined after flux residue removal. It is recognized that for certain joints (blind joints) this is not possible.

PB-49.2 When visually possible there shall be evidence that the brazing filler metal has penetrated the joint. In a butt braze there shall be no concavity. The braze may be repaired or rebrazed.

PB-49.3 The presence of a crack in the brazing filler metal shall be cause for rejection. Liquid penetrant examination may be used if desired. The braze may be repaired or rebrazed (see PB-33).

PB-49.4 The presence of a crack in the base metal adjacent to a braze shall be cause for rejection even if the crack is filled with brazing alloy. Repair is not permitted.

PB-49.5 Pinholes or open defects in the braze shall be cause for rejection. The joint may be rebrazed.

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PB-49.6 Rough fillets, particularly those with a convex appearance, are cause for rejection. Such joints may be repaired or rebrazed.

PB-50 EXEMPTIONS

Certain brazed joints regardless of their service temperatures may be exempt from the additional mechanical testing of this Section providing that the design application does not assume any benefit from the brazed joint strength. It shall however meet the requirements of those qualification tests required by Section IX of the Code (see PB-1.1, Scope).

MARKING AND REPORTS

PB-51 GENERAL

The provisions for marking and reports given in PG-104 through PG-113 shall apply to brazed boilers and parts thereof.

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PART PL
REQUIREMENTS FOR LOCOMOTIVE BOILERS

INTRODUCTION

PL-1 GENERAL

The rules in Part PL are applicable to steam locomotive boilers and their parts and appurtenances. These rules shall be used in conjunction with the general requirements in Part PG, and the specific requirements in the applicable Parts of this Section that apply to the method of fabrication used.

PL-2 SCOPE

PL-2.1 All locomotive boilers of riveted construction or partial riveted construction, regardless of size and capacity (including those that would otherwise fall under the provisions of PL-2.3), shall have the riveting done in accordance with the rules of this Part and Part PR.

PL-2.2 Boiler proper limits for locomotive boilers with dome-type throttles are shown in Figure PL-2.2-1. Boiler proper limits for locomotive boilers with front-end-type throttles are shown in Figure PL-2.2-2.

PL-2.3 With the exception of the requirements for riveting in PL-2.1, the rules in this Part apply to all locomotive boilers equal to or larger than 30 in. (750 mm) in outside diameter, to be attached to steam locomotives operating on track gaged 24 in. (600 mm) and greater.

PL-3 TESTING AND STAMPING

PL-3.1 Locomotive boilers constructed without all parts within the scope of PL-2.2 shall be hydrostatically tested by blocking openings with temporary plugs or plates where appliances are not installed. A Partial Data Report, Form PL-1, shall be completed prior to stamping and releasing the boiler as a "part" to the owner/operator/jurisdiction for final assembly.

PL-3.2 Locomotive boilers constructed with all parts within the scope of PL-2.2 shall be hydrostatically tested with all parts in place except for pressure relief valves. The Manufacturer's Data Report, Form PL-1, shall be completed and the boiler stamped.

MATERIALS

PL-5 GENERAL

Materials subject to stress due to pressure used in the construction of pressure parts for locomotive-type boilers shall conform to one of the specifications given in Section II. These materials shall be limited to those for which allowable stress values for Section I construction are given in Section II, Part D, Tables 1A and 1B, except as otherwise specifically permitted or limited in this Part and Parts PG, PW, PWT, and PFT.

PL-5.1 In addition to the uses permitted in Part PG and the application notes in Section II, Part D, Table 1A, SA-675 Grades 60, 65, and 70 may be used for pressure-retaining studs and bolts.

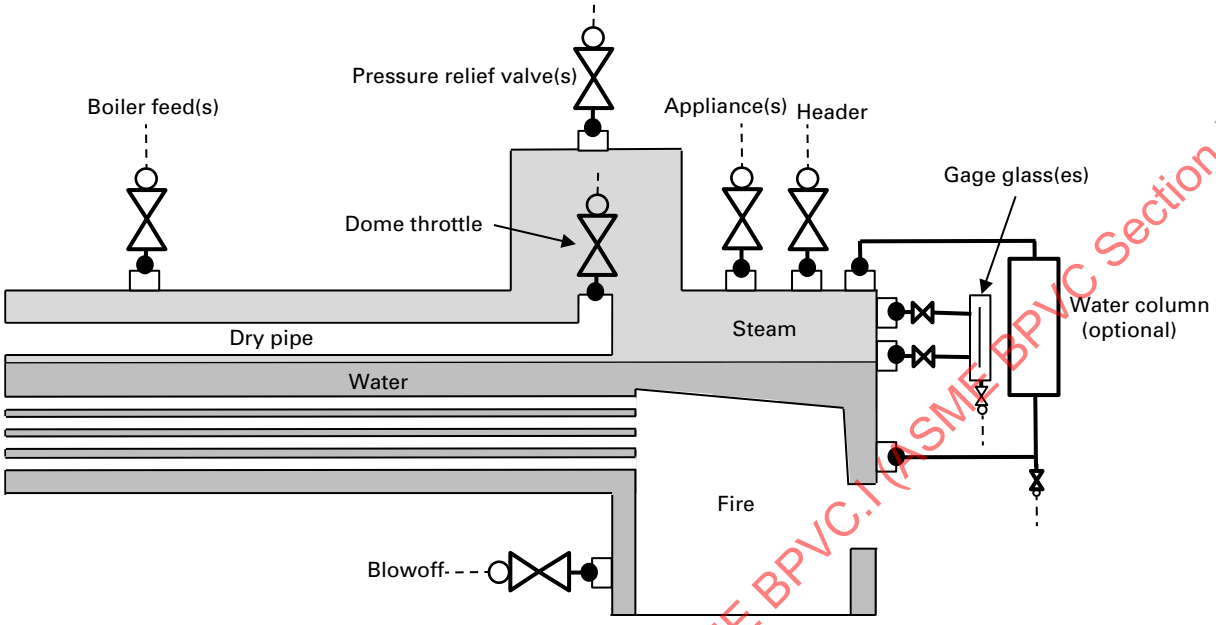
PL-5.2 In addition to the uses permitted in Part PG and the application notes in Section II, Part D, Table 1A, SA-675 and SA-696 bar stock may be used to make hollow cylindrical pressure-retaining parts. The axis of the cylindrical part shall be aligned with the axis of the bar stock, such that the material along the bar's centerline is removed in making the part.

PL-5.3 For threaded staybolts, SA-31 Grade A or SA-675 Grade 45, 50, or 55 shall be used.

PL-5.4 In addition to the uses permitted in Part PG and the application notes in Section II, Part D, Table 1A, SA-696 Grades B and C; SA-675 Grade 60, 65, or 70; SA-216 Grade WCA; and SA-217 Grade WC1 may be used for staybolt sleeves and caps.

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Figure PL-2.2-1
Steam Locomotive Boiler With Dome Throttle



Administrative Jurisdiction and Technical Responsibility

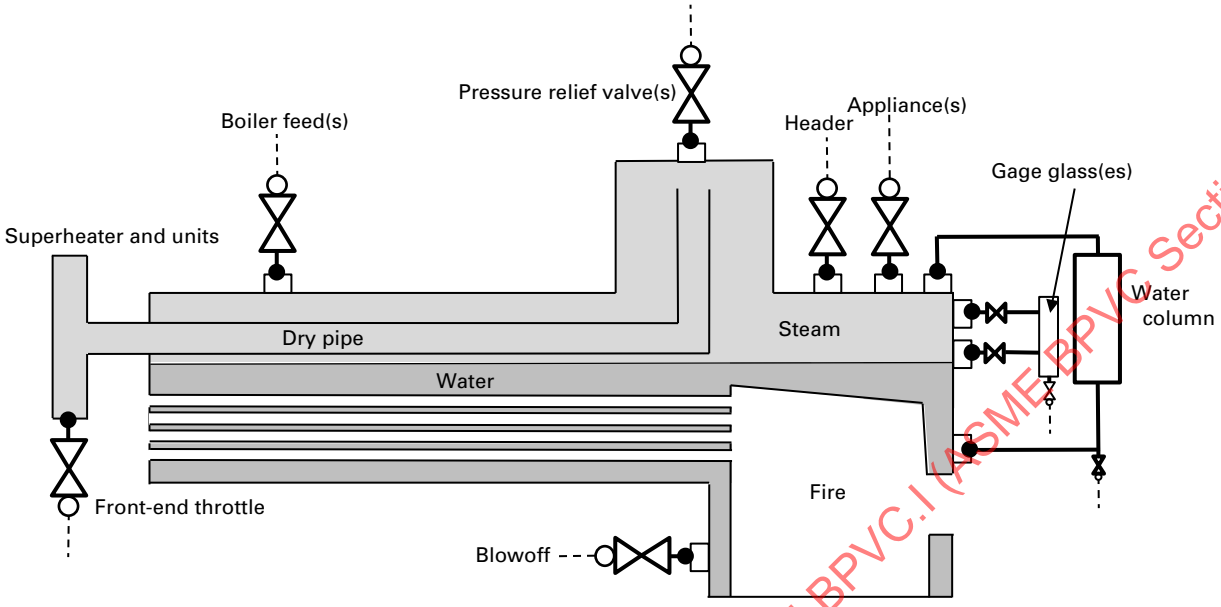
Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble).

Boiler External Piping and Joint — The ASME BPVC has total administrative jurisdiction (mandatory certification by stamping the Certification Mark with appropriate Designator, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.

Non-Boiler External Piping and Joint — Not Section I jurisdiction (see applicable ASME B31 Code).

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Figure PL-2.2-2
Steam Locomotive Boiler With Front-End Throttle



Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble).

●——— Boiler External Piping and Joint — The ASME BPVC has total administrative jurisdiction (mandatory certification by stamping the Certification Mark with appropriate Designator, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.

○- - - - - Non-Boiler External Piping and Joint — Not Section I jurisdiction (see applicable ASME B31 Code).

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PL-6 IN THE COURSE OF PREPARATION

PL-7 ALLOWABLE STRESS VALUES FOR MATERIALS

PL-7.1 Unless otherwise provided by PL-7.2, allowable material stresses shall be taken as the lesser of (a) or (b), as follows:

(a) the minimum ultimate tensile strength of the material at room temperature as required by the material specification, divided by the regulatory design margin as mandated by the applicable jurisdiction, but not less than 4

(b) the allowable stress at operating temperature as provided by Section II, Part D, Tables 1A and 1B

PL-7.2 Maximum allowable stresses of the following components shall be adhered to by designs performed in accordance with this Part:

(a) Staybolt stresses shall not exceed 7,500 psi (52 MPa). Staybolts support the firebox sheets.

(b) Brace stresses shall not exceed 9,000 psi (62 MPa). Braces shall be considered those structures other than staybolts supporting the shell plates. Diagonal stays as defined in PFT-32 shall be considered braces under Part PL.

DESIGN

(23) PL-17 GENERAL

The rules in PL-18 through PL-49 apply specifically to the design of steam locomotive boilers and parts thereof. These rules shall be used in conjunction with the general requirements for design in Part PG and with the specific requirements for design in the applicable Parts of this Section that apply to the method of fabrication used.

PL-18 CYLINDRICAL BOILER SHELL

PL-18.1 Maximum Allowable Working Pressure. Maximum allowable working pressure for cylindrical shells under internal pressure shall be determined using PG-27 or A-317. Conical shell course stresses shall be calculated at the largest diameter of the course.

PL-18.2 Riveted Joints. Except as otherwise specified in this Part, riveted joints shall conform to Part PR and its associated appendices.

PL-18.3 Welded Joints. Except as otherwise specified in this Part, welded joints shall conform to PG-26 and Part PW.

PL-18.4 Openings in Cylindrical Shell. Cylindrical shell openings (nozzles) shall be designed in accordance with PG-32 through PG-37, PW-15, PW-16, PR-15, and PR-16.

PL-20 REINFORCING AND DOUBLING PLATES ON UNSTAYED PORTIONS OF THE BOILER

PL-20.1 Reinforcing and doubling plates may be attached with the following:

(a) rivets

(b) patch bolts, with or without nuts, having threads meeting the requirements of ASME B1.1M, Class 2

NOTE: *Patch bolt* is a term recognized within the locomotive industry, owing to its origin as a repair and construction technology. Many years of successful postconstruction application have demonstrated the technology to be robust enough for new construction. Further, patch bolts may be the only feasible attachment method for certain geometries of reinforcing or doubling plates.

(c) full-penetration welded stays

(d) fillet-welded pins with a radial fit of +0.000 in. to +0.010 in. (+0.00 mm to +0.25 mm) so as to have full bearing (contact) with the holes in the plates or other attachments

(e) fillet welds

(f) a combination of the attachment methods in (a) through (e)

Studs or staybolts threaded completely through the shell and reinforcing plate may be credited as attachment points. The thickness of a riveted doubling plate when used to reinforce an opening must be at least 75% of the shell thickness, and the material must be equal to or greater in ultimate tensile strength than the shell plate. No credit for extra material strength in the doubling plate shall be taken. Riveted doubling plates should not have fasteners on the longitudinal centerline of the opening being reinforced. Doubling plates shall not be used where the doubling plate or the plate it is attached to is exposed to the direct products of combustion. See PL-27.5.

PL-20.1.1 When applying doubling plates, the plates shall be firmly drawn together by temporary fasteners or other suitable clamping means prior to application of the final fasteners.

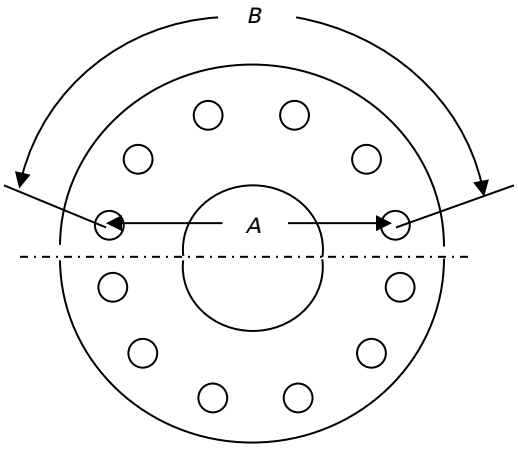
PL-20.1.2 If a patch bolt is used to clamp two or more structures together, only the structure farthest from the head of the patch bolt shall be threaded. Clearance holes shall be provided in the intervening structures. Clearance holes shall be sized as appropriate to the service intended, whether to resist tension loading, shear loading, or a combination of both types of loading.

PL-20.2 Riveted plates with outside calking shall have a total cross section of fasteners to comply with PR-15.4.

PL-20.3 Riveted reinforcing plates or doubling plates shall have enough fasteners so that the total shear strength of the fasteners equals at least 82% of the total ultimate tensile strength of the cross-sectional area of shell metal removed on the longitudinal centerline of the opening. Openings, nozzles, and reinforcement shall be designed

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Figure PL-20.4.1-1
Round Riveted Plate



in accordance with PG-32 through PG-37, PW-15, PW-16, PR-15, and PR-16.

PL-20.4 The equations in PL-20.4.1 and PL-20.4.2 apply to reinforcing or doubling plates applied to the cylindrical shell of the boiler. The efficiency calculated should be equal to or greater than the longitudinal seam efficiency of the shell course to which the reinforcing or doubling plate is attached. If the efficiency of the attachment is less than the efficiency of the seam as calculated in PR-9, the shell thickness in the area of the doubling plate shall be calculated in PG-27 using the value of E calculated for the reinforcing or doubling plate.

PL-20.4.1 The efficiency of a round riveted plate, as shown in Figure PL-20.4.1-1, shall be calculated using the following equation:

$$E = \frac{B - [nd]}{A}$$

where

A = longitudinal distance between the ends of arc B, in. (mm)
B = length of arc between extreme rivet holes in the half arc of holes completely above or below the horizontal centerline, in. (mm)
d = diameter of rivet holes, in. (mm)
E = efficiency
n = number of spaces between rivets in arc B

PL-20.4.2 The efficiency of a diamond riveted plate, as shown in Figure PL-20.4.2-1, shall be calculated using the following equation:

$$E = [(p - d)A]/p$$

where

A = factor for the angle of the patch

$$= \frac{2}{\sqrt{3 \cdot \sin^2(\text{angle}) + 1}}$$

d = diameter of rivet holes, in. (mm)
E = efficiency
p = smallest pitch of rivet in the outside angular rivet row, in. (mm)

PL-20.5 Attachment of Manhole Frames by Riveting. Manhole frames on shells or drums shall have a curvature to match the shell at the point of application before final attachment. On boilers over 48 in. (1 200 mm) in diameter, manhole frames shall be riveted to the shell or drum with two rows of rivets, which may be pitched as shown in Figure PL-20.5-1.

Attachment of nozzles and reinforcement by riveting shall meet the requirements of PR-15 and PR-16.

PL-21 REQUIREMENTS FOR DOMES OF LOCOMOTIVE BOILERS

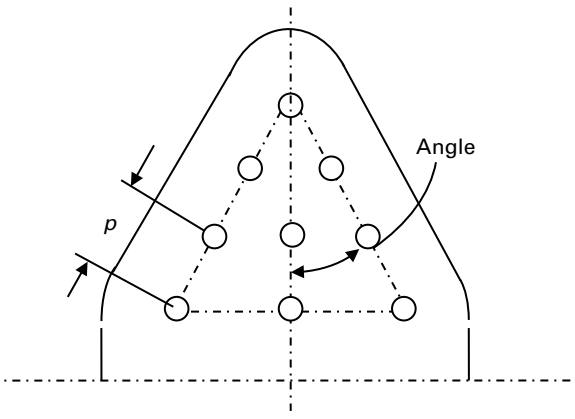
Domes of locomotive boilers shall meet the requirements of PFT-45.

PL-21.1 Domes of Welded Construction.

PL-21.1.1 Domes of welded construction shall meet the requirements of PFT-45.1.

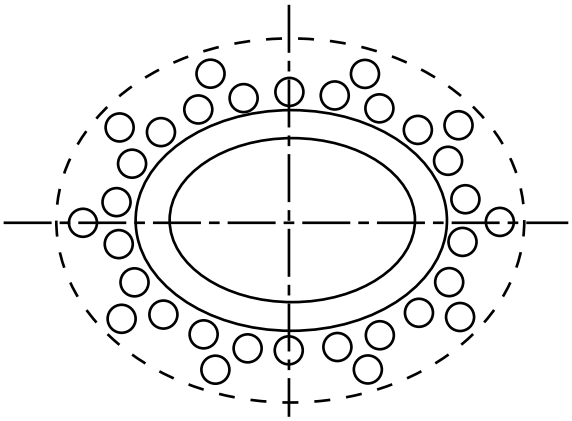
PL-21.1.2 Blind-flange dome lids for steam domes may be designed using the rules in PG-31 or ASME B16.5.

Figure PL-20.4.2-1
Diamond Riveted Plate



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Figure PL-20.5-1
Manhole Frame



PL-21.2 Domes of Riveted Construction.

PL-21.2.1 The longitudinal joint of a riveted dome 24 in. (600 mm) or larger in inside diameter shall be of butt- and double-strap construction. Alternatively, the dome may be made without a seam of one piece of steel pressed into shape; its flange shall be double-riveted to the shell.

(23) **PL-21.2.2** A dome may have a longitudinal lap-type seam, and its flange may be single-riveted to the shell, provided all the following conditions are met:

(a) The dome inside diameter is less than 24 in. (600 mm).

(b) The product of the inside diameter in inches (millimeters) and the maximum allowable working pressure in psi (MPa) does not exceed 4,000 (700 for SI Units).

(c) The maximum allowable stress used in calculating the minimum thickness or MAWP is 0.44 times the maximum allowable stress value at the design temperature of the metal, as listed in the tables specified in PG-23 (see PG-27.4.2).

PL-21.3 Dome Construction — General.

PL-21.3.1 Where a dome has a bottom flange at the attachment point to the boiler, it shall be formed with a corner radius, measured on the inside radius, of at least twice the thickness of the plate for plates 1 in. (25 mm) in thickness or less, and at least 3 times the thickness of the plate for plates over 1 in. (25 mm) in thickness, but not to exceed 8 times the thickness of the dome flange.

PL-21.3.2 Inward-facing flanges on domes with lids of the type where the dome-lid bolt circle lies outside the gasket may have through holes tapped to accept taper studs with a taper thread pitch of 11 threads per inch (per 25 mm) to 14 threads per inch (per 25 mm) and a diameter taper of $^{3}/_{4}$ in. in 12 in. (19 mm in 300 mm). Thread engagement shall be determined using the formula in PG-39.4.

PL-21.3.3 Maximum allowable working pressure for the cylindrical portion of the dome shall be determined using PG-27. In the case of a slightly tapered dome due to the forming process, the largest diameter shall be used.

PL-21.3.4 Domes and manhole frames attached to shells or heads of boilers may be riveted or welded to the shell, along with any independent reinforcing or doubling plates as needed to conform to PG-33. The thickness of each independent riveted reinforcing or doubling plate shall not be less than given in Table PL-21.3.4-1. Maximum stress in tension of rivets in manhole frames having a thickness of $^{7}/_{8}$ in. (22 mm) or less, and rivets in dome flanges, shall not exceed 7,200 psi (50 MPa).

PL-21.4 Unstayed Flat Dome Heads.

PL-21.4.1 The minimum thickness of unstayed flat dome heads with a centrally located flanged lid designed in accordance with PG-31 and PL-21.1.2 shall conform to the requirements given in this paragraph. This paragraph applies to dome heads as shown in Figure PL-21.4.1-1. In addition, the minimum flange length and minimum inside corner radius requirements of Figure PG-31, illustration (a), shall apply.

PL-21.4.2 The notations used in Figure PL-21.4.1-1 and in PL-21.4.3 are defined as follows:

A_b = cross-sectional area of the bolts using the root diameter of the thread or least diameter of unthreaded position, if less

A_m = total required cross-sectional area of the bolts, taken as the greater of A_{m1} and A_{m2}

A_{m1} = total cross-sectional area of the bolts required for the operating conditions
= W_{m1}/S_{bt}

A_{m2} = total cross-sectional area of bolts required for gasket seating
= W_{m2}/S_{ba}

B = inside diameter of opening in dome head

b = effective gasket seating width

C = bolt circle diameter (not to exceed the flat portion of the head)

$$C_1 = 0.315\left(\frac{d}{B}\right) + 0.722\left(\frac{B}{d}\right)$$

$$C_2 = 0.41\left(\frac{d}{B}\right) - 0.506\left(\frac{B}{d}\right)$$

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$$C_3 = \frac{0.3419G^3 - 0.3354Gd^2 + 0.555Gd^2 \ln\left(\frac{d}{G}\right)}{d^3}$$

$$C_4 = \frac{0.1190Gd^2 - 0.2393G^3 + 0.7215Gd^2 \ln\left(\frac{d}{G}\right)}{d^3}$$

$$C_5 = \frac{0.3419C^3 - 0.3354Cd^2 + 0.555Cd^2 \ln\left(\frac{d}{C}\right)}{d^3}$$

$$C_6 = \frac{0.1190Cd^2 - 0.2393C^3 + 0.7215Cd^2 \ln\left(\frac{d}{C}\right)}{d^3}$$

$$C_7 = \frac{G^2\left[0.0949G^2 - 0.3080d^2 \ln\left(\frac{d}{G}\right) + 0.0321d^2\right]}{d^4}$$

$$C_8 = \frac{0.0664G^4 + 0.2063d^4 - 0.2662G^2d^2 - 0.4004G^2d^2 \ln\left(\frac{d}{G}\right)}{d^4}$$

$$C_9 = C_4 - C_3\left(\frac{C_2}{C_1}\right)$$

$$C_{10} = C_6 - C_5\left(\frac{C_2}{C_1}\right)$$

$$C_{11} = C_8 - C_7\left(\frac{C_2}{C_1}\right)$$

d = inside diameter of steam dome head
G = diameter of gasket load reaction
H = cover hydrostatic end load
= $0.785G^2P$
H_p = cover gasket contact surface compression load
= $2b(3.14)GmP$
m = gasket factor
P = maximum allowable working pressure (see PG-21)
S_{ba} = bolt allowable stress at ambient temperature
S_{bt} = bolt allowable stress at design temperature
S_{ha} = head allowable stress at ambient temperature
S_{ht} = head allowable stress at design temperature
t_h = minimum required dome head thickness
W = average of the required bolt load for gasket seating and the load available from the bolt area actually used
= $S_{ba}(A_m + A_b)/2$
W_{m1} = minimum required bolt load for operating conditions
= $H + H_p$
W_{m2} = minimum required bolt load for gasket seating
= $3.14bGy$
y = gasket seating load

NOTE: Variables b, G, m, and y are as defined in Section VIII, Division 1, Mandatory Appendix 2.

PL-21.4.3 The required thickness of dome heads with bolted dome lids shall be calculated for both design conditions and gasket seating using the following equations and the greater of the two values shall be used. For design conditions, the value of P shall be the maximum allowable working pressure and S_{ht} shall be used for the allowable stress. For gasket seating, the value of S_{ha} shall be used for the allowable stress.

(a) Design Conditions

(1) Calculate moments for design conditions, as follows:

(-a) Moment due to cover gasket contact compression load

(-1) Radial

$$M_{rHp} = -0.143H_p\left(\frac{d}{G}\right)C_9$$

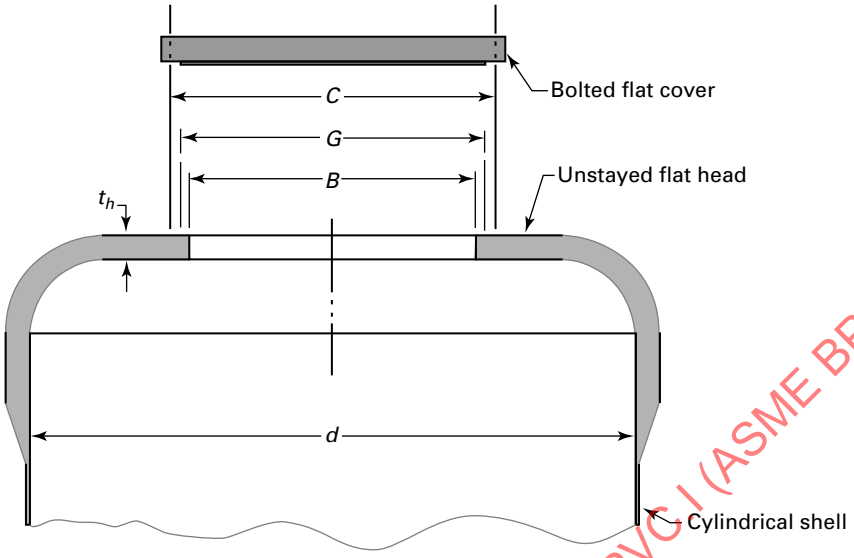
(-2) Tangential

Table PL-21.3.4-1
Thickness of Riveted Reinforcing Rings for Dome Openings

Thickness of Shell Plate, in. (mm)	Minimum Thickness of Reinforcing Ring or Flange, in. (mm)
1/4 (6) to 3/8 (10)	1/4 (6)
Over 3/8 (10) to 7/16 (11)	5/16 (8)
Over 7/16 (11) to 1/2 (13)	3/8 (10)
Over 1/2 (13) to 9/16 (14)	7/16 (11)
5/8 (16) to 3/4 (19), incl.	1/2 (13)
7/8 (22) to less than 1 (25)	5/8 (16)
1 (25) to less than 1 1/2 (38)	11/16 (17)
1 1/2 (38) to 2 (50), incl.	3/4 (19)
Over 2 (50)	1 (25)

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Figure PL-21.4.1-1
Steam Dome Top Flange



GENERAL NOTE: See PL-21.4.2 for nomenclature.

$$M_{tHp} = 0.029H_p\left(\frac{d^2}{BG}\right)\left(\frac{C_3}{C_1}\right)$$

(-b) Moment due to bolt load

(-1) *Radial*

$$M_{rW_{m1}} = 0.143W_{m1}\left(\frac{d}{C}\right)C_{10}$$

(-2) *Tangential*

$$M_{tW_{m1}} = -0.029W_{m1}\left(\frac{d^2}{BC}\right)\left(\frac{C_5}{C_1}\right)$$

(-c) Moment due to pressure load

(-1) *Radial*

$$M_{rP} = 0.203Pd^2C_{11}$$

(-2) *Tangential*

$$M_{tP} = -0.166\,P\left(\frac{d^3}{B}\right)\left(\frac{C_7}{C_1}\right)$$

(-d) Total operating moment

(-1) *Radial*

$$M_{ro} = M_{rHp} + M_{rW_{m1}} + M_{rp}$$

(-2) *Tangential*

$$M_{to} = M_{tH_P} + M_{tW_{m1}} + M_{tP}$$

(-3) *Maximum Absolute Moment.* Values for M_{ro} or M_{to} may be negative; use their absolute value in calculating M_o.

$$M_o = \text{MAX}\,(|M_{ro}|,\ |M_{to}|)$$

(2) The required thickness for design conditions is

$$t_{ho} = \left(\frac{4M_o}{S_{ht}}\right)^{0.5}$$

(b) *Gasket Seating*

(1) Calculate moments for gasket seating, as follows:

(-a) Moment due to cover gasket contact compression load

(-1) *Radial*

$$M_{rgW} = -0.143W\left(\frac{d}{G}\right)C_9$$

(-2) *Tangential*

$$M_{tgW} = 0.029W\left(\frac{d^2}{BG}\right)\left(\frac{C_3}{C_1}\right)$$

(-b) Moment due to gasket seating bolt load

(-1) *Radial*

$$M_{rbW} = 0.143W\left(\frac{d}{C}\right)C_{10}$$

(-2) *Tangential*

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$$M_{tbW} = -0.029W\left(\frac{d^2}{BG}\right)\left(\frac{C_S}{C_1}\right)$$

(-c) Total gasket seating moment

(-1) Radial

$$M_{rg} = M_{rgW} + M_{rbW}$$

(-2) Tangential

$$M_{tg} = M_{tgW} + M_{tbW}$$

(-3) Maximum Absolute Moment. Values for M_{rg} or M_{tg} may be negative; use their absolute value in calculating M_g.

$$M_g = \text{MAX}\left(\left|M_{rg}\right|, \left|M_{tg}\right|\right)$$

(2) The required thickness for gasket seating is

$$t_{hg} = \left(\frac{4M_g}{S_{ha}}\right)^{0.5}$$

(c) The required thickness of the steam dome head is the greater of t_{ho} and t_{hg}.

$$t_h = \text{MAX}\left(t_{ho}, t_{hg}\right)$$

PL-24 FLUES

PL-24.1 Maximum allowable working pressure and nominal wall thickness for flues shall be determined using Table PL-24.1-1.

PL-24.2 Except as otherwise specified in this Part, flues shall be attached per the requirements of PFT-12.2; however, flues shall not be attached by welding alone.

PL-24.3 Flue-hole diameter shall not exceed $^1/_{16}$ in. (1.5 mm) greater than the outside diameter of the flue at the swage or the full O.D., whichever is applicable. If ferrules are used, they shall have a wall thickness no greater than $^1/_{16}$ in. (1.5 mm), and the hole inside diameter shall be no greater than $^1/_{16}$ in. (1.5 mm) larger than the O.D. of the ferrule when applied to the flue. Holes shall be made round if they exceed $^1/_{32}$ in. (0.8 mm) out of round.

PL-24.4 All flues smaller than 3 in. (75 mm) O.D. shall be rolled and beaded or rolled and welded on the firebox end. At least 1 in 10 distributed evenly on the front flue sheet shall be rolled and beaded or rolled and welded. All flues 3 in. (75 mm) O.D. and larger shall be rolled and beaded or rolled and welded at both ends. All adjacent flues smaller than 3 in. (75 mm) O.D. that are within the area occupied by the larger superheater flues shall be rolled and beaded or rolled and welded at both ends. At least 1 in 10 of the remaining flues smaller than 3 in. (75 mm) O.D. shall be beaded or welded on the front flue sheet, in addition to rolling. Where less than all flues are welded or beaded on the front flue sheet, those welded or beaded shall be distributed as evenly as practicable throughout the flue pack.

PL-24.4.1 Flues shall be re-expanded upon completion of seal welding or beading, or both.

PL-24.4.2 When flues are applied by rolling and seal welding, the seal weld shall protrude beyond the sheet a distance of $^1/_8$ in. to $^1/_4$ in. (3 mm to 6 mm) inclusive [see Figure PFT-12.1, illustration (e)] and the end of the flue shall not protrude past the weld. The end of the flue shall be ground or polished to eliminate any sharp edges.

PL-24.4.3 Prior to welding, beading, or both, ensure that the flue is satisfactorily seated in the sheet. Seal welding may be done with water in the boiler, provided the water is heated to between 100°F and 120°F (38°C and 50°C).

PL-24.4.4 Some acceptable types of attachments are shown in Figure PFT-12.1, illustrations (a) through (g).

PL-24.5 Ferrous or nonferrous ferrules may be used on either or both ends of flues. When seal welding over ferrous ferrules used in straight-rolled and seal-welded flues, the weld shall attach to the sheet and not just to the ferrule. Care shall be taken to avoid contamination of seal welds when nonferrous ferrules are used.

PL-27 STAYED SURFACES

Stayed surfaces in locomotive boilers shall be defined as the back head, wrapper, roof sheet, throat sheet, mud ring, front flue sheet, combustion chamber, and firebox. The boiler shell where it is stayed to the combustion chamber shall not be considered a stayed surface. Volumetric examination of welds on stayed surfaces of P-No. 1, Group No. 1, 2, or 3 materials is not required except for welds on knuckles within the stayed surfaces where the weld on the knuckle is less than 45 deg to the longitudinal axis of the knuckle.

PL-27.1 Maximum allowable working pressure for roof sheets over the firebox and combustion chamber and above the horizontal centerline shall be determined in accordance with PFT-23.2. Staybolt stress on the top row of side-sheet staybolts as described in PL-30.3 shall be considered, and support shall be provided as necessary to maintain a maximum staybolt stress of 7,500 psi (52 MPa).

PL-27.2 Maximum allowable working pressure for flat firebox, shell, and syphon sheets shall be determined in accordance with PG-46.

PL-27.3 Maximum allowable working pressure for curved stayed sheets with pressure on the concave side shall be determined in accordance with PFT-23.1.

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Table PL-24.1-1
Maximum Allowable Working Pressure for Steel Flues for Firetube Locomotive Boilers

U.S. Customary Units

Outside Diameter of Flue, in.	Nominal Wall Thickness, in.									
	0.095	0.109	0.120	0.134	0.148	0.165	0.180	0.203	0.220	0.238
	Maximum Allowable Working Pressure, psi									
1	470	690	860	...	...	...	...	...	...	...
1.5	320	460	570	720	860	...	...	...	...	...
1.75	270	400	490	620	740	890	...	...	...	...
2	240	350	430	540	650	780	900	...	...	...
2.25	210	310	380	480	580	690	800	960	...	...
2.5	190	280	350	430	520	630	720	860	970	1,080
3	160	230	290	360	430	520	600	720	810	900
3.25	...	210	270	330	400	480	550	660	750	830
3.5	...	200	250	310	370	450	520	620	690	770
4	...	180	220	270	330	390	450	540	610	680
4.5	...	160	190	240	290	350	400	480	540	600
5	...	...	180	220	260	320	360	430	490	540
5.375	...	...	160	200	240	290	340	400	450	500
5.5	...	...	...	200	240	290	330	390	440	490
6	...	...	...	180	220	260	300	360	410	450

SI Units

Outside Diameter of Flue, mm	Nominal Wall Thickness, mm									
	2.5	2.8	3.0	3.4	3.8	4.2	4.6	5.2	5.6	6.0
	Maximum Allowable Working Pressure, MPa									
25	3.2	4.8	5.9	...	...	...	...	...	...	...
38	2.2	3.2	3.9	5.0	5.9	...	...	...	...	...
44	1.9	2.8	3.4	4.3	5.1	6.1	...	...	...	...
51	1.7	2.4	3.0	3.7	4.5	5.4	6.2	...	...	...
57	1.4	2.1	2.6	3.3	4.0	4.8	5.5	6.6	...	...
64	1.3	1.9	2.4	3.0	3.6	4.3	5.0	5.9	6.7	7.4
76	1.1	1.6	2.0	2.5	3.0	3.6	4.1	5.0	5.6	6.2
83	...	1.4	1.9	2.3	2.8	3.3	3.8	4.6	5.2	5.7
89	...	1.4	1.7	2.1	2.6	3.1	3.6	4.3	4.8	5.3
102	...	1.2	1.5	1.9	2.3	2.7	3.1	3.7	4.2	4.7
114	...	1.1	1.3	1.7	2.0	2.4	2.8	3.3	3.7	4.1
127	...	...	1.2	1.5	1.8	2.2	2.5	3.0	3.4	3.7
137	...	...	1.1	1.4	1.7	2.0	2.3	2.8	3.1	3.4
140	...	...	...	1.4	1.7	2.0	2.3	2.7	3.0	3.4
152	...	...	...	1.2	1.5	1.8	2.1	2.5	2.8	3.1

GENERAL NOTE: This Table applies to flues conforming to the material requirements of PG-9.

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PL-27.4 Maximum allowable working pressure for curved stayed sheets with pressure on the convex side shall be determined as follows:

(U.S. Customary Units)

$$P = \frac{t^2SC}{p^2} + \frac{4{,}000t}{R}$$

(SI Units)

$$P = \frac{t^2SC}{p^2} + \frac{27.6t}{R}$$

where

C = factor from PG-46 according to sheet thickness and stay attachment method
P = maximum allowable working pressure, psi (MPa)
p = maximum pitch measured between straight lines (horizontal, vertical, or inclined) passing through the centers of the staybolts in different rows, in. (mm); shall not exceed $(7.62CtR)^{0.5}$ and shall not exceed $32t$
R = radius of sheet on convex side, in. (mm)
S = maximum allowable stress, psi (MPa) (see PL-7.1)
t = sheet thickness, in. (mm)

PL-27.5 When a flat shell plate not less than $^3/_8$ in. (10 mm) in thickness is strengthened with a securely fastened doubling plate covering the full area of the stayed surface and having a thickness of not less than two-thirds that of the shell plate, then the value of t used in accordance with PL-27.2 shall be three-fourths of the combined thickness of the shell plate and doubling plate but not more than $1^1/_2$ times the thickness of the shell plate. For supporting points such as stays or braces, the applicable value of C given in PG-46.1 may be increased 15%. See PL-20.1 for doubling plates or liners used for reinforcement of openings. When applying doubling plates, the plates shall be firmly drawn together by temporary fasteners or other suitable clamping means prior to application of the final fasteners.

The following shall be considered attachment points for securing the doubling plate to the shell plate, which may or may not provide a support point (see Figure PL-27.5-1):

(a) a staybolt threaded through both plates, accounting for any additional loads on the staybolt

(b) a patch bolt threaded through one plate, as required in PL-20.1.2

(c) a staybolt through both plates attached by full-penetration welds

(d) fillet-welded pins through both plates with a pin-to-hole radial fit of +0.000 in. to +0.010 in. (+0.00 mm to +0.25 mm) so as to have full bearing (contact) with the holes in the plates or other attachments

(e) fillet welds wherever used to attach the doubling plate to the flat shell plate

The maximum pitch between attachment points securing the doubling plate to the shell plate shall be determined using the equation in PG-46.1 using the following values for C and the thickness of the shell plate alone:

C = 2.1 for doubling plates attached by threaded staybolts only, patch bolts only, fillet-welded pins only, or a combination of thereof
= 2.2 for doubling plates attached by a combination of threaded staybolts and rivets, fillet-welded pins and rivets, or patch bolts and rivets, provided that at least half the attachment points are rivets, and the perimeter may or may not be fillet welded
= 2.5 for doubling plates attached by rivets only

If such a doubling plate is applied by continuous or intermittent fillet welds with the two plates held together with welded stays meeting the requirements for stayed surfaces, the value of C shall be 2.8. The maximum pitch limitation of $8^1/_2$ in. (216 mm) in PG-46.5 shall not apply, but in no case shall the pitch exceed 15 times the stay diameter.

Cross-sectional tension stress on attachment points, calculated as if the working pressure is attempting to separate the plates, shall not exceed 0.25 of the ultimate tensile strength, as given in Section II, Part D, of the rivets, stays, pins, or patch bolts. Stress shall be calculated in accordance with PFT-26. Cross-sectional tension stress taken at the throat of a fillet weld shall not exceed 0.25 of the ultimate tensile strength of the shell plate, as given in Section II, Part D.

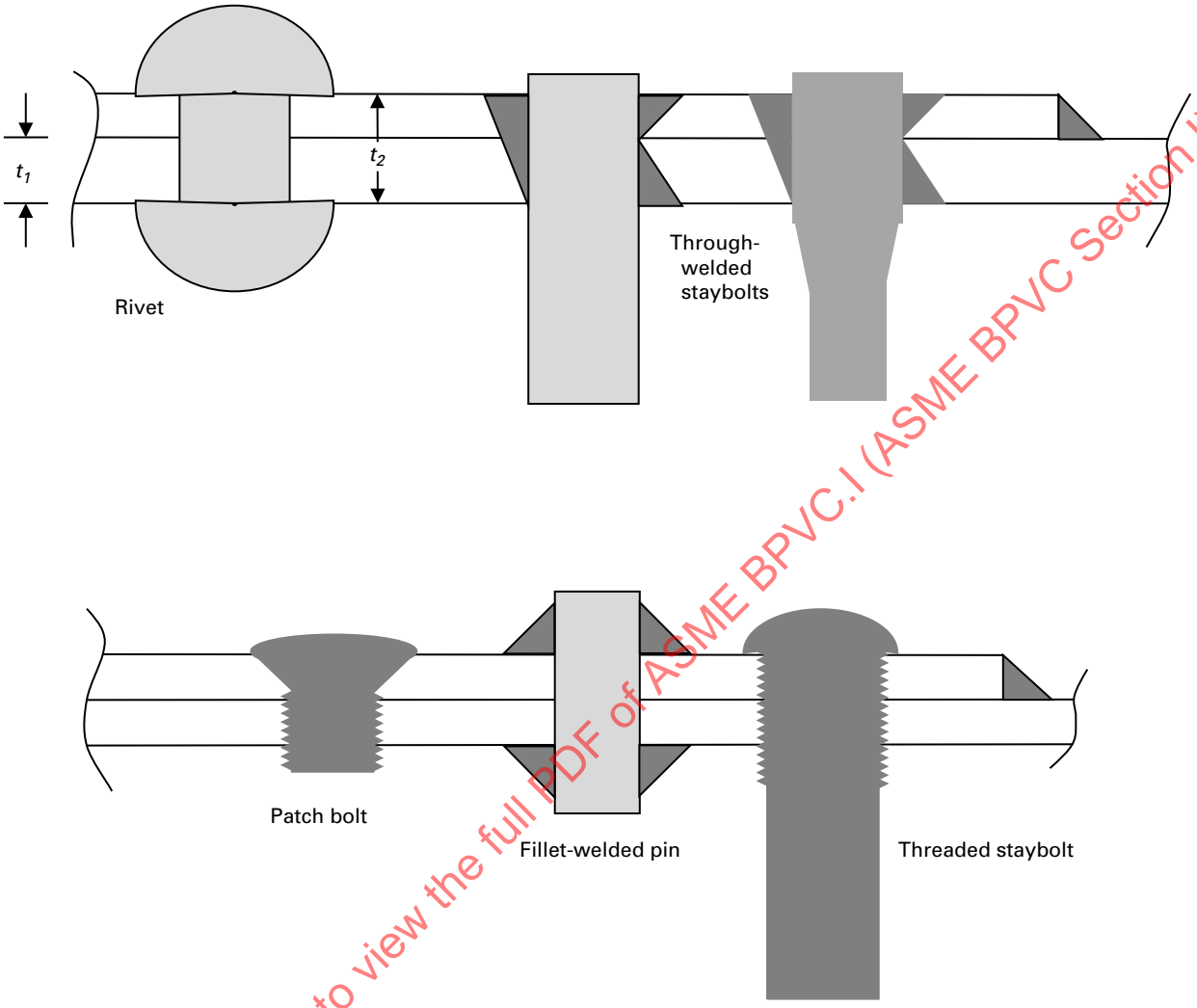
CAUTION: Doubling plates shall not be used on any stayed plate that is exposed to the direct products of combustion.

PL-27.6 Lap seams in stayed areas may be considered as doubling plates. The reinforced area shall be defined by the perimeter drawn through the centerline of the outside fasteners of the seam. The rules in PL-27.5 apply to the doubled area. The value allowed for the combined thickness, t_d, of the two plates shall not exceed $1^1/_2$ times the thickness of the thicker plate. To determine the effective plate thickness to be used in calculating the pitch between extreme support points using PG-46, the proportionate lengths between support points of the doubled thickness and the unreinforced plate thickness shall be averaged in proportion to their respective lengths.

PL-27.6.1 Fillet-welded lap seams where both edges are welded may be used where the welds are not exposed to the products of combustion. Weep holes shall be provided at a distance of no more than 36 in. (900 mm) along the longitudinal centerline of the seam in the external sheet. Weep holes shall be at least $^1/_8$ in. (3 mm) in diameter.

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Figure PL-27.5-1
Examples of Doubler Attachment Methods



GENERAL NOTES:

(a) The C value (see PL-27.4) shall be as follows:

C = 2.1 when using a combination of fillet-welded pins, patch bolts, and threaded staybolts
= 2.2 when using a combination of rivets and fillet-welded pins, patch bolts, or threaded staybolts on at least half of the attachment points
= 2.5 when using rivets only
= 2.8 when using continuous or intermittent fillet welds, stay welded through both sheets

(b) The t value shall be as follows:

t = value of combined thickness used in equation
= $0.75t_2$ but no more than $1.5t_1$, provided $t_1 \geq 0.375$ in. (9.5 mm)

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PL-27.6.2 Single- or double-riveted lap seams may be used within any stayed area. No credit for reinforcement shall be taken for a single-riveted lap seam.

PL-27.6.3 To determine the effective thickness of the plate between two support points where a lap seam is present, refer to Figures PL-27.6.3-1 and PL-27.6.3-2. The following equation shall be used:

$$T_e = \frac{L_1 t}{L} + \frac{L_2 t_d}{L} + \frac{L_3 t_1}{L}$$

where

L = overall pitch, in. (mm)
L_1 = pitch between support points on one side of lap seam, in. (mm)
L_2 = pitch between support points on lap seam, in. (mm)
L_3 = pitch between support points on other side of lap seam, in. (mm)
t = actual thickness of first plate, in. (mm)
t_1 = actual thickness of second plate, in. (mm)
t_d = allowed combined thickness of both plates
= 1.5 times thickness of thicker plate maximum, in. (mm)
T_e = effective thickness of plate between support points defined by length L, in. (mm)

Figure PL-27.6.3-1
Double-Riveted Lap Seam in Stayed Area

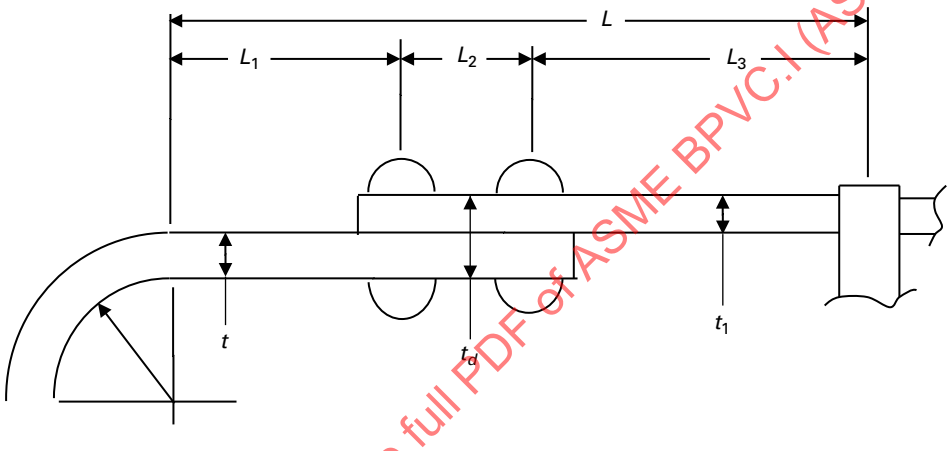
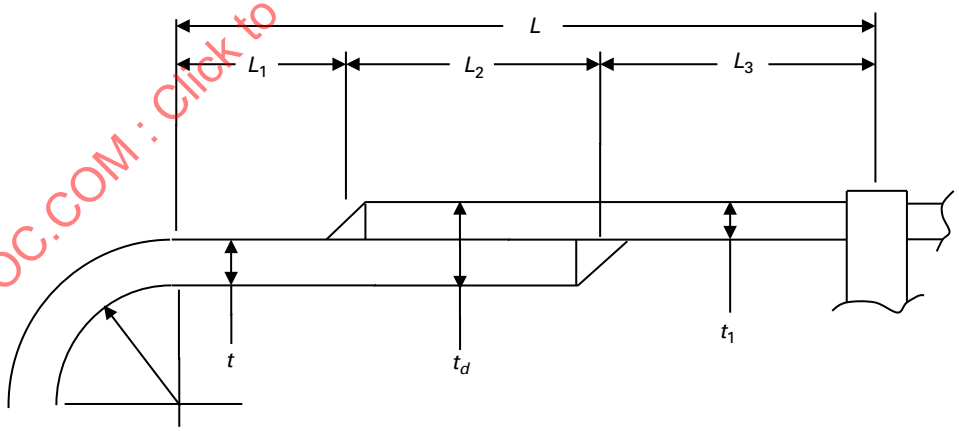
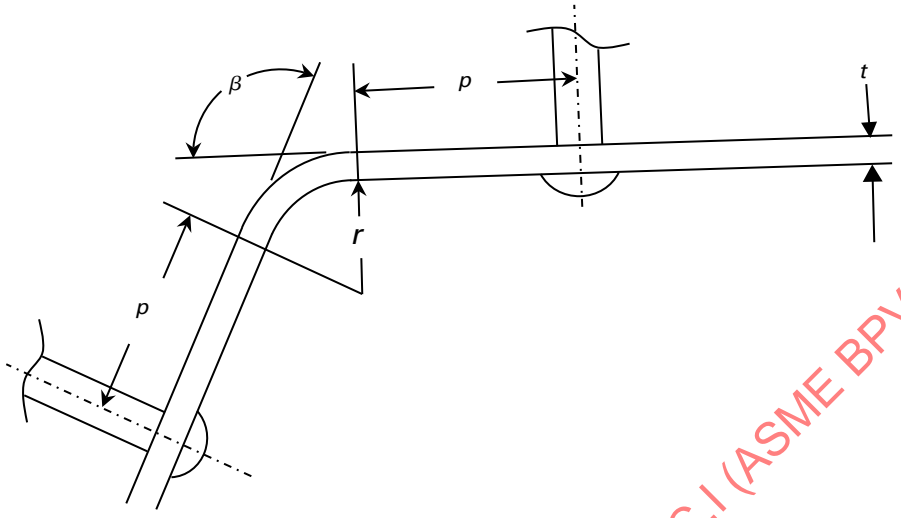


Figure PL-27.6.3-2
Double-Fillet-Welded Lap Seam in Stayed Area



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Figure PL-27.7-1
Upper Corner of Firebox



GENERAL NOTE: Max. $r = p$ as calculated by PG-46; min. $r = 3t$. If r exceeds the maximum, the curved plate shall be calculated as a flat plate in accordance with PG-46.

PL-27.7 For stays at the upper corners of fireboxes, the pitch from the staybolt next to the corner to the point of tangency to the corner curve shall be given by the following equation (see Figure PL-27.7-1):

$$p = \left(\frac{90}{\beta}\right)\sqrt{C\frac{t^2 S}{P}}$$

where

C = factor for the thickness of plate and type of stay used as required in PG-46
P = maximum allowable working pressure, psi (MPa)
p = maximum allowable pitch, in. (mm)
S = maximum allowable stress, psi (MPa), given in PL-7.1
t = thickness of plate, in. (mm)
β = angle, deg, between 90 deg and 180 deg, inclusive

PL-28 MUDRING (FIREBOX FOUNDATION RING)

The requirements of PL-28 shall be used for mudring construction not covered by other Parts of this Code. Firebox mudrings may be made of one-piece shapes or weldments. Welding shall be in accordance with Part PW.

PL-28.1 Proportions. Firebox mudrings shall be proportioned such that the width of the ring is equal to or greater than the minimum required width of the firebox water legs. The height of the ring shall be sufficient to accommodate the fastening system used to attach the side sheets. The height of the ring shall be sufficient for the design pressure, and the maximum width is determined by the desired water leg width or PG-46, whichever is less.

PL-28.2 Connection Design. Figure PL-28.2-1 shows some acceptable means of attaching the mudring to side sheet. Exterior boiler sheets shall extend to the bottom of the firebox mudring minus the distance to allow either a fillet weld or calking edge (see Figure PL-28.2-1). The interior and exterior firebox sheets shall be connected to the mudring with sufficient fasteners to resist the applied shearing forces and bending moments. Where fillet-welded pins are used, the cross-sectional area of the weld in shear around the circumference of the pin shall be at least 1.25 times the cross-sectional area of the pin.

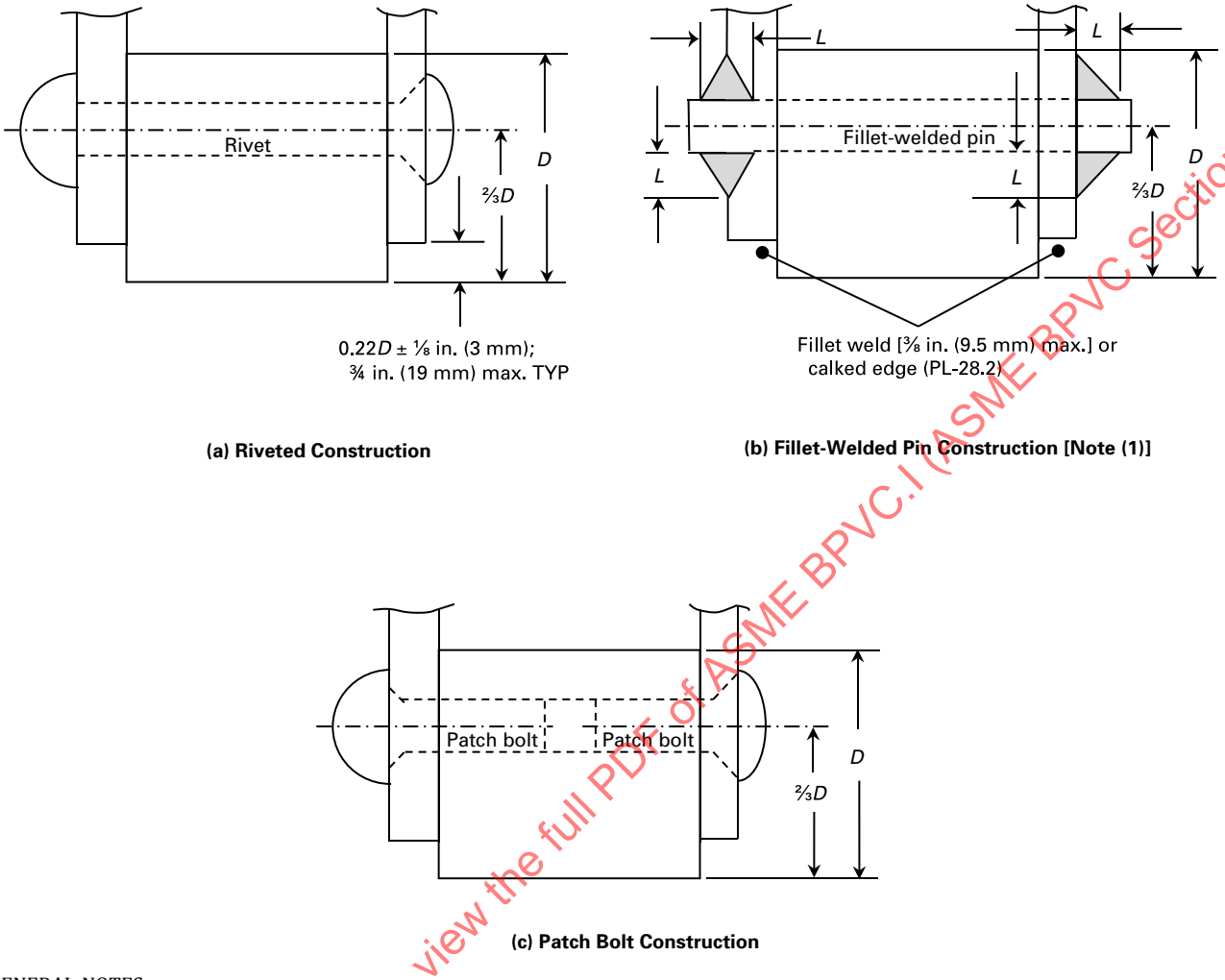
PL-28.3 Supports. Boiler supports, whether attached to the wrapper or the mudring, shall accommodate boiler expansion without introducing additional stress.

PL-28.4 Corners. If flanged corners are used for the firebox, the minimum inside and outside radii of the mudring shall be as shown in Table PL-28.4-1.

PL-28.5 Washout Plugs. Washout plugs shall be provided at various points above the mudring to allow the removal of sediments. The plugs shall be positioned such that minimal material can collect behind the plug during washing of the boiler. The plugs shall be of large enough diameter to allow foreign material, such as staybolts, to be removed, but not less than NPS 1½ in. (DN 40).

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Figure PL-28.2-1
Some Examples of Acceptable Mudring Construction



(a) Riveted Construction

(b) Fillet-Welded Pin Construction [Note (1)]

(c) Patch Bolt Construction

GENERAL NOTES:
(a) Mudrings may be attached by welding. See Figures PG-31 and PFT-21.
(b) D = height of mudring

NOTE: (1) L = fillet weld dimensions = $^{3}/_{8}$ in. (10 mm) min.

PL-30 STAYBOLTS

Staybolts shall be considered all round attachment bars of any length between the firebox and the shell that are used to support the firebox and flat areas of the shell. Throat braces attached to the lower portion of the boiler barrel and the throat sheet shall be considered braces.

PL-30.1 Staybolts shall be fabricated and installed in accordance with PG-47, PFT-28.2, PFT-28.3, and PFT-29, except that staybolts attached by welding shall have telltale holes conforming to PG-47.1. Full-penetration-welded staybolts shall be postweld heat treated in accordance with PW-39 after installation.

PL-30.2 Staybolt stress shall not exceed 7,500 psi (52 MPa) at the smallest cross-sectional area of the staybolt.

PL-30.3 Location, area supported, and spacing of staybolts shall be in accordance with PG-48, PG-49, PFT-23, PFT-25, PFT-26, PFT-27, and PL-27, except that the maximum staybolt stress allowed shall be 7,500 psi (52 MPa).

When 7,500 psi (52 MPa) is used as the allowable stress value in PG-49 to calculate the required area of a staybolt, the results are not required to be multiplied by 1.1.

PL-30.4 Staybolts may be attached by fillet welds provided the following conditions are met.

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Table PL-28.4-1
Radii for Firebox Mudrings

Mudring Width, in. (mm)	Minimum Inside Radius, in. (mm)	Maximum Outside Radius
Less than 4 (100)	1½ (38)	Inside radius plus larger mudring width at corner considered
4 (100) to less than 6 (150)	2½ (64)	Inside radius plus larger mudring width at corner considered
6 (150) or greater	3 (75)	Inside radius plus larger mudring width at corner considered

PL-30.4.1 The stress value for the smallest cross sectional area shall not exceed 7,500 psi (50 MPa).

PL-30.4.2 The weld leg length parallel to the longitudinal axis shall be greater than or equal to ¼ in. (6.5 mm). The weld shear area parallel to the longitudinal axis shall be no less than 1.25 times the minimum cross sectional area of the staybolt (minus the cross-sectional area of the telltale hole) as determined by the following equation (see Figure PL-30.4.2-1):

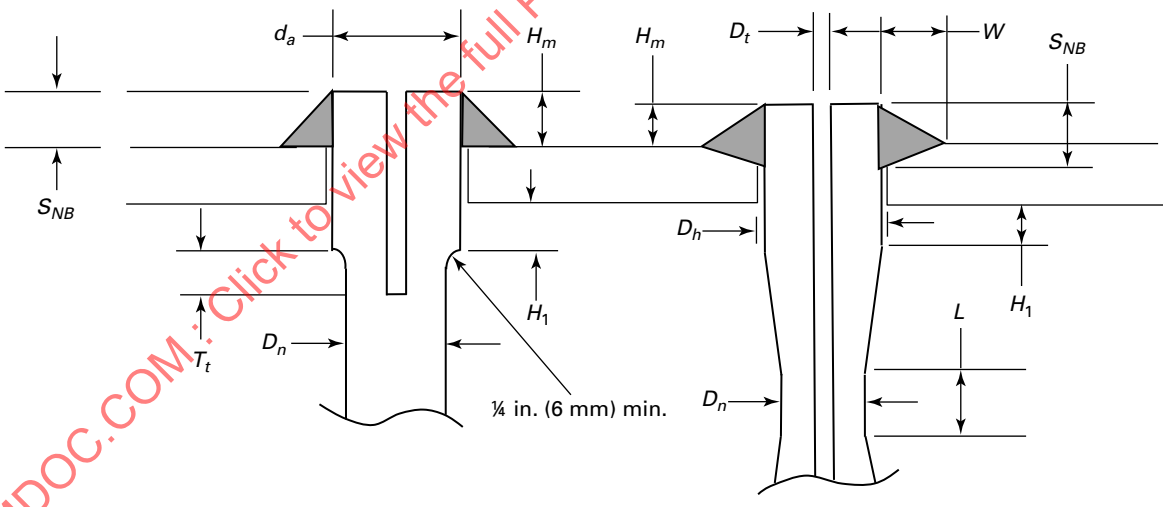
$$d_a \times \pi \times S_{NB} \geq 1.25 \times A_\sigma$$

PL-30.4.3 Staybolt ends directly exposed to the products of combustion shall extend past the fireside of the sheet no more than ⅜ in. (10 mm).

PL-30.4.4 The hole through which the staybolt is inserted shall be 1/32 in. to 1/16 in. (0.8 mm to 1.5 mm) larger than staybolt head diameter. The finished holes shall be true, cleaned of burrs, and nominally coaxial. The staybolt shall be nominally centered in the hole.

PL-30.4.5 Fillet-welded staybolts may be straight cylindrical bars or have a reduced body between the water sides of the sheets. If reduced body fillet-welded staybolts are used, the dimensions in Table PL-30.4.5-1 shall be used. The reduced section may be cylindrical, tapered, or in the form of a radius with the smallest cross sectional area being nominally centered between the water sides of each sheet. If the reduced section consists of two tapered sections and a cylindrical

Figure PL-30.4.2-1
Fillet-Welded Staybolts



Legend:
A_σ = minimum cross-sectional area of staybolt (minus the cross-sectional area of the telltale hole)
d_a = nominal bolt diameter on ends of staybolt, maximum 1⅜ in. (35 mm)
D_h = hole diameter, 1/32 in. to 1/16 in. (0.8 mm to 1.5 mm) inclusive, larger than d_a
D_n = smallest diameter of reduced shank of staybolt
D_t = diameter of telltale hole
H_1 = ⅛ in. to ½ in. (3 mm to 13 mm) inclusive
H_m = maximum height of staybolt on fireside = ⅜ in. (10 mm)
L = reduced section, nominally centered, no less than ½ in. (13 mm) long
S_{NB} = the weld leg length parallel to the longitudinal axis, minimum = ¼ in. (6.5 mm), maximum = ⅜ in. (10 mm) (see PL-30.4.2)
T_t = ½ in. (13 mm) minimum
W = weld leg width on sheet, minimum = ⅜ in. (10 mm)

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Table PL-30.4.5-1
Fillet-Welded Staybolt: Examples of Nominal Dimensions Permitted ±0.02 in. (±0.5 mm)

Minimum Bolt Diameter at Ends, d_a, in. (mm)	Maximum Bolt Diameter at Ends, d_a, in. (mm)	Bolt Diameter at Reduced Section, D_n, in. (mm)	Minimum Weld Leg, S_{NB}, in. (mm)
0.897 (23)	1.100 (28)	0.709 (18)	0.250 (6.5)
0.938 (24)	1.125 (29)	0.750 (19)	0.250 (6.5)
1.000 (25)	1.200 (31)	0.813 (21)	0.250 (6.5)
1.063 (27)	1.260 (32)	0.875 (22)	0.250 (6.5)
1.125 (29)	1.330 (34)	0.938 (24)	0.250 (6.5)
1.220 (31)	1.375 (35)	1.000 (25)	0.250 (6.5)

section at the center, the cylindrical section shall be no less than ½ in. (13 mm) long.

PL-30.4.6 Fillet-welded stays shall use the same factor C in PG-46 as threaded staybolts.

PL-30.4.7 Welding shall be performed using a method where localized heat input is minimized in order to produce the least distortion practical in the sheets.

PL-30.4.8 PWHT is not required for fillet-welded stays of P-No. 1, Group 1, 2, or 3 materials.

PL-30.4.9 Volumetric examination is not required for fillet-welded stays of P-No. 1, Group 1, 2, or 3 materials.

PL-30.4.10 In staybolts less than 8 in. (200 mm), telltale holes at least 3/16 in. (5 mm) shall be drilled in each end of the staybolt to a depth not less 1¼ in. (32 mm) or ½ in. (13 mm) beyond the inside of the plate or where the reduced section begins for cylindrical reduced sections, whichever is greater. For tapered reduced sections and reduced sections profiled to a radius, telltale holes shall be drilled the full length of the staybolt.

PL-33 CROWN BARS

Crown bars shall be designed in accordance with PFT-30. Crown bars shall stand clear of crown sheet by no less than 1½ in. (38 mm). See Figure PL-33-1.

PL-36 BRACES

For steam locomotive boilers, braces shall be defined as follows:

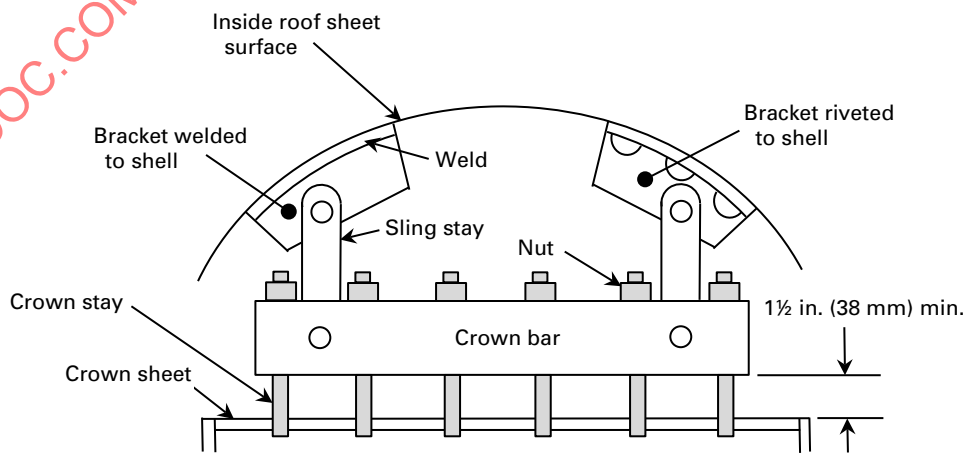
back-head and flue-sheet braces: structural supports for the back head and flue sheets, with one attachment point on the shell of the boiler and the other end attached to the back head or flue sheet.

throat braces: typically attached to the rear flue sheet of the firebox and the inside surface of the boiler shell to support the rear flue sheet between flues and the highest row of staybolts on the throat sheet.

through-braces: braces that support two opposing heads or vertical sides of the shell.

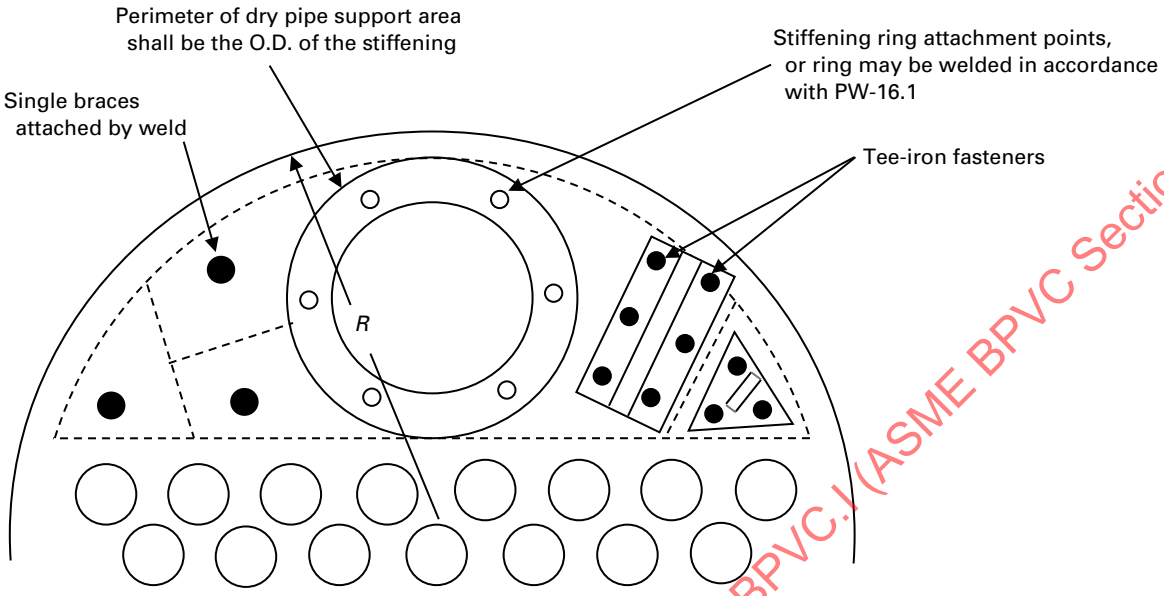
PL-36.1 Braces may be diagonal or perpendicular and may be attached by welding, rivets, crowfoot brace and pins, or any combination thereof. Braces attached by welding shall meet the requirements of PW-19 and PFT-32. Gusset braces consisting of a flat plate either as a full triangle or a truncated triangle on a diagonal may be attached by welding, rivets, patch bolts (with nuts when in tension), bolts, or any combination thereof. Tee irons spanning an area needing support may be used in lieu of braces, provided the support

Figure PL-33-1
Example of Crown Bar Installation



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Figure PL-36.2.1-1
Support Perimeters



Legend:
R = inside radius of shell

structures at the ends of the tee-iron span are not stressed beyond what is allowed by this Section.

CAUTION: While patch bolts may be used, they should be used only when other means of attachment are not possible or practical, or where it can be shown that patch-bolt attachment is superior.

PL-36.2 Front Flue-Sheet Supports.

PL-36.2.1 Area supported by the dry pipe and dry-pipe reinforcing ring shall be determined in accordance with PL-36.2.2, and deducted from the area needing support as defined in this Part. See Figure PL-36.2.1-1.

PL-36.2.2 The area supported by the stiffening ring shall be considered self-supporting provided that the stiffening ring is thick enough for the span considered as calculated in PG-46 for a solid plate equal in thickness to the stiffening ring, and that the stiffening ring attachment locations to the flue sheet comply with the requirements in PL-36.1. The minimum thickness of the stiffening ring should also accommodate the thickness required for the superheater header or Y-pipe mounting studs. See Figure PL-36.2.1-1.

PL-36.2.3 Flue-sheet attachment to the shell shall be in accordance with PR-11 or PFT-11.

PL-36.3 The spacing of support locations, braces, rivets, or patch bolts shall be determined in accordance with PG-48, PFT-25, PFT-26, and PFT-27, except that the maximum stress allowed shall be 9,000 psi (62 MPa).

PL-36.4 Patch bolts may be used to fasten tee irons and other brackets to which braces are attached and these patch bolts shall have nuts applied.

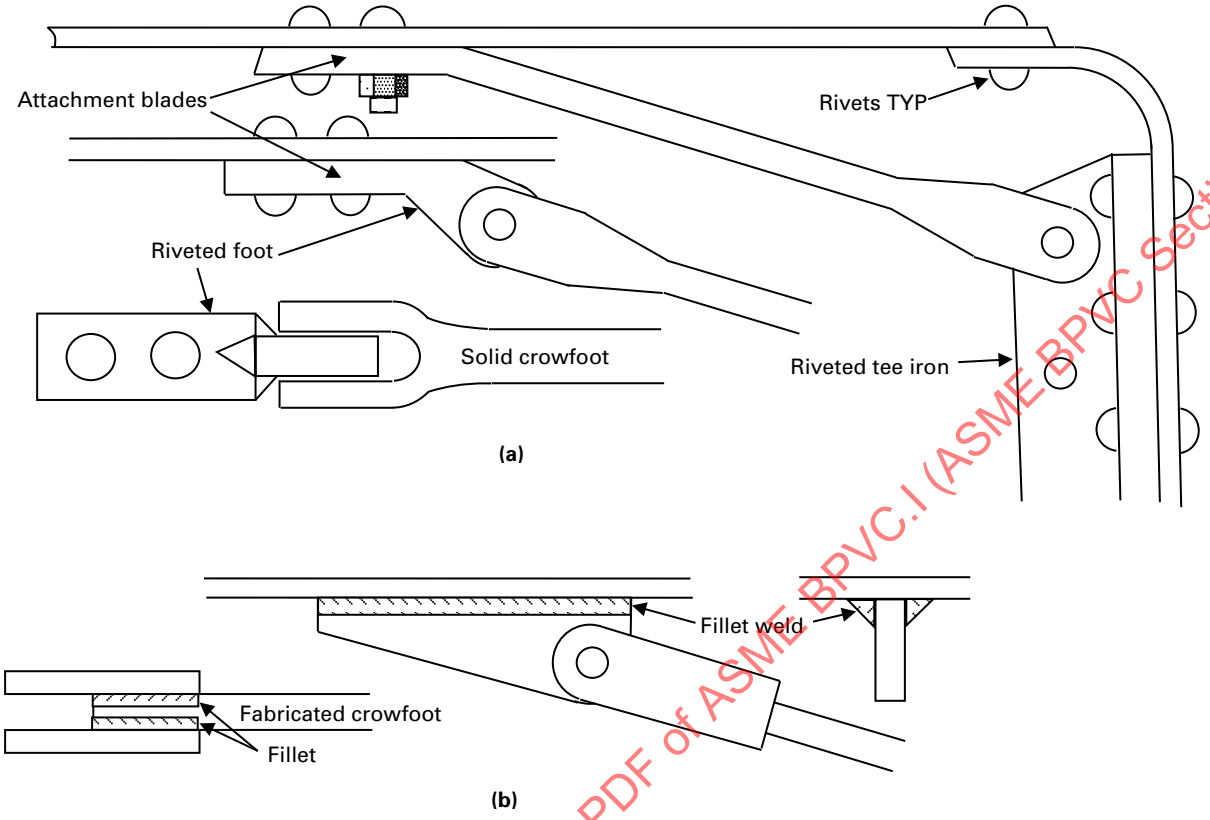
PL-36.5 Stresses in diagonal braces (see Figure PL-36.5-1) shall be calculated in accordance with PFT-32, except that the maximum brace stress allowed shall be 9,000 psi (62 MPa). Stress for each brace shall be calculated individually for the area supported by that brace. Stresses in braces attached to a common tee iron that are symmetrically spaced on the tee iron may be calculated by taking the total load on the tee iron and dividing by the number of braces attached to that tee iron.

PL-36.6 Braces attached to tee irons, brackets, crowfeet, or similar construction where the braces are either pinned or integral with structures attached directly to the supported plate shall be in accordance with PL-36.6.1 through PL-36.6.12.

PL-36.6.1 The feet for braces to back head and front flue sheet shall be distributed so as not to concentrate the load on any one section. No supporting value shall be assigned to the stiffness of inside liner plates on flat surfaces, except as provided in PL-27.5.

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Figure PL-36.5-1
Typical Forms of Diagonal Braces



PL-36.6.2 All rivet and clevis pin holes shall conform to the requirements in Mandatory Appendix V, and the pin diameter shall be made as close as practicable to the hole diameter, but no less than 6% below the hole diameter.

PL-36.6.3 Determine the required cross-sectional area of the brace by first computing the total load to be carried by the brace, and dividing the total load by the maximum allowable stress of the material, not to exceed 9,000 psi (62 MPa), in accordance with PL-36.5 and PFT-32.

PL-36.6.4 The cross-sectional area of pins required to resist double shear shall be at least 0.75 times the required cross-sectional area of the brace.

PL-36.6.5 The material surrounding the eye of a clevis or crowfoot stay shall be 1.25 times greater than the required cross-sectional area of the brace.

PL-36.6.6 Cross-sectional areas through the blades of diagonal braces at the attachment rivet hole(s) where attached to the shell of the boiler shall be at least equal to the required rivet section, that is, at least equal to 1.25 times the required cross-sectional area of the brace.

PL-36.6.7 Each branch of a crowfoot shall be designed to carry at least 0.67 times the total load on the brace.

PL-36.6.8 The net cross-sectional areas through the sides of a crowfoot, tee iron, or similar fastening at the rivet holes shall be at least 1.25 times greater than the required cross-sectional area of a brace.

PL-36.6.9 The combined cross-sectional area of the fasteners at each end of the brace shall be at least 1.25 times greater than the required cross-sectional area of a brace.

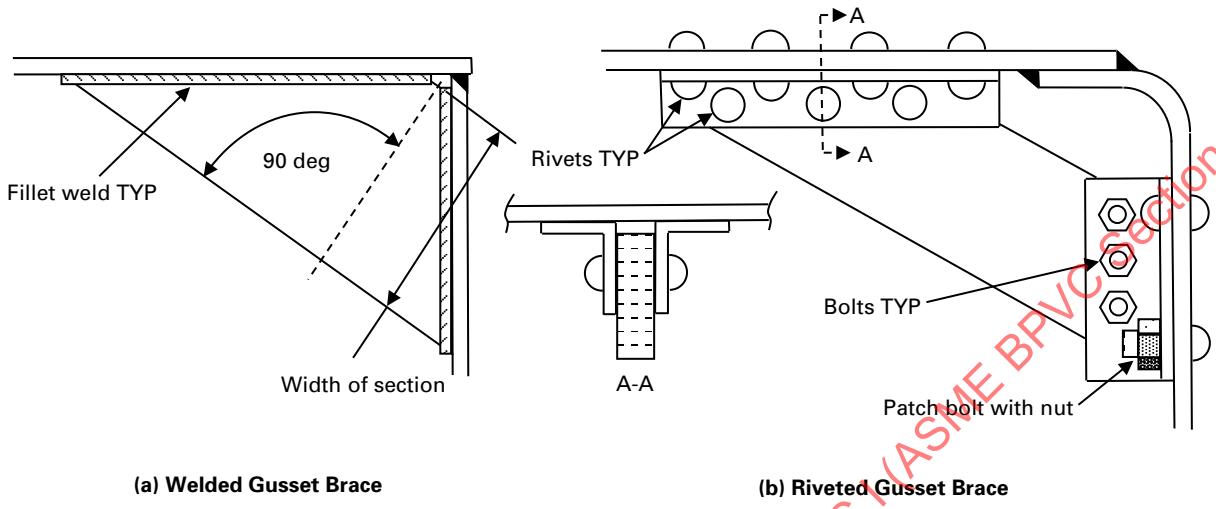
PL-36.6.10 Where fillet welds are used for attachment or fabrication of a crowfoot, welds shall be in accordance with PW-19.

PL-36.6.11 Braces exceeding 120 diameters in length shall comply with PG-46.8.

PL-36.6.12 Pin-connected braces shall be installed in such a manner as to uniformly support the load on the plate to which they are attached.

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Figure PL-36.7-1
Typical Forms of Gusset Braces



(a) Welded Gusset Brace

(b) Riveted Gusset Brace

PL-36.7 Gusset braces (see Figure PL-36.7-1) when constructed of triangular right-angled web plates secured to single- or double-angle bars along the two sides at right angles shall have a cross-sectional area (in a plane at right angles to the longest side and passing through the intersection of the two shorter sides) not less than 10% greater than would be required for a diagonal brace to support the same surface. The cross-sectional area shall be calculated by the equation of PFT-32.1, assuming the diagonal brace is at the same angle as the longest side of the gusset plate. Welds attaching gusset braces shall be in accordance with PW-19.4.1 as it applies to the attachment on each shell plate. All material shall be as required by PG-5 and Mandatory Appendix V.

PL-36.8 Through-braces shall be designed as outlined in PL-36.8.1 through PL-36.8.3.

PL-36.8.1 Welded through-braces may be full-penetration or partial-penetration welded. In all cases the area of the weld in shear measured parallel to the brace and around the full diameter of the brace shall not be less than 1.25 times the required cross-sectional area of the brace. However, in no case shall the size of the weld be less than $^{3}/_{8}$ in. (10 mm).

PL-36.8.2 Threaded through-braces, whether threaded in the sheet or not, shall have a nut and washer applied to stay on the outside of the sheet. Nuts with or without washers may be applied to the brace on the inside, or pressure side, of the sheet. Nuts shall not be exposed to the products of combustion within the firebox. Material shall be in accordance with PG-5.

PL-36.8.3 Through-braces shall conform to PG-46.

PL-36.9 Staying Segments of Heads With Structural Shapes. Tee irons (see Figures PL-36.9-1 and PL-36.9-2) or other structural shapes may be used to support a sheet where other methods of support are not possible. Special consideration must be given to the supporting structures at either end of the span being supported to ensure that those structures are not overstressed. The load on the structures at either end shall be calculated for an area outlined as being halfway to the next supporting structure and to the center of the span of the structural shape.

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Figure PL-36.9-1
Tee Iron

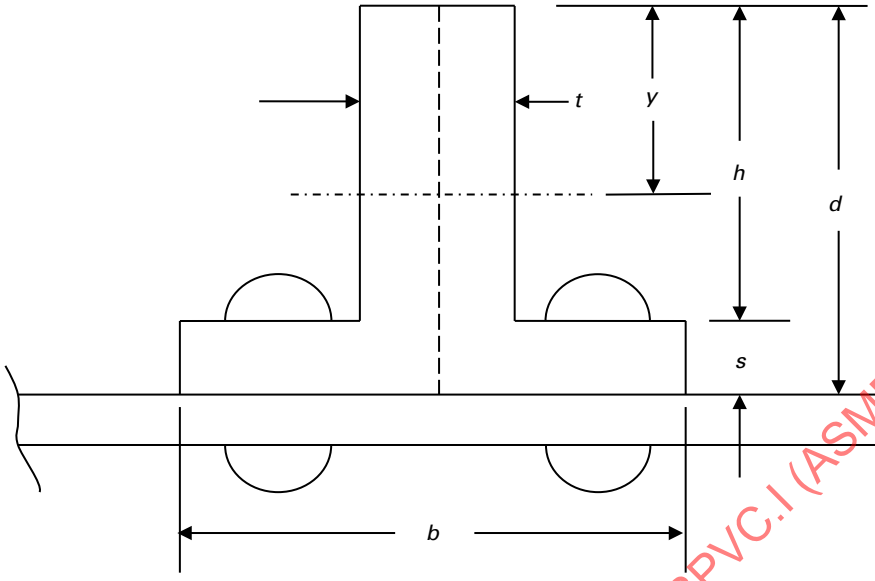
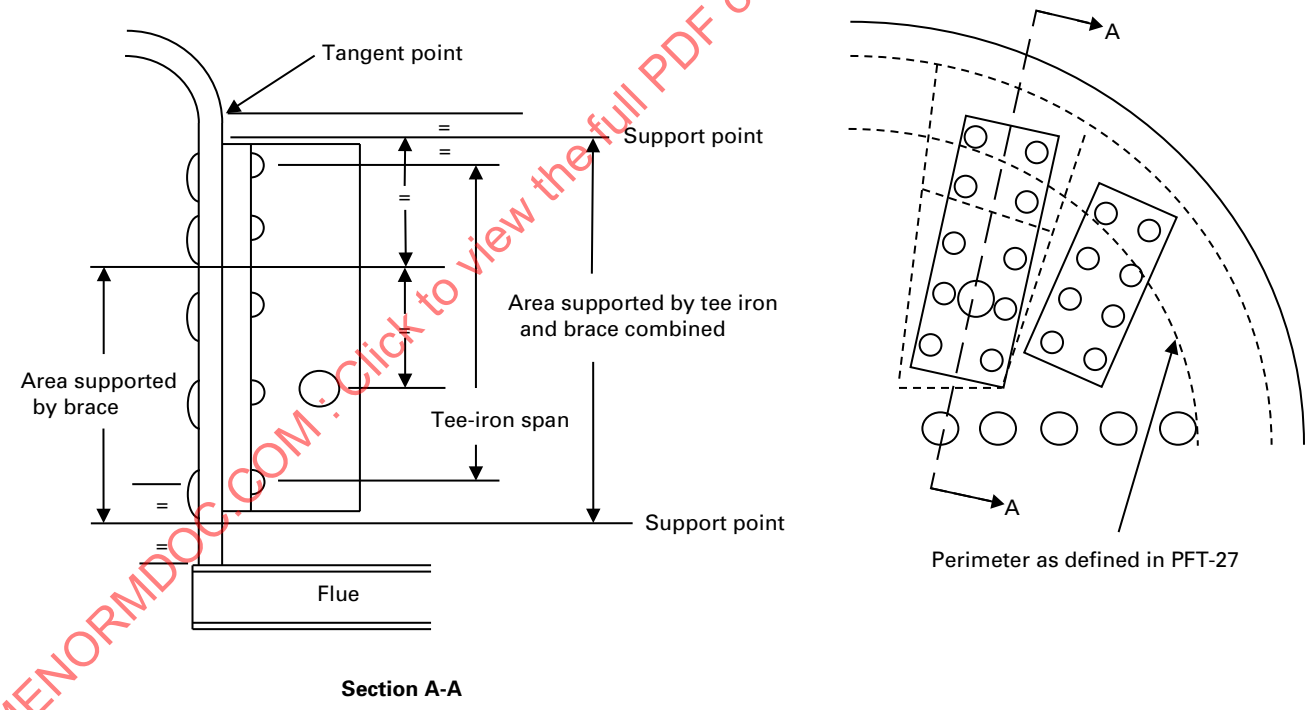


Figure PL-36.9-2
Tee-Iron Support Area



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(23) **PL-36.9.1** Stress at the center of the span in solid tee irons or in tee irons meeting the following requirements shall be calculated as in eqs. (1) through (4), of (c)(2), with the maximum extreme fiber stress in the structural shape being limited to 15,000 psi (103 MPa):

(a) fabricated using two back-to-back angles to form the leg

(b) fastened together by rivets on a pitch not exceeding that required in PG-46 using a C factor according to the thickness of the leg of the angle being fastened

(c) the load carried evenly by the tee iron, with fasteners meeting the following requirements:

(1) attached to the shell on a pitch not exceeding that required in PG-46 using a C factor corresponding to the thinner of the leg of the tee iron or the shell plate

(2) shall be calculated with eq. (1), with the maximum extreme fiber stress in the structural shape being in accordance with PL-7.1, not to exceed 15,000 psi (103 MPa)

$$S = \frac{Wl}{8Z} \tag{1}$$

$$I = \frac{\left[ty^3 + b(d-y)^3 - (b-t)(d-y-s)^3\right]}{3} \tag{2}$$

$$y = d - \left[\frac{d^2t + s^2(b-t)}{2(bs+ht)}\right] \tag{3}$$

$$Z = \frac{I}{y} \tag{4}$$

where

b = width of cross part of tee fastened to shell, in. (mm)
d = total height of tee iron, including thickness of cross part of tee, in. (mm)
h = height of vertical leg only, in. (mm)
I = moment of inertia, in.^{4} (mm^4)
l = maximum span of tee iron between supports, in. (mm)
S = surface fiber stress at center of span of tee iron, psi (MPa), not to exceed 15,000 psi (103 MPa)
s = thickness of cross part of tee iron, in. (mm)
t = thickness of vertical leg, in. (mm)
W = total load on tee iron, lbf (N)
y = distance from open end of vertical leg to neutral axis, in. (mm)
Z = section modulus, in.^{3} (mm^3)

PL-36.9.2 Where a tee iron or structural shape is supported at or near one end only by a brace or stay, and the remainder of the span is supported only by the tee iron or structural shape, the area supported by the brace or stay shall be the area defined by one of the following:

(a) an outline halfway between the tee-iron rivets and the nearest support structure on the sides and end where the brace is located

(b) halfway between the edge of the flues and the nearest attachment point of the tee iron, and halfway between the brace on the tee iron and the nearest support structure to the tee iron on the end opposite the brace

(c) halfway between the shell and the nearest attachment point on the tee iron for unflanged heads, and halfway between the point of tangency of the flange and the nearest attachment point of the tee iron on flanged heads

No credit for the strength of the tee iron may be taken for support on the end with the brace, and the brace stress shall not be more than 9,000 psi (62 MPa).

PL-36.9.3 To determine the extreme fiber stress on a tee iron or structural shape supported at or near one end only by a brace or stay, calculate the load carried by the tee iron using the entire area supported by that tee iron, then subtract the load carried by the brace as calculated in PL-36.9.1(c). The remaining load shall be used to calculate the extreme fiber stress on the tee iron over the entire span of the tee iron, which is the length between the extreme fasteners of the tee iron. The extreme fiber stress on the tee iron shall not exceed 15,000 psi (103 MPa).

PL-36.9.4 For reinforcement of flat heads, refer to PL-20 and PL-27.

PL-39 ARCH TUBES, CIRCULATORS, AND THERMIC SYPHONS

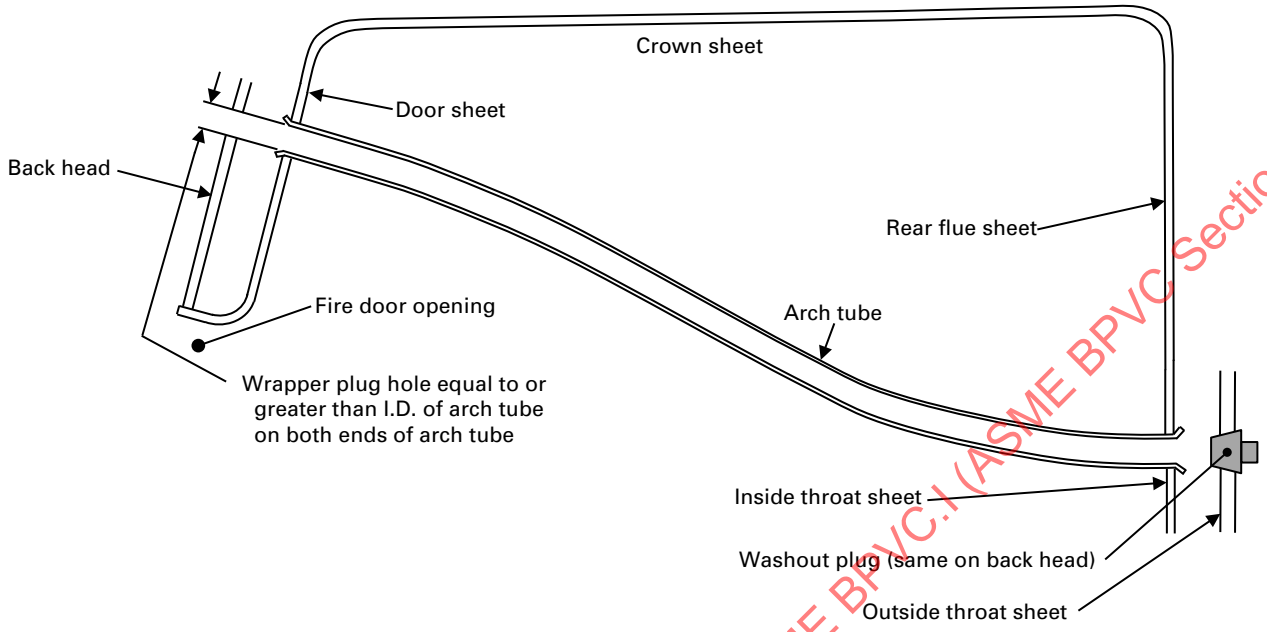
PL-39.1 Arch Tubes. Arch tubes (see Figure PL-39.1-1) shall meet the requirements of PL-39.1.1 and PL-39.1.2.

PL-39.1.1 A washout plug opening with a minimum diameter equal to the inside diameter of the arch tube shall be provided on the exterior boiler sheet at each arch tube end. Such washout plug openings shall be arranged to enable installation of a mechanical tube cleaner and washout hose.

PL-39.1.2 Arch tubes shall be installed per the requirements of PWT-11.1. Structural loading of the arch tubes caused by the brick arch shall be accounted for by using eq. (1) or eq. (1M) to determine the minimum thickness.

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Figure PL-39.1-1
Arch Tubes



(U.S. Customary Units)

$$t = \frac{PD}{16{,}000} + 0.125 \quad (1)$$

(SI Units)

$$t = \frac{PD}{111} + 3.175 \quad (1M)$$

where

D = outside diameter of tube, in. (mm)
P = maximum allowable working pressure, psi (MPa)
t = thickness of tube wall, in. (mm)

PL-39.2 Circulators.

PL-39.2.1 Maximum allowable working pressure for circulators (see Figures PL-39.2.1-1 and PL-39.2.1-2) shall be in accordance with PG-27; however, the minimum wall thickness shall be $^{3}/_{8}$ in. (10 mm). Circulators shall be inserted completely through the crown sheet and shall be welded with a partial-penetration weld and cover fillet weld on the fire side of the sheet in accordance with Figure PW-16.1, illustration (y). A cover fillet weld at least as wide as the partial-penetration weld and no less than $^{1}/_{4}$ in. (6 mm) shall be done in accordance with PW-16.2 and Figure PL-39.2.1-2. Attachment of the circulator legs to the side sheets shall be made using a flanged diaphragm or diaphragm plate that may be flanged integrally with the sheet or may be inserted as a flush patch. Circulator legs shall be inserted into the diaphragm plate at least 1 in. (25 mm) and fillet welded with a t_{min} in accordance with PW-16.2. If installed as a flush patch, the diaphragm plate shall be large enough to encompass at least one row of adjacent staybolts. Postweld heat treatment (PWHT) and volumetric examination are not required.

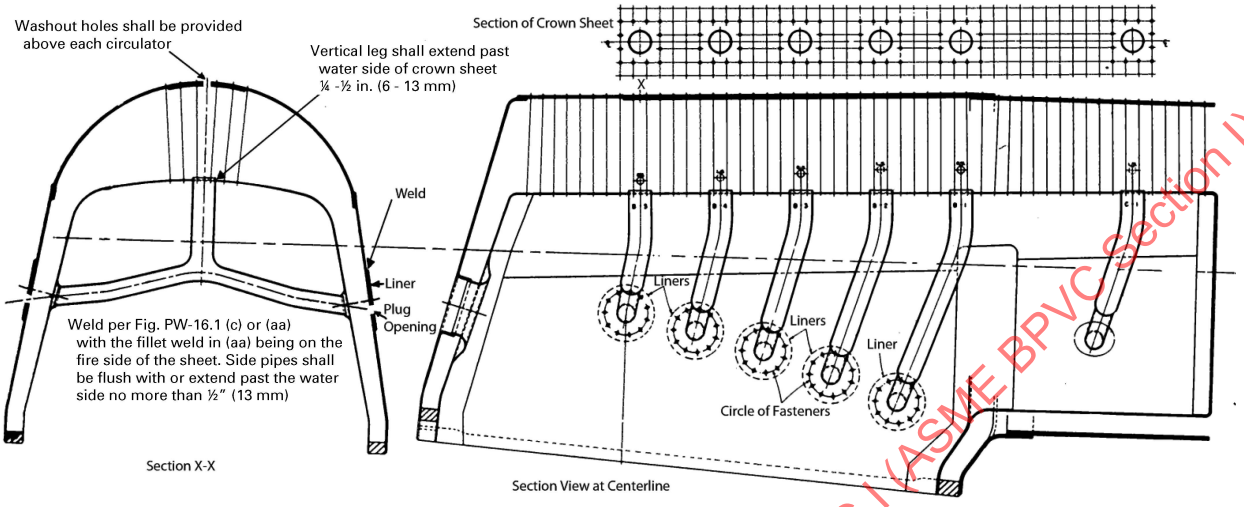
PL-39.2.2 Circulators shall be fabricated using full thickness butt welds. Volumetric examination and PWHT shall be done as required in Part PW.

PL-39.3 Thermic Syphons. Thermic syphon walls shall be designed in accordance with PL-27 and PL-30 (see Figure PL-39.3-1). Thermic syphon neck walls shall be designed in accordance with PG-27 but shall not be less than $^{3}/_{8}$ in. (10 mm) thickness. Welds on the thermic syphon unit shall be full penetration, and the unit shall be stress relieved in accordance with PW-39. Volumetric examination is not required.

PL-39.3.1 Flanges transitioning from the vertical walls of the thermic syphon to the crown sheet shall be long enough to include at least one row of crown bolts between the flange radius and the attachment weld. If flanges are made separately from the vertical body of the thermic syphon, they shall be attached to the body with full-penetration butt welds and shall be long enough to contain at least one row of staybolts in

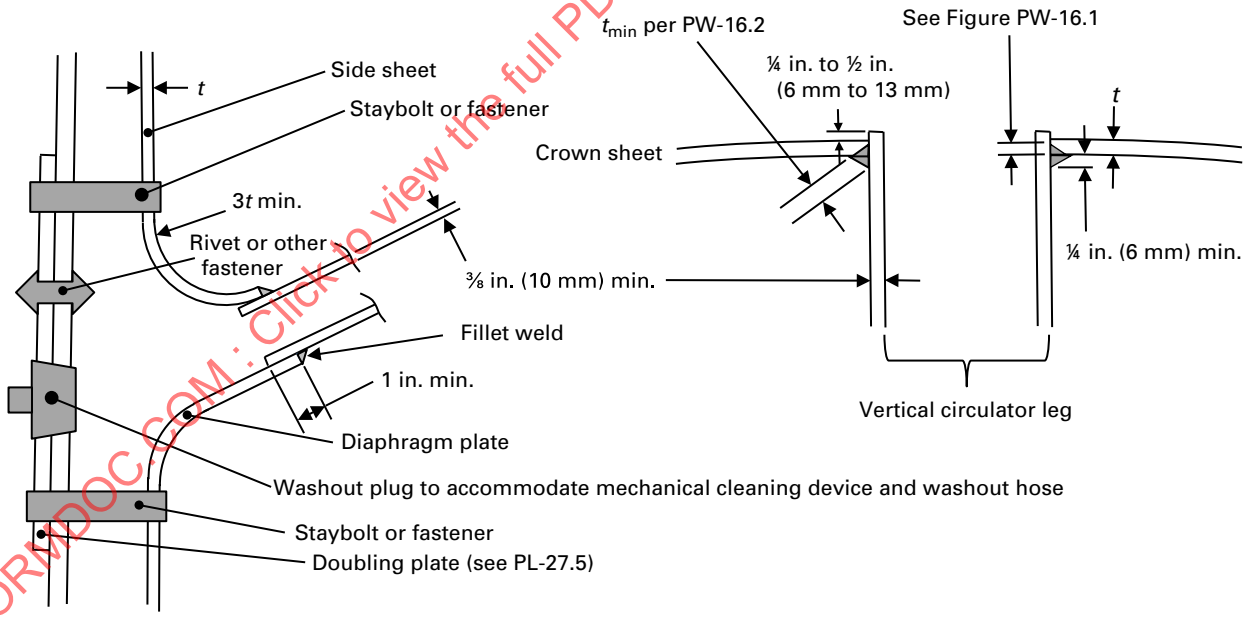
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Figure PL-39.2.1-1
Circulators



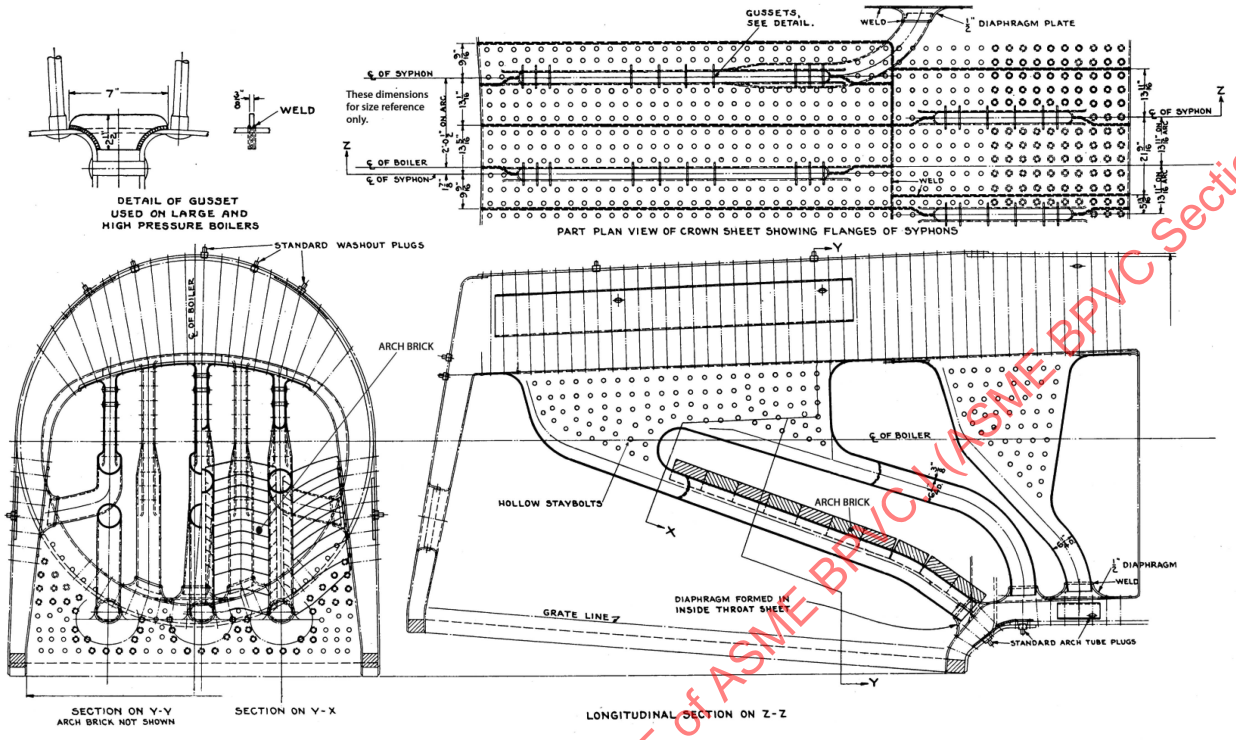
GENERAL NOTE: From *Locomotive Cyclopedia*, Fig. 3.176, p. 299, Simmons-Boardman Publishing Corp., 1944.

Figure PL-39.2.1-2
Circulator Attachment Section Views



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Figure PL-39.3-1
Example of Thermic Syphon Installation



GENERAL NOTE: From *Locomotive Cyclopedia*, Fig. 3.171, p. 295, Simmons-Boardman Publishing Corp., 1944.

the vertical body section as well as at least one row of crown bolts.

PL-39.3.2 Attachment welds to the crown sheet shall be full-penetration butt welds. PWHT and volumetric examination are not required.

PL-39.3.3 Thermic syphon necks shall slide inside the diaphragm plate on the throat sheet at least 2 in. (50 mm). A fillet weld shall be used to attach the thermic syphon neck to the diaphragm plate, and the weld shall have a t_{min} in accordance with PW-16.2. PWHT and volumetric examination are not required.

PL-39.3.4 Flanged diaphragm plates for the thermic syphon necks shall be flanged integrally with the firebox sheets or shall be applied as flush patches with full-penetration butt welds.

PL-39.3.5 A washout plug opening shall be provided on the boiler exterior sheet at the top end of the thermic syphon and at the neck. Each washout plug opening shall be arranged to enable access for a washout hose. The neck washout plug opening shall be arranged to enable insertion of a mechanical tube cleaner.

PL-42 GAGE GLASSES AND WATER COLUMNS

PL-42.1 General. Gage glasses and water columns shall be installed in accordance with PG-12, PG-60, PL-42.2, and PL-42.3.

PL-42.2 Gage Glass Number and Placement. All locomotive boilers that meet the requirements of Part PL shall have at least two gage glasses. The lowest reading of any gage glass shall be at least 3 in. (75 mm) above the highest point of the crown sheet, for locomotive boilers over 36 in. (900 mm) inside diameter.

PL-42.2.1 For locomotive boilers between 36 in. (900 mm) and 30 in. (750 mm) inclusive in inside diameter, the lowest reading of any gage glass shall be at least 2 in. (50 mm) above the highest point of the crown sheet.

PL-42.2.2 Gage glasses shall be mounted directly to the boiler proper. One of the required two gage glasses may be mounted on a water column that is directly mounted to the boiler.

PL-42.2.3 The placement and height of the gage glass shall be such to ensure the water level can be accurately determined for all operating conditions.

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PL-42.2.4 The highest point on the crown sheet when sitting on level track shall be indicated on the back head of the boiler.

PL-42.3 Gage Glass Connection.

PL-42.3.1 The bottom mounting for the gage glass shall extend at least 1½ in. (38 mm) into the boiler but no farther than halfway between the inside and outside sheets of the waterleg, whichever is less, and shall extend beyond any obstruction directly above or below the connection. The center of the bottom connection shall not be located closer to the side and above any arch tube opening within a boundary described by a semicircle based on the horizontal centerline of the arch tube with a radius of 6 in. (150 mm), described from the center point of the arch tube. The connection passage shall be straight and horizontal and shall be arranged to allow entry of a mechanical cleaner such as a reamer.

PL-42.3.2 Gage glasses shall have top and bottom shutoff valves, of such construction as to provide a smooth flow and to prevent the buildup of scale and sediment in the valve body. Globe-type valves shall not be used. The bottom gage glass connection shall have a drain valve of at least NPS ⅜ in. (DN 10) with associated piping being no less than nominal NPS ⅜ in. (DN 10) with an inside diameter of no less than ⅜ in. (10 mm). The drain piping shall be arranged to discharge below the locomotive cab.

PL-42.3.3 The top and bottom of the gage glass and associated piping shall be adequately supported and braced to prevent movement and minimize vibration.

PL-42.3.4 The steam connection of a gage glass shall be connected above the highest visible water level of the gage glass. The steam connection, and associated piping, shall be without sags, pockets, dips, or siphons in the piping that may allow the buildup of scale and sediment. The steam connection shall be as close to the top of the boiler (wrapper roof sheet) as practical and no lower than the highest visible level of the gage glass.

PL-42.3.5 Tubular-type water-level indicators shall be equipped with suitable safety shielding to prevent discharge of glass pieces into the locomotive cab if the gage glass breaks. Tubular-type water-level indicators shall be suitable for the design pressure and temperature.

PL-42.3.6 Placement and illumination of the gage glasses shall be such that the water level may be quickly observed by the operating crew when they are in their normal operating positions within the locomotive cab.

PL-42.3.7 Multiple gage glasses and water columns shall not be attached to a single top or bottom connection or any type of shared connection with another device. Each gage glass and water column shall have its own independent top and bottom connection to the boiler.

PL-42.3.8 The top and bottom gage glass and water column connections shall be arranged and provided with provision to allow mechanical cleaning of the water passage to the boiler. Each connection passage shall be straight without sags, pockets, or dips and shall be arranged to allow entry of a mechanical cleaner such as a reamer.

PL-43 BOILER BLOWOFF SYSTEMS

Boiler blowoff piping may extend through only one valve for bottom or surface blowoff systems.

PL-45 FEEDWATER SUPPLY

Feedwater supply shall be in accordance with PG-61. Feedwater shall be discharged into the boiler from its delivery pipe at the coolest part of the boiler practicable, and no closer to the firebox than a point halfway between the front flue sheet and the firebox. Boilers under this Part shall have at least two means of supplying water to the boiler. At least one live steam injector shall be used.

PL-48 DRY PIPE

Maximum allowable working pressure for the dry pipe of a boiler with a dome-type throttle shall be determined in accordance with PG-28.

PL-49 INTERNAL OR DOME THROTTLE VALVES (23)

Throttle valves installed on the pressure side of a locomotive boiler shall be equipped with an indicator to show whether the valve is open or closed. In the case of a manually operated handle to open and close the valve at the operator's station, the location of the handle in the quadrant may be used to indicate the position of the valve.

Internal throttle valves shall be designed to the same MAWP of the boiler and withstand the required hydrostatic test of the boiler.

Throttle valve bodies and standpipes shall be braced to resist mechanical forces from the operating linkage and inertial forces associated with normal railroad operation (e.g., coupling, slack)

PL-54 PRESSURE RELIEF VALVES

PL-54.1 Maximum Allowable Working Pressure (MAWP). Every locomotive boiler within the scope of Part PL shall be equipped with at least two pressure relief valves, the total capacity of which shall be sufficient to discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 5% above the highest set pressure at which any valve is set, and in no case more than 5% above the maximum allowable working pressure.

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At least one valve shall have a marked set pressure not to exceed the maximum allowable working pressure. The other valve or valves may have a marked set pressure that is higher than the lowest set valve, with the highest valve setting not to exceed 6 psi (40 kPa) above MAWP.

NOTE: Often steam locomotive style pressure relief valves that are designed to act as both an overpressure protection device and a pressure-regulating device are used for this service.

PL-54.2 Mechanical Requirements. Pressure relief valves shall conform to the requirements of PG-71.3, PG-73.1, and PG-73.2 with the following exceptions or additions.

(a) Pressure relief valves shall be of the top discharge type.

(b) A lifting device as specified in PG-73.2.4 is not required if other means of providing freedom of movement or lift testing is conducted on a periodic basis.

(c) Flanged or welded connections per PG-73.2.11 are not required for pressure relief valves used for pressures greater than 15 psig (100 kPa) regardless of size; however the connection shall be designed to ensure the connection is secure at all design conditions.

(d) Pressure relief valves under Part PL must be sealed in accordance with PG-73.2.9 or, in lieu of sealing, shall be certified per regulation 49 CFR 230.49.

(e) For pressure relief valves manufactured with bottom guides, the area of the opening of the connection between the boiler and the pressure relief valve must be at least 25% larger than the area of the valve bore minus the net cross-sectional area of the bottom guide.

PL-54.3 Material Requirements. Material requirements shall be in accordance with PG-73.3.

PL-54.4 Capacity Certification. Pressure relief valves shall be certified for capacity as required by PG-69 and PG-73.4. As an alternative to capacity certification, the initial verification procedure of PL-54.7 may be used to determine if an adequate amount of capacity is available from the installed pressure relief valves.

PL-54.5 Production Testing. All pressure relief valves shall be production tested in accordance with PG-73.5. The operation verification test in PL-54.7 may be considered as the set pressure test required by PG-73.5.2 when performed by the valve manufacturer.

PL-54.6 Valve Stamping and Marking. Each pressure relief valve shall be marked in accordance with PG-110 with the following provisions:

(a) If an accumulation test will be used to determine the adequacy of the valve capacity in lieu of capacity certification testing, no capacity shall be applied to the stamping or nameplate. "By Accum Test" shall be marked instead of a capacity value.

(b) Each valve shall be serialized by the valve Manufacturer to allow for referencing on the boiler data report [see PL-54.7(b)(8)].

PL-54.7 Sizing and Initial Verification of Steam Locomotive Style Pressure Relief Valves.

(a) Required pressure relief valve capacity may be determined using the maximum designed steaming output of the boiler by using calculations as outlined in A-44. Capacity certified pressure relief valves shall then be selected with a total rated capacity equal to or greater than the required capacity.

(b) Where the valves are not capacity certified, or where an existing valve will be used in a new boiler part, an accumulation test may be used to verify that the installed capacity is adequate.

(1) Accumulation testing may be hazardous because the boiler is being run at maximum fire, and pressure relief valve capacity has not been verified. It should be done only under carefully controlled conditions by trained and knowledgeable personnel.

(2) Boiler pressure shall be continuously monitored by both an operating gage and a calibrated test gage.

(3) The pressure relief valves shall first have been set in accordance with the operational verification test requirements in accordance with PL-54.8.

(4) The accumulation test shall be performed by shutting off all other steam-discharge outlets from the boiler and forcing the fire to the maximum.

(5) The locomotive shall be secured from movement, cylinder and valve vents blocked open, and throttle unsecured so that it may be opened if necessary to relieve excess pressure.

(6) Should the pressure approach the limits specified in PL-54.1 the throttle shall be opened enough to relieve the pressure and the fire reduced to prevent further accumulation of pressure. Corrective action to supply additional capacity shall then be taken.

(7) The safety relief valves shall be sufficient to prevent an excess pressure beyond that specified in PL-54.1.

(8) Where the pressure relief valve capacity has been verified by an accumulation test, the valves shall be used only on the boiler on which they were tested. The valve identification numbers and set pressures shall be recorded on the data report for that specific boiler by the boiler manufacturer.

PL-54.8 Operational Verification of Steam Locomotive Pressure Relief Valves.

(a) Operational verification of steam locomotive pressure relief valves may be accomplished by testing the valves on a steam test stand.

(b) As an alternative, the valves may be set on the locomotive boiler.

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(1) A calibrated test gage shall be used in addition to the boiler operating gage.

(2) The boiler pressure shall be brought up at a controlled rate and the valves alternately set until the lowest set valve is set to open at the tolerance in PG-72.2 with a blowdown not less than 2% of MAWP.

(3) The low set valve may then be gagged, and the higher set valve(s) shall then be set to open within the set pressure tolerance in PG-72.2. The blowdowns for the higher set valves shall be set such that the blowdown is greater than 2% of MAWP, and the valves will close below the lowest set valve set pressure.

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PART PA
ALTERNATIVE RULES FOR BOILER CONSTRUCTION

PA-1 GENERAL

Components designed and constructed to the rules of Section VIII, Division 2 may be installed in a Section I boiler, provided all other requirements of Section I are satisfied by a Section I certificate holder and the requirements of Part PA are met.

PA-2 CODE BOUNDARIES AND INTERFACES

The design and fabrication of components shall be per Section VIII, Division 2. The interface between Section VIII, Division 2 components and other parts of the Section I system shall be of welded construction and shall also meet the thickness requirements of Section I.

PA-3 DESIGN SPECIFICATION AND DESIGN REPORT

When required by Section VIII, Division 2, a Certified User's Design Specification and Certified Manufacturer's Design Report shall be provided for the component.

PA-4 CONSTRUCTION

PA-4.1

Layered construction as permitted in Section VIII, Division 2 is not permitted in Section I construction.

PA-4.2

Components constructed of Section VIII, Division 2 rules shall have all joints of Category A in accordance with Type No. 1, and all joints of Category B in accordance with Type No. 1 or 2.

PA-5 MATERIALS

Materials shall comply with Section I, PG-5.5 and shall be limited to those permitted by both Section I and Section VIII, Division 2 and to the design temperature limits of Section VIII, Division 2.

PA-6 HYDROSTATIC TEST

The shop hydrostatic test pressure(s) shall be the larger of the test pressures determined by Section VIII, Division 2 and Section I, PG-99.1. The equivalent stress limits due to hydrostatic testing of the Section VIII, Division 2 components shall not exceed those prescribed by Section VIII, Division 2. After installation into a power boiler, such components shall also be subjected to that system's hydrostatic test.

PA-7 DATA REPORTS AND STAMPING

PA-7.1

Components constructed to Section VIII, Division 2 rules shall be stamped with the Certification Mark with "U2" Designator and additional marking as required by Section VIII, Division 2. Section VIII, Division 2, Form A-1, Manufacturer's Data Report for Pressure Vessels, shall be completed for documentation. A Section VIII, Division 2 nameplate shall be furnished and marked "Section I, Part PA."

PA-7.2

Form A-1, Manufacturer's Data Report for Pressure Vessels, shall be included in the Section I Master Data Report for the completed boiler unit (see PG-113) and shall state "Components designed and constructed to Section VIII, Division 2, as permitted by Part PA."

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PART PWT
REQUIREMENTS FOR WATERTUBE BOILERS

GENERAL

PWT-1 GENERAL

The rules in Part PWT are applicable to watertube boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the special requirements in the applicable Parts of this Section that apply to the method of fabrication used. The rules in Part PWT do not apply to external piping.

MATERIALS

PWT-5 GENERAL

PWT-5.1 Materials used in the construction of pressure parts for watertube boilers shall conform to one of the specifications in Section II and shall be limited to those for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B, for Section I construction or as otherwise specifically permitted in Part PG and Part PWT.

PWT-5.2 Mud drums of boilers shall be of either wrought steel or cast steel as designated in SA-216.

DESIGN

PWT-8 GENERAL

The rules in the following paragraphs apply specifically to the design of watertube boilers and parts thereof and shall be used in conjunction with the general requirements for design in Part PG as well as with the specific requirements for design in the applicable Parts of this Section that apply to the method of fabrication used.

PWT-9 TUBES AND PIPE

PWT-9.1 Economizer, boiler generator, and superheater tubes shall comply with the specifications as listed in PG-9.

PWT-9.2 Seamless steel pipe not exceeding NPS 1½ (DN 40) complying with SA-53 or SA-106 may be threaded into the tubesheet, drum, or steel fitting of a watertube boiler. Steel fittings, if used, must fully cover the threads.

PWT-9.3 A tube in which a fusible plug is to be installed shall be not less than 0.22 in. (5.6 mm) in thickness at the plug in order to secure four full threads for the plug (see also A-20).

PWT-11 TUBE CONNECTIONS

Tubes, pipe, and nipples may be attached to shells, heads, headers, and fittings by one of the following methods.

PWT-11.1 Tubes may be attached by expanding, flaring, beading, and seal welding in the following combinations illustrated in Figure PWT-11:

(a) expanded and flared [illustration (a)]

(b) expanded and beaded [illustration (b)]

(c) expanded, flared, seal welded, and re-expanded after welding [illustration (c)]

(d) expanded, seal welded, and re-expanded after welding or seal welded and expanded after welding [illustration (d)] or

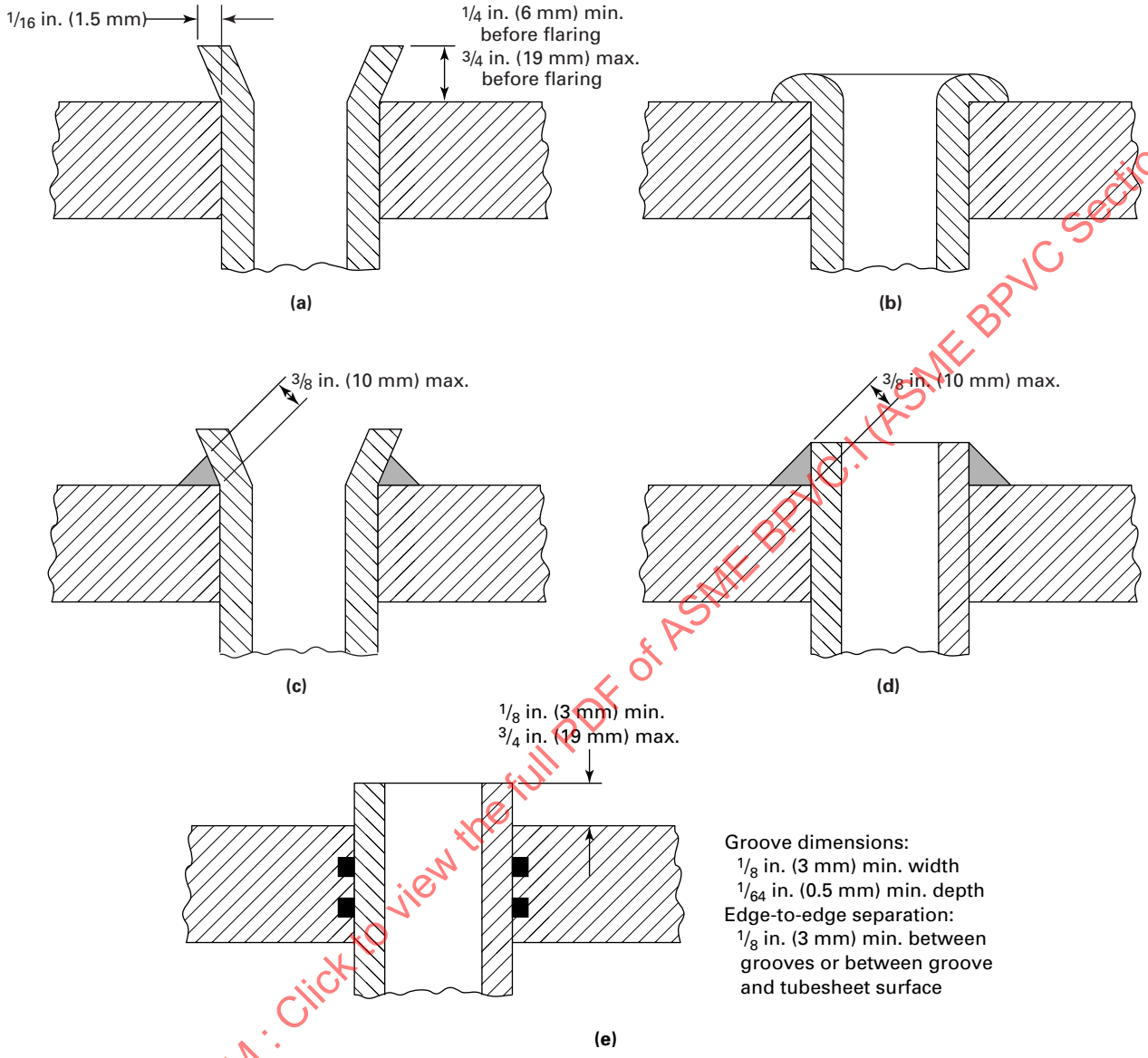
(e) expanded only, in tubesheets having a thickness not less than $\frac{5}{8}$ in. (16 mm), where the tube holes contain one or more grooves, as shown in Figure PWT-11. Tube hole grooves may have either a rounded or square profile.

The end of all tubes that are flared shall project through the tubesheet or header not less than $\frac{1}{4}$ in. (6 mm) nor more than $\frac{3}{4}$ in. (19 mm) before flaring. Where tubes enter at an angle, the maximum limit of $\frac{3}{4}$ in. (19 mm) shall apply only at the point of least projection. Tubes that are expanded and flared without seal welding shall be flared to an outside diameter of at least $\frac{1}{8}$ in. (3.0 mm) greater than the diameter of the tube hole. For tubes that are seal welded, the maximum throat of seal welds shall be $\frac{3}{8}$ in. (10 mm). Tubes which are only expanded into grooved tube holes shall project through the tubesheet or header not less than $\frac{1}{8}$ in. (3 mm) but not more than $\frac{3}{4}$ in. (19 mm).

PWT-11.2 Superheater, reheater, waterwall, or economizer tubes may be welded to tubular manifolds, headers, or drums and tube ends or weld necks may be welded to drums, all without expanding or flaring, provided the connections comply with the requirements of PW-15 and PW-16. The welds shall be postweld heat treated when required by PW-39.

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Figure PWT-11
Examples of Acceptable Forms of Tube Attachment



PWT-11.3 Pipe used for tubes as provided in PWT-9.2 may be attached by threading instead of expanding and flaring, provided the requirements in PG-39.5 are conformed to.

PWT-11.4 Watertubes not exceeding 2 in. (50 mm) O.D. may be welded to tapered ferrules that are attached to the drum by a driven interference fit. In addition to the interference fit, the ferrules shall be held in place by retainer clamps attached to the drum with stud bolts. Welded stud bolts shall comply with PW-27.2 and PW-28.6. When tapped holes are provided for the studs, the stud bolts shall comply with PG-39.4. The minimum cross-sectional area of the remaining studs shall be determined by the following equation, but shall not be less than that of a 3/8 in. (10 mm) stud.

$$A = 0.25\pi D^2 NP/S$$

where

A = the root area of the stud
D = the outside diameter of the ferrule at the inside surface of the drum
N = the number of fittings retained by the stud
P = the design pressure

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S = the allowable stress of the stud material at its design temperature

PWT-12 STAYBOLTING BOX-TYPE HEADERS AND WATERLEGS

The front and back sheets of staybolted box-type headers and waterlegs may be joined together by welding by any of the methods described in PFT-21 for fireboxes and waterlegs, provided the thickness and header width requirements of PFT-21 and Figure PFT-21 are met.

PWT-13 STAYING SEGMENT OF HEADS

The rules in PFT-25.2 shall be used to determine if staying is required.

PWT-14 FIRING DOORS

A watertube boiler shall have the firing doors of the inward-opening type, unless such doors are provided with substantial and effective latching or fastening devices or otherwise so constructed as to prevent them, when closed, from being blown open by pressure on the furnace side.

These latches or fastenings shall be of the positive self-locking type. Friction contacts, latches, or bolts actuated by springs shall not be used. The foregoing requirements for latches or fastenings shall not apply to coal openings of downdraft or similar furnaces.

All other doors, except explosion doors, not used in the firing of the boiler may be provided with bolts or fastenings in lieu of self-locking latching devices.

Explosion doors, if used and if located in the setting walls within 7 ft (2.1 m) of the firing floor or operating platform, shall be provided with substantial deflectors to divert the blast.

PWT-15 ACCESS AND FIRING DOORS

The minimum size of an access or fire door opening, in which the minimum furnace dimension is 24 in. (600 mm), shall be not less than 12 in. × 16 in. (300 mm × 410 mm) or equivalent area, 11 in. (280 mm) to be the least dimension in any case. A circular opening shall be not less than 15 in. (380 mm) in diameter.

For furnace dimensions less than 24 in. (600 mm), the opening should be 2¾ in. × 3½ in. (70 mm × 89 mm) or larger where possible. In cases where the size or shape of the boiler prohibits an opening of that size, two openings with a minimum size of 1 in. (25 mm) may be used, preferably opposite each other, to permit inspection and cleaning of the furnace. If the burner is removable so as to permit inspection and cleaning through the burner opening, a separate access opening need not be provided.

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PART PFT
REQUIREMENTS FOR FIRETUBE BOILERS

GENERAL

PFT-1 GENERAL

The rules in Part PFT are applicable to firetube boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the specific requirements in the applicable Parts of this Section that apply to the method of fabrication used.

MATERIALS

PFT-5 GENERAL

PFT-5.1 Materials used in the construction of pressure parts for firetube boilers shall conform to one of the specifications given in Section II and shall be limited to those for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B, or as otherwise specifically permitted in Parts PG and PFT.

PFT-5.2 Waterleg and doorframe rings of vertical firetube boilers and of locomotive and other type boilers shall be of wrought iron or steel or cast steel as designated in the SA-216. The ogee or other flanged construction may be used as a substitute in any case.

DESIGN

PFT-8 GENERAL

The rules in the following paragraphs apply specifically to the design of firetube boilers and parts thereof and shall be used in conjunction with the general requirements for design in Part PG as well as with the specific requirements for design in the applicable Parts of this Section that apply to the method of fabrication used.

PFT-9 THICKNESS REQUIREMENTS

PFT-9.1 Shell and Dome. The thickness after forming shall be as determined in accordance with the rules in Part PG.

PFT-9.2 Tubesheet.

PFT-9.2.1 The thickness shall be as determined in accordance with Parts PG and PFT.

PFT-9.2.2 When buttwelded to the shell of a firetube boiler, a formed tubesheet with a straight flange longer than $1\frac{1}{2}$ times the tubesheet thickness shall have a straight flange thickness not less than 0.75 times the thickness of the shell to which it is attached.

PFT-10 SHELL JOINTS

Longitudinal and circumferential welded joints of a shell or drum shall comply with the rules in Part PW.

PFT-11 ATTACHMENT OF HEADS AND TUBESHEETS

Flat heads and tubesheets of firetube boilers shall be attached by one of the following methods:

PFT-11.1 Flanged heads and tubesheets shall be formed with a minimum outside corner radius of 3 times the plate thickness [see Figure A-8, illustrations (a-1), (b-1), (c), (i), and (j)], and attached in accordance with either PFT-11.2 or PFT-11.3.

PFT-11.2 By flanging and butt welding in accordance with Parts PG and PW.

PFT-11.3 By attaching an outwardly or inwardly flanged tubesheet to the shell by fillet welding provided the following requirements are met:

PFT-11.3.1 The tubesheet is supported by tubes, or stays, or both.

PFT-11.3.2 The joint attaching an outwardly flanged tubesheet is wholly within the shell and forms no part thereof.

PFT-11.3.3 Inwardly flanged tubesheets are full fillet welded inside and outside.

PFT-11.3.4 The throat dimension of the full fillet weld is equal to not less than 0.7 of the thickness of the head.

PFT-11.3.6 The construction conforms in all other respects to the requirements of this Section, including welding and postweld heat treating, except that volumetric examination is not required.

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PFT-11.3.7 This construction shall not be used on the rear head of a horizontal-return tubular boiler and inwardly flanged tubesheets shall not be used on a boiler with an extended shell.

PFT-11.3.8 On inwardly flanged tubesheets, the length of flange shall conform to the requirements of PW-13 and the distance of the outside fillet weld to the point of tangency of the knuckle radius shall be not less than $\frac{1}{4}$ in. (6 mm).

PFT-11.4 By attaching an unflanged tubesheet to the shell by welding, provided the requirements of PFT-11.4.1 through PFT-11.4.7 are met

PFT-11.4.1 The tubesheet is supported by tubes, or stays, or both.

PFT-11.4.2 The welded joint may be made through the tubesheet or shell thickness. When the weld joint is made through the shell, a minimum of 80% of the pressure load shall be carried by the tubes, stays, or both.

PFT-11.4.3 The weld is a full penetration weld equal at least to the full thickness of the base metal applied from either or both sides. When the full penetration weld is made through the shell, an external fillet weld with a minimum throat of $\frac{1}{4}$ in. (6 mm) shall be provided, and no weld prep machining shall be performed on the flat tubesheet. The distance from the edge of the completed weld to the peripheral edge of the tubesheet shall not be less than the thickness of the tubesheet.

PFT-11.4.4 The shell or wrapper sheet, where exposed to primary furnace gases[23] and not water cooled, does not extend more than $\frac{1}{8}$ in. (3 mm) beyond the outside face of the tubesheet.

PFT-11.4.5 The weld attaching a furnace or a lower tubesheet of a vertical firetube boiler to the furnace sheet is wholly within the furnace sheet and is ground flush with the upper or water side of the tubesheet.

PFT-11.4.6 The construction conforms in all other aspects to the requirements of this Section including welding, and postweld heat treatment, except that volumetric examination is not required.

PFT-11.4.7 This construction shall not be used on the rear head of a horizontal-return tubular boiler.

PFT-12 TUBES

PFT-12.1 Allowable Working Pressure.

PFT-12.1.1 The maximum allowable working pressure of tubes or flues of firetube boilers shall be as given in PG-28.1 and PG-28.3. The minimum thickness requirement of PG-9.3 does not apply to firetubes.

PFT-12.1.2 The maximum allowable working pressure for copper tubes or nipples subjected to internal or external pressure shall not exceed 250 psi (1.7 MPa). The maximum temperature shall not exceed 406°F (208°C).

The maximum allowable working pressure for copper-clad tubes subjected to external pressure shall be determined by the formula in PG-28.3, in which t may be increased by one-half the thickness of the cladding.

PFT-12.2 Attachment of Tubes.

PFT-12.2.1 Figure PFT-12.1 illustrates some of the acceptable types of tube attachments. Such connections shall be

(a) expanded and beaded as in illustrations (a), (b), and (d)

(b) expanded and beaded and seal welded as in illustration (c)

(c) expanded and seal welded as in illustration (e)

(d) welded, as in illustrations (f) and (g)

Tube ends attached by expanding and welding are subject to the provisions specified in PFT-12.2.1.1 through PFT-12.2.1.3.

PFT-12.2.1.1 Where no bevel or recess is employed, the tube shall extend beyond the tubesheet not less than a distance equal to the tube thickness or $\frac{1}{8}$ in. (3 mm), whichever is the greater, and not more than twice the tube thickness or $\frac{1}{4}$ in. (6 mm), whichever is the lesser [see Figure PFT-12.1, illustration (e)].

PFT-12.2.1.2 The tubesheet hole may be beveled or recessed. The depth of any bevel or recess shall not be less than the tube thickness or $\frac{1}{8}$ in. (3 mm), whichever is greater. The finished weld may incorporate all or part of the tube end; however, the finished weld profile shall not be below the outside face of the tubesheet. Where the hole is beveled or recessed, the projection of the tube beyond the tubesheet shall not exceed a distance equal to the tube wall thickness [see Figure PFT-12.1, illustrations (f) and (g)].

PFT-12.2.1.3 On types of welded attachment shown in Figure PFT-12.1, illustrations (c) and (e), the tubes shall be expanded before and after welding. On types shown in illustrations (f) and (g), the tubes may be expanded.

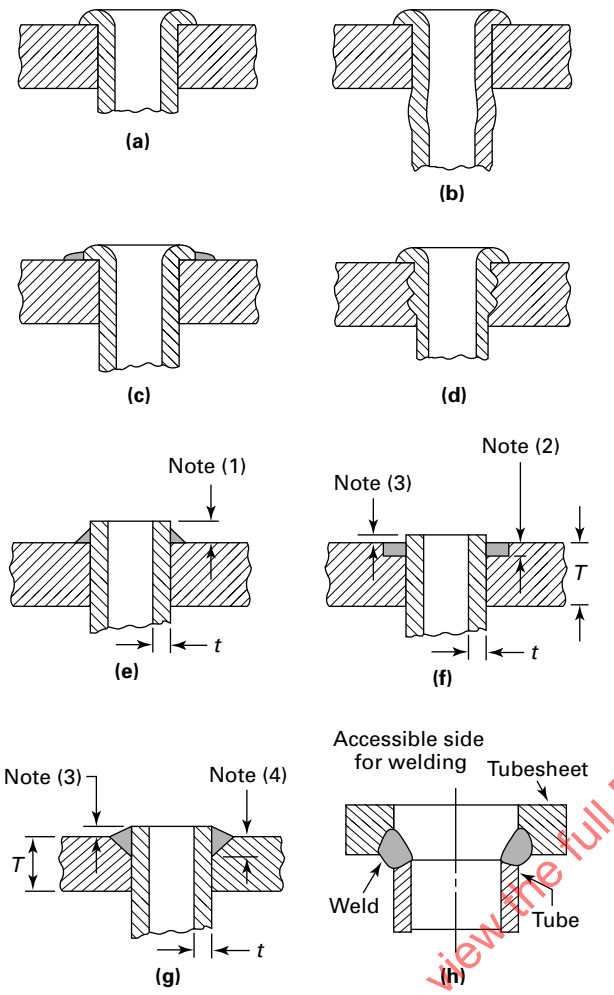
PFT-12.2.2 Expanding of tubes by the Prosser method may be employed in combination with any beaded or seal welded attachment method [see Figure PFT-12.1, illustration (b)].

PFT-12.2.3 After seal welding as shown by Figure PFT-12.1, illustrations (c) and (e), a single hydrostatic test of the boiler shall suffice.

PFT-12.2.4 The inner surface of the tube hole in any form of attachment may be grooved or chamfered.

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Figure PFT-12.1
Some Acceptable Forms of Tube Attachment on Firetube Boilers



NOTES:
(1) Not less than t or $\frac{1}{8}$ in. (3 mm), whichever is the greater, and not more than $2t$ or $\frac{1}{4}$ in. (6 mm), whichever is the lesser.
(2) Not less than t or $\frac{1}{8}$ in. (3 mm), whichever is the greater (see PFT-12.2.1.2).
(3) Not more than t.
(4) Not less than t or $\frac{1}{8}$ in. (3 mm), whichever is the greater (see PFT-12.2.1.2).

PFT-12.2.5 The sharp edges of tube holes shall be taken off on both sides of the plate with a file or other tool.

PFT-12.2.6 Welded tube attachments as shown by Figure PFT-12.1, illustration (h), may be made with partial or no insertion of the tube into the flat tubesheet. The following requirements shall be met for these attachments:

(a) The tube and tubesheet materials shall be restricted to P-No. 1, P-No. 3, or P-No. 4 materials.

(b) The maximum design temperature at the weld joint shall be less than or equal to

(1) the temperature limit for Section I shown in Section II, Part D, Subpart 1, Table 1A

(2) the temperature where the time-dependent properties begin to govern

(c) The weld shall be a full-penetration weld made from the I.D. of the tube. The throat of the weld shall be equal to or greater than the thickness of the tube. The root pass shall be made using the GTAW process.

(d) PWHT per PW-39 is mandatory. The exemptions to PWHT noted in Tables PW-39-1 through PW-39-14 shall not apply.

(e) In addition to meeting the performance qualification requirements of Section IX, before making a production weld each welder and welding operator shall demonstrate their ability to achieve complete weld penetration and minimum thickness by successfully welding six test pieces. The test pieces shall be welded in a mockup of the production weld. The mockup shall be of identical position, dimensions, and materials as that of the production weld. The test pieces shall be visually examined to verify complete penetration and sectioned to verify minimum weld thickness. The results shall be recorded and maintained with the performance qualification record.

(f) Each weld surface on the tube I.D. shall receive either a magnetic particle or liquid penetrant examination in accordance with A-260 or A-270 of Nonmandatory Appendix A, as applicable. In addition, a visual examination of the weld surface on the tube O.D. shall be performed. The maximum practicable number of these welds, but in no case fewer than 50%, shall be visually examined. Visual examination shall show complete penetration of the joint root and freedom from cracks.

COMBUSTION CHAMBERS

PFT-13 COMBUSTION CHAMBER TUBESHEET

PFT-13.1 The maximum allowable working pressure on a tubesheet of a combustion chamber, where the crown sheet is not suspended from the shell of the boiler, shall be determined by the following equation:

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(U.S. Customary Units)

$$P = 27{,}000\,\frac{t(D - d)}{WD}$$

(SI Units)

$$P = 186\,\frac{t(D - d)}{WD}$$

where

D = least horizontal distance between tube centers on a horizontal row
d = inside diameter of tubes
P = maximum allowable working pressure
t = thickness of tubesheet
W = distance from the tubesheet to opposite combustion chamber sheet

Where tubes are staggered, the vertical distance between the center lines of tubes in adjacent rows must not be less than

$$1/2\,\sqrt{2dD + d^2}$$

Example: Required the maximum allowable working pressure of a tubesheet supporting a crown sheet stayed by crown bars. Horizontal distance between centers, $4\frac{1}{8}$ in.; inside diameter of tubes, 2.782 in.; thickness of tubesheets $\frac{11}{16}$ in.; distance from tubesheet to opposite combustion-chamber sheet, $34\frac{1}{4}$ in.; measured from outside of tubesheet to outside of back plate; material, steel. Substituting and solving the following equation:

$$P = \frac{(4.125 - 2.782) \times 0.6875 \times 27{,}000}{34.25 \times 4.125} = 176 \text{ psi}$$

PFT-13.2 Sling stays may be used in place of girders in all cases covered in PFT-13.1, provided, however, that when such sling stays are used, girders or screw stays of the same sectional area shall be used for securing the bottom of the combustion chamber to the boiler shell.

PFT-13.3 When girders are dispensed with and the top and bottom of combustion chambers are secured by sling stays, the sectional area of such stays shall conform to the requirements of rules for stayed surfaces.

PFT-14 GENERAL

PFT-14.1 Furnaces may be constructed using seamless pipe, electric resistance welded pipe within the limitations of PG-9.5, or fusion welded plate of the double welded butt type. A sample of the longitudinal weld, made with the addition of filler metal, of each section of a furnace shall be subjected to a bend test in accordance with PW-53. No volumetric examination of the longitudinal or circumferential welds is required.

PFT-14.2 When the longitudinal joint will be subjected to complete volumetric examination in accordance with PW-51 or PW-52, the individual bend test for each section of the furnace is not required.

PFT-15 PLAIN CIRCULAR FURNACES

PFT-15.1 Plain circular furnaces may be made up to any length, using sections where desired. The thickness may not be less than $\frac{5}{16}$ in. (8 mm).

PFT-15.2 The maximum allowable working pressure shall be determined in accordance with PG-28.3.

PFT-17 RING-REINFORCED TYPE

Horizontal cylindrical flues or furnaces (Figure PFT-17.2) may be constructed with circular stiffening rings, provided the requirements of PFT-17.1 through PFT-17.11.1 are met.

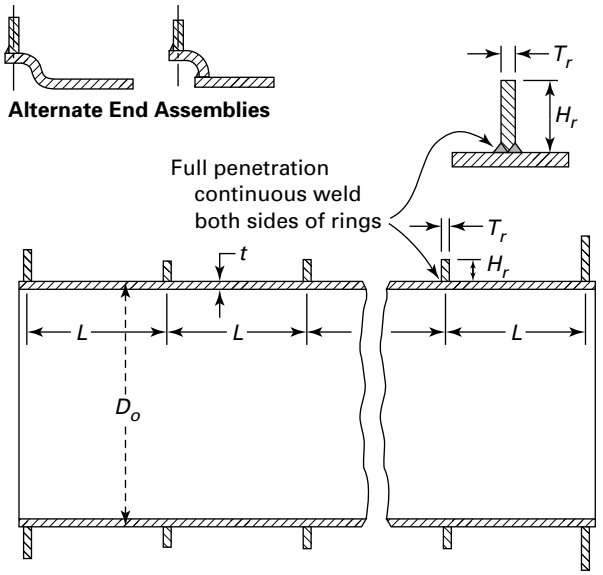
PFT-17.1 The stiffening ring is rectangular in cross section and is fabricated from one piece of plate, or from plate sections or bars provided full penetration welds are used in assembling.

PFT-17.2 The stiffening ring after fabrication has a thickness of not less than $\frac{5}{16}$ in. (8 mm) and not more than $\frac{13}{16}$ in. (21 mm) and in no case thicker than $1\frac{1}{4}$ times the furnace wall thickness.

PFT-17.3 The ratio of the height of the stiffening ring to its thickness, H_r/T_r, is not greater than 8 nor less than 3.

PFT-17.4 The stiffening ring is attached to the furnace by a full penetration joint, welded from both sides.

Figure PFT-17.2
Acceptable Type of Ring-Reinforced Furnace



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PFT-17.5 The thickness of the furnace wall or flue is a minimum of $^{5}/_{16}$ in. (8 mm).

PFT-17.6 The spacing L of the rings on the furnace is not greater than $60t$ or 36 in. (900 mm), whichever is smaller.

PFT-17.8 The boiler design permits replacement of the furnace. A flared or welded ogee ring is an acceptable type of assembly.

PFT-17.10 The maximum allowable working pressure shall be determined in accordance with PG-28.3.

PFT-17.11 The design of stiffening rings is determined by the use of the symbols given in PG-28.3, and the equation given in this paragraph.

PFT-17.11.1 The moment of inertia for a stiffening ring shall be determined by the following procedure.

Step 1. Assuming that the furnace has been designed and D_o, L_s, and t are known, select a rectangular member to be used for a stiffening ring and determine its area A_s and its moment of inertia I. Then calculate B by the following equation:

$$B = \frac{PD_o}{t + (A_s / L_s)}$$

where B = factor on the right-hand side of the applicable chart in Section II, Part D.

Step 2. Enter the right-hand side of the chart at the value of B determined in Step 1.

Step 3. Follow horizontally to the material line for the correct temperature.

Step 4. Move down vertically to the bottom of the chart and read the value of A.

Step 5. Compute the value of the required moment of inertia I_s by the following equation:

$$I_s = \frac{D_o^2 L_s [t + (A_s / L_s)] A}{14}$$

Step 6. If the required I_s is greater than the moment of inertia I for the section selected in Step 1, select a new section with a larger moment of inertia and determine a new value of I_s.

If the required I_s is smaller than I for the section selected in Step 1, that section should be satisfactory.

PFT-18 CORRUGATED FURNACES

PFT-18.1 The maximum allowable working pressure on corrugated furnaces, such as the Leeds suspension bulb, Morison, Fox, Purves, or Brown, having plain portions at the ends not exceeding 9 in. (230 mm) in length (except flues especially provided for), when new and practically circular, shall be computed as follows:

$$P = Ct/D$$

where

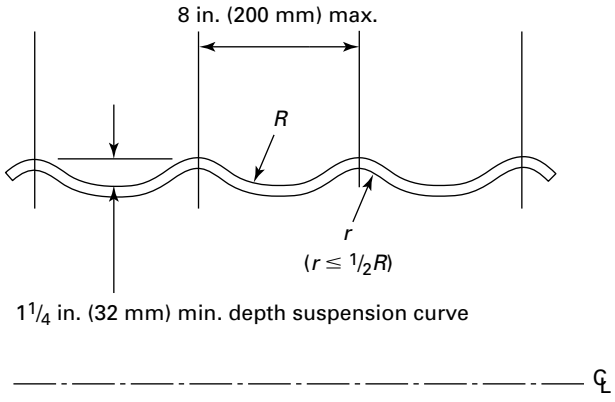
C = 17,300 (119), a constant for Leeds furnaces, when corrugations are not more than 8 in. (200 mm) from center to center and not less than $2^{1}/_{4}$ in. (57 mm) deep
= 15,600 (108), a constant for Morison furnaces, when corrugations are not more than 8 in. (200 mm) from center to center and not less than $1^{1}/_{4}$ in. (32 mm) deep, and the radius of the outer corrugation r, is not more than one-half of the radius of the suspension curve R (see Figure PFT-18.1)
= 14,000 (97), a constant for Fox furnaces, when corrugations are not more than 8 in. (200 mm) from center to center and not less than $1^{1}/_{2}$ in. (38 mm) deep
= 14,000 (97), a constant for Purves furnaces, when rib projections are not more than 9 in. (230 mm) from center to center and not less than $1^{3}/_{8}$ in. (35 mm) deep
= 14,000 (97), a constant for Brown furnaces, when corrugations are not more than 9 in. (230 mm) from center to center and not less than $1^{5}/_{8}$ in. (41 mm) deep

D = mean diameter
P = maximum allowable working pressure
t = thickness, not less than $^{5}/_{16}$ in. (8 mm) for Leeds, Morison, Fox, and Brown, and not less than $^{7}/_{16}$ in. (11 mm) for Purves furnaces

In calculating the mean diameter of the Morison furnace, the least inside diameter plus 2 in. (50 mm) may be taken as the mean diameter.

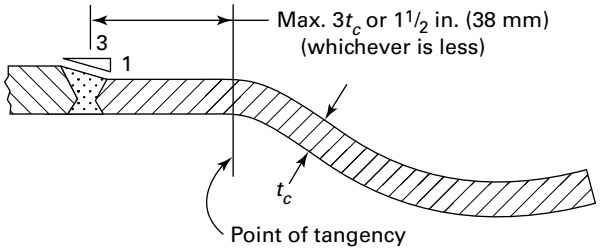
PFT-18.2 The thickness of a corrugated or ribbed furnace shall be ascertained by actual measurement by the furnace manufacturer, by gaging the thickness of the corrugated portions. For the Brown and Purves

Figure PFT-18.1
Morison Furnace



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Figure PFT-19
Connection Between Plain and Corrugated Furnace



furnaces, the measuring point shall be in the center of the second flat; for the Morison, Fox, and other similar types, in the center of the top corrugation, at least as far in as the fourth corrugation from the end of the furnace.

PFT-19 COMBINED PLAIN CIRCULAR AND CORRUGATED TYPE

Combination type furnaces for external pressure may be constructed by combining a plain circular section and a corrugated section provided

PFT-19.1 Each type of furnace is designed to be self-supporting, requiring no support from the other furnace at their point of connection.

PFT-19.2 Paragraphs PG-28.3 and PFT-15 are used for calculating the maximum allowable working pressure of the plain section. In applying the length in the text, or L in the equations, the value used shall always be twice the actual length of the plain section. The actual length of the plain section is the distance measured from the center line of the head attachment weld to the center line of the full penetration weld joining the two sections.

PFT-19.3 The maximum allowable working pressure of the corrugated section shall be determined from PFT-18.

PFT-19.4 The full penetration weld joining a plain self-supporting section to a corrugated self-supporting section shall be located as shown in Figure PFT-19.

PFT-20 ATTACHMENT OF FURNACES

PFT-20.2 Fillet-Welded Construction. In a scotch type boiler, a furnace may be attached to an outwardly flanged opening in a front tubesheet by a circumferential fillet weld, or a furnace may be attached to either tubesheet by flaring the end that extends beyond the outside face of the head to an angle of 20 deg to 30 deg, and using a circumferential fillet weld, provided the requirements of PFT-20.2.1 through PFT-20.2.5 are met.

PFT-20.2.1 The area of the head around the furnace is stayed by tubes, stays, or both in accordance with the requirements of this Section.

PFT-20.2.2 The joint is wholly outside the furnace.

PFT-20.2.3 The throat dimension of the full fillet weld is not less than 0.7 times the thickness of the head.

PFT-20.2.4 Unless protected by refractory material, the furnace does not extend beyond the outside face of the tubesheet a distance greater than the thickness of the tubesheet. Any excess shall be removed before welding.

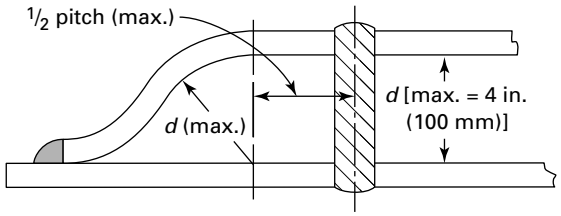
PFT-20.2.5 The construction conforms in all other respects to the requirements of this Section including welding and postweld heat treating, except that volumetric examination is not required.

PFT-20.3 Full Penetration Weld Construction. A furnace may be attached by a full penetration weld with the furnace extending at least through the full thickness of the tubesheet or head but not beyond the toe of the weld, and the toe shall not project beyond the face of the tubesheet or head by more than $^3/_8$ in. (10 mm) unless protected from overheating by refractory material or other means. Alternatively, the furnace may abut the tubesheet or head with a full-penetration weld made through the furnace. The weld may be applied from either or both sides and shall have an external fillet weld with a minimum throat of $^1/_4$ in. (6 mm). No weld preparation machining shall be performed on the flat tubesheet or head. The edge of the tubesheet or head shall be examined when required by PG-93 and shall not extend beyond the edge of the furnace by more than $^3/_8$ in. (10 mm) unless protected from overheating by refractory material or other means.

PFT-20.4 Throat Sheets. Throat sheets and inside and outside front furnace sheets when fully stayed may be attached as required in PFT-11.4.

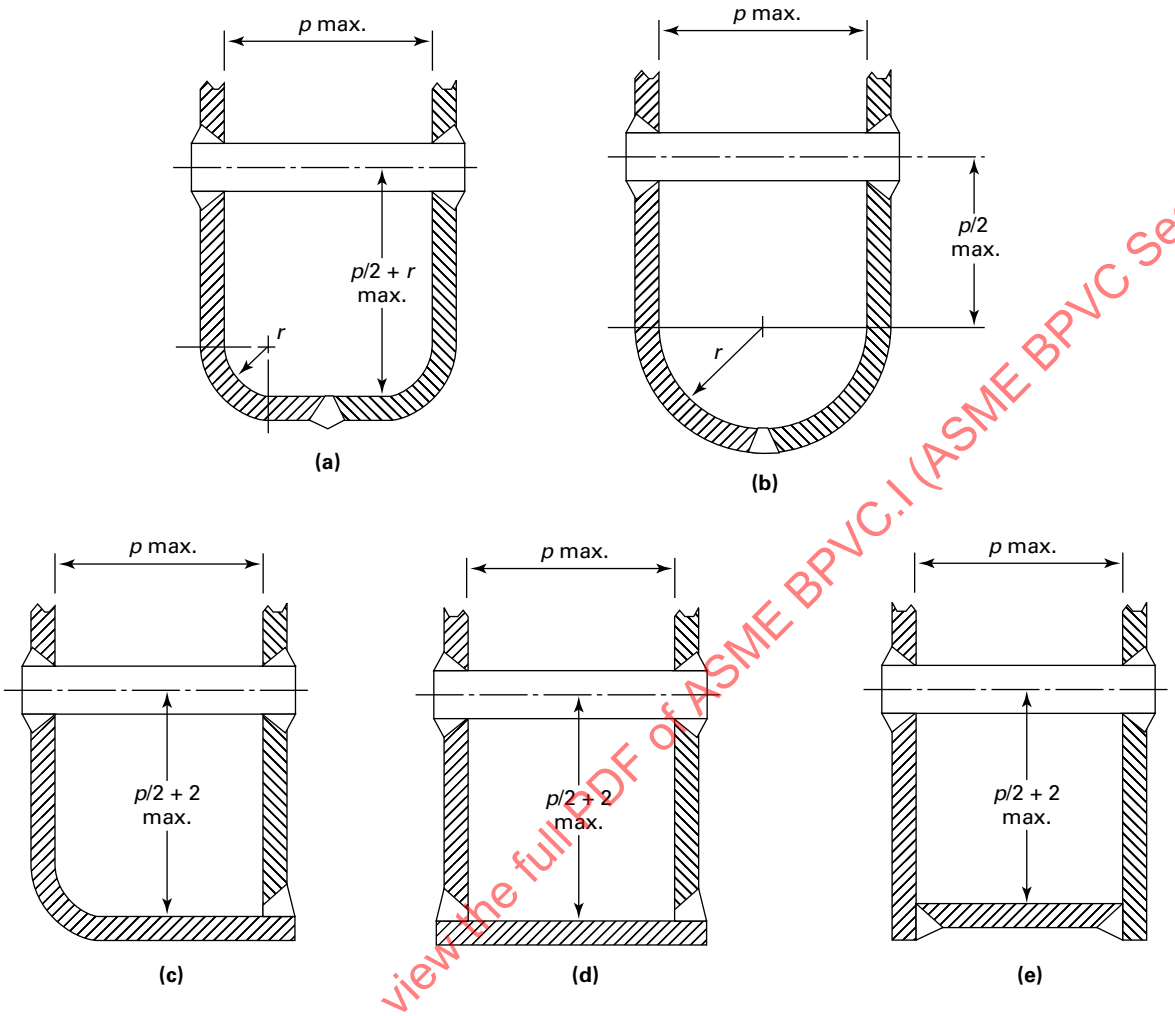
PFT-20.5 Furnace Sheets Attached by Welding. Vertical firetube boilers may be constructed by welding the ogee bottom of the furnace sheet to the outside shell as shown in Figure PFT-20, provided the requirements of PFT-20.5.1 through PFT-20.5.7 are met.

Figure PFT-20
Welding Ogee Ring



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Figure PFT-21
Some Acceptable Methods of Forming Waterleg Joints by Welding



PFT-20.5.1 The tube or crown sheet is fully supported by tubes, or stays, or both.

PFT-20.5.2 The joint is wholly within the shell and forms no part thereof.

PFT-20.5.3 The weld is not in contact with primary furnace gases.[23]

PFT-20.5.4 The throat dimension of the full fillet weld is not less than 0.7 times the thickness of the furnace sheet.

PFT-20.5.5 The maximum depth of the waterleg does not exceed 4 in. (100 mm), and the radius of the ogee is not greater than the inside width of the waterleg.

PFT-20.5.6 The pitch of the lower row of staybolts meets the requirements of PFT-27.5.

PFT-20.5.7 The construction conforms in all other respects to Code requirements including welding and postweld heat treating, except that volumetric examination is not required.

PFT-20.6 Openings. No calculation need be made to determine the availability of compensation for openings in tubesheets or heads for furnace connections that span between the tubesheets or heads.

PFT-21 FIREBOXES AND WATERLEGS

PFT-21.1 The width of waterlegs at the mudring in vertical firetube and firebox boilers shall not exceed the maximum allowable pitch calculated using PG-46.1, eq. (1), using 2.1 or 2.2 for the value of C depending on the plate thickness. The bottom edges of the plates forming a waterleg may be joined by flanging one or both plates as shown in Figure PFT-21, illustrations

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(a) through (c). Similar construction details are acceptable, provided the pitch and waterleg width requirements are met.

PFT-21.2 As an alternative, the bottom edges of the plates forming a waterleg may be joined using a flat plate, or mudring, attached between the waterleg sides as shown in Figure PFT-21, illustrations (d) and (e). The required thickness of the mudring shall be calculated using PG-46.1, eq. (1), using 2.2 for the value of C, depending on the plate thickness, and a value of p equal to the waterleg inside width, but shall be not less than $\frac{1}{2}$ in. (13 mm).

PFT-21.3 For waterlegs of vertical firetube boilers that are attached to tubesheets or crownsheets, the unstayed distance from a line of support on the tubesheet or crown sheet provided by tubes or stays to the inside surface of the outer wall of the waterleg shall comply with the spacing requirements of PFT-25.2 [see Figure A-8, illustration (p)].

STAYED SURFACES

PFT-22 GENERAL

The rules of Parts PG and PW pertaining to stays and stayed surfaces that are applicable to firetube boilers shall be used in conjunction with the following requirements.

PFT-23 WORKING PRESSURE FOR STAYED CURVED SURFACES

PFT-23.1 The maximum allowable working pressure for a stayed curved surface shall be the sum of the pressure as determined in PFT-23.1.1 and the lesser pressure determined from either PFT-23.1.2 or PFT-23.1.3.

PFT-23.1.1 The maximum working pressure computed without allowing for the holding power of the stays, due allowance being made for the weakening effect of any holes provided for construction.

PFT-23.1.2 The maximum working pressure obtained by the equation given in PG-46 using 1.3 for the value of C.

PFT-23.1.3 The maximum working pressure obtained by the following equation:

$$P_1 = \frac{A_1 S}{A_2}$$

where

A_1 = cross-sectional area of stay
A_2 = maximum area supported by stay
P_1 = pressure corresponding to the strength of the stay
S = allowable stress of stay as given in Section II, Part D, Subpart 1, Table 1A

PFT-23.2 The maximum allowable working pressure for a stayed wrapper sheet of a locomotive-type boiler shall be the lesser of the value obtained in PFT-23.1 or the value obtained in the following equation:

$$P = \frac{StE}{R - \Sigma(s \times \sin a)}$$

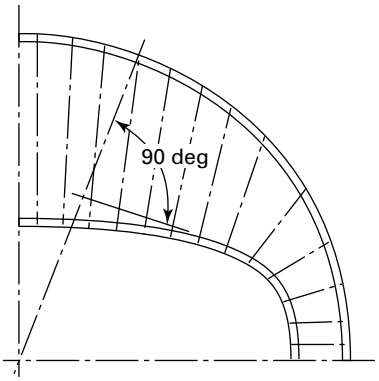
where

a = angle any crown stay makes with the vertical axis of boiler
E = minimum efficiency of wrapper sheet through joints or stay holes
P = maximum allowable working pressure
R = radius of wrapper sheet
S = allowable stress as given in Section II, Part D, Subpart 1, Table 1A
s = transverse spacing of crown stays in the crown sheet
t = thickness of wrapper sheet
$\Sigma\ (s \times \sin a)$ = summated value of transverse spacing for all crown stays considered in one transverse plane and on one side of the vertical axis of the boiler

The above equation applies to the longitudinal center section of the wrapper sheet, and in cases where E is reduced at another section, the maximum allowable working pressure based on the strength at that section may be increased in the proportion that the distance from the wrapper sheet to the top of the crown sheet at the center bears to the distance measured on a radial line through the other section, from the wrapper sheet to a line tangent to the crown sheet and at right angles to the radial lines (see Figure PFT-23.1).

PFT-23.3 Furnaces of Vertical Boilers. In a vertical firetube boiler, the furnace length, for the purpose of calculating its strength and spacing staybolts over its

Figure PFT-23.1
Stayed Wrapper Sheet of Locomotive-Type Boiler



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surface, shall be measured from the fire side face of flat tubesheets or the point of tangency of flanged tubesheets to the inside of the lower mud ring.

PFT-23.3.1 A furnace for a vertical firetube boiler 38 in. (970 mm) or less in outside diameter that requires staying shall have the furnace sheet supported by one or more rows of staybolts, the circumferential pitch not to exceed 1.05 times that given by the equation in PG-46.

The longitudinal pitch between the staybolts shall not exceed that given by the following equation:

(U.S. Customary Units)

$$L = \left(\frac{56{,}320t^2}{PR}\right)^2$$

(SI Units)

$$L = \left(\frac{77.05t^2}{PR}\right)^2$$

where

L = longitudinal pitch of staybolts
P = maximum allowable working pressure
R = outside radius of furnace
t = thickness of furnace sheet

When values by this formula are less than the circumferential pitch, the longitudinal pitch may be as large as the allowable circumferential pitch.

The stress in the staybolts shall not exceed the allowable stress given in Section II, Part D, Subpart 1, Table 1A, and determined by PFT-26.1.

PFT-23.3.2 In furnaces over 38 in. (970 mm) in outside diameter and combustion chambers not covered by special rules in this Section, which have curved sheets subject to pressure on the convex side, neither the circumferential nor longitudinal pitches of the staybolts shall exceed 1.05 times that given by the rules in PG-46.

PFT-23.4 Upper combustion chambers of vertical submerged tubular boilers made in the shape of a frustrum of a cone when not over 38 in. (970 mm) in outside diameter at the large end may be used without stays if computed by the rule for plain cylindrical furnaces in PFT-14, making D in the formula equal to the outside diameter at the large end, provided that the longitudinal joint conforms to the requirements of PFT-14.

PFT-23.5 For furnaces of PFT-23.4 when over 38 in. (970 mm) in outside diameter at the large end, that portion which is over 30 in. (760 mm) in diameter shall be fully supported by staybolts, and PFT-23.3.2 shall apply. The top row of staybolts shall be at a point where the cone top is 30 in. (760 mm) or less in diameter.

In calculating the pressure permissible on the unstayed portion of the cone, the vertical distance between the horizontal planes passing through the cone top and through the center of the top row of staybolts shall be taken as L in PG-28.3.1.1. D_o in PG-28.3.1.1 shall be taken as the inside diameter at the center of the top row of staybolts.

PFT-24 STAYING HORIZONTAL RETURN TUBE BOILERS

When stays are required, the portion of the heads below the tubes in a horizontal-return tubular boiler shall be supported by through-stays attached by welding under PW-19 or with nuts inside and outside at the front head and by attachments which distribute the stress at the rear head.

The distance in the clear between the bodies of the stays or of the inside stays where more than two are used shall not be less than 10 in. (250 mm) at any point.

PFT-25 STAYING SEGMENTS OF HEADS

PFT-25.1 A segment of a head shall be stayed by head-to-head through stays or diagonal stays.

PFT-25.2 Stays shall be used in the tubesheets of a firetube boiler if the distance between the edges of the tube holes exceeds the maximum pitch of staybolts for the corresponding plate thickness and pressure given in PG-46.

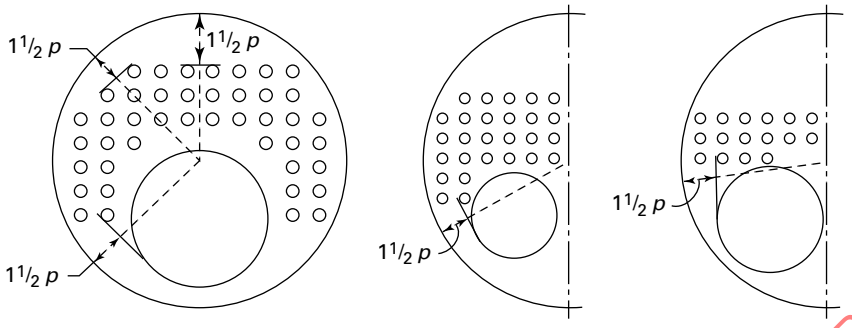
Any part of the tubesheet that comes between the tube, furnace, or water-cooled turnaround chamber, and the shell need not be stayed if the greatest distance measured along a radial line from the inner surface of the shell to the center point of tangent to any two tube holes or tube hole and furnace or water-cooled turnaround chamber on the shell side of such holes does not exceed 1.5 times the value of p obtained by applying the formula of PG-46 with C equal to 1.8 or 1.9 depending upon the plate thickness. The tube holes, or tube hole and furnace or water-cooled turnaround chamber (see Figure PFT-25), to which a common tangent may be drawn in applying this rule, shall not be at a greater distance from edge to edge than the maximum pitch referred to.

PFT-26 AREA SUPPORTED BY STAY

PFT-26.1 Except as specified in PFT-26.3, the full pitch dimensions of the stays shall be employed in determining the area to be supported by a stay, and the area occupied by the stay shall be deducted therefrom to obtain the net area. The product of the net area in square inches by the maximum allowable working pressure in psi gives the load to be supported by the stay. (23)

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Figure PFT-25
Example of Staying of Heads Adjacent to Cylindrical Furnaces



PFT-26.2 Except as specified in PFT-26.3, where stays come near the outer edge of the surfaces to be stayed and special allowances are made for the spacing, the load to be carried by such stays shall be determined by neglecting the added area provided for by these special allowances.

Example: If the maximum pitch by PG-46 would make a staybolt come 6 in. (150 mm) from the edge of the plate and a special allowance would make it come 7 in. (180 mm), the distance of 6 in. (150 mm) shall be used in computing the load to be carried.

PFT-26.3 When stays are adjacent to a formed flange with a radius ranging from $3t$ to $32t$, the flange may be considered self-supporting for a distance d, measured from the outer surface of the flange. The load on the area between the inside of the shell and this perimeter shall not be considered when calculating the load on supports inboard of the perimeter. The area inboard of the perimeter is supported by the flange for a half-pitch dimension (see Figure PFT-26.3-1). For flange radii larger than $32t$, the requirements of PG-16.1 apply.

$$d = t\left[-0.00025\left(\frac{r}{t}\right)^3 + 0.021\left(\frac{r}{t}\right)^2 + 0.37\frac{r}{t} + 0.36\right]$$

where

d = flange self-support distance, in. (mm)
r = flange outside radius, in. (mm)
t = thickness of plate, in. (mm)

PFT-27 MAXIMUM SPACING

PFT-27.1 The maximum distance between the edges of tube holes and the centers of stays shall be p as determined by the formula in PG-46, using the value of C given for the thickness of plate and type of stay used.

PFT-27.2 For a flanged head welded to the shell, the maximum distance between the outer surface of the supporting flange and lines parallel to the surface of the shell passing through the center of the stays shall be p as determined by the formula in PG-46, plus d, as defined in PFT-26.3, using the C factor that applies to the thickness of the head plate and type of stay used [see Figure PFT-27.2-1; Figure A-8, illustrations (i) and (j)].

PFT-27.3 For unflanged heads, the maximum distance between the inner surface of the shell and the centers of stays shall not be more than one-half the maximum allowable pitch as determined by PG-46, using 2.5 for the value of C, plus 2 in. (50 mm) [see Figure A-8, illustration (k)].

PFT-27.4 The pitch of diagonal stays attached by welding between the shells and tubesheets of horizontal tubular and scotch boilers, and for other stays when the supported plate is not exposed to radiant heat, as determined by PG-46, may be greater than 8½ in. (216 mm), but shall not exceed 15 times the stay diameter.

PFT-27.5 The pitch of the lower row of staybolts of a vertical firetube boiler, which is required to be stayed by the rules in this Section, and which is fabricated by welding the ogee bottom of the furnace sheet to the outside shell, shall not exceed one-half the maximum allowable pitch as determined by PG-46, measured from the center of the staybolt to the tangent of the ogee (see Figure PFT-20).

PFT-27.6 The spacing of staybolts around door holes fabricated by fusion welding of the full penetration type of two-flanged sheets, which are required to be stayed by the rules of this Section [see Figure PFT-21, illustrations (a) and (b)], shall not exceed one-half the maximum allowable pitch determined by PG-46, measured from the center of the staybolt to the points of tangency of the flanges.

PFT-27.7 If the furnace sheets are required to be stayed by the rules of this Section, the spacing of staybolts around door holes and the spacing of the first row of staybolts from the bottom of a mud ring fabricated by fusion welding of the full penetration type when either or both sheets are not flanged [see Figure A-8, illustrations (l) through (n)] shall not exceed one-half the maximum

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pitch determined by PG-46, plus 2 in. (50 mm), measured from the center of the staybolt to the root of the weld.

PFT-27.8 The maximum distance from the first row of stays to a full penetration weld in compression applied from either or both sides of the tubesheet, attaching the crown sheet of a furnace or combustion chamber to a stayed head or tubesheet shall not exceed the pitch determined by PG-46, measured from the center of the stay to the furnace or combustion chamber side of the head or tubesheet [see Figure A-8, illustrations (o) and (p)].

PFT-27.9 When a flanged-in manhole opening with a flange depth of not less than three times the required thickness of the head, or when an unflanged manhole ring meeting the requirements of PG-32 through PG-39 is provided in a flat stayed head of a firetube boiler, as shown in Figure A-8, illustrations (q) and (r), the load created by the unsupported area of the manway shall be supported by the stays surrounding the manway. When the manway is in close proximity to the shell, the load may be shared by the shell by reducing the area supported by the stays by 100 in.^{2} (64 500 mm^2), provided the requirements of both PFT-27.9.1 and PFT-27.9.2 are met.

PFT-27.9.1 The distance between the manhole opening and the inside of the shell does not exceed one-half the maximum allowable pitch for an unflanged manhole and one-half the maximum allowable pitch plus the radius of the head flange for a flanged-in manhole in a flanged head.

PFT-27.9.2 The distance between the centers of the first row of stays, or the edges of tube holes, and the manhole opening does not exceed one-half the maximum allowable pitch as determined by PG-46.

PFT-27.10 In applying these rules and those in PG-46 to a head or plate having a manhole or reinforced opening, the spacing applies only to the plate around the opening and not across the opening.

PFT-27.11 For stays at the upper corners of fireboxes, the pitch from the staybolt next to the corner to the point of tangency to the corner curve shall be (see Figure PFT-27.11-1)

$$p = \left(\frac{90}{\text{Angularity of tangent lines } (\beta)}\right)\sqrt{C\frac{t^2S}{P}}$$

where

C = factor for the thickness of plate and type of stay used as required in PG-46
P = maximum allowable working pressure
S = maximum allowable stress value given in Section II, Part D, Subpart 1, Table 1A
t = thickness of plate
β = angle, deg, 90 deg ≤ β ≤ 180 deg

PFT-28 STAYBOLTS AND STAYS

PFT-28.1 The required area at the point of least net cross section of staybolts and stays shall be as given in PG-49. The maximum allowable stress per square inch at point of least net cross-sectional area of staybolts and stays shall be given as in Section II, Part D, Subpart 1, Table 1A. In determining the net cross-sectional area of drilled or hollow staybolts, the cross-sectional area of the hole shall be deducted.

PFT-28.2 The length of the stay between supports shall be measured from the inner faces of the stayed plates. The stresses are based on tension only. For computing stresses in diagonal stays, see PFT-32.

PFT-28.3 When stay rods are screwed through sheets and riveted over, they shall be supported at intervals not to exceed 6 ft (1.8 m). Stay rods over 6 ft (1.8 m) in length may be used without support if fitted with nuts and washers or attached by welding under PW-19, provided the least cross-sectional area of the stay rod is not less than that of a circle 1 in. (25 mm) in diameter and the requirements of PG-46.8 are met.

PFT-29 FLEXIBLE AND FILLET-WELDED STAYBOLTS (23)

PFT-29.1 Flexible-type staybolts having a cover cap welded under the provisions of PW-15 to the outer sheet may be used in the construction of locomotive-type boilers, provided the bolts are hollow-drilled from the threaded end into and partly through the ball head to allow for proper inspection, and so that any breakage is disclosed by leakage at the inner end. These welded joints need not be postweld heat treated or volumetrically examined.

PFT-29.2 Locomotive-type boilers [e.g., traction engine boilers, locomotive boilers under 30 in. (750 mm) in outside diameter, miniature live steam boilers] not falling under Part PL may use fillet-welded staybolts in accordance with PL-30.4.

PFT-30 CROWN BARS AND GIRDER STAYS

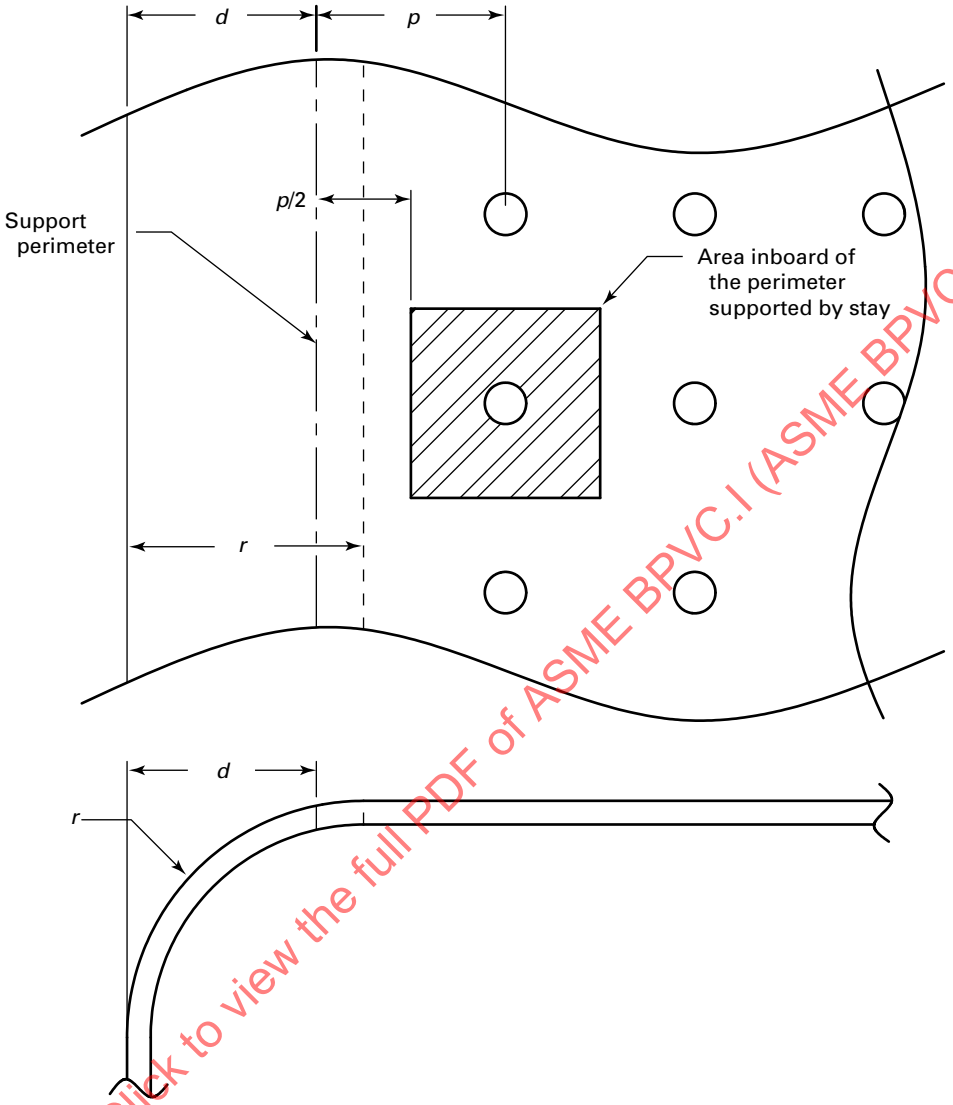
PFT-30.1 Crown bars and girder stays for tops of combustion chambers and back connections, or wherever used, shall be proportioned to conform to the following equation:

$$P = \frac{Cd^2t}{(W - p)D_1W}$$

where

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Figure PFT-26.3-1
Area Supported by Stay Defined in PFT-26.3



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Figure PFT-27.2-1
Maximum Spacing as Defined in PFT-27.2

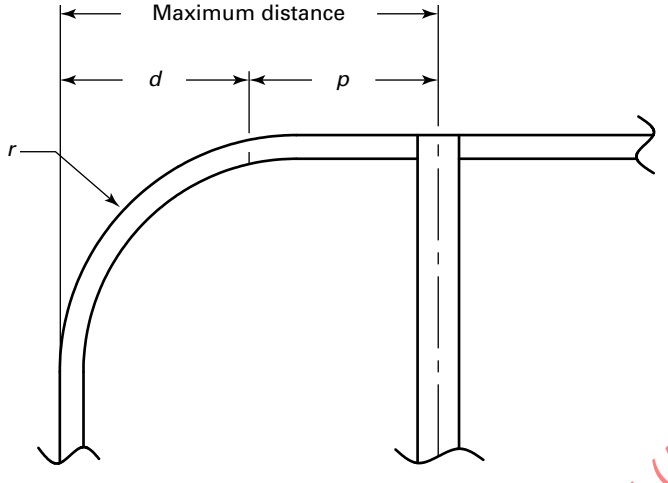
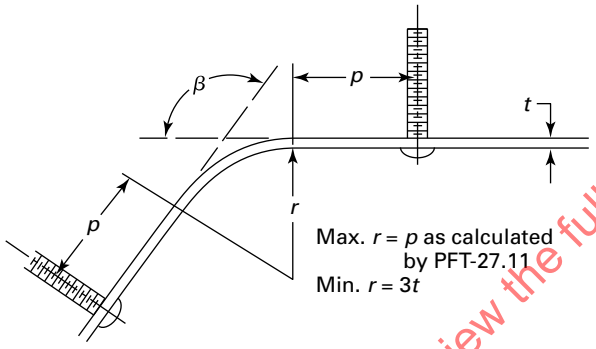


Figure PFT-27.11-1
Pitch of Staybolts Adjacent to Upper Corners of Fireboxes



GENERAL NOTE: If the radius r exceeds the pitch, the curved plate shall be stayed as a flat plate in accordance with PG-46.

C = 7,000 (48) when girder is fitted with one supporting bolt
= 10,000 (69) when the girder is fitted with two or three supporting bolts
= 11,000 (76) when the girder is fitted with four or five supporting bolts
= 11,500 (79) when the girder is fitted with six or seven supporting bolts
D_1 = distance between girders from center to center
d = depth of girder
P = maximum allowable working pressure
p = pitch of supporting bolts
t = thickness of girder
W = extreme distance between supports of, in a scotch marine boiler, the distance from the fire side of the tubesheet to the fire side of the back connection plate

Example: Given W = 34 in., p = 7.5 in., D_1 = 7.75 in., d = 7.5 in., t = 2 in.; three stays per girder, C = 10,000; then substituting in the following equation:

$$P = \frac{10{,}000 \times 7.5 \times 7.5 \times 2}{(34 - 7.5) \times 7.75 \times 34} = 161.1 \text{ psi}$$

Sling stays, if used between crown bars and boiler shell or wrapper sheet, shall be proportioned so as to carry the entire load without considering the strength of the crown bars.

PFT-30.2 In a form of reinforcement for crown sheets where the top sheet of the firebox is a semicircle and the top part of the circle not exceeding 120 deg in arc is reinforced by arch bars extending over the top and down below the top row of staybolts at the sides of the furnace beneath the semicircular crown sheet, the maximum allowable working pressure shall be determined by adding to the maximum allowable working pressure for a plain circular furnace of the same thickness, diameter, and length determined by the formula in PG-28.3, the pressure P_1 determined from the following equation, which is a modification of the formula in PFT-23:

(U.S. Customary Units)

$$P_1 = 10{,}000{,}000 \frac{bd^3}{D_1 D^3}$$

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(SI Units)

$$P_1 = 69\,000\,\frac{bd^3}{D_1\,D^3}$$

where

b = net width of crown bar
D = two times the radius of the crown sheet
D_1 = longitudinal spacing of crown bar that shall not exceed twice the maximum allowable staybolt pitch
d = depth of crown bar

provided that the maximum allowable working pressure must not exceed that determined by the equation for furnaces of the ring-reinforced type, in PG-28.3 when L is made equal to D_1, and also provided that the diameter of the holes for the staybolts in the crown bars does not exceed $\frac{1}{3}b$, and the cross-sectional areas of the crown bars is not less than 4 in.^{2} (2 580 mm^2). PG-46 governs the spacing of the staybolts or bolts attaching the sheet to the bars, and PFT-28, the size of the staybolts or bolts.

For constructions in which the crown sheet is not semicircular, or in which other features differ from those specified above, a test shall be made in accordance with PG-18 and the working pressure shall be based thereon.

PFT-30.3 Cast iron supporting lugs, legs, or ends shall not be used.

PFT-31 STAY TUBES

PFT-31.1 When tubes are used as stays in multitubular boilers to give support to the tubesheets, the required cross-sectional area of such tubes shall be determined in accordance with PG-49.

PFT-31.2 The required tubesheet thickness and maximum pitch of stay tubes shall be calculated using the following equations:

$$t = \sqrt{\frac{P}{CS}\left(p^2 - \frac{\pi d^2}{4}\right)}$$

$$p = \sqrt{\frac{CSt^2}{P} + \frac{\pi d^2}{4}}$$

where

C = 2.1 for tubesheets not over $\frac{7}{16}$ in. (11 mm) thick
= 2.2 for tubesheets over $\frac{7}{16}$ in. (11 mm) thick
d = outside diameter of the tube
P = design pressure
p = maximum pitch measured between the centers of tubes in different rows, which may be horizontal, vertical, or inclined
S = maximum allowable stress value for the tubesheet material given in Section II, Part D, Subpart 1, Table 1A
t = required thickness of tubesheet

PFT-31.3 No calculation need be made to determine the availability of the required cross-sectional area or the maximum allowable pitch for tubes within or on the perimeter of a nest of tubes that are spaced at less than twice their average diameter.

PFT-31.4 Stay tubes may be attached by any of the acceptable means shown in Figure PFT-12.1.

PFT-32 STRESSES IN DIAGONAL STAYS

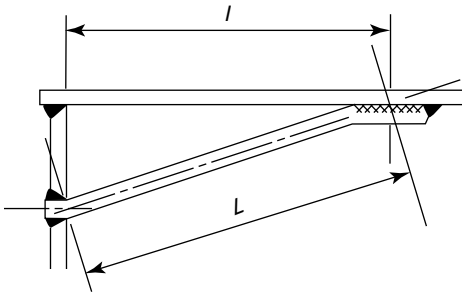
PFT-32.1 To determine the required area of a diagonal stay, multiply the area of a direct stay required to support the surface by the slant or diagonal length of the stay, and divide this product by the length of a line drawn at right angles to surface supported to center of palm of diagonal stay, as follows:

$$A = aL / l$$

where

A = sectional area of diagonal stay
a = sectional area of direct stay
L = length of diagonal stay as indicated in Figure PFT-32
l = length of line drawn at right angles to boiler head or surface supported to center of palm of diagonal stay, as indicated in Figure PFT-32, in. (mm)

Figure PFT-32
Measurements for Determining Stresses in Diagonal Stays



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Example: Given diameter of direct stay = 1 in., $a = 0.7854$ in.^{2}, $L = 60$ in., $l = 48$ in.; substituting and solving

$$A = (0.7854 \times 60)/48$$
$$= 0.98 \text{ sectional area, in.}^2$$
$$\text{Diameter (of diagonal stay)} = \sqrt{(0.9817 \text{ in.}^2 \times 4)/(3.14)}$$
$$= 1.118 \text{ in.}$$

Consequently, the next larger standard size of $1\frac{1}{8}$ in. diameter is selected.

PFT-32.2 For staying segments of tubesheets such as in horizontal-return tubular boilers, where L is not more than 1.15 times l for any stay, the stays may be calculated as direct stays allowing 90% of the allowable stress value given in Section II, Part D, Subpart 1, Table 1A.

DOORS AND OPENINGS

PFT-40 WELDED DOOR OPENINGS

Welding may be used in the fabrication of door holes provided the sheets are stayed around the opening in accordance with the requirements of PFT-27.6 and PFT-27.7.

No calculations need be made to determine the availability of compensation for door openings spanning between the plates of waterlegs. The required thickness of circular access openings shall be determined in accordance with PG-28.3. The required thickness of door openings of other than circular shape shall be calculated using PG-46.1, eq. (1), using 2.1 or 2.2 for the value of C, depending on the plate thickness, and a value of p equal to the waterleg inside width. Volumetric examination of the joining welds is not required.

PFT-41 OPENINGS IN WRAPPER SHEETS

Openings located in the curved portion of the wrapper sheet of a locomotive type boiler shall be designed in accordance with the rules in PG-32.

PFT-42 FIRESIDE ACCESS OPENINGS

The minimum size of an access or fire door opening, in which the minimum furnace dimension is 24 in. (600 mm), shall be not less than 12 in. × 16 in. (300 mm × 400 mm) or equivalent area, 11 in. (280 mm) to be the least dimension in any case. A circular opening shall be not less than 15 in. (380 mm) in diameter.

For furnace dimensions less than 24 in. (600 mm), the opening should be $2\frac{3}{4}$ in. × $3\frac{1}{2}$ in. (70 mm × 89 mm) or larger where possible. In cases where the size or shape of the boiler prohibits an opening of that size, two openings with a minimum size of 1 in. (25 mm) may be used, preferably oppposite each other, to permit inspection and cleaning of the furnace. If the burner is removable so as to permit inspection and cleaning through the burner opening, a separate access opening need not be provided.

The bonnet or smoke hood of a vertical flue or tubular boiler shall be provided with an access opening at least 6 in. × 8 in. (150 mm × 200 mm) for the purpose of inspection and cleaning the top head of the boiler.

PFT-43 REQUIREMENTS FOR INSPECTION OPENINGS

All firetube boilers shall have sufficient inspection openings, handholes, or washout plugs with a minimum of four openings to permit inspection of the waterside of the tubesheets, furnaces, and tubes and to permit flushing of loose scale and sediment from the boiler. Except where space restrictions would prohibit entry to the boiler, a manhole shall be provided in the upper portion of the shell. All openings shall meet the requirements of PG-32 through PG-44. Where washout plugs are used, the minimum size shall be NPS $1\frac{1}{2}$ (DN 40), except for boilers 16 in. (400 mm) or less in inside diameter, the minimum size shall be NPS 1 (DN 25).

PFT-44 OPENING BETWEEN BOILER AND PRESSURE RELIEF VALVE

The opening or connection between the boiler and the pressure relief valve shall have at least the area of the valve inlet.

After the boiler Manufacturer provides for the opening required by the Code, a bushing may be inserted in the opening in the shell to suit a pressure relief valve that will have the capacity to relieve all the steam that can be generated in the boiler and which will meet the Code requirements. The minimum size of the connection and opening for the pressure relief valve shall be not less than NPS $\frac{1}{2}$ (DN 15).

No valve of any description shall be placed between the required pressure relief valve or valves and the boiler, or on the discharge pipe between the pressure relief valve and the atmosphere. When a discharge pipe is used, the cross-sectional area shall be not less than the full area of the valve outlet or of the total of the areas of the valve outlets discharging thereinto and shall be as short and straight as possible and so arranged as to avoid undue stresses on the valve or valves.

DOMES

PFT-45 REQUIREMENTS FOR DOMES

PFT-45.1 The longitudinal joint of a dome may be butt welded or the dome may be made without a seam of one piece of steel pressed into shape. The dome flange may be double full fillet lap welded to the shell if all welding complies fully with the requirements for welding in

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Part PW. Volumetric examination of the fillet welds may be omitted. The opening shall be reinforced in accordance with PG-32 through PG-44.

PFT-45.3 When a dome is located on the barrel of a locomotive-type boiler or on the shell of a horizontal-return tubular boiler, the outside diameter of the dome shall not exceed six-tenths the inside diameter of the shell or barrel of the boiler unless the portion of the barrel or shell under the dome (the neutral sheet) is stayed to the head or shell of the dome by stays which conform in spacing and size to the requirements given in PG-46. With such stayed construction the outside diameter of a dome located on the barrel or shell of a boiler is limited to eight-tenths of the barrel or shell inside diameter.

PFT-45.4 All domes shall be so arranged that any water can drain back into the boiler.

PFT-45.5 Flanges of domes shall be formed with a corner radius, measured on the inside, of at least twice the thickness of the plate for plates 1 in. (25 mm) in thickness or less, and at least three times the thickness of the plate for plates over 1 in. (25 mm) in thickness.

PFT-45.6 In a locomotive-type boiler with a dome on a tapered course, the maximum allowable diameter of the dome shall be based on that diameter of the tapered course which intersects the axis or center line of the dome.

SETTING

PFT-46 METHOD OF SUPPORT

PFT-46.1 The design and attachment of lugs, hangers, saddles, and other supports shall meet the requirements of PG-22.1 and PG-55.

PFT-46.2 In applying the requirements of PFT-46.1, localized stresses due to concentrated support loads, temperature changes, and restraint against dilation of the boiler due to pressure shall be provided for. Lugs, brackets, saddles, and pads shall conform satisfactorily to the shape of the shell or surface to which they are attached or with which they are in contact.

PFT-46.3 A horizontal-return tubular boiler over 72 in. (1 800 mm) in diameter shall be supported from steel hangers by the outside-suspension-type setting, independent of the furnace side walls.

PFT-46.4 A horizontal-return tubular boiler, 14 ft (4.3 m) or more in length, or over 54 in. (1 350 mm) and up to and including 72 in. (1 800 mm) in diameter, shall be supported by the outside-suspension-type setting as specified in PFT-46.3, or, for wall-supported boilers, at four points by not less than eight steel lugs set in pairs. A horizontal-return tubular boiler up to and including 54 in. (1 350 mm) in diameter shall be supported by the outside-suspension-type setting as specified in PFT-46.3, or, for wall-supported boilers, by not less than two steel lugs on each side. If more than four lugs are used on wall-supported boilers, they shall be set in four pairs, the lugs of each pair to be spaced not over 2 in. (50 mm) apart and the load to be equalized between them (see Figure PFT-46.1). If the boiler is supported on structural steel work, the steel supporting members shall be so located that heat from the furnace cannot impair their strength.

PFT-46.5 Figure PFT-46.2 illustrates an acceptable design of hanger bracket for welded attachment to welded horizontal-return tubular boilers with the additional requirement that the hanger pin be located at the vertical center line over the center of a welded contact surface. The bracket plates shall be spaced at least 2½ in. (64 mm) apart, but this dimension shall be increased if necessary to permit access for the welding operation.

PFT-46.6 Wet-bottom stationary boilers shall be supported so as to have a minimum clearance of 12 in. (300 mm) between the underside of the wet-bottom and the floor to facilitate inspection. Other types of firetube boilers set horizontally shall be supported so that they have a minimum clearance of 12 in. (300 mm) between the metal surface of the shell and the floor. Boiler insulation, saddles, or other supports shall be arranged so that inspection openings are readily accessible.

PIPING, FITTINGS, AND APPLIANCES

PFT-47 WATER LEVEL INDICATORS

PFT-47.1 Boilers of the horizontal firetube type that exceed 16 in. (400 mm) in inside diameter shall be so set that when the water is at the lowest visible level in the gage glass there shall be at least 3 in. (75 mm) above the lowest permissible water level as determined by the Manufacturer.

Horizontal firetube boilers that do not exceed 16 in. (400 mm) in inside diameter shall have the lowest visible level in the gage glass at least 1 in. (25 mm) above the lowest permissible water level as determined by the Manufacturer.

PFT-47.2 Boilers of locomotives shall have at least one gage glass provided with top and bottom shutoff cocks and lamp.

The lowest visible level in the gage glass shall be not less than 3 in. (75 mm) for boilers over 36 in. (900 mm) in inside diameter. The lowest visible level shall be not less than 2 in. (50 mm) above the lowest permissible water level as determined by the Manufacturer for boilers 36 in. (900 mm) or less but greater than 16 in. (400 mm) in inside diameter. The lowest visible level

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Figure PFT-46.1
Spacing and Weld Details for Wall-Support Lugs Set in Pairs on Horizontal-Return Tubular Boilers

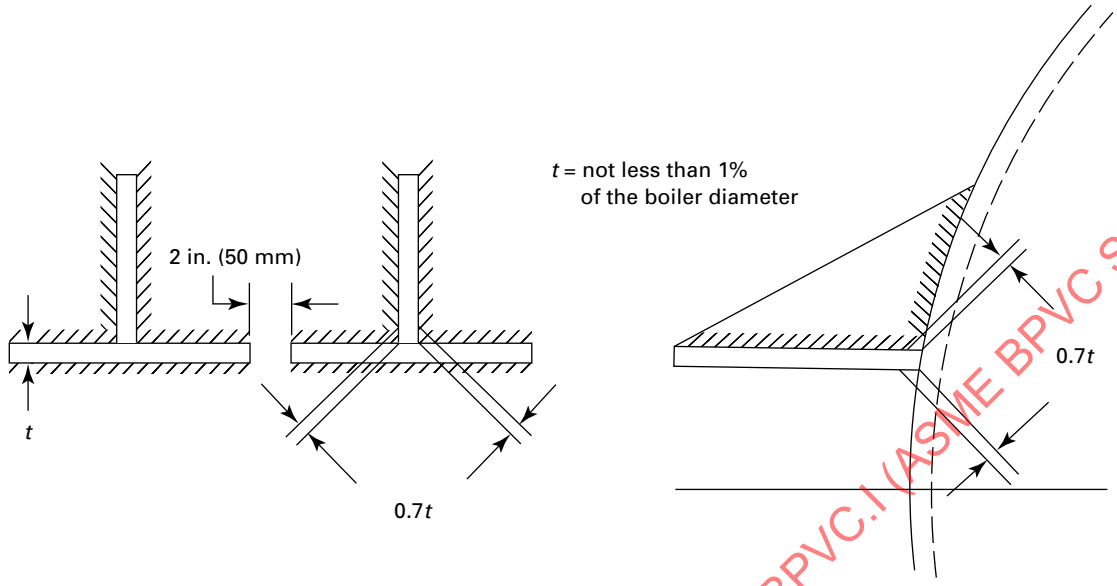
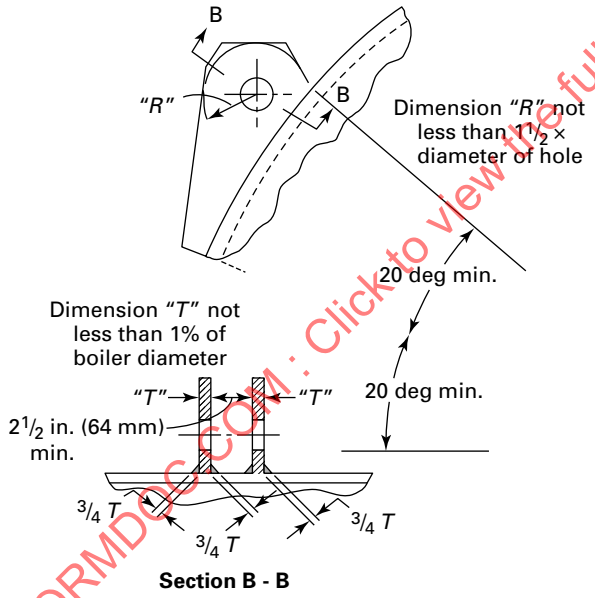


Figure PFT-46.2
Welded Bracket Connection for Horizontal-Return Tubular Boilers



shall be not less than 1 in. (25 mm) above the lowest permissible water-level as determined by the Manufacturer for boilers 16 in. (400 mm) or less in inside diameter. These are minimum dimensions, and on large locomotives and those operating on steep grades, the height should be increased, if necessary, to compensate for change of water level on descending grades.

The bottom mounting for the gage glass and for water column if used must extend not less than 1½ in. (38 mm) inside the boiler and beyond any obstacle immediately above it, and the passage therein must be straight and horizontal.

Tubular gage glasses shall be equipped with a protecting shield.

PFT-48 FEED PIPING

PFT-48.1 When a horizontal-return tubular boiler exceeds 40 in. (1 000 mm) in diameter, the feedwater shall discharge at about three-fifths the length from the end of the boiler that is subjected to the hottest gases of the furnace (except a horizontal-return tubular boiler equipped with an auxiliary feedwater heating and circulating device), above the central rows of tubes. The feed pipe shall be carried through the head or shell farthest from the point of discharge of the feedwater in the manner specified for a surface blowoff in PG-59.3.2, and be securely fastened inside the shell above the tubes.

PFT-48.2 In vertical tubular boilers the feedwater shall be introduced at a point not less than 12 in. (300 mm) above the crown sheet. When the boiler is under pressure, feedwater shall not be introduced through the openings or connections used for the water column or gage glass. In closed systems the water may be introduced through any opening when the boiler is not under pressure.

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PFT-49 BLOWOFF PIPING

PFT-49.1 Blowoff piping of firetube boilers that is exposed to products of combustion shall be attached by screwing into a tapped opening with provisions for a screwed fitting or valve at the other end.

PFT-49.2 Blowoff piping of firetube boilers which is not exposed to products of combustion may be attached by any method provided in this Section except by expanding into grooved holes.

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PART PFH
OPTIONAL REQUIREMENTS FOR FEEDWATER HEATER (WHEN LOCATED WITHIN SCOPE OF SECTION I RULES)

PFH-1

A feedwater heater is a heat exchanger in which feedwater to be supplied to a boiler is heated by steam or water extracted from the boiler or the prime mover. When such a feedwater heater is located within the limit of Section I piping, as defined by PG-58.2, it falls within the scope of Section I rules. With this arrangement, the feedwater heater may be constructed in compliance with Section VIII, Division 1, subject to the following conditions.

PFH-1.1 The feedwater heater shall conform with Section VIII, Division 1 rules for unfired steam boilers [UW-2(c)].

PFH-1.1.1 Welds shall be postweld heat treated to the minimum holding time and temperature requirements of Section VIII, Division 1 unless the welds satisfy the exemptions for postweld heat treatment in both Section I and Section VIII, Division 1.

PFH-1.2 The maximum allowable working pressure of the primary (feedwater) side of the heater shall be not less than the design pressure requirements of ASME B31.1, para. 122.1.3.

PFH-1.3 The design temperature of the tubes shall be not less than the saturated steam temperature corresponding to the maximum allowable working pressure of the shell. If the steam entering the shell side of the feedwater heater is superheated, the design temperature of the tubes in the desuperheating zone shall be not less than the saturation temperature corresponding to maximum allowable shell side working pressure plus 35°F (20°C).

PFH-1.4 The feedwater heater shall be stamped with the Certification Mark with the "U" Designator and be documented with the ASME U-1 Data Form.

PFH-1.5 A nameplate per UG-119 shall be furnished and shall show the additional information "and Part PFH of Section I."

PFH-1.6 The Master Data Report for the completed boiler unit (see PG-113) shall indicate "Feedwater heater constructed to Section VIII, Division 1, as permitted by Part PFH."

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PART PMB
REQUIREMENTS FOR MINIATURE BOILERS

GENERAL

PMB-1 GENERAL

The rules in Part PMB are applicable to miniature boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the special requirements in the applicable Parts of this Section that apply to the method of fabrication used.

PMB-2 SCOPE

PMB-2.1 The classification miniature boilers applies to boilers that do not exceed the following limits:

(a) 16 in. (400 mm) inside diameter of shell

(b) 20 ft^2 (1.9 m^2) heating surface (not applicable to electric boilers)

(c) 5 ft^3 (0.14 m^3) gross volume,[27] exclusive of casing and insulation

(d) 100 psig (700 kPa) maximum allowable working pressure

PMB-2.2 If a boiler meets the miniature classification, the rules in this Part shall supplement the rules for power boilers and take precedence over them when there is conflict. Where any of the limits in PMB-2.1 are exceeded, the rules for power boilers shall apply.

MATERIALS

(23) PMB-5 GENERAL

PMB-5.1 Unless specifically permitted elsewhere in this Section, materials used in the construction of pressure parts for miniature boilers shall conform to one of the specifications in Section II and shall be limited to those permitted by PG-6, PG-7, PG-8, and PG-9 for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B. Miscellaneous pressure parts shall conform to the requirements of PG-11.

PMB-5.2 Seamless and welded shells made from pipe for miniature boilers shall be not less than $^3/_{16}$ in. (5.0 mm) in thickness. Shells or heads made from plate shall be not less than $^1/_4$ in. (6 mm) in thickness. Heads used as tubesheets, with tubes expanded, shall be at least $^5/_{16}$ in. (8 mm) in thickness.

PMB-5.3 Steam boiler parts of not over 600 in.^{3} (0.01 m^3) in volume may be cast from copper alloy complying with requirements of SB-61 or SB-62 of wall thickness not less than $^1/_4$ in. (6 mm). Such steam boiler parts shall be equipped with at least one brass washout plug of not less than $^1/_2$ in. (13 mm) and shall be tested to a hydrostatic pressure of 600 psi (4 MPa).

PMB-5.4 Heads or parts of miniature boilers, when not exposed to the direct action of the fire, may be made of cast iron or malleable iron provided it complies with a specification permitted in this Section.

PMB-5.5 Miniature electric boilers of the immersion heater element type may be fabricated of austenitic stainless steel types 304, 304L, 316, 316L, and 347 from the material specifications listed in PG-6 and PG-9, provided that a precautionary statement indicating that the boiler shall be operated using only deionized water, having a maximum conductance of 1 microsiemen per cm (1 μS/cm) [minimum specific resistivity of 1 megohm per cm (1 MΩ/cm)], is clearly marked on the boiler in a visible location.

PMB-5.6 Due to the small size of parts of miniature boilers, the requirements of Identification, PG-77.1, need not be met, provided the Manufacturer certifies on the Data Report accompanying the boiler that the material is in accordance with the requirements of this Section. Provisions shall be made by Manufacturers whereby they shall be able to supply complete information regarding the material and details of construction of any boiler built under the provisions of this Code.

DESIGN

PMB-8 GENERAL

The rules in the following paragraphs apply specifically to the design of miniature boilers and parts thereof and shall be used in conjunction with the general requirements for design in Part PG as well as with the specific requirements for design in the applicable Parts of this Section that apply to the method of fabrication used.

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PMB-9 WELDING

Miniature boilers may be constructed by fusion welding in accordance with all the requirements of this Section except that postweld heat treatment, volumetric examination of the welded joints, and nondestructive examinations described in PG-93.1 are not required.

PMB-10 WASHOUT OPENINGS

PMB-10.1 Every miniature boiler exceeding 12 in. (300 mm) internal diameter or having more than 10 ft^2 (0.9 m^2) of heating surface shall be fitted with not less than three brass washout plugs of 1 in. (25 mm), which shall be screwed into openings in the shell near the bottom. Boilers not exceeding 12 in. (300 mm) internal diameter and having less than 10 ft^2 (0.9 m^2) of heating surface need have not more than two 1 in. (25 mm) openings for cleanouts, one of which may be used for the attachment of the blowoff valve; these openings shall be opposite to each other where possible. All threaded openings in the boiler shall be provided with a welded reinforcement, if necessary, to give four full threads therein.

PMB-10.2 Miniature boilers of a design employing a removable top cover flange for inspection and cleaning need not be fitted with washout openings.

PMB-11 FEEDWATER SUPPLY

PMB-11.1 Every miniature boiler shall be provided with at least one feed pump or other feeding device, except where it is connected to a water main carrying sufficient pressure to feed the boiler or where it is operated with no extraction of steam (such as in a closed system). In the latter case, in lieu of a feeding device, a suitable connection or opening shall be provided to fill the boiler when cold. Feedwater openings or connections to miniature boilers shall be not less than NPS $\frac{1}{2}$ (DN 15) for iron or steel pipe and NPS $\frac{1}{4}$ (DN 8) for brass or copper pipe.

PMB-11.2 The feed pipe shall be provided with a check valve and a stop valve of a size not less than that of the pipe. The feedwater may be delivered through the blowoff opening if desired.

PMB-12 BLOWOFF

Each miniature boiler shall be equipped with a blowoff connection, not less than NPS $\frac{1}{2}$ (DN 15), located to drain from the lowest water space practicable. The blowoff shall be equipped with a valve or cock not less than NPS $\frac{1}{2}$ (DN 15).

PMB-13 GAGE GLASSES

PMB-13.1 Each miniature boiler for operation with a definite water level shall be equipped with a gage glass for determining the water level. The lowest permissible water level of vertical boilers shall be at a point one-third of the height of the shell above the bottom head or tubesheet. Where the boiler is equipped with an internal furnace, the lowest permissible water level shall be not less than one-third of the length of the tubes above the top of the furnace tubesheet. In the case of small boilers operated in a closed system where there is insufficient space for the usual gage glass, water level indicators of the glass bull's-eye type may be used.

PMB-13.2 Miniature boilers shall have the lowest visible part of the gage glass located at least 1 in. (25 mm) above the lowest permissible water level specified by the Manufacturer.

PMB-14 FIXTURES AND FITTINGS

All valves, pipe fittings, and appliances connected to a miniature boiler shall be equal at least to the requirements of Class 125 (PN 20) or Class 150 (PN 20) of the appropriate ASME Standard listed in PG-42.

PMB-15 PRESSURE RELIEF VALVES

PMB-15.1 Each miniature boiler shall be equipped with a sealed pressure relief valve of not less than NPS $\frac{1}{2}$ (DN 15).

PMB-15.2 The minimum relieving capacity of the pressure relief valve shall be determined in accordance with PG-67.2.

PMB-15.3 All other provisions for pressure relief valves in this Section shall be complied with.

PMB-16 STEAM STOP VALVES

Each steam line from a miniature boiler shall be provided with a stop valve located as close to the boiler shell or drum as is practicable, except when the boiler and steam receiver are operated as a closed system.

PMB-17 AUTOMATIC DEVICES

All miniature boilers operated with gas, electricity, oil, or mechanical firing shall be provided with an automatic low-water fuel cutoff, except electric boilers of the electrode type as provided for in PEB-16.

PMB-21 HYDROSTATIC TESTS AND INSPECTION

PMB-21.1 In addition to the inspections required elsewhere in this Section, each miniature boiler pressure vessel shall be inspected while being tested at a hydrostatic pressure equal to three times the maximum allowable working pressure.

PMB-21.1.1 A minimum metal temperature of 60°F (15°C) is permitted during the hydrostatic test in PMB-21.1, provided the shell thickness is $\frac{3}{8}$ in. (10 mm) or less and provided only P-No. 8 or the following

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specific P-No. 1 materials are used in the construction of the pressure vessel:

(a) SA-53 Pipe Grade E or S
(b) SA-106 Pipe
(c) SA-516 Plate
(d) SA-105 Forgings
(e) SA-234 Fittings

PMB-21.2 Completed miniature boilers with mechanically assembled boiler external piping (BEP) and trim shall be given a final hydrostatic test at a pressure not less than $1\frac{1}{2}$ times the MAWP of the pressure vessel. Miniature electric boilers shall be given a final hydrostatic test in accordance with PEB-17.2

PMB-21.3 For completed miniature boilers with welded or brazed boiler external piping (BEP) or trim, the inspection requirements of PG-90.1 and the hydrostatic test requirements of PG-99 apply.

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PART PEB
REQUIREMENTS FOR ELECTRIC BOILERS

GENERAL

PEB-1 GENERAL

The rules in Part PEB are applicable to electric boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the special requirements in the applicable Parts of this Section that apply to the method of fabrication used.

PEB-2 SCOPE

PEB-2.1 This Part contains special rules for construction of electric boilers, both of the electrode and immersion resistance element type. This Part does not include electric boilers where the heat is applied externally to the boiler pressure vessel by electric resistance heating elements, induction coils, or other electrical means. These types of electric boilers shall be constructed in accordance with other applicable Parts of this Section.

PEB-2.2 Electric boilers and parts thereof that do not exceed the diameter, volume, or pressure limits of PMB-2 may be constructed using the applicable paragraphs of Part PMB in conjunction with this Part.

PEB-2.3 An electrode type boiler is defined as an electric boiler in which heat is generated by the passage of an electric current using water as the conductor.

PEB-2.4 An immersion resistance element type boiler is defined as an electric boiler in which heat is generated by the passage of an electric current through a resistance heating element directly immersed in water, or enclosed in a pipe immersed in water.

PEB-2.5 Electric boilers may be field assembled provided the boiler is manufactured and assembled in compliance with the provisions and requirements of Part PEB and other applicable Parts of this Section.

PEB-3 OPTIONAL REQUIREMENTS FOR THE BOILER PRESSURE VESSEL

The boiler pressure vessel may be constructed in compliance with the ASME Pressure Vessel Code Section VIII, Division 1, rules for unfired steam boilers [UW-2(c)] subject to the conditions specified in PEB-3.1 through PEB-3.4.

PEB-3.1 The Manufacturer who certifies and stamps the completed boiler shall specify to the Certification Holder with the "U" Designator all additional requirements of Part PEB, which are not requirements of Section VIII, Division 1, and shall ensure that these requirements are satisfied.

PEB-3.1.1 Welds shall be postweld heat treated to the minimum holding time and temperature requirements of Section VIII, Division 1 unless the welds satisfy the exemptions for postweld heat treatment in both Section I and Section VIII, Division 1.

PEB-3.2 These additional requirements are

PEB-3.2.1 The materials of construction shall comply with the requirements of PEB-5.1 and PEB-5.3.

PEB-3.2.2 Inspection openings shall comply with the requirements of PEB-10.

PEB-3.3 The boiler pressure vessel shall be stamped with the Certification Mark with the "U" Designator and the letters "UB," and be documented with the ASME U-1 or U-1A Data Report.

PEB-3.4 The master Data Report Form P-2A for the Electric Boiler shall indicate "Boiler pressure vessel constructed to Section VIII, Division 1 as permitted by Part PEB."

MATERIALS

PEB-5 GENERAL

PEB-5.1 Unless specifically permitted elsewhere in this section, materials used in the construction of pressure parts for electric boilers shall conform to one of the specifications in Section II and shall be limited to those permitted by PG-6, PG-7, PG-8, and PG-9 for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B. Miscellaneous pressure parts shall conform to the requirements of PG-11.

PEB-5.2 Seamless or welded shells, plates, or heads of electric boilers shall not be less than $^{3}/_{16}$ in. (5 mm) in thickness.

PEB-5.3 Electric boilers of the immersion heater element type may be fabricated of austenitic stainless steel type 304, 304L, 316, 316L, and 347 from the material (23)

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specifications listed in PG-6 and PG-9, provided that a precautionary statement indicating that the boiler shall be operated using only deionized water, having a maximum conductance of 1 microsiemen per cm (1 μS/cm) [minimum specific resistivity of 1 megohm per cm (1 MΩ/cm)], is clearly marked on the boiler in a visible location.

DESIGN

PEB-8 GENERAL

PEB-8.1 The rules in the following paragraphs apply specifically to the design of electric boilers and parts thereof. They shall be used in conjunction with the general requirements for design in Part PG, any applicable requirements in Part PMB for miniature boilers, and with the specific requirements for design in applicable Parts of this Section that apply to the method of fabrication used.

PEB-8.2 Responsibility of design of electric boilers bearing the "E" Designator shall be that of the Certification Holder with the "E" Designator.

PEB-8.3 Electric immersion heating element support plates shall be supplied using one of the following options:

(a) by a Section I "S" or "M" Certificate Holder. The design shall be to the rules of PG-31 and PG-35.

(b) by a Section I "S" or "M" Certificate Holder, or by a Section VIII, Division 1 "U" Certificate Holder. The design shall be to the rules of Section VIII, Division 1, Mandatory Appendix 41. In the "Remarks" section of the Section I Manufacturer's Data Report, the Manufacturer shall include the statement, "Electric immersion heater element support plate(s) designed in accordance with Section VIII, Division 1, Mandatory Appendix 41." When the part is manufactured by a "U" Certificate Holder, the Section VIII, Division 1, Form U-2, Manufacturer's Partial Data Report shall be referenced on Form P-2A, Manufacturer's Data Report.

(c) as a manufacturer's standard pressure part per PG-11.

PEB-9 WELDING

Electric boilers may be constructed by fusion welding in accordance with all the requirements of this Section except that postweld heat treatment, volumetric examination of the welded joints, and the nondestructive examinations described in PG-93.1 are not required when the limitations in PMB-2.1 are not exceeded.

PEB-10 INSPECTION OPENINGS

PEB-10.1 Electric boilers of a design employing a removable cover, or removable internal electric heating elements that will permit access for inspection, and cleaning and having an internal volume (exclusive of casing and insulation) of not more than 5 ft^3 (0.14 m^3) need not be fitted with washout or inspection openings.

PEB-10.2 Electric boilers of more than 5 ft^3 (0.14 m^3) not provided with a manhole, shall have an inspection opening or handhole located in the lower portion of the shell or head. The inspection opening shall not be smaller than NPS 3 (DN 80). In addition, electric boilers of the resistance heating element type designed for steam service shall have an inspection opening or handhole at or near the normal waterline.

PEB-11 FEEDWATER SUPPLY

PEB-11.1 The feedwater source to electric boilers shall be capable of meeting the applicable requirements of PG-61. Feedwater connections to an electric boiler shall not be smaller than NPS ½ (DN 15), except as permitted by PMB-11.

PEB-11.2 Electric boilers that do not exceed the diameter, volume, or pressure limits of PMB-2, may have the feedwater delivered through the blowoff opening if desired.

PEB-12 BOTTOM BLOWOFF

PEB-12.1 The blowoff piping for each electric boiler pressure vessel having a normal water content not exceeding 100 gal (380 L) is required to extend through only one valve.

PEB-12.2 The minimum size of blowoff pipes and fittings shall be NPS 1 (DN 25), except that for boilers of 200 kW input or less the minimum size of pipe and fittings may be NPS ¾ (DN 20). Electric boilers that do not exceed the diameter, volume, or pressure limits of PMB-2 may have blowoff connections in accordance with PMB-12.

PEB-13 WATER LEVEL INDICATORS

PEB-13.1 Electric boilers of the electrode type shall have at least one gage glass. The gage glass shall be located as to indicate the water levels both at startup and under maximum steam load conditions as established by the Manufacturer.

PEB-13.2 Electric boilers of the resistance element type shall have at least one gage glass. The lowest visible water level in the gage glass shall be at least 1 in. (25 mm) above the lowest permissible water level as determined by the Manufacturer. Each electric boiler of this type shall also be equipped with an automatic low-water cutoff on each boiler pressure vessel so located as to automatically cut off the power supply to the heating elements before the surface of the water falls below the visible level in the gage glass.

PEB-13.3 Tubular gage glasses on electric boilers shall be equipped with protective rods or shields.

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PEB-14 PRESSURE GAGES

Pressure gages shall meet the requirements of PG-60.6.

PEB-15 PRESSURE RELIEF VALVES

PEB-15.1 Each electric boiler shall have at least one pressure relief valve. Electric boilers with a power input more than 1,100 kW shall have two or more pressure relief valves.

(23) **PEB-15.2** The minimum pressure relief valve relieving capacity for electric boilers shall be 3½ lbm/hr/kW (1.6 kg/hr/kW) input. The pressure setting shall be not higher than the MAWP stamped on the completed boiler (see PEB-18.3.2).

PEB-15.3 Pressure relief valves shall be mounted in accordance with PG-71.2 with the spindle vertical. Electric boilers that do not exceed the diameter, volume, or pressure limits of PMB-2, may have a pressure relief valve(s) installed in other than the vertical position, provided that

(a) the valve design is satisfactory for such position

(b) the valve is not larger than NPS ¾ (DN 20)

(c) the maximum angle of deviation from vertical does not exceed 30 deg

(d) the nozzle location is such that no material that could interfere with the operation of the valve can accumulate at the valve inlet

(e) the discharge opening of the valve body and discharge piping is oriented so that drainage is adequate

PEB-16 AUTOMATIC DEVICES

Electric boilers shall be provided with pressure and/or temperature controls and an automatic low-water fuel cutoff. No low-water cutoff is required for electrode type boilers.

PEB-17 HYDROSTATIC TEST

PEB-17.1 Each electric boiler pressure vessel shall be hydrostatically tested at completion of fabrication in accordance with PG-99 or PMB-21, as applicable.

PEB-17.2 In addition to the above, after assembly of the boiler pressure vessel and the mechanically assembled boiler external piping and trim, the completed electric boiler shall be given a final hydrostatic test at a pressure not less than the pressure relief valve setting.

PEB-17.3 When the electric boiler is to be marked with the "E" Designator, the Designator shall be applied after completion of the hydrostatic test of PEB-17.2.

PEB-18 INSPECTION AND STAMPING OF BOILERS

PEB-18.1 Inspection of electric boilers shall be as required by PG-90.1 and PG-90.3. Witness by the Authorized Inspector of the hydrotest required in PEB-17.2 for the completed boiler may be omitted for electric boilers that meet all the following limitations:

(a) 800 kW maximum per vessel

(b) 600 V maximum

(c) mechanically assembled boiler external piping (BEP) only

When the Authorized Inspector does not perform a final inspection of the completed boiler, the Manufacturer or Assembler shall make an equivalent examination. The equivalent examination shall be in accordance with a quality control procedure meeting the requirements of PEB-18.2 and PEB-18.5.

PEB-18.1.1 Electric boilers exceeding the size limitations specified in PEB-18.1, and having only mechanically assembled external piping (BEP) and trim, shall have a final inspection by the Authorized Inspector, who shall also witness the hydrostatic test called for in PEB-17.2.

PEB-18.1.2 For electric boilers having welded or brazed boiler external piping (BEP) or trim, the inspection requirements of PG-90.1 and the hydrostatic test requirements of PG-99 apply.

PEB-18.2 Each electric boiler Manufacturer shall comply with the applicable requirements of PG-104 and PG-105.

PEB-18.2.1 An electric boiler Manufacturer or Assembler applying for or renewing the "E" stamp shall have its facilities and organizations subject to a joint review by its Authorized Inspection Agency and the legal jurisdiction involved (see last paragraph of PG-105.4).

PEB-18.2.2 A Manufacturer or Assembler assembling units where the final shop inspection by the Authorized Inspector is not mandatory (see PEB-18.1), shall be subject to periodic review by its Authorized Inspection Agency. The review shall be conducted on a quarterly basis or more frequently if deemed necessary by the Authorized Inspection Agency. The frequency of this review may be reduced subject to written agreement between the Manufacturer or Assembler and its inspection agency and the written approval of the appropriate legal jurisdiction. However, in no case shall the review be less than once every 6 months.

PEB-18.3 The stamping of electric boilers shall conform to the requirements of PG-106. Completed electric boilers shall be marked with the "S" or "M" Designator by the Manufacturer of the boiler pressure vessel except when the boiler pressure vessel is constructed under the provisions of PEB-3(see PEB-18.4). When the trim, fixtures and fittings (such as valves), threaded boiler external piping, and appurtenances are connected to an electric boiler by a Manufacturer or Assembler not authorized to apply the Certification Mark with the "S" or "M" Designator, the boiler assembler shall apply a

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Certification Mark with the "E" Designator to the completed assembly. Certification Holders with the "E" Designator are limited to the use of assembly methods that do not require welding or brazing.

PEB-18.3.1 The stamping of the boiler pressure vessel shall be located as called for in PG-111.8 and need not indicate the kW input or the maximum designed steaming capacity.

PEB-18.3.2 The stamping of the complete electric boiler shall be on a separate metallic plate and shall be in accordance with PG-106.4. The MAWP shall be that established by the completed boiler assembler holding the Certification Mark with the "S," "M," or "E" Designator, but in no case higher than the MAWP stamped on the boiler shell. The MAWP shall be listed on Part II of Form P-2A, Manufacturers' Data Report for All Types of Electric Boilers. This plate shall be located on the assembly so that it is readily visible from the operating floor.

PEB-18.3.3 The stamping required by PEB-18.3.2 need not be done in the presence of the Authorized Inspector for electric boilers that do not receive final inspection by the Authorized Inspector (see PEB-18.1).

PEB-18.4 For boiler pressure vessels constructed under the provisions of PEB-3, the inspection and stamping requirements of Section VIII, Division 1, UG-116(c) for special service pressure vessels (UB), shall be followed.

PEB-18.5 Those Manufacturers and Assemblers providing an equivalent examination of completed electric boilers when final inspection is not witnessed by the Authorized Inspector (see PEB-18.1), shall provide oversight by a Certified Individual (CI).

PEB-18.5.1 A Certified Individual (CI) shall be an employee of the Manufacturer or Assembler and shall be qualified and certified by the Manufacturer or Assembler. Qualifications shall include as a minimum

(a) knowledge of the requirements of this Section for the application of Certification Marks

(b) knowledge of the Manufacturer's quality program

(c) training commensurate with the scope, complexity, or special nature of the activities to which oversight is to be provided

The Manufacturer or Assembler shall maintain a record containing objective evidence of the Certified Individual's qualifications, training, and certification.

PEB-18.5.2 The duties of a Certified Individual (CI) shall be to assure that each use of the Certification Mark as permitted in PEB-18.3.3 is in accordance with the requirements of this Section and is documented on the Certificate of Conformance on Form P-2A, Manufacturers' Data Report for All Types of Electric Boilers. The CI shall also

(a) verify that each electric boiler, to which a Certification Mark is applied, meets all applicable requirements of this Section

(b) sign the Certificate of Conformance, Form P-2A, prior to release of control of the boiler

PEB-19 MANUFACTURER'S DATA REPORT FOR ELECTRIC BOILERS

PEB-19.1 This form consists of two parts. Part I is to be completed by the Manufacturer of the boiler pressure vessel who is the Certification Holder with the "S" or "M" Designator and the Manufacturer's inspection agency. Part II is to be completed by the Manufacturer or Assembler responsible for the completed electric boiler who shall be authorized to use the Certification Mark with the "S," "M," or "E" Designator.

PEB-19.2 When the boiler pressure vessel is constructed by a Certification Holder with the "U" Designator and certified on a U-1 or U-1A Data Report, Part 1 shall be completed by the Certification Holder with the "S," "M," or "E" Designator to the extent indicated in Table A-351.1.

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PART PVG
REQUIREMENTS FOR ORGANIC FLUID VAPORIZERS

GENERAL

PVG-1 GENERAL

The rules in Part PVG are applicable to organic fluid vaporizers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the special requirements in the applicable Parts of this Section that apply to the method of fabrication used.

MATERIALS

PVG-5 GENERAL

PVG-5.1 Materials used in the construction of pressure parts for organic fluid vaporizers shall conform to one of the specifications in Section II and shall be limited to those for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 1A and 1B. Pressure relief valve materials shall conform to PG-73.3.3.

PVG-5.2 The requirements for materials given in Part PG shall apply in all respects to organic fluid vaporizers.

DESIGN

PVG-8 GENERAL

The rules in the following paragraphs apply specifically to the design of organic fluid vaporizers and parts thereof and shall be used in conjunction with the general requirements for design in Part PG as well as with the specific requirements for design in the applicable Parts of this Section that apply to the method of fabrication used.

PVG-9 GENERAL REQUIREMENTS

The Manufacturer shall be responsible for providing in the design the limited heat absorption rates, proper furnace proportions, etc., which will permit satisfactory and safe operation of the vaporizers under all conditions of operation.

PVG-10 GAGE GLASSES

Gage glasses shall be of the flat glass type with forged steel frames. Gage cocks shall not be used.

PVG-11 DRAIN VALVES

Suitable drain valves of the globe or angle type may be used in lieu of the blowoff valve required in ASME B31.1.

PVG-12 PRESSURE RELIEF VALVES

PVG-12.1 Pressure relief valves shall be of a totally enclosed type so designed that vapors escaping beyond the valve seat shall not discharge into the atmosphere except through a discharge pipe that will carry such vapors to a safe point of discharge. Discharge piping from the relief valve should be designed and installed in accordance with the vaporizer manufacturer's and the fluid manufacturer's recommendations and should consider any applicable safety concerns and any other applicable codes and standards. A suitable condenser that will condense all the vapors discharged from the pressure relief valve or other safe catchment may be used. Any discharge piping should not affect the performance or capacity of the relief valve. The pressure relief valve shall not have a lifting lever. In addition to the marking requirements of PG-110, the letters "PVG" shall be marked on the pressure relief valve or its nameplate. The vaporizer shall be designed in accordance with the rules in this Code for a working pressure of at least 40 psi (280 kPa) above the operating pressure at which it will be used. Valve body drains are not mandatory. (23)

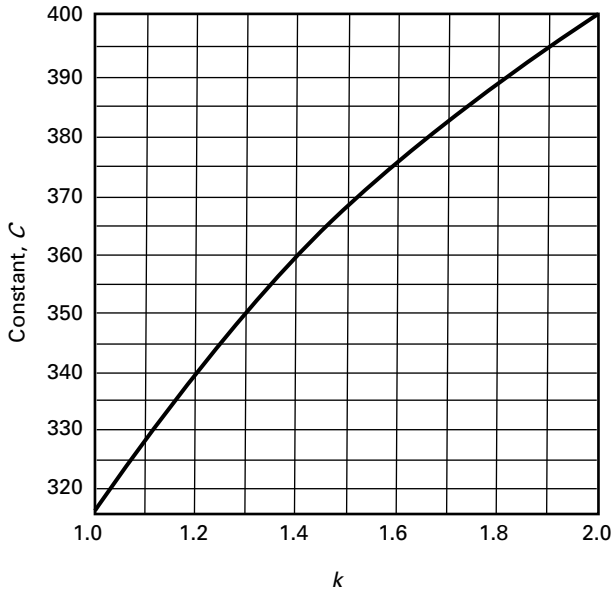
PVG-12.2 Pressure relief valves should be disconnected from the vaporizer at least once yearly (or as recommended by the vaporizer Manufacturer or valve manufacturer). If disconnected, the pressure relief valve should be inspected, repaired if necessary, tested, and then replaced on the vaporizer.

PVG-12.3 In order to minimize the loss by leakage of material through the pressure relief valve, a rupture disk that bears the ASME Certification Mark with the UD Designator in accordance with Section XIII may be installed between the pressure relief valve and the vaporizer, provided the requirements of PVG-12.3.1 and PVG-12.3.2 are met.

PVG-12.3.1 The rupture disk shall be installed in accordance with Section XIII, para. 8.2.

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Figure PVG-12
Constant, *C*, for Vapor Related to Ratio of Specific Heats ($k = c_p/c_v$)



GENERAL NOTE:
Flow formula calculations

$$W = K(CAP\sqrt{M/T})$$

(U.S. Customary Units)

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

(SI Units)

$$C = 39.48\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

PVG-12.3.2 The maximum pressure of the range for which the disk is designed to rupture does not exceed the opening pressure for which the pressure relief valve is set or the maximum allowable working pressure of the vessel.

PVG-12.4 Pressure relief valve discharge capacity shall be determined from the following equation:

$$W = CKAP\sqrt{M/T}$$

where

A = discharge area of pressure relief valve
C = constant for vapor that is a function of the ratio of Specific Heats $k = c_p/c_v$ (see Figure PVG-12). Note: Where k is not known, $k = 1.001$.
K = coefficient of discharge for the design
M = molecular weight
P = (set pressure × 1.03) + Atmosphere Pressure
T = absolute temperature at inlet, °F + 460 (°C + 273)
W = flow of vapor

PVG-12.5 Pressure relief valves for organic fluid vaporizers shall be tested and certified under PG-69, and they shall be stamped per PG-110.

PVG-12.6 The required minimum pressure relief valve relieving capacity shall be determined from the following equation: (23)

$$W = \frac{C \times H \times 0.75}{h}$$

where

C = maximum total weight or volume of fuel burned per hour, lbm/hr (kg/h) or ft^3/hr (m^3/h)
H = heat of combustion of fuel, Btu/lbm (J/kg) or Btu/ft^3 (J/m^3) (see A-17)
h = latent heat of heat transfer fluid at relieving pressure, Btu/lbm (J/kg)
W = weight of organic fluid vapor generated per hour

The sum of the pressure relief valve capacities marked on the valves shall be equal to or greater than W.

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PART PFE
REQUIREMENTS FOR FEEDWATER ECONOMIZERS

PFE-1 GENERAL

A feedwater economizer is a heat exchanger in which feedwater to be supplied to a boiler is heated by flue gases exiting the boilers. When an economizer is provided with a Section I boiler and resides within the limits of boiler external piping, it shall be constructed in accordance with Section I rules. When the economizer is located outside the limits of boiler external piping, the economizer shall be constructed in accordance with the rules of either Section I or Section VIII, Division 1.

Data Reports for Section I economizers within the limits of boiler external piping shall be referenced and incorporated into the Master Data Report (see PG-113).

Section I or Section VIII, Division 1 economizers outside the limits of boiler external piping are stand-alone pressure vessels, and Data Reports for such economizers may be referenced on the Master Data Report for the completed boiler.

PFE-2 DESIGN

PFE-2.1

The maximum allowable working pressure (MAWP) of the primary (feedwater) side of the economizer shall be not less than the design pressure requirements of ASME B31.1, para. 122.1.3(a)(1). When selecting the MAWP of the economizer, consideration should be given to the dead head pressure of the feedwater pump as this pressure may exceed the value selected above.

PFE-2.2

The design temperature of the tubes shall be the greater of either the saturated steam temperature corresponding to the MAWP of the economizer or the maximum mean metal temperature under operating conditions.

PFE-3 PRESSURE RELIEF

PFE-3.1 (23)

The economizer shall be provided with pressure relief valves in accordance with PG-67.2.1.6. Economizers constructed to Section VIII, Division 1 shall be provided with overpressure protection in accordance with the requirements of Section VIII, Division 1, UG-150 through UG-156.

PFE-3.2

The pressure relief valves for Section I economizers shall be documented on Form P-7, Manufacturer's Data Report for Pressure Relief Valves.

PFE-3.3

In all cases, for both Section I and Section VIII, Division 1 economizers, the heat absorption of the economizer shall be included in the economizer nameplate stamping.

PFE-4 MATERIALS

When the feedwater-regulating valve is located between the boiler and economizer, the economizer may be constructed using austenitic stainless steel, but materials shall be limited to those listed in PG-12.3.

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PART PTFH
REQUIREMENTS FOR LIQUID PHASE THERMAL FLUID HEATERS

GENERAL

PTFH-1 GENERAL

The rules in Part PTFH are applicable to liquid phase thermal fluid heaters and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the special requirements of this Part that apply to the method of fabrication used. The rules in this Part do not apply to solar boiler molten salt receivers or to concentrated solar trough systems that use a heat transfer medium (thermal fluid).

PTFH-2 SCOPE

These rules apply to closed loop liquid phase thermal fluid heaters (flooded pressure vessel) in which a heat transfer medium (thermal fluid) is heated but no vaporization takes place within the vessel. The heat transfer medium shall not have a vapor pressure at operating temperature greater than 20 psia (138 kPa) (5.3 psig or 36.5 kPa).

PTFH-3 THERMAL FLUIDS

Thermal fluids are fluids other than water that are chemically stable over a large temperature range and are specifically designed for use as a heat transfer medium.

(a) Depending on the fluid selection and operating parameters, systems may be open or closed to the atmosphere.

(b) Systems closed to the atmosphere may be pressurized with an inert gas blanket.

MATERIALS

PTFH-5 GENERAL

PTFH-5.1 Materials used in the construction of pressure vessel parts for liquid phase thermal fluid heaters shall conform to those permitted in Section I for which allowable stress values are given in Section II, Part D, Tables 1A and 1B. Pressure relief valve materials shall conform to PG-73.3.

PTFH-5.2 The requirements for materials given in Part PG shall apply in all respects to liquid phase thermal fluid heaters.

PTFH-5.3 The heater Manufacturer is responsible for ensuring the selected materials are compatible with the intended thermal fluid service.

DESIGN

PTFH-8 GENERAL REQUIREMENTS

PTFH-8.1 The heater Manufacturer shall be responsible for providing a design that shall permit satisfactory and safe operation of the heater under all normal conditions of operation.

PTFH-8.2 The design of the heater shall take into consideration the recommendations of the manufacturer of the heat transfer medium regarding the maximum allowable bulk fluid and film temperatures. [Film (skin) temperature is the maximum allowable temperature of heat transfer fluid that is in immediate contact with the heater surfaces].

PTFH-9 APPURTENANCES AND EXTERNAL PIPING

PTFH-9.1 Liquid phase thermal fluid heaters are intended to operate in a liquid state within a closed loop circulating system (the system may be pressurized or open to the atmosphere). The external piping associated with a liquid phase thermal fluid heater consists of (as a minimum) the required inlet and outlet connections for circulating the thermal fluid through heater, vent and drain connections (as applicable), and a pressure relief valve connection(s) as shown in Figure PTFH-9.1-1.

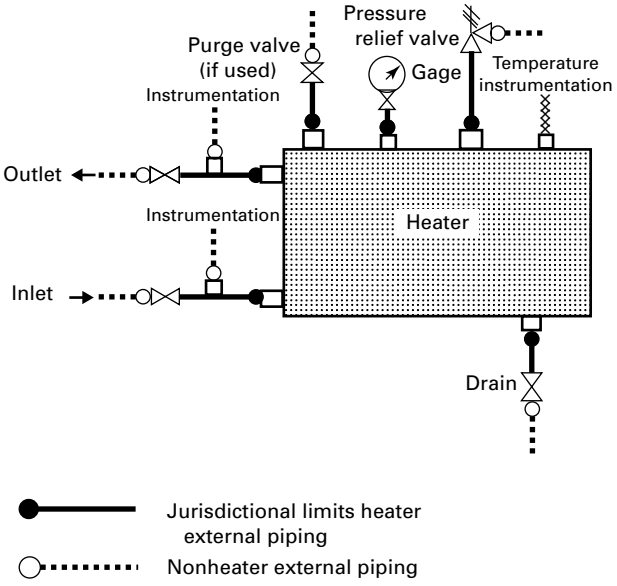
(a) A high-point vent or purge valve(s) shall be provided in either the heater or the connecting piping to ensure that all air has been exhausted from the heater and connected piping during filling, and the pressure vessel and piping are completely flooded with the thermal fluid.

(b) The closed loop operation of a liquid phase thermal fluid heater eliminates the need for a liquid make-up feed system. A suitable low-point drain shall be provided in the heater or connecting piping to allow the heat transfer medium to be drained out of the pressure vessel when necessary.

(c) External piping associated with liquid phase thermal fluid heaters shall be designed in accordance with the applicable requirements of ASME B31.1. All

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Figure PTFH-9.1-1
Liquid Phase Thermal Fluid Heater: External Piping



external piping connections to the liquid phase thermal fluid heater shall be attached as provided in PG-59.1.1.1, PG-59.1.1.2, and PG-59.1.1.3 except that threaded connections larger than 1 in. NPT (25 mm) shall not be used. Copper and copper alloys shall not be used.

(d) External piping associated with liquid phase thermal fluid heaters shall be provided with a means of adding heat transfer medium to the heater or system while under pressure in accordance with the Manufacturer's recommendations.

PTFH-9.2 Welded or mechanically assembled heater external piping shall meet the requirements of PG-104 for Code certification.

PTFH-9.3 The jurisdictional limits of heater external piping shall extend from the heater inlet and outlet connections up to and including the first stop valve as shown in Figure PTFH-9.1-1. When multiple heaters are connected to common supply and return piping, and the heaters contain openings of a size that permit entry into the thermal fluid space of the pressure vessel, the inlet and outlet piping of each shall be equipped with two stop valves. Vent and drain connections attached directly to the heater shall be equipped with a gate, globe, or needle valve and either a cap or plug.

PTFH-10 PROVISIONS FOR THERMAL EXPANSION OF THE HEAT TRANSFER MEDIUM

Liquid phase thermal fluid heaters shall have provisions for the volumetric expansion of the heat transfer medium as the temperature of the fluid increases. A closed loop system shall be equipped with a thermal expansion tank and a sight glass or other liquid-level indicator that provides a visible or audible indication of a low fluid level in the tank during operation.

(a) The volume of the expansion tank shall be consistent with the volume and capacity of the system. The minimum required expansion tank capacity shall be determined by calculating the volume of fluid in the heater and system and multiplying it by the coefficient of expansion at temperature of the heat transfer medium being used.

(b) Expansion tanks that are open to the atmosphere do not require an expansion tank with a Certification Mark or a pressure relief valve. The expansion tank shall be vented to the atmosphere and shall be installed with piping directing any fluid discharge or overflow to a safe point of discharge. The discharge piping shall be in accordance with PTFH-12.6.

(c) Expansion tanks that are closed to the atmosphere or are internally pressurized with an inert gas shall have an expansion tank with a Section I or Section VIII, Division 1 Certification Mark.

(1) The design pressure of the expansion tank shall be based on the system design and the fluid used.

(2) The expansion tank shall be equipped with a liquid service pressure relief valve in accordance with Section I or Section VIII, Division 1.

(3) The pressure relief valve shall be of a totally enclosed type and shall be installed with discharge piping directing any fluid to a safe point of discharge (see PTFH-12.6).

(d) The system shall have provisions for shutdown of the heat source to the heater in the event of a drop in fluid level in the expansion tank below the Manufacturer's recommended safe minimum level.

PTFH-11 INSTRUMENTATION

PTFH-11.1 Pressure. Each liquid phase thermal fluid heater shall have a pressure gage(s) so located that it is visible and easily read from the operating floor. The pressure gage(s) or indicator(s) shall be installed so that it shall indicate the pressure in the heater at all times.

PTFH-11.2 Temperature. Each liquid phase thermal fluid heater shall have a temperature gage or other instrumentation indicating the temperature of the fluid in the heater at or near the outlet connection from the heater. The temperature gage or indicator shall be so located that it is visible and easily read from the operating floor at all times during operation.

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PTFH-11.3 Fluid Flow. Each liquid phase thermal fluid heater shall have instrumentation that visibly indicates flow of the heat transfer medium through the heater during operation. Instrumentation that monitors or indicates differential pressure across the heater or other device in the associated closed loop circulation system may be used. The instrumentation shall be so located that it is visible and easily read from the operating floor. The fluid flow instrumentation shall have provisions for shutdown of the heat source to the heater in the event of an interruption or cessation of the fluid flow during operation.

PTFH-12 OVERPRESSURE PROTECTION

PTFH-12.1 Intended Service Conditions. The heater Manufacturer shall ascertain and identify all intended service conditions including normal operating and upset conditions and identify any potential overpressure scenarios based on the characteristics of the heat transfer fluid. The heater Manufacturer shall consider methods of overpressure protection that can be used to mitigate each scenario. Intended service conditions shall also include but are not limited to the following conditions:

(a) the heater and the system are open to the atmosphere

(b) the heater and the system are closed to the atmosphere

(c) the system is internally pressurized with an inert gas (blanketed)

PTFH-12.2 Pressure Relief Valves. Each liquid phase thermal fluid heater shall have at least one pressure relief valve. For heaters having more than 500 ft^2 (47 m^2) of liquid heating surface or an electric heating capacity greater than 1,100 kW, two or more pressure relief valves shall be provided. The heater Manufacturer shall ensure that the specified pressure relief valves are suitable for the intended service conditions of thermal fluid heaters as defined in PTFH-12.1. The type and rating of the pressure relief valve(s) shall be determined by the characteristics of the thermal fluid selected for the system.

Systems whose intended service conditions are described in PTFH-12.1 shall be provided with a pressure relief valve(s) designed for liquid service in accordance with PTFH-12.3.

PTFH-12.3 Liquid Service Pressure Relief Valve. The liquid service pressure relief valve as required in PTFH-12.2 shall be designed in accordance with the rules of this Section with the following additional requirements:

(a) Pressure relief valves for liquid phase thermal heaters shall be of a totally enclosed type designed for liquid service.

(b) The pressure relief valves shall have a relieving capacity that shall discharge fluid without allowing the pressure to rise more than 10% or 3 psi (20 kPa) (whichever is greater) above the maximum allowable working pressure (MAWP) stamped on the completed heater.

(c) The pressure relief valve setting shall be no higher than the MAWP stamped on the completed heater.

(d) The inlet connection to the valve shall be not less than NPS ½ (DN 15).

(e) The pressure relief valve shall not have a lifting lever.

(f) Valve body drains are not required.

(g) The pressure relief valve shall be provided with suitable discharge piping.

(h) In addition to the marking requirements of PG-110, the letters "PTFH" shall be marked on the pressure relief valve or its nameplate.

PTFH-12.4 Certification. Pressure relief valves for liquid service shall be tested and certified as provided in PG-69 and the applicable requirements in PG-73. The manufacturer's capacity certification of pressure relief valves for incompressible fluids shall be conducted on water at a temperature between 40°F and 125°F (5°C and 50°C) and at a pressure that does not exceed the set pressure of the valve under test by 10% or 3 psi, whichever is greater. The valve shall be plainly marked by the manufacturer with the required data in accordance with PG-110(e)(3).

PTFH-12.5 Thermal Fluid.

PTFH-12.5.1 The heater Manufacturer shall tag the pressure relief valve with the following:

(a) the manufacturer, trade name, and designator or type of thermal fluid

(b) the relieving capacity of the thermal fluid for which the system was designed

PTFH-12.5.2 The remarks section of the heater Manufacturer's Data Report shall include the following:

(a) manufacturer, trade name, and designator or type of thermal fluid

(b) the maximum designed flow rate, gal/min (L/min)

(c) the maximum operating temperature of the heater

PTFH-12.6 Pressure Relief Valve and Discharge Piping. Pressure relief valves and the associated discharge piping shall be installed in accordance with the heater Manufacturer's recommendations.

(a) The installation of the pressure relief valve(s) required in PTFH-10(c)(2) and PTFH-12.3(g) shall include but not be limited to the following requirements:

(1) The pressure relief valve(s) shall be connected to the pressure vessel independent of any other connection, and shall be attached as close as possible without any unnecessary intervening pipe or fitting. The characteristics of the intervening piping system shall be such that the pressure drop shall not reduce the relieving capacity

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below that required nor adversely affect the proper operation of the pressure relief valve. Cast iron fittings shall not be used.

(2) Every pressure relief valve shall be connected so as to stand in an upright position, with the spindle vertical.

(3) The opening or connection between the pressure vessel and the pressure relief valve shall have at least the area of the valve inlet.

(4) No valve of any description shall be placed between the required pressure relief valve or valves and the pressure vessel or on the discharge piping between the pressure relief valve and the atmosphere.

(b) The discharge piping required in PTFH-10(b), PTFH-10(c), and PTFH-12.3(g) shall include but not be limited to the following requirements:

(1) The design and sizing of the discharge piping shall take into consideration the conditions listed in PTFH-12.1, the location of the pressure relief valve (if installed), and the backpressure in the discharge piping system during discharge of the thermal fluid.

(2) When a pressure relief valve(s) is used, the size of the discharge lines shall be such that any pressure that may exist or develop will not reduce the relieving capacity below that required to properly protect the vessel or will adversely affect the proper operation of the pressure relief valve(s).

(3) The cross-sectional area of discharge piping connected to a relief valve shall be not less than the full area of the pressure relief valve outlet. When multiple relief valves are installed, the common discharge line shall meet the requirements of (2).

(4) Discharge piping shall be so arranged as to direct any fluid that may be released to a safe point of discharge.

(5) Discharge piping shall be so designed to provide adequate drainage and prevent liquid from collecting in the discharge flow path or at the outlet of the pressure relief valve if installed. The possibility of solidification of fluid leakage into the discharge piping system shall be considered.

PTFH-13 TEMPERATURE-LIMITING CONTROLS

Each liquid phase thermal fluid heater shall have a temperature limiting control(s). This device(s) shall not be used to prevent or eliminate system over pressure scenarios.

(a) For fuel fired thermal fluid heaters, a manual reset over temperature device shall be used to monitor and limit the bulk temperature of the thermal fluid to prevent overheating of the thermal fluid.

(b) For electrically fired thermal fluid heaters, a manual reset over temperature device shall be used to monitor and limit either the bulk temperature or the element sheath temperature to prevent overheating of the thermal fluid.

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PART PHRSG
REQUIREMENTS FOR HEAT RECOVERY STEAM GENERATORS

PHRSG-1 GENERAL

The rules of this Part, PHRSG, shall be used in conjunction with the general requirements of Part PG as well as with the special requirements in the applicable parts of this Section that apply to the method of fabrication used.

If a boiler meets the scope requirements of PHRSG-2, the rules of this Part shall supplement the rules for power boilers and take precedence over them when there is a conflict.

PHRSG-2 SCOPE

The rules of this Part apply to a heat recovery steam generator, HRSG, which has as its principal source of thermal energy a hot gas stream having high ramp rates and temperatures such as the exhaust of a gas turbine.[28] Such an HRSG may utilize supplemental firing and may have one or more superheaters, reheaters, evaporators, economizers, and/or feedwater heaters, which are housed in a common gas path enclosure. The sections cannot be individually isolated from the gas stream.

PHRSG-3 REQUIREMENTS FOR SUPERHEATER AND REHEATER CONDENSATE REMOVAL CONNECTIONS

PHRSG-3.1

Except as permitted by PHRSG-3.5, each superheater and reheater shall be equipped with at least one condensate detection and removal connection meeting all the following requirements:

(a) The detection device shall utilize drain pots with dual element detection or single element detection with time delay to close, or any other suitable detection and removal method.

(b) Connections shall be capable of being opened under pressure so that condensate created during turbine purge cycles can be removed.

(c) Connections shall be sized and located such that condensate will be evacuated under all conditions where condensate is present in the superheater or reheater.

(d) Condensate removal piping required to be opened under pressure shall meet the requirements of PHRSG-3.3 and PHRSG-3.4.

Connections for the purpose of removing condensate are not limited in size as defined by PG-59.3.5 and are permitted to serve also as the drain connection as required by PG-59.4.

PHRSG-3.2

Condensate removal piping as defined by PHRSG-3.1 from superheaters or reheaters of different pressure levels that are required to be opened or operated simultaneously, and which discharge into a common collection device (e.g., manifold, blowdown tank, or flash tank), shall be designed so that when discharging, a high back pressure is not developed within the collection device that prevents flow or causes a reversal of flow. In addition, boiler components shall be designed such that condensate cannot flow from one superheater or reheater to another or from one part of a superheater or reheater to another.

PHRSG-3.3

Piping intended for removal of condensate or unvaporized water from steam spaces, such as superheaters or reheaters when the boiler is under pressure, shall extend through and include the second valve. The design pressure of the piping as required by PHRSG-3.1 and PHRSG-3.2 shall be equal to the MAWP of the steam space that the condensate removal piping is connected to plus the lesser of 25% of the MAWP or 225 psi (1.55 MPa).

PHRSG-3.4

All condensate removal piping systems shall be made up of drain piping and two drain valves in series and be routed to a blowdown tank, flash tank, manifold, or other collection device. The piping and valves shall provide draining capacity such that condensate pooling in superheaters and reheaters is prevented. The collection device shall not be operated at a higher pressure than the space being drained.

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PHRSG-3.5

When the HRSG is a multiple pressure steam generator (see PG-106.12), the requirements of PHRSG-3.1 through PHRSG-3.4 apply only to the superheater sections of the high-pressure section and to each reheater. Drain requirements of PG-59.4 are applicable for superheater sections not covered by PHRSG-3.

PHRSG-4 DESUPERHEATER DRAIN POTS

Where desuperheater spray water is injected into superheater or reheater piping as a means to control steam temperature, the following shall be provided:

(a) Drain pots to detect and remove unvaporized spray water shall be installed in the boiler proper or boiler external piping either upstream or downstream of the desuperheater to ensure malfunctions of these devices will not allow water to enter hot boiler components. Drain pots shall include automatic detection of water and automatic operation of the drain pot valves as shown in Figure PHRSG-4. Piping from the drain pot shall conform to the requirements of PHRSG-3.

(b) Drain pot connection size shall be no smaller than one NPS less than the pipe it is attached to, except it need not be greater than NPS 12 (DN 300). See Table PHRSG-4.

(c) Drain pots, with single element level control with time delay to close, are an acceptable method of detecting and removing unvaporized spray water.

(d) Piping layouts shall be sloped in all operating conditions so that unvaporized spray water from the desuperheater cannot bypass the drain pot.

(e) All desuperheater drain piping shall be routed to a blowdown or flash tank, manifold, or other collection device. The collection device shall not operate at a higher pressure than the space being drained.

PHRSG-5 CERTIFICATION

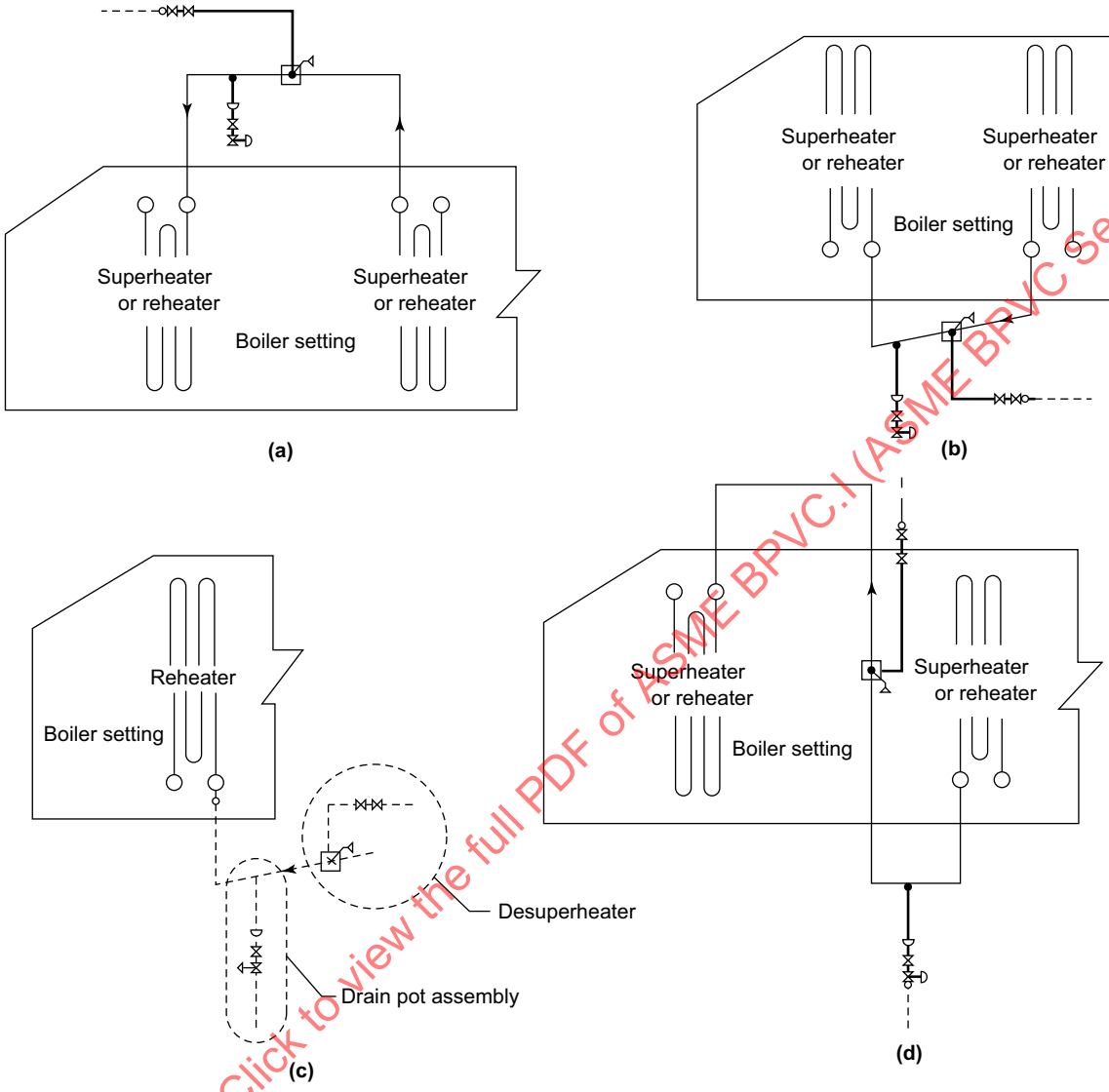
Manufacturer's Data Reports shall be prepared in accordance with the requirements specified in Part PG. However, when the rules of Part PHRSG are used, each component affected shall be identified on the Manufacturer's Data Report with the appropriate PHRSG paragraph referenced.

Table PHRSG-4
Minimum Drain Pot Size

Attaching Pipe Size, NPS (DN)	Minimum Drain Pot Size, NPS (DN)
4 (100)	3 (75)
6 (150)	4 (100)
8 (200)	6 (150)
10 (250)	8 (200)
12 (300)	10 (250)
14 (350) and larger	12 (300)

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Figure PHRSG-4
Some Acceptable Desuperheater Spraywater Protection Device Arrangements (23)



Administrative Jurisdiction and Technical Responsibilities

Boiler Proper—The ASME Boiler and Pressure Vessel Code (BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble).

Boiler External Piping and Joint—The ASME BPVC has total administrative jurisdiction (mandatory certification by stamping the Certification Mark with appropriate Designator, ASME Data Forms, and authorized inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.

Non-Boiler External Piping and Joint—Not Section I jurisdiction (see applicable ASME B31 Code)

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MANDATORY APPENDIX III
(23) CRITERIA FOR REAPPLICATION OF A CERTIFICATION MARK

Reapplication of the ASME Single Certification Mark shall be in accordance with ASME CA-1.

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MANDATORY APPENDIX IV
LOCAL THIN AREAS IN CYLINDRICAL SHELLS AND IN SPHERICAL SEGMENTS OF HEADS

IV-1 SCOPE

The rules of this Mandatory Appendix permit the thickness of local thin areas (LTAs) to be less than the required thickness:

(a) in cylindrical shells under internal pressure required by PG-27

(b) in spherical segments of heads (such as hemispherical heads and the spherical portion of torispherical and ellipsoidal heads) under internal pressure on the concave side required by PG-29.1 and PG-29.11

(c) Local thin areas on the inside or outside of cylindrical shells or spherical segments of heads designed for internal pressure are acceptable, provided they meet the requirements of this Mandatory Appendix.

IV-2 CYLINDRICAL SHELLS

The thickness of local thin areas on the inside or outside surface of a cylindrical shell designed for internal pressure may be less than required by PG-27 provided the local thin areas satisfy the following rules:

(a) Nomenclature (see Figure IV-2-1)

C = projected circumferential length of LTA, in.
L = projected axial length of LTA, in.
LTA = local thin area
t_L = minimum thickness of LTA, in.
θ = see Figure IV-2-1

See PG-27.3 for other nomenclature used in this Mandatory Appendix.

(b) Single LTA

(1) The single LTA shall satisfy the following equations:

$$\frac{t_L}{t} \geq 0.9 \tag{1}$$

$$L \leq \sqrt{(R \cdot t)} \tag{2}$$

$$C \leq 2\sqrt{(R \cdot t)} \tag{3}$$

$$t - t_L \leq \frac{3}{16} \text{ in.} \tag{4}$$

(2) No edge of an LTA shall be closer than $2.5\sqrt{(R \cdot t)}$ from a structural discontinuity such as a head or stiffener.

(3) The minimum axial distance between the edge of the LTA and the edge of any nonreinforced opening shall be equal to or greater than the inside diameter of the opening plus $\sqrt{(R \cdot t)}$.

(4) The minimum axial distance between the edge of the LTA and the reinforcement limit of a reinforced opening shall be equal to or greater than $\sqrt{(R \cdot t)}$.

(5) The blend between the LTA and the thicker surface shall be with a taper length not less than three times the LTA depth as shown in Figure IV-2-1, illustration (b). The minimum bottom blend radius shall be equal to or greater than two times the LTA depth as shown in Figure IV-2-1, illustration (b).

(6) The longitudinal stresses on the LTA from mechanical loads other than internal pressure shall not exceed $0.3S$.

(7) These requirements shall only be applied at the temperatures where the allowable stresses listed in allowable stress tables in Section II, Part D are not controlled by time-dependent properties.

(c) Multiple LTAs. A pair of local thin areas with finished axial length L_1 and L_2 are acceptable if the individual LTA satisfies the requirements of (b) above, either condition in (1) or (2) below is met, and the requirements in (3) through (6) below are met.

(1) When $\theta \leq 45$ deg, the minimum axial separation [see Figure IV-2-1, illustration (c)] shall be the greater of

$$\frac{(1.0 + 1.5 \cos \theta)(L_1 + L_2)}{2} \text{ or } 2t$$

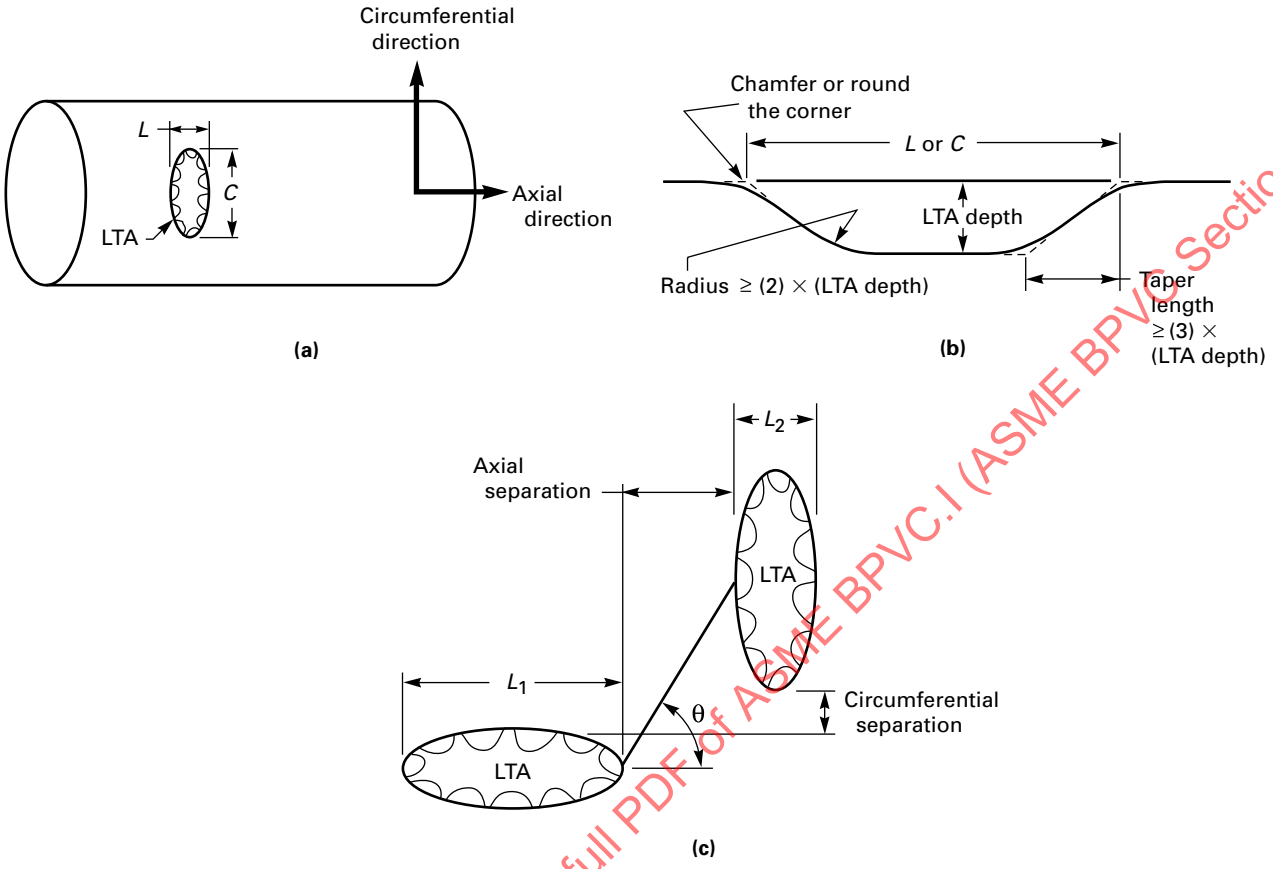
(2) When $\theta > 45$ deg, both of the following shall be met:

(-a) The minimum axial separation shall be equal to or greater than

$$\frac{2.91 \cos \theta (L_1 + L_2)}{2}$$

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Figure IV-2-1
Symbols



(-b) The minimum circumferential separation shall be equal to or greater than 2*t*.

(3) Multiple pairs of LTA are acceptable provided all pairs meet the rules of a single pair specified in (2)(-b) above.

(4) Multiple local thin areas may be combined as a single LTA. The resultant single LTA is acceptable if it satisfies the rules of (2)(-a) above.

(d) Recording Location of LTAs. The required minimum thickness *t* and the dimensions t_L, *L*, and *C* of the LTA shall be noted on the Manufacturer's Data Report. The location of the LTA shall be specified in sufficient detail on the Manufacturer's Data Report to identify it clearly to the end user and the in-service inspector.

(e) Code Requirements. All other applicable Code requirements shall be met.

(f) Manufacturer's Data Report. The use of this Mandatory Appendix shall be shown on the Manufacturer's Data Report.

IV-3 SPHERICAL SEGMENTS OF HEADS

The thickness of local thin areas on the inside or outside surface of spherical segments of heads (such as hemispherical heads and the spherical portion of torispherical and ellipsoidal heads) under pressure on the concave side, may be less than required by PG-29.1 and PG-29.11 provided the local thin areas satisfy the following conditions:

(a) Nomenclature (See Figures IV-3-1 through IV-3-5)

D_L = maximum dimension of LTA, in.
LTA = local thin area
R = inside radius for spherical segment, in.
t = required head thickness per PG-29, in.
t_L = minimum thickness of LTA, in.

(b) Single LTA

(1) The single LTA shall satisfy the following equations:

$$\frac{t_L}{t} \geq 0.9 \qquad (1)$$

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$$D_L \leq \sqrt{(R \cdot t)} \quad (2)$$

$$t - t_L \leq \frac{3}{16} \text{ in.} \quad (3)$$

(2) The minimum distance between the edge of the LTA and the edge of any unreinforced opening shall be equal to or greater than the inside diameter of the opening plus $\sqrt{(R \cdot t)}$.

(3) The minimum distance between the edge of the LTA and the reinforcement limit of a reinforced opening shall be equal to or greater than $\sqrt{(R \cdot t)}$.

(4) No edges of an LTA shall be closer than $2.5\sqrt{(R \cdot t)}$ from a structural discontinuity.

(5) A constant thickness junction between head and cylindrical shell is not considered a discontinuity for LTA rules.

(6) The blend between the LTA and the thicker surface shall be with a taper length not less than three times the LTA depth. The minimum bottom blend radius shall be equal to or greater than two times the LTA depth. The blend requirements are shown in Figure IV-3-1

(7) The LTA for a torispherical head must lie entirely within the spherical portion of the head. See Figure IV-3-2.

(8) The LTA for an ellipsoidal head must lie entirely within a circle, the center of which coincides with the axis of the vessel and the diameter of which is equal to 80% of the shell inside diameter. See Figure IV-3-3.

(9) The LTA for a hemispherical head is acceptable within any portion of the head except as limited by (4) above. See Figure IV-3-4.

(10) The provisions of these rules do not apply to the knuckle portion of a torispherical or to the region outside the region of an ellipsoidal head or to flat heads.

(11) These rules shall only be applied at temperatures where the allowable stresses listed in the allowable stress tables in Section II, Part D are not controlled by time-dependent properties.

(c) Multiple LTAs

(1) Multiple LTAs may be combined and evaluated as a single LTA. The encompassed areas of the combined LTAs shall be within the D_L dimension.

(2) Each LTA in the encompassed area shall meet the rules of (b)(1) above.

(3) Multiple LTAs may be treated as single LTAs provided their edges are no closer than $\sqrt{(R \cdot t)}$.

(d) Recording Locations of LTAs. The location and dimensions t_L and D_L of the LTA shall be noted on the Manufacturer's Data Report.

(e) Code Requirements. All other applicable code requirements shall be met.

(f) Manufacturer's Data Report. The use of this Mandatory Appendix shall be shown on the Manufacturer's Data Report.

Figure IV-3-1
Blend Requirements

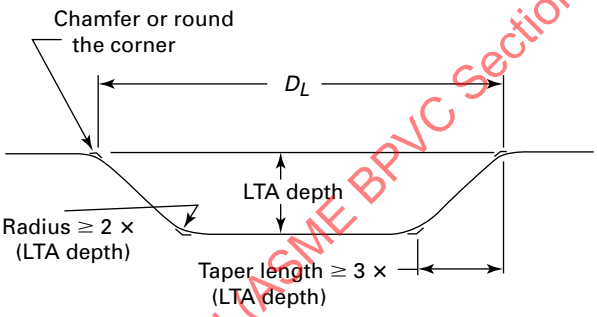


Figure IV-3-2

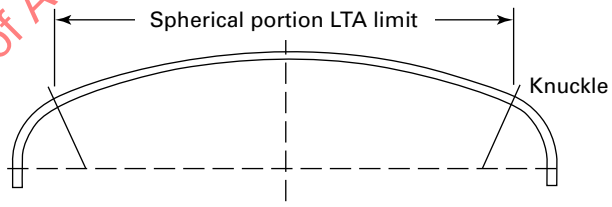
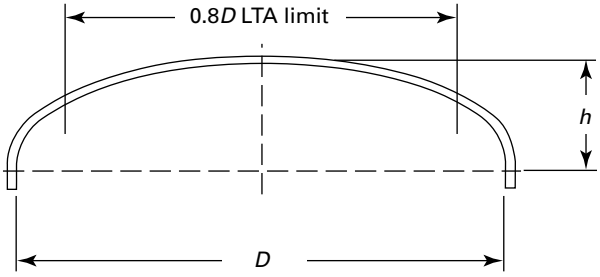


Figure IV-3-3



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Figure IV-3-4

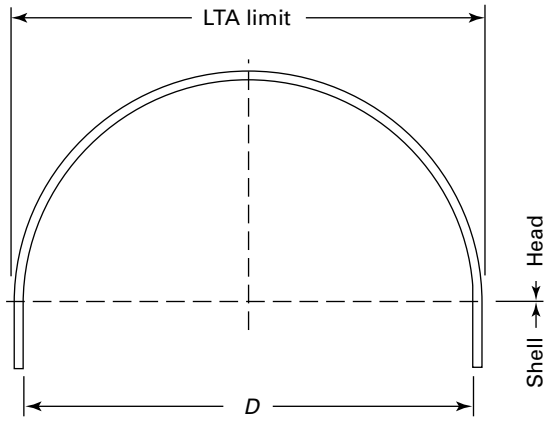
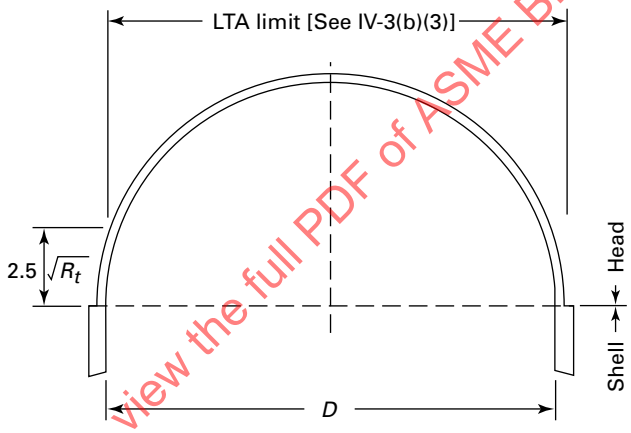


Figure IV-3-5



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MANDATORY APPENDIX V
ADDITIONAL RULES FOR BOILERS FABRICATED BY RIVETING

V-1 SCOPE

The rules of this Mandatory Appendix are for boilers or component parts thereof that are fabricated by riveting.

V-2 FIREBOXES, COMBUSTION CHAMBERS, AND FURNACES

V-2.1 GENERAL

Fireboxes, combustion chambers, and furnaces of riveted construction shall meet the requirements of this Mandatory Appendix and Part PR.

(23) V-2.2 PLAIN CIRCULAR FURNACES

Plain circular furnaces of riveted construction shall be 18 in. (450 mm) inside diameter minimum and shall meet the following requirements:

(a) Circumferential and longitudinal joints shall have an efficiency of E= 0.5 or

(U.S. Customary Units)

$$E = \frac{PD}{20{,}000t}$$

(SI Units)

$$E = \frac{PD}{137t}$$

whichever is greater,
where

D = outside diameter, in. (mm)
P = MAWP, psi (MPa)
r = thickness of furnace wall material, in. (mm)

To determine the MAWP, multiply the value P_a as determined in PG-28 by the joint efficiency.

(b) When shell plates exceed $^5/_8$ in. (16 mm) in thickness, the portion of the plates forming the laps of the circumferential joints, where exposed to the fire or products of combustion, shall be machined down as shown in Figure V-2.2-1 to a thickness not over $^9/_{16}$ in. (14 mm) and shall conform to the requirements of PR-11.

(c) Buttstrap seams shall be used only where they are protected from contact with the fire or flame.

(d) Plain circular furnaces of riveted construction, 18 in. (450 mm) to 38 in. (950 mm) inside diameter may have a riveted longitudinal joint of the lap type provided the furnace does not exceed 36 in. (900 mm) in length. For a furnace that exceeds 36 in. (900 mm) in length, a butt and single- or double-strap construction shall be used with the longitudinal joint located below the grate or protected by other means from contact with the fire or products of combustion.

(e) Plain circular furnaces of riveted construction over 38 in. (950 mm) inside diameter shall be fully stayed as flat surfaces per the requirements of PG-46 and PFT-27.

(f) When the longitudinal joint of a furnace is of lap-riveted construction and supported by staybolts, a staybolt in each circular row shall be located near the longitudinal joint as shown in Figure V-2.2-2.

V-2.3 RING-REINFORCED TYPE

Ring-reinforced furnaces shall be of seamless or welded construction and shall meet the requirements of PFT-17.

V-2.4 CORRUGATED FURNACES

Corrugated furnaces shall be of seamless or welded construction and shall meet the requirements of PFT-18.

V-2.5 COMBINED PLAIN CIRCULAR AND CORRUGATED TYPE

Plain circular and corrugated type furnaces may be connected with a riveted circumferential joint meeting the applicable requirements of V-2.2 and Part PR.

V-2.6 ATTACHMENT OF FURNACES

Furnaces may be attached to an inwardly or outwardly flanged head or tubesheet by riveting in accordance with the rules of Part PR and applicable rules in this Mandatory Appendix.

V-2.7 FIREBOXES AND WATERLEGS

Fireboxes and waterlegs of riveted construction shall meet the requirements of Part PR and the applicable rules in this Appendix.

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Figure V-2.2-1
Riveted Circumferential Joint for Circular Furnace Plates Over $^{5}/_{8}$ in. (16 mm)

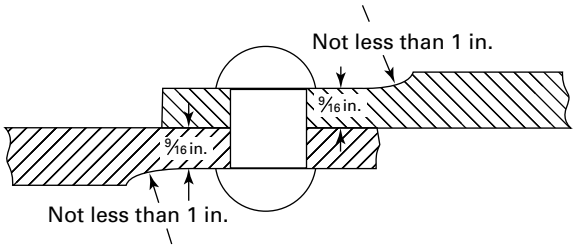
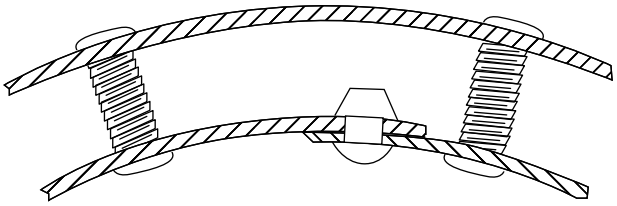


Figure V-2.2-2
Proper Location of Staybolts Adjacent to Longitudinal Joint in Furnace Sheet



V-3 DESIGN OF STAY PINS AND RIVETED STAY ATTACHMENTS

(a) All rivet holes and clevis pin holes shall conform to the fabrication requirements of PR-21. Clevis pins shall be machined with an outside diameter as close to the hole size as practicable, but not less than 6% below the hole size.

(b) The feet for stays or braces (crowfeet) attached to heads and tubesheets shall be distributed as evenly as practicable on the area being supported. No supporting value shall be assigned to the stiffness of inside liner plates on flat surfaces. Braces attached to tee irons, brackets, crowfeet, or similar construction where the braces are either pinned or integral with structures attached directly to the supported plate shall be in accordance with the following:

(1) The minimum required cross-sectional area of the stay shall be determined by the rules in PFT-28.

(2) The area of pins required to resist double shear shall be at least 0.75 times the required cross-sectional area of the stay.

(3) The material surrounding the eye of a clevis or crowfoot stay shall be 1.25 times greater than the required cross-sectional area of the stay.

(4) The cross-sectional area of the blade end of a diagonal stay at the attachment rivet hole(s) shall be 1.25 times greater than the required cross section of the stay.

(5) Each branch of a crowfoot shall be designed to carry at least 0.67 times the total load on the stay.

(6) The net cross-sectional areas through the sides of a crowfoot, tee iron, or similar fastening at the rivet holes shall be at least 1.25 times greater than the required cross-sectional area of a stay.

(7) The combined cross-sectional area of the rivets at each end of the stay or brace shall be at least 1.25 times greater than the required cross-sectional area of a stay.

V-4 STAYING OF UPPER SEGMENTS OF TUBE HEADS BY STEEL STRUCTURAL SHAPES

(a) When the shell of a boiler does not exceed 36 in. (900 mm) in inside diameter and is designed for an MAWP not exceeding 100 psi (0.7 MPa), the segment of the head above the tubes may be stayed by structural shapes. Sizes required are specified in Table V-4-1 and Figure V-4-1. However, structural shapes of equal thickness and greater depth of outstanding leg (leg perpendicular to the head or tubesheet) may be substituted for those specified in Table V-4-1.

(b) When the diameter of a shell falls between the shell diameters in Table V-4-1 or is less than 30 in. (760 mm) in inside diameter, the tabular values of the next largest size shall be used. Rivets used to attach structural shapes to heads and tubesheets and used to join the outstanding legs of angled bar shall be the same diameter, after driving, as those used on the boiler shell long seam.

(c) The rivets attaching structural shapes to heads and tubesheets shall be spaced not more than 4 in. (100 mm) apart. The centers of the end rivets shall be not more than 3 in. (75 mm) from the ends of the structural shape. The rivets through the outstanding legs shall be spaced not more than 8 in. (200 mm) apart; the centers of the end rivets shall not be more than 4 in. (100 mm) from the ends of the structural shapes. The ends of the structural shapes shall be considered those of the outstanding legs, the ends of which overlap a circle 3 in. (75 mm) inside the straight flange of the head or tubesheet as shown in Figure V-4-1.

(d) The distance from the center of the structural shapes to the boiler shell, marked "A" in Figure V-4-1, shall not exceed the values in Table V-4-1, but in no case shall the edge of the portion of the lower angle attached to the head or tubesheet be closer than 2 in. (50 mm) to the top of the tube holes.

V-5 RIVETED ATTACHMENTS

(a) Attachment of nozzles and reinforcement by riveting shall meet the requirements of PR-15 and PR-16.

(b) Manhole frames on shells or drums shall have the proper curvature. Manhole frames on boilers over 48 in. (1.2 mm) in diameter shall be riveted to the shell

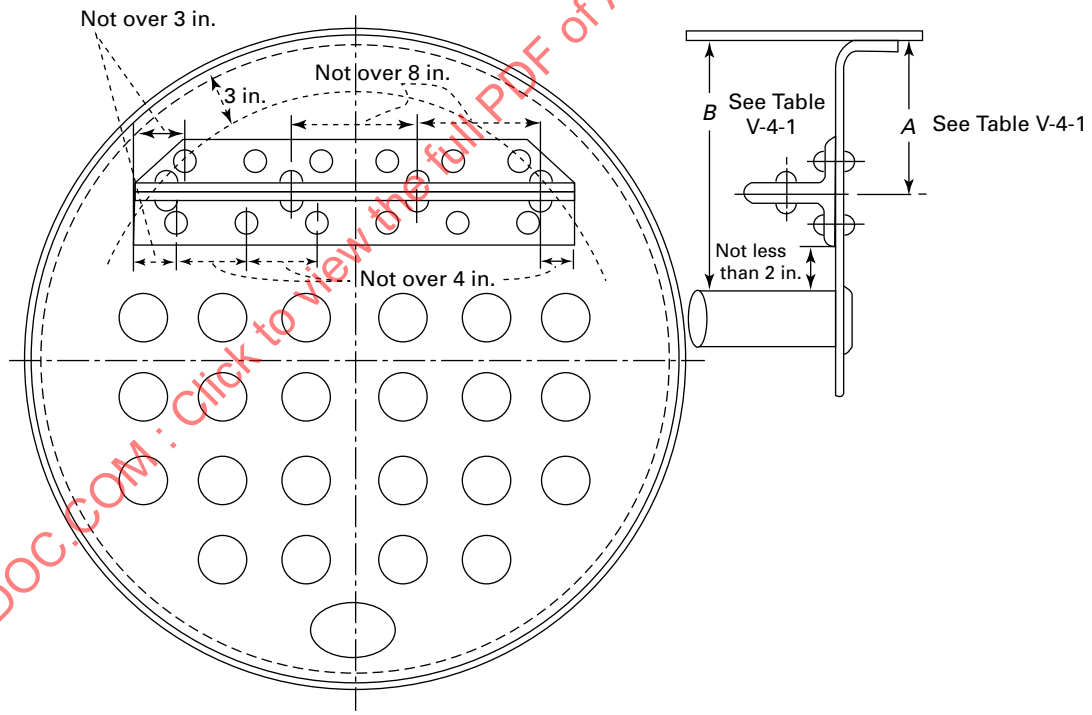
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Table V-4-1
Sizes of Angles Required for Staying Segments of Heads

	Height of Segment Dimension, *B*, in Figure V-4-1, in. (mm)						
	10 (250)	11 (280)	12 (300)	13 (330)	14 (350)	15 (380)	16 (400)
	Thickness, in. (mm)						
30 (760) Shell Dia.							
Angle 3 × 2½ (75 × 64)	⅜ (10)	7/16 (11)	9/16 (14)	...	...	...	...
Angle 3½ × 3 (89 × 75)	5/16 (8)	⅜ (10)	7/16 (11)	9/16 (14)	...	...	...
Angle 4 × 3 (100 × 75)	5/16 (8)	5/16 (8)	⅜ (10)	7/16 (11)	½ (13)	...	...
34 (860) Shell Dia.							
Angle 3½ × 3 (89 × 75)	...	7/16 (11)	½ (13)	11/16 (17)	...	...	...
Angle 4 × 3 (100 × 75)	...	5/16 (8)	7/16 (11)	½ (13)	5/8 (16)	...	...
Angle 5 × 3 (125 × 75)	...	5/16 (8)	5/16 (8)	5/16 (8)	⅜ (10)	½ (13)	...
36 (900) Shell Dia.							
Angle 4 × 3 (100 × 75)	...	...	7/16 (11)	9/16 (14)	5/8 (16)	¾ (19)	...
Angle 5 × 3 (125 × 75)	...	...	5/16 (8)	⅜ (10)	7/16 (11)	½ (13)	5/8 (16)
Angle 6 × 3 (150 × 75)	...	...	...	...	⅜ (10)	⅜ (10)	7/16 (11)
Dimension *A* in Figure V-4-1	6½ (165)	7 (175)	7½ (190)	8 (200)	8½ (215)	9 (230)	9½ (240)

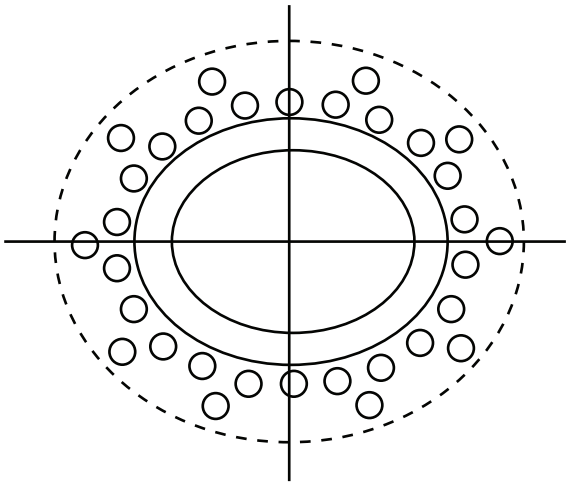
GENERAL NOTE: The short legs of the angles are attached to the head of the boiler.

Figure V-4-1
Staying of Head With Steel Angles in Tubular Boiler



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Figure V-5-1
Method of Riveting Manhole Frames to Shells or Drums With Two Rows of Rivets



or drum with two rows of rivets, which may be pitched as shown in Figure V-5-1.

V-6 DOMES (23)

(a) The longitudinal joint of a riveted dome 24 in. (600 mm) or over in inside diameter shall be of butt- and double-strap construction. Alternatively, the dome may be made without a seam of one piece of steel pressed into shape; its flange shall be double-riveted to the shell.

(b) A dome less than 24 in. (600 mm) in inside diameter, for which the product of the inside diameter in inches (millimeters) and the maximum allowable working pressure in psi (MPa) does not exceed 4,000 for Customary Units (700 for SI Units), may have a longitudinal seam of the lap type. Its flange may be single-riveted to the shell, provided the value of S is multiplied by 0.44 when calculating the minimum thickness or maximum allowable working pressure of the dome (see PG-27.2.2).

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MANDATORY APPENDIX VI
ESTABLISHING GOVERNING CODE EDITIONS, ADDENDA, AND CASES FOR BOILERS AND REPLACEMENT PARTS

VI-1 GENERAL

After Code revisions are approved by ASME, they may be used beginning with the date of issuance shown on the Code. Except as noted below, revisions become mandatory 6 months after the date of issuance. Code Cases are permissible and may be used beginning with the date of approval by ASME. Only Code Cases that are specifically identified as being applicable to this Section may be used. At the time a Code Case is applied, only the latest revision may be used. Code Cases that have been incorporated into this Section or have been annulled shall not be used.

Changes to the Code and Code Cases related to design, material, fabrication, examination, inspection, testing, overpressure protection, and field assembly made prior to completion of the boiler or replacement part may be critical to the intended service conditions of the boiler. These changes must be considered by the Manufacturer. Application of such changes shall be a matter of agreement between the Manufacturer and the user.

As used in this Mandatory Appendix, the term "Inspector" shall be considered to include "Authorized Inspector," "Qualified Inspector," and "Certified Individual," as applicable.

VI-2 DESIGN

The Manufacturer of the completed boiler (see PG-104) shall establish the Code Edition, Addenda, and Code Cases to be used for design of a boiler, including parts thereof, or a replacement part to be stamped with the ASME Certification Mark required by this Section.

(a) Except as provided in (b) and (c), the Code Edition and Addenda used to design a boiler, parts thereof, and replacement parts shall be either those that are mandatory on the date the boiler or replacement part is contracted, or those that have been approved and issued by ASME prior to the contract date but are not yet mandatory (see VI-1).

(b) Existing pressure parts that have been stamped and certified to an earlier or later edition and addenda than those used for design, and that have never been placed in service (i.e., they were placed in stock for future use) may be used provided they are acceptable to the Manufacturer.

(c) It is permitted to provide a replacement part "in kind" (i.e., identical in fit and material to the part being replaced) for an existing boiler and to certify the part as meeting the Code Edition and Addenda to which the existing boiler is certified.

VI-3 MATERIALS

For pressure-containing parts, the Manufacturer shall use material conforming to one of the specifications listed as approved for use in the Edition and Addenda specified for design. Also, the material specification edition must be listed as approved for use in the Guideline for Acceptable ASTM Editions or in the Guideline for Acceptable Non-ASTM Editions in Section II, Part A or Part B.

For replacement parts provided "in kind," the material shall be produced in accordance with the material specification revision listed in Section II as described above at the time the part is certified.

VI-4 FABRICATION

The Edition and Addenda used to govern fabrication shall be either those governing design or the Edition and Addenda approved and issued at the time the activity is performed.

VI-5 EXAMINATION

"Examination" refers to activities performed by the Manufacturer that include nondestructive examination. The Edition and Addenda used to govern examination shall be either those governing design or the Edition and Addenda approved and issued at the time the activity is performed.

VI-6 INSPECTION

"Inspection" refers to activities performed by the Inspector. The Code Edition and Addenda used to govern inspection shall be the same as those governing design.

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VI-7 TESTING

The Code Edition and Addenda used to govern testing of the item shall be the same as those governing design.

VI-8 OVERPRESSURE PROTECTION

The Code Edition and Addenda used to govern overpressure protection shall be the same as those governing design except the pressure relief valves shall be manufactured and assembled in accordance with the Code in effect when the valves are built.

VI-9 FIELD ASSEMBLY

The Edition and Addenda used to govern field assembly shall be either those governing design or the Edition and Addenda approved and issued at the time the activity is performed.

VI-10 CERTIFICATION

The Edition and Addenda used to govern Code certification shall be the same as those governing design.

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MANDATORY APPENDIX VII
ALTERNATE METHODS FOR APPLYING THE ASME CERTIFICATION MARK

(23) VII-1 REQUIREMENTS FOR ALTERNATE METHODS

Acceptable alternate methods include etching (laser, plasma, or chemical), peening, and engraving. The following requirements apply:

(a) The applied ASME Certification Mark shall be permanent, clearly legible, and identical in size and configuration to the ASME-issued stamp.

(b) The process controls for the method of marking shall be described in the Quality Control System and shall be acceptable to the Authorized Inspector.

(c) The external surface condition where the marking is to be applied shall be clean, uncoated, and unpainted.

(d) Additional provisions for alternative methods in applying the ASME Certification Mark shall be in accordance with ASME CA-1.

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MANDATORY APPENDIX VIII
LOCAL HEATING OF WELDS IN CYLINDRICAL COMPONENTS OF P-NO. 15E MATERIALS WHEN USING ELECTRIC RESISTANCE HEATING

VIII-1 SCOPE

The rules of this Appendix describe the minimum requirements that are to be followed during the setup and application of local controlled heat to weld joints, as opposed to heating the complete weldment in a furnace or oven. This Appendix applies specifically to the heating of P-No. 15E materials when using electric resistance heating pads.

VIII-2 GENERAL

During the manufacture, fabrication, and repair of P-No. 15E cylindrical components, it may be necessary to heat components before welding (preheating), between passes, or after welding [postheating or postweld heat treatment (PWHT)]. This Appendix provides instructions and minimum requirements for performing heating or heat treatment of welds when using electric resistance heating pads.

VIII-3 TERMINOLOGY FOR LOCAL HEATING

This section defines the terms used in describing local circumferential band heating. See Figures VIII-3-1 and VIII-3-2. Minimum requirements for these regions are presented later in this Appendix.

axial temperature gradient: the change in temperature along the length of the component; usually stated as a maximum temperature difference between two points located a specified distance apart.

component orientation: for the purpose of this Appendix, orientation of cylindrical components or PWHT in the horizontal position shall mean that the longitudinal axis of the main component lies in the horizontal position, and in the vertical position shall mean that the longitudinal axis of the main component lies in the vertical position.

control thermocouple: a single temperature-measuring device that is located within the control zone to control the temperature of that control zone.

control zone: a grouping of one or more electrical heating pads that are controlled electrically based on input from a single temperature-measuring device (typically a thermocouple). One or more zones may be present in both the circumferential and/or axial directions.

gradient control band (GCB): the surface area over which insulation and/or supplementary heat source(s) may be placed. The gradient control band encompasses the soak band, the heated band, and sufficient adjacent base metal to ensure that harmful temperature gradients are not generated within the heated band.

gradient control heaters: extra heaters that, under certain circumstances, are installed adjacent to the heated band to add heat to control thermal temperature gradients, or to provide thermal biasing to counter increased thermal mass or to counter a vertical bias in the temperature distribution in the heated band during PWHT in the vertical position. Also called blocking heaters.

heated band (HB): the surface area over which the heat is applied to achieve the required temperature in the soak band. The heated band consists of the soak band width on the outside surface of the component plus any adjacent base metal necessary both to control the temperature and to achieve an acceptable temperature on the inside of the pipe or tube.

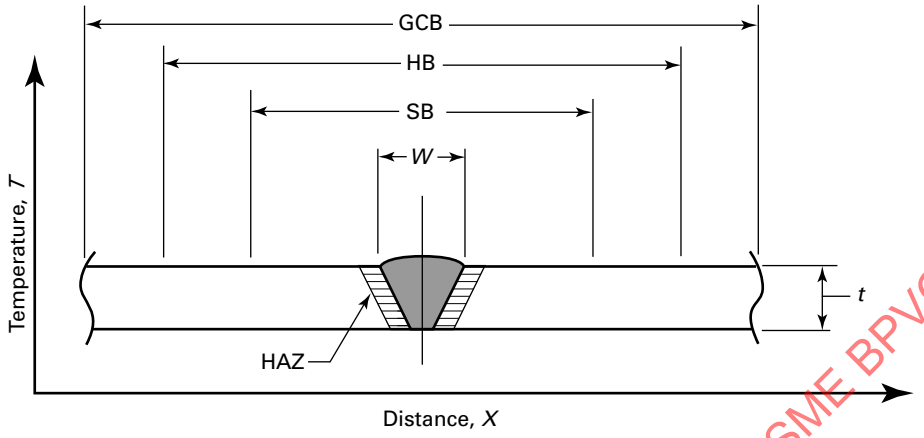
monitoring thermocouple: a temperature-measuring device used to measure the temperature at the position where it is located.

soak band (SB): the through-thickness volume of metal that is required to be heated to within the postweld heat treatment temperature range. At a minimum, it shall consist of the weld metal, the HAZ, and a portion of the base metal adjacent to and on each side of the weld being heated.

through-thickness temperature gradient: the difference between the temperature on the outside of the weld or component and the temperature on the inside of that same component, on the same radial line, and in the same axial plane.

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Figure VIII-3-1
Definitions of Terms for Local Circumferential Band Heating of Cylindrical Component Welds



Legend:
GCB = gradient control band (minimum width of insulation and/or gradient heat source)
HAZ = heat-affected zone
HB = heated band (width of heat source)
SB = soak band width on the outside surface of the material over which the holding temperature equals or exceeds the minimum and equals or is below the maximum required. The minimum width is typically specified as W plus a multiple of t on each side of the weld.
t = nominal thickness of component, branch connection, nozzle neck, or attachment
W = widest width of butt or attachment weld

VIII-4 LOCAL CIRCUMFERENTIAL BAND HEATING

Local heating of parts or components shall be accomplished by heating circumferential bands. Since local heating of cylindrical components is typically from the outside, when designing heat treatment procedures, radial (through-thickness) temperature gradients shall be considered.

VIII-4.1 SOAK BAND

The requirements for soak band width shall at a minimum be equal to the following (where referenced, t = wall thickness):

(a) Soak Band Width for Preheat. The minimum requirement for preheating shall be an area 3 in. (75 mm) or 1.5t, whichever is greater, in all directions from the point of welding.

(b) Soak Band Width for PWHT. The minimum requirements for PWHT shall be as follows:

(1) For components less than or equal to NPS 4 (DN 100), the soak band shall be 1.5t on each side of the weld at its greatest width.

(2) For components greater than NPS 4 (DN 100) but less than or equal to NPS 8 (DN 200), the soak band shall be 6t on each side of the weld at its greatest width.

(3) For components greater than NPS 8 (DN 200), the soak band shall be 10t on each side of the weld at its greatest width.

(c) Soak Band Width for Postheating. The minimum requirement for postheating shall be t or 2 in. (50 mm), whichever is less, on each side of the weld at its greatest width.

VIII-4.2 HEATED BAND

The requirements for heated band width for PWHT shall at a minimum be equal to the soak band width plus 4t on each side of the weld, where t = nominal wall thickness.

VIII-4.3 GRADIENT CONTROL BAND

The primary function of this band is to control the axial temperature gradient at the outer edges of the heated band. It also serves to minimize heat loss in the heated band. The width of the insulated area directly affects the axial temperature gradient.

The requirements for the gradient control band width shall at a minimum be equal to the following:

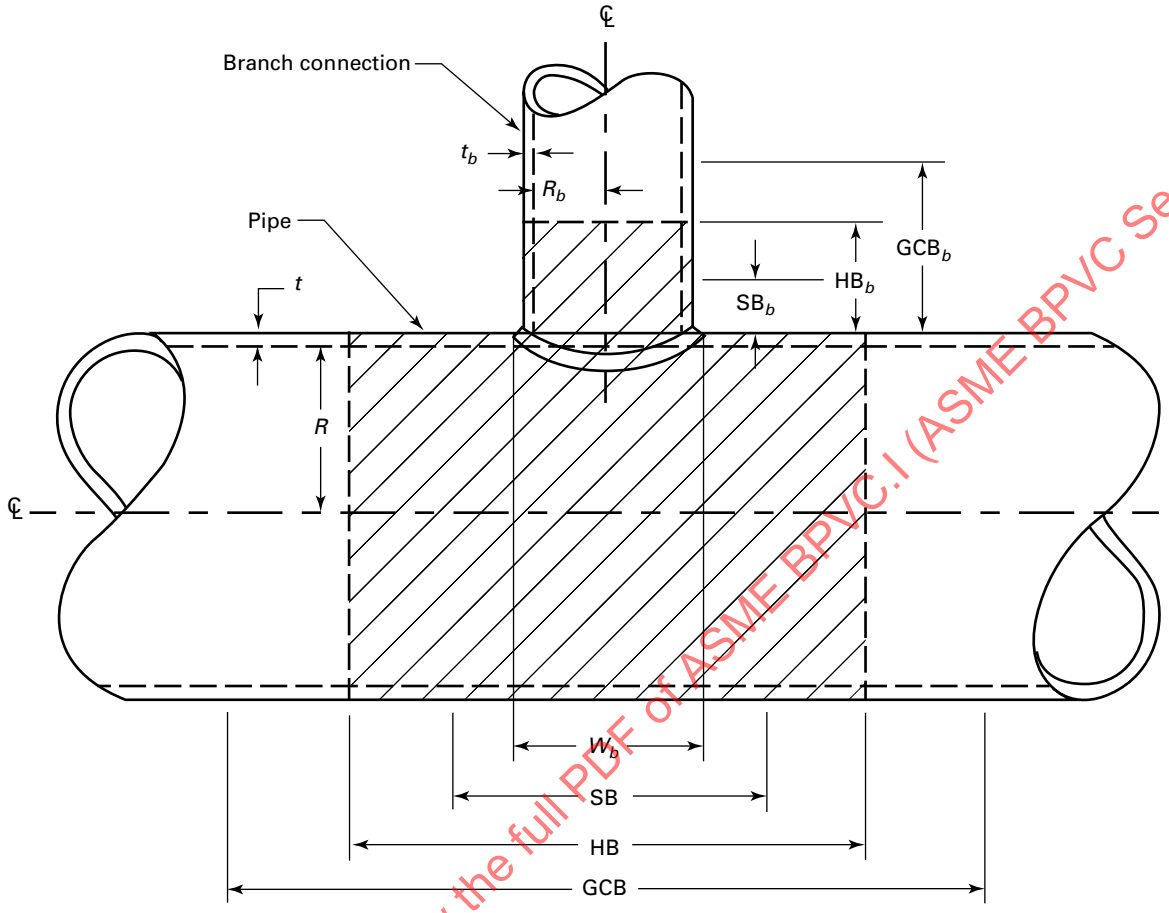
(a) Gradient Control Band Width for Preheating and Postheating. The insulation may be limited to covering the heaters to protect the welder.

(b) Gradient Control Band Width for PWHT. Requirements for the gradient control band width shall be the heated band width plus 4t on each side of the weld, where t = nominal wall thickness.

NOTE: If the component wall thickness changes, attachments are present within the gradient control band, or the pipe is being welded to flanges, valves, etc., the use of supplemental heat source(s) within the gradient control band may be required.

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Figure VIII-3-2
Definitions of Terms for Local Circumferential Band With Branch Connection Attachment Weld to Cylindrical Component



Legend:

GCB, GCB $_b$ = gradient control band (minimum width of insulation and/or gradient heat source)
HB, HB $_b$ = heated band (width of heat source) shown as shaded area
R, R_b = inside radius of pipe or branch connection
SB = soak band width on the outside surface of the material over which the holding temperature equals or exceeds the minimum and equals or is below the maximum required. The minimum width is typically specified as W plus a multiple of t on each side of the weld attaching the branch connection.
SB $_b$ = soak band width on the outside surface of the material on the branch connection. The minimum width is typically specified as W plus a multiple of t on each side of the weld attaching the branch connection.
t, t_b = nominal thickness of component or branch connection
W_b = widest width of weld attaching the branch connection to the component

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VIII-4.4 AXIAL TEMPERATURE GRADIENT

The axial temperature distribution plays an important role in limiting induced stresses during PWHT. The temperature gradient shall be controlled such as to be reasonably uniform around the component.

(a) Axial Temperature Gradient for Preheating and Postheating. Control of the axial temperature gradient is not required.

(b) Axial Temperature Gradient for PWHT. The maximum axial temperature gradient for PWHT shall be limited such that the temperature at the outer edge of the heated band shall be no less than one-half the temperature at the edge of the soak band during heating, soak time, and cooling.

VIII-5 MEASUREMENT OF TEMPERATURE

Measurement of temperature is required during heating operations. During the heating cycle, whenever temperatures exceed 800°F (425°C), a continuous record of the temperature shall be made.

VIII-5.1 TEMPERATURE-INDICATING CRAYONS AND PAINTS

Temperature-indicating crayons and paint are permissible only up to 600°F (316°C). Above that temperature, thermocouples shall be used and shall be attached using the capacitor discharge method of welding.

VIII-5.2 SELECTION OF THERMOCOUPLES

(a) Thermocouples shall be selected based on their maximum recommended temperature rating.

(1) Type J, Iron–Constantan shall not be used above 1,400°F (760°C).

(2) Type K, Chromel–Alumel shall not be used above 2,300°F (1 260°C).

(b) The maximum size of thermocouple wire to be used in local heating (with attachment by capacitor discharge welding) shall be #20 American Wire Gage (AWG), which has a diameter of 0.032 in. (0.81 mm).

VIII-5.3 INSTALLATION OF THERMOCOUPLES

Thermocouples shall be attached using capacitor discharge welding. Each wire shall be attached separately to the surface of the workpiece. The maximum separation of the wires shall be held to ¼ in. (6 mm).

(a) PW-39.8 and Table PW-39-5, General Note (b) provide a special allowance for attachment of thermocouples by low-energy [limited to 125 W-sec (joule)] capacitor discharge welding without requiring a welding procedure, a welder performance qualification, or subsequent PWHT.

(b) After capacitor discharge welding, the thermocouple welds shall be carefully inspected for proper attachment before covering with insulation or application of heat. This shall be accomplished by repositioning the insulation back to the O.D. surface, then bending the wires flush with the surface. If the weld remains intact, the thermocouple has been attached securely.

(c) The thermocouple shall be tied or taped to the workpiece approximately 2 in. to 3 in. (50 mm to 75 mm) away from the attachment point to minimize stress on the point of thermocouple attachment (hot junction).

(d) The thermocouple wire shall be kept under insulation for at least 4 in. (100 mm) from the welded junction to minimize heat conduction along the wire, away from the hot junction.

VIII-5.4 CONTROL THERMOCOUPLES

Control thermocouple locations shall be based on the location of the heating pads and the component being heated. Each electrically separate circuit containing heating pads shall be known as a control zone and shall be controlled by one control thermocouple. This thermocouple shall be approximately centrally located such that it experiences the greatest expected temperature within the control area. When installing the control thermocouple, an electrically separate, spare control thermocouple shall be installed immediately adjacent to it.

VIII-5.5 MONITORING THERMOCOUPLES

Monitoring thermocouples shall be placed to ensure that all of the parameters specified to control the local heating operation are being achieved. They shall be placed to measure the maximum and minimum anticipated metal temperatures. To achieve this, thermocouples shall be placed at the centerline of the weld, the edge of the soak band, and the edge of the heated band. These shall be located as described in VIII-6.3.4. There shall also be at least one thermocouple, either control or monitoring, located under each heating pad.

VIII-6 DESIGN OF THE HEATING PROCESS

Choice of the size, the number, and the electrical configuration of electric heating pads shall be based on the geometrical configuration of the parts, the soak band area, and the heated band areas.

All heating pads used in a single heat treatment shall be manufactured from the same materials and shall be of the same watt density.

Prior to installation, each heater shall be inspected for broken ceramic beads and frayed heater wires. If found and judged to be detrimental to the process, the heaters shall be replaced.

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Table VIII-6.3.2-1
Control Zones

Piping Size, NPS (DN)	Minimum Required Number of Circumferential Control Zones and Control Thermocouple Locations
Less than 6 (150)	One control zone with the control thermocouple at twelve o'clock
6 (150) and up to 12 (300)	Two control zones with control thermocouples at twelve o'clock and six o'clock
14 (350) and up to 30 (750)	Four control zones with control thermocouples at twelve o'clock, three o'clock, six o'clock, and nine o'clock
Over 30 (750)	Number of control zones and associated thermocouples as required by actual heater configuration, circumferential spacing of heaters, control bands etc., but with one control thermocouple at twelve o'clock

VIII-6.1 PREHEAT

(a) Heating pads shall be symmetrically located on either side of the weld preparation. The heating pads shall be installed such that the edges of the pads shall be approximately 1 in. (25 mm) away from the edge of the weld preparation.

(b) Each side of the weld shall be considered a separate and distinct heated area with its own temperature monitoring and control zones.

(c) Preheat temperature shall be monitored at a number of locations around the weld, with each location 0.5 in. (13 mm) away from the edge of the weld preparation. At a minimum, the six o'clock position shall be monitored to ensure that the minimum preheat has been achieved.

(1) There shall be at least one control thermocouple installed per control zone, and in the case of horizontally oriented pipe and tube, at least one of these control thermocouples shall be installed at the twelve o'clock position.

(2) One control or monitoring thermocouple shall be installed under each heater.

VIII-6.2 POSTHEATING

Heating pads shall be symmetrically located over the centerline of the weld. There shall be at least one control thermocouple installed per control zone, and in the case of horizontally oriented components, at least one of these control thermocouples shall be installed at the twelve o'clock position.

VIII-6.3 POSTWELD HEAT TREATMENT

VIII-6.3.1 Heating Pads. The heating pads across the soak band shall be installed in such a way the gaps between the heaters are minimized. When the nominal wall thickness of the pipe is less than or equal to 1 in. (25 mm), the gaps between the heaters shall not be greater than $^{3}/_{8}$ in. (10 mm). When the nominal wall thickness of the component exceeds 1 in. (25 mm), the gaps between the heaters shall not be greater than one-third the wall thickness. Where this is not possible, a monitoring thermocouple shall be welded in the center of the gap.

(a) There shall be *no overlapping* of heaters.

(b) Heater tails shall not be allowed to cross any other pad or heater tail.

(c) Heater tails shall be insulated from the pipe.

(d) Heater tails shall be brought out through the insulation as close to the edge of the heater as possible.

VIII-6.3.2 Control Zones. Control zones shall as a minimum be laid out as per Table VIII-6.3.2-1.

VIII-6.3.3 Location of Thermocouples. At least one thermocouple shall be installed at both the twelve o'clock and six o'clock positions on the weld centerline. These thermocouples may be either a control thermocouple or a monitoring thermocouple. Additional thermocouples may be necessary depending on the part configuration and size. Monitoring thermocouples shall also be installed at the outer edges of the soak band and at the outer edges of the heated band.

VIII-6.3.4 Examples of Thermocouple Locations. Figures VIII-6.3.4-1 through VIII-6.3.4-4 show examples of the thermocouple locations for common local circumferential band PWHT applications. In some instances, both monitoring and control thermocouples have been shown. Figures VIII-6.3.4-1 through VIII-6.3.4-3 provide required monitoring and control thermocouple locations for PWHT of butt welds in horizontally oriented components with one, two, and four control zones. Figure VIII-6.3.4-4 provides required monitoring thermocouple locations for PWHT of a weld attaching a branch connection. Control thermocouples shall be attached as required by the control zone layout.

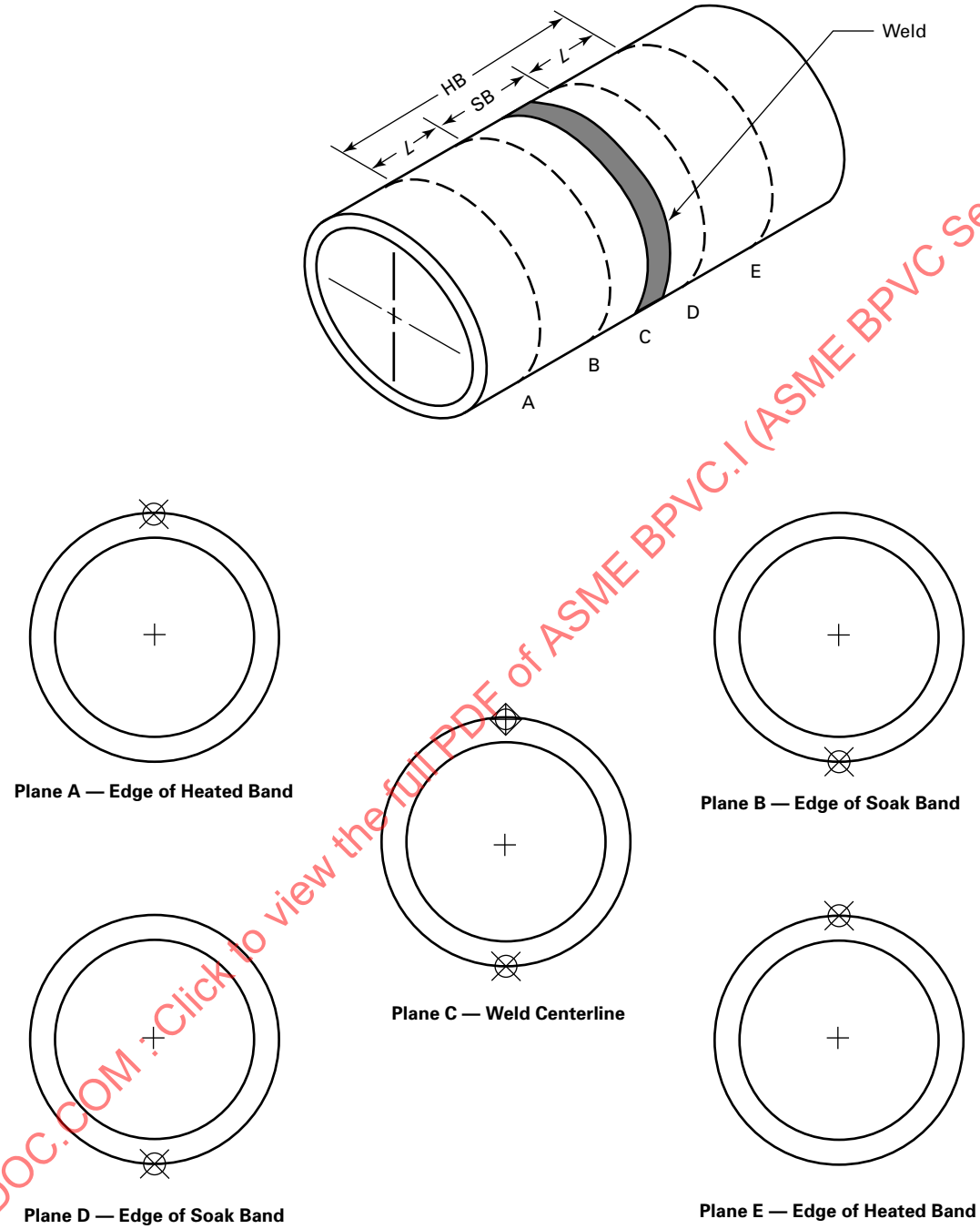
VIII-6.4 SPECIAL CONSIDERATIONS

VIII-6.4.1 Circumferential Welds Joining Components in the Horizontal Position. Due to natural internal convection heat flow, the twelve o'clock position on a circumferential weld in horizontally oriented piping cylindrical components will be considerably hotter than the six o'clock position. To avoid exceeding the maximum allowed temperature, one control thermocouple shall always be installed at the twelve o'clock position. In addition, control zones and control thermocouples shall be installed as specified in VIII-6.4.2 through VIII-6.4.7.

VIII-6.4.2 Butt Welds Joining Components in the Vertical Position. Due to natural internal convection heat flow, the upper side of the heated band in vertical components will be hotter than the lower side. Several approaches may be used to address this issue.

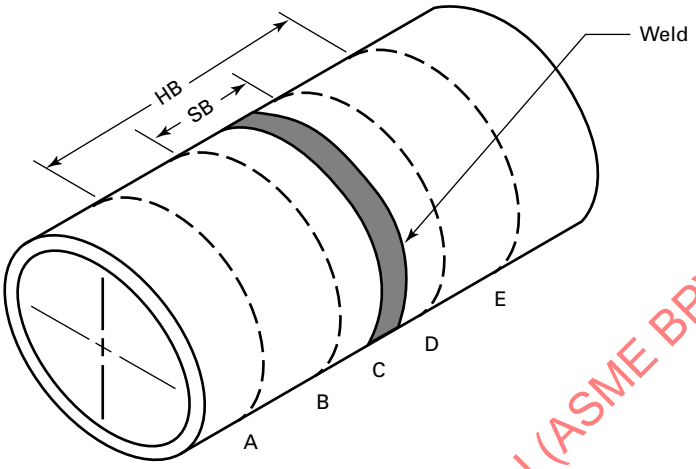
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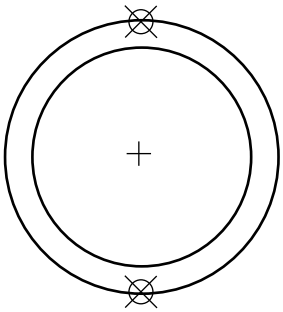
Figure VIII-6.3.4-1
Location of Thermocouples (Monitoring and Control) for Pipe Sizes Up to 6 NPS (150 DN) and One Control Zone



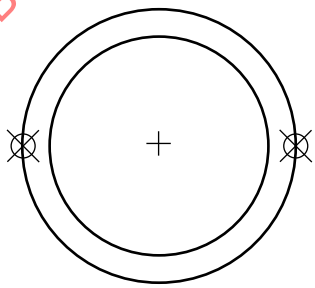
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Figure VIII-6.3.4-2
Location of Thermocouples (Monitoring and Control) for Pipe Sizes 8 NPS Through 12 NPS (200 DN Through 300 DN) and Two Control Zones

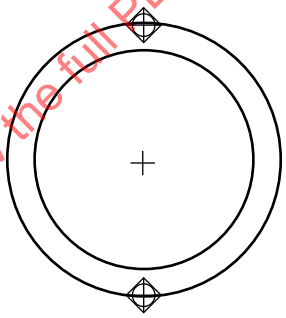




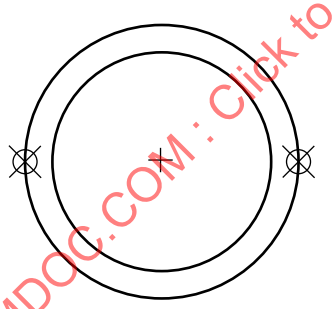
Plane A — Edge of Heated Band



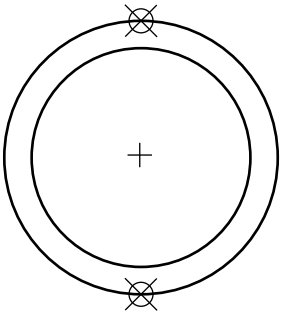
Plane B — Edge of Soak Band



Plane C — Weld Centerline



Plane D — Edge of Soak Band



Plane E — Edge of Heated Band

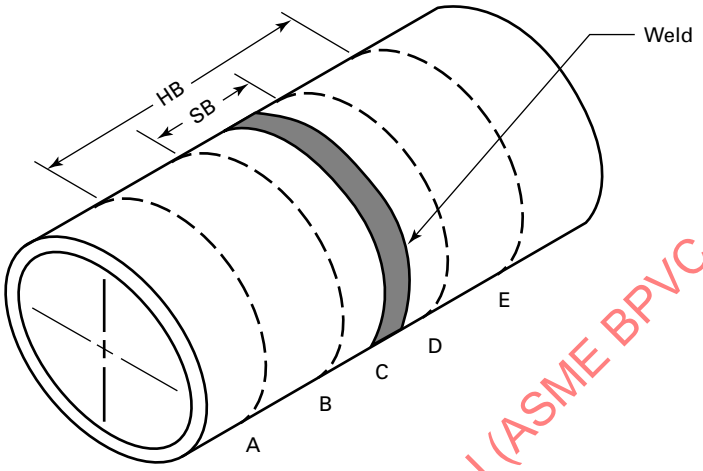
Legend

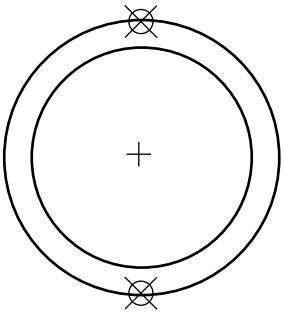
Monitoring thermocouple location on outer surface

Control thermocouple location on outer surface

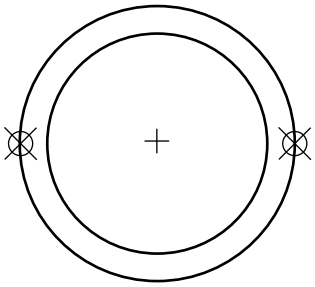
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Figure VIII-6.3.4-3
Location of Thermocouples (Monitoring and Control) for Pipe Sizes 14 NPS Through 30 NPS (350 DN Through 750 DN) and Four Control Zones

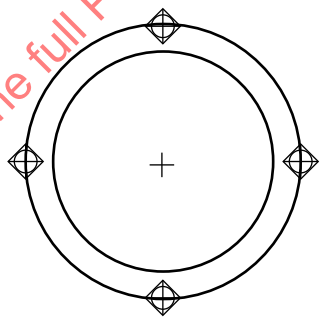




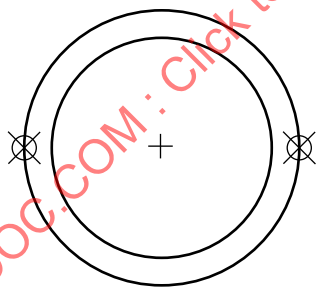
Plane A — Edge of Heated Band



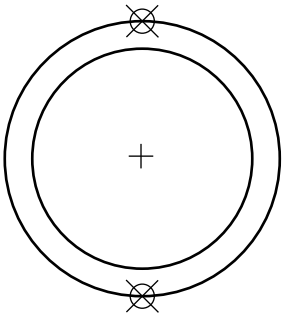
Plane B — Edge of Soak Band



Plane C — Weld Centerline



Plane D — Edge of Soak Band



Plane E — Edge of Heated Band

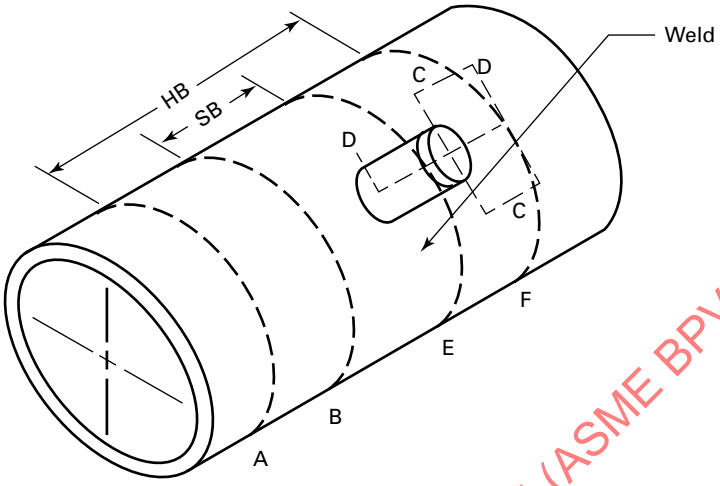
Legend

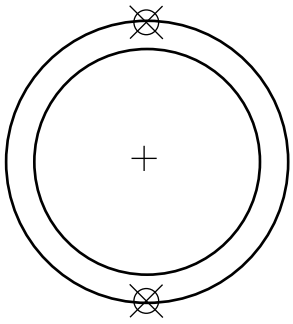
Monitoring thermocouple location on outer surface

Control thermocouple location on outer surface

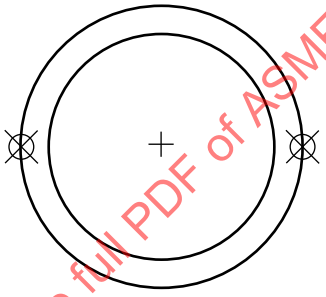
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Figure VIII-6.3.4-4
Location of Monitoring Thermocouples for Branch Nozzle or Attachment

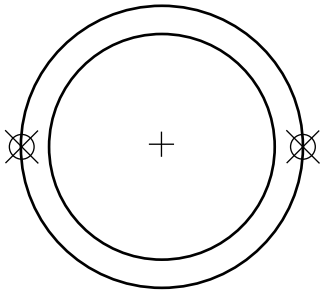




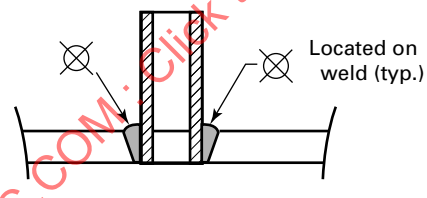
Planes A and F — Edge of Heated Band



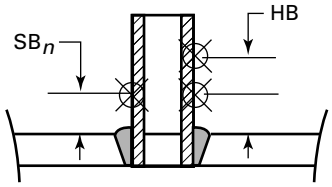
Plane B — Edge of Soak Band



Plane E — Edge of Soak Band



Section C-C



Section D-D

Legend

⊗ Monitoring thermocouple location on outer surface

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(a) Air circulation dams may be placed inside the pipe, preferably above the weld, to block the "chimney effect" within the pipe.

(b) The heated band may be biased such that approximately 60% of the heated band area is below the weld.

(c) Separate control zones above and below the weld may be used. For electric resistance heating, gradient control or blocking heaters may also be installed below the weld to balance the heat flow and in effect form a biasing of the heated band.

VIII-6.4.3 Butt Welds Joining Components to Valves and Flanges. During PWHT of butt welds between cylindrical components and components such as valve bodies or heavy flanges, consideration shall be given to the uneven conductive heat loss (or so-called heat sink effect) on each side of the weld. To counter this, the heat input may be biased to the thicker side of the joint. This may be accomplished by the following:

(a) use of separate control zones on the thicker and thinner components.

(b) biasing the heating elements toward the heavier component.

(c) reducing the volume of insulation used on the thinner-section heated band to achieve the desired temperature profile across the soak band.

In such instances, additional monitoring thermocouples shall be used to ensure that the required temperatures are achieved on both the thinner and heavier wall thickness components.

VIII-6.4.4 Welds Joining Branch Connections or Attachments to Cylindrical Components.

(a) For welds joining branch connections or attachments to cylindrical components, circumferential band PWHT practices shall be used on both the piping cylindrical components and the connection. The entire nozzle or attachment shall be included in the soak band.

(b) For branch connections where the heating pads fitted to the weld will not contour to the shape without leaving larger than normal gaps between the heaters, additional monitoring thermocouples shall be placed in the expected cold spots to ensure that the cold spots achieve the desired temperature.

(c) Where small branch connections, ½ in. to 1½ in. (13 mm to 38 mm) diameter, are welded to larger sections, circumferential bands around both the larger component and smaller branch connection shall be heated using heaters with control thermocouples on the larger component and with monitoring thermocouples on the smaller branch connection. If separate control zones are used for the larger component and smaller branch connection, they shall each have separate control thermocouples.

VIII-6.4.5 Intersection With Branch Connections and Attachments Not Requiring PWHT.

(a) The soak band, heated band, and/or gradient control band of welds that require PWHT may intersect branch connections or attachments that do not require PWHT. To avoid distortion and/or induced residual stresses during PWHT, the temperature gradient across the components that are intersected shall be minimized. This may require the application of a supplementary heat source(s) to the branch connection or attachment.

Alternatively, a reasonably uniform temperature shall be maintained across these components. The soak band, heated band, or gradient control band, whichever intersects, shall be extended in the axial direction such that it ends beyond the weld on the opposite side connecting the attachment or associated pad to the component for at least half of the soak band, heated band, or gradient control band, whichever is appropriate.

Figure VIII-6.4.5-1 provides an example of such an approach when the heated band from a weld requiring PWHT intersects a nozzle that does not require PWHT.

(b) Although the nonspecific term "reasonably uniform" is used in (a) to describe the temperature drop across the intersected component, the aim is to maintain a reasonably constant temperature drop across the intersected component. However, to provide a measurable limit, a maximum temperature drop is recommended.

The maximum temperature drop across an intersected component shall be 100°F (56°C) or that resulting from application of the maximum permissible axial temperature gradient (i.e., 50% of the temperature at the edge of soak band divided by $2\sqrt{Rt}$), whichever is less. Based on experience or analysis, larger temperature gradients across nozzles or attachments may exhibit permissible levels of distortion or residual stress.

VIII-6.4.6 Proximity of Pipe-to-Nozzle Welds to Shell or Head. Consideration shall be given to whether local circumferential band PWHT of pipe-to-nozzle welds may result in heating the nozzle and/or surrounding shell or head section to temperatures that may cause distortion and harmful induced stresses.

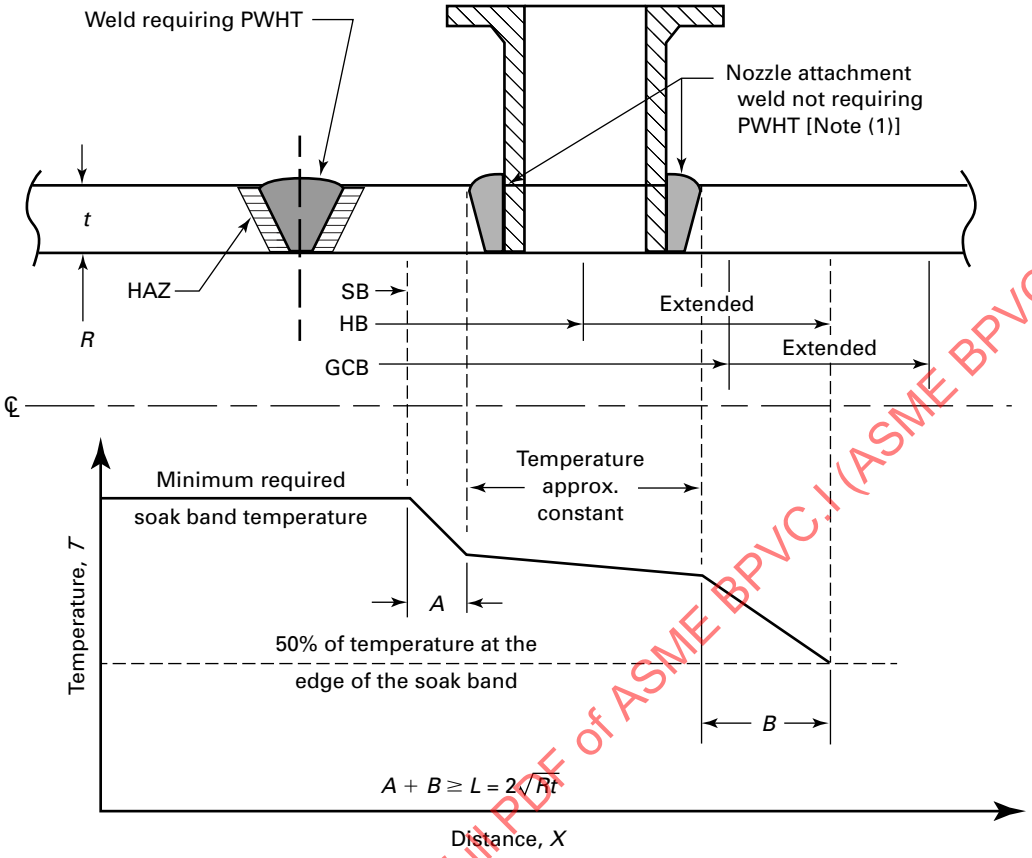
VIII-6.4.7 Lower Critical Temperature (LCT) of P-No. 15E Weld Metal. Variations in P-No. 15E weld metal chemistry are known to have a significant effect on its lower critical transformation temperature. Consideration shall therefore be given to ensuring that the upper limit of the heat treatment temperature does not exceed the LCT of the weld metal.

VIII-7 THE THERMAL CYCLE, PWHT

It is important to control the following four aspects of the thermal cycle associated with heating operations: temperature uniformity, the heating rate above a specified

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Figure VIII-6.4.5-1
Example of One Approach When the Heated Band from Weld Requiring PWHT Intersects Weld Not Requiring PWHT



Legend:
GCB = gradient control band (minimum width of insulation and/or gradient heat source)
HB = heated band (width of heat source)
L = minimum distance over which the temperature may drop to one half of that at the edge of the soak band
R = inside radius of pipe
SB = soak band (width of the volume of the material where the holding temperature equals or exceeds the minimum and equals or is below the maximum required. The minimum width is typically specified as a multiple of t on each side of the weld.)
t = nominal thickness of pipe

GENERAL NOTES:
(a) The total distance over which the temperature drops from that at the edge of the soak band to 50% (A plus B) is greater than or equal to $L = 2\sqrt{Rt}$.
(b) The intent is to maintain an "approximately constant" temperature across the intersected component. However, a maximum temperature drop of 100°F (55°C) or that resulting from application of the maximum recommended axial temperature gradient, whichever is less, is permitted.

NOTE: (1) The nozzle attachment weld "not requiring PWHT" does not imply that such a weld would not require PWHT. It simply means that it does not require PWHT now. For example, it may have previously received PWHT.

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temperature, the specified hold temperature and time, and the cooling rate down to a specified temperature.

(a) Maximum Temperature Differences for PWHT. During heating and cooling, the maximum temperature difference within the heated band shall be 250°F (139°C), or as limited by the maximum axial temperature gradient.

(b) The Maximum Heating Rate. Above 800°F (425°C), the rate of heating shall be not more than 400°F/hr (222°C/h) divided by the maximum material thickness in inches (millimeters, the thickness divided by 25 shall be used), but in no case more than 400°F/hr (222°C/h).

(c) The Maximum Hold Temperature and Time. During hold, the requirements for the maximum hold temperature and time shall be as defined in PW-39.

(d) The Maximum Cooling Rate. Above 800°F (425°C), the rate of cooling shall be not more than 500°F/hr (278°C/h) divided by the maximum material thickness in inches (millimeters, the thickness divided by 25 shall be used), but in no case more than 500°F/hr (278°C/h).

(23) VIII-8 INSULATION

(a) Classification of Insulation. The requirements for the gradient control band width are based upon insulation R values of 2°F-ft^2-hr/Btu to 4°F-ft^2-hr/Btu (0.35°C-m^2/W to 0.70°C-m^2/W). Refractory ceramic fiber insulation with a density of 6 lbm/ft^3 to 8 lbm/ft^3 (96.1 kg/m^3 to 128.1 kg/m^3) meets this requirement. A layer at least 1 in. (25 mm) thick shall be used for temperatures up to 1,200°F (650°C); a layer at least 2 in. (50 mm) thick shall be used for temperatures above 1,200°F (650°C).

(b) Attachment of Insulation. The pieces of insulation shall be sized such that when the piece(s) are wrapped around the component, the component surfaces shall be fully covered, with the ends of the insulation either butted against each other or overlapped to preclude heat loss. No gaps shall be permitted in the insulation layer, and any inadvertent gaps shall be filled with insulation. The insulation may be held in place with banding or tie wire. The insulation shall not be compressed to less than three-quarters of its original thickness during banding or tying.

(c) During heating, the insulation has a tendency to shrink and thus create gaps. Inspection shall therefore be carried out at various times during the heating cycle to identify and rectify any gaps that may occur during the heating.

(d) When multiple layers of insulation are used, the seams shall be staggered to minimize the possibility of gaps.

(e) The insulation shall extend beyond the edge of the heated band out to the edge of the gradient control band to diminish heat loss and to ensure that the permissible maximum axial temperature gradient from heated to unheated sections is not exceeded.

VIII-9 QUALITY ASSURANCE SYSTEM

VIII-9.1 INTRODUCTION

To ensure that local heating operations are in compliance with various codes, standards, practices, or specifications, all heating shall be performed in accordance with an established quality assurance system.

All work shall be performed in accordance with a written quality assurance system. This system shall be described in a Quality Assurance Manual and shall define the organizational structure, responsibilities, procedures, processes, and resources for implementing quality management. The written description of the quality assurance system shall be available for review.

VIII-9.2 PROCESS CONTROL

Written procedures and associated drawings shall be used. The Standard Procedure for Local Heating shown in Form VIII-9.2-1, or an equivalent, shall be used in conjunction with a drawing/sketch that specifies placement of thermocouples, heat sources (including control zones), and insulation.

VIII-9.3 DOCUMENTATION

A record of the thermal cycle shall be produced. The temperature resolution of the record shall be within 5°F (3°C), and the time resolution shall be within 5 min.

(a) The record of the thermal cycle shall be submitted to the customer upon the completion of local heating. The record of the thermal cycle shall contain information such as the temperature and time scales and correspondence between thermocouple numbers on the record and those on the drawing/sketch. The records provided may be either electronic or printed copy.

(b) Copies of the procedures, drawings/sketches, Certificates of Conformance for thermocouples and extension wire, and calibration records for temperature-recording devices shall be submitted to the customer along with the record of the thermal cycle for each weld or group of welds.

(c) Form VIII-9.3-1, Standard Documentation Checklist for Local Heating, shall be used as a basis for provision of documentation. This checklist and supporting documentation shall be submitted to the customer at the completion of local heating.

VIII-9.4 CONTROL OF INSPECTION, MEASURING, AND TEST EQUIPMENT

All thermocouples and extension wire shall be traceable to Certificates of Conformance. Calibration of temperature-recording devices shall be traceable to national

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standards such as those maintained by the National Institute for Standards and Technology (NIST).

VIII-9.5 TRAINING

All personnel performing local heating shall be trained in the proper use and application of the associated processes and equipment, including safety, calibration, maintenance, and inspection considerations. Each organization shall be responsible for defining its own training program, and documentation of such training shall be maintained and made available on request.

VIII-9.6 SERVICING

All equipment shall be serviced at appropriate intervals as recommended by the manufacturer to ensure proper performance. Documentation of such servicing shall be maintained and made available on request.

VIII-10 OTHER CONSIDERATIONS

Additional issues, including the following, shall be considered when performing local heating of components:

(a) the structural integrity of the component.

(b) the strength of the component at temperature. The component should have sufficient strength at temperature to be self-supporting.

(c) the potential for the components to experience an unacceptable permanent distortion.

(d) natural convection within the component.

(e) natural convection within otherwise sealed-off sections of cylindrical components. Closing valves, blinding flanges, and other techniques to seal off a section of cylindrical components may not prevent this form of natural convection. The resulting circulating airflow may cause undesirable heat transfer on the inside surface of the component. For pipe in the horizontal position, this may result in significant temperature differences between the twelve o'clock and six o'clock positions.

(f) natural drafts. These can occur when a flow of air is possible through parts of a cylindrical component system that are not sealed off. This is often referred to as the "chimney effect." Such flow can result in considerable convection losses on the inside surface of the component.

(g) thermal expansion of the component. Large thermal stresses can develop during PWHT if adequate provisions to permit thermal growth are not made.

(h) the presence of internal fluids within or adjacent to the heated area.

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FORM VIII-9.2-1 STANDARD PROCEDURE FOR LOCAL HEATING

Procedure No. _____ Revision No. _____ Date _____

Governing Code _____

Workpiece Identification Number _____

Material Specification _____

Component Dimensions _____

Thermocouple, Heater, and Insulation Layout Drawing Number _____

Thermal Cycle

Heating Rate _____ °__ /hr (specify max. or min.) above_____°_____

Hold Temperature Range_____ to_____ °_____ .

Minimum Hold Time _____ hr Maximum Hold Time _____ hr

Cooling Rate _____ __ /hr (specify max. or min.) above_____ °____

Procedure

Step 1. Match procedure/drawings to workpiece, including verification of workpiece identification number. Check the appropriateness of specified thermal cycle to the material and application.

Completed by: _____ Date _____

Step 2. Install and test power/control equipment, including power supplies, temperature controllers, and temperature recorders.

Completed by: _____ Date _____

Step 3. Check validity of calibration date on all temperature recorders. Enter serial number and date next calibration due for each recorder.

Serial number _____ Date next calibration due _____

Serial number _____ Date next calibration due _____

Serial number _____ Date next calibration due _____

Serial number _____ Date next calibration due _____

Completed by _____ Date _____

Step 4. Install thermocouples (including spares) per drawing/sketch using approved methods. Direct attachment by capacitor discharge welding (VIII-5.3) is recommended.

Completed by_____ Date_____

Step 5. Verify specified (per drawing/sketch) placement of thermocouples.

Verified by _____ Date _____
(QC Inspector)

Step 6. Install heat sources and insulation per drawing/sketch using approved methods.

Completed by _____ Date_____

Step 7. Verify specified (per drawing/sketch) placement of heat sources and insulation before the start of heating.

Verified by _____ Date_____
(QC Inspector)

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FORM VIII-9.2-1 STANDARD PROCEDURE FOR LOCAL HEATING (Cont'd)

Step 8. Install and connect thermocouple extension wire. Check operation of all thermocouples. Check for reversal of thermocouple polarity. Note that it may only be possible to detect a double polarity reversal visually. (When checking for polarity reversal, use the mnemonic device "BIG-RED-NEGATIVE" as a guide.)

Completed by _____ Date _____

Step 9. Install and connect power cables. Check operation of all heat sources.

Completed by _____ Date _____

Step 10. Obtain approval to begin the heating operation.

Approved by _____ Date _____
(QC Inspector)

Step 11. Perform and document periodic checks during heating, including equipment operation (recorder and power supplies) and adherence to specified heating rate. If a deviation occurs during heating, follow approved corrective action. If it appears that achieving the hold temperature will be difficult and requires excessive time, the QC Inspector should be notified and a decision made regarding whether to continue heating.

Completed by _____ Date _____ Time _____

Completed by _____ Date _____ Time _____

Completed by _____ Date _____ Time _____

Step 12. Verify the start of the hold period, i.e., all soak band thermocouples are within the required temperature range.

Verified by _____ Date _____
(QC Inspector)

Step 13. Perform and document periodic checks during the hold period, including equipment operation (recorder and power supplies) and adherence to required hold temperature range. If a deviation occurs during the hold period, follow approved corrective action. A maximum time in the hold temperature range may be specified for certain materials. If it appears that the maximum time limit will be exceeded, the QC Inspector should be notified and a decision made regarding whether to continue heating.

Completed by _____ Date _____ Time _____

Completed by _____ Date _____ Time _____

Completed by _____ Date _____ Time _____

Completed by _____ Date _____ Time _____

Completed by _____ Date _____ Time _____

Step 14. Verify completion of the hold period, i.e., all soak band thermocouples remained within the required temperature range for the minimum required time. Must be verified before the start of cooling.

Verified by _____ Date _____
(QC Inspector)

Step 15. Perform and document periodic checks during cooling period, including equipment operation (recorder and power supplies) and adherence to specified cooling rate. If a deviation occurs during cooling, follow approved corrective action.

Completed by _____ Date _____ Time _____

Completed by _____ Date _____ Time _____

Completed by _____ Date _____ Time _____

Step 16. Deactivate power/control equipment after the temperature is below that where cooling-rate control is required.

Completed by _____ Date _____

Step 17. Remove all equipment after the temperature is safe for personnel. Cut thermocouple wires, and mark locations of attached thermocouples for light filing/grinding.

Completed by _____ Date _____

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FORM VIII-9.2-1 STANDARD PROCEDURE FOR LOCAL HEATING (Cont'd)

Step 18. Note any deviations such as heating rate, hold time, temperature, or cooling rate that occurred during the thermal cycle. If no deviations occurred, enter "None."

_____

_____

_____

_____

_____

Completed by _____ Date _____

Step 19. Complete and submit to the Customer appropriate documentation in accordance with Standard Documentation Checklist for Local Heating (Form VIII-9.3-1).

Received by _____ Date _____
(Customer's Representative)

FORM VIII-9.3-1 STANDARD DOCUMENTATION CHECKLIST FOR LOCAL HEATING

The following documentation shall be provided by the supplier of local heating services at the completion of work:

☐ 1. Procedure (Form VIII-9.2-1) with all required information completed

☐ 2. Drawings/sketches for thermocouple, heater, and insulation layout

☐ 3. Certificates of Conformance for thermocouple and extension wire

☐ 4. Certified Material Test Reports for any filler metals being used that match the P-No. 15E materials (The customer shall provide a copy of the CMTRs for filler metals matching the P-No. 15E materials being heat treated, which shall include the Lower Critical Transformation Temperature.)

☐ 5. Calibration records for temperature-recording device

☐ 6. Hardness testing results (if applicable)

7. Strip chart record of the entire thermal cycle with the following information:

- ☐ a. Date(s), time period, and location of work performed
- ☐ b. Identification of contractor/personnel performing the work
- ☐ c. Identification number of the workpiece
- ☐ d. Temperature and time scales
- ☐ e. Correspondence between thermocouple numbers on the chart(s) and on the drawing/sketch
- ☐ f. Heating rate above specified temperature
- ☐ g. Hold period temperature and time
- ☐ h. Cooling rate above specified temperature

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NONMANDATORY APPENDIX A
EXPLANATION OF THE CODE CONTAINING MATTER NOT MANDATORY UNLESS SPECIFICALLY REFERRED TO IN THE RULES OF THE CODE

EFFICIENCY OF JOINTS

A-1 EFFICIENCY OF RIVETED JOINTS

A-1.1 Introduction. The efficiency of a riveted joint is the ratio of the strength of a unit length of the joint to the same unit length of the solid plate. The efficiency of the joint may be calculated by the general method described in the examples presented in A-2 through A-6.

A-1.2 Nomenclature. The notations in A-2 through A-6 are defined as follows:

a = cross-sectional area of rivet after driving, in.^{2} (mm^2)
b = thickness of buttstrap, in. (mm)
c = crushing strength of plate, psi (MPa), as determined by testing or the values from PR-7
d = diameter of rivet after driving [diameter of rivet hole (see PR-21.1)], in. (mm)
N = number of rivets in double shear in a unit length of joint
n = number of rivets in single shear in a unit length of joint
p = pitch of rivets on the row having the greatest pitch, in. (mm)
S = shearing strength of rivet in double shear, psi (MPa) (see PG-14.2)
s = shearing strength of rivet in single shear, psi (MPa) (see PG-14.2)
TS = nominal tensile strength of plate, psi (MPa)
t = thickness of plate, in. (mm)

A-2 SINGLE-RIVETED LAP JOINT

(a) Strength of solid plate

$$A = ptTS$$

(b) Strength of plate between rivet holes

$$B = (p - d)tTS$$

(c) Shearing strength of one rivet in single shear

$$C = nsa$$

(d) Crushing strength of plate in front of one rivet

$$D = dtc$$

Divide the lesser of (b), (c), or (d) by (a) to get the efficiency. Refer to Figure A-2-1.

A-3 DOUBLE-RIVETED LAP JOINT

(a) Strength of solid plate

$$A = ptTS$$

(b) Strength of plate between rivet holes

$$B = (p - d)tTS$$

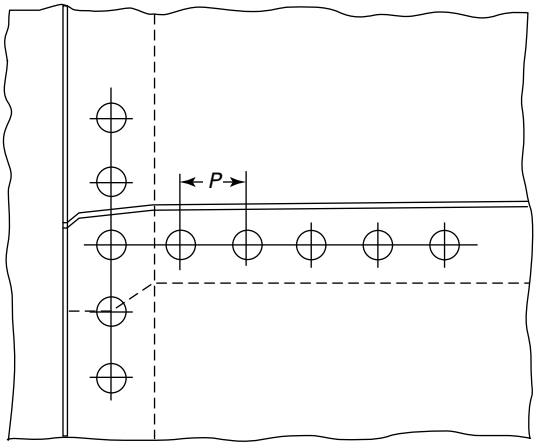
(c) Shearing strength of two rivets in single shear

$$C = nsa$$

(d) Crushing strength of plate in front of two rivets

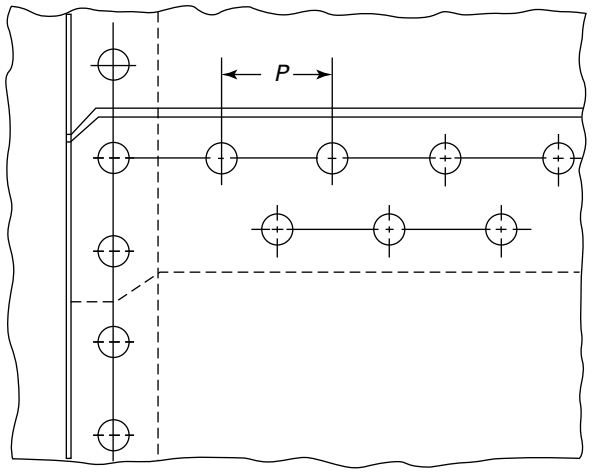
$$D = ndtc$$

Figure A-2-1
Single-Riveted Lap Joint, Longitudinal or Circumferential



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Figure A-3-1
Double-Riveted Lap Joint, Longitudinal or Circumferential



Divide the lesser of (b), (c), or (d) by (a) to get the efficiency. Refer to Figure A-3-1.

A-4 DOUBLE-RIVETED BUTTSTRAP AND DOUBLE-STRAP JOINT

(a) Strength of solid plate

$$A = ptTS$$

(b) Strength of plate between rivet holes in the outer row

$$B = (p - d)tTS$$

(c) Shearing strength of two rivets in double shear plus the shearing strength of one rivet in single shear

$$C = NSa + nsa$$

(d) Strength of plate between rivet holes in the second row plus the shearing strength of one rivet in single shear in the outer row

$$D = (p - 2d)tTS + nsa$$

(e) Strength of plate between rivet holes in the second row plus the crushing strength of the buttstrap in front of one rivet in the outer row

$$E = (p - 2d)tTS + dbc$$

(f) Crushing strength of plate in front of two rivets plus the crushing strength of the buttstrap in front of one rivet

$$F = Ndtc + ndbc$$

(g) Crushing strength of plate in front of two rivets plus the shearing strength of one rivet in single shear

$$G = Ndtc + nsa$$

Divide the lesser of (b), (c), (d), (e), (f), or (g) by (a) to get the efficiency. Refer to Figure A-4-1.

A-5 TRIPLE-RIVETED BUTTSTRAP AND DOUBLE-STRAP JOINT

(a) Strength of solid plate

$$A = ptTS$$

(b) Strength of plate between rivet holes in the outer row

$$B = (p - d)tTS$$

(c) Shearing strength of four rivets in double shear plus the shearing strength of one rivet in single shear

$$C = NSa + nsa$$

(d) Strength of plate between rivet holes in the second row plus the shearing strength of one rivet in single shear in the outer row

$$D = (p - 2d)tTS + nsa$$

(e) Strength of plate between rivet holes in the second row plus the crushing strength of the buttstrap in front of one rivet in the outer row

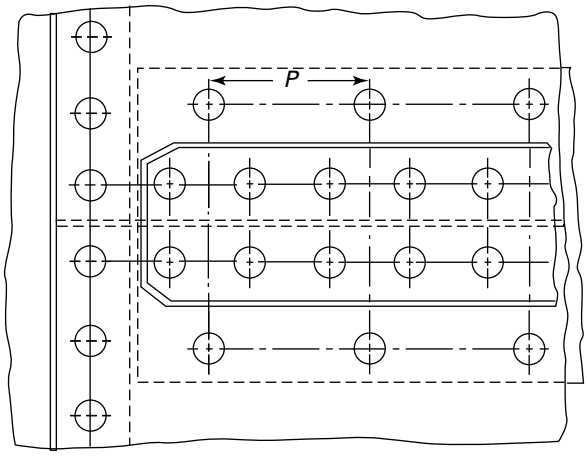
$$E = (p - 2d)tTS + dbc$$

(f) Crushing strength of plate in front of four rivets plus the crushing strength of the buttstrap in front of one rivet

$$F = Ndtc + ndbc$$

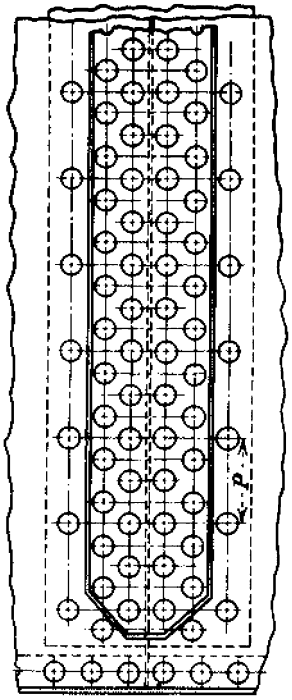
(g) Crushing strength of plate in front of four rivets plus the shearing strength of one rivet in single shear

Figure A-4-1
Double-Riveted Buttstrap and Double-Strap Joint



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Figure A-5-1
Triple-Riveted Buttstrap and Double-Strap Joint



$$G = Ndtc + nsa$$

Divide the lesser of (b), (c), (d), (e), (f), or (g) by (a) to get the efficiency. Refer to Figure A-5-1.

A-6 QUADRUPLE-RIVETED BUTTSTRAP AND DOUBLE-STRAP JOINT

(a) Strength of solid plate

$$A = ptTS$$

(b) Strength of plate between rivet holes in the outer row

$$B = (p - d)tTS$$

(c) Shearing strength of eight rivets in double shear plus the shearing strength of three rivets in single shear

$$C = NSa + nsa$$

(d) Strength of plate between rivet holes in the second row plus the shearing strength of one rivet in single shear in the outer row

$$D = (p - 2d)tTS + sa$$

(e) Strength of plate between rivet holes in the third row plus the shearing strength of two rivets in the second row in single shear and one rivet in single shear in the outer row

$$E = (p - 4d)tTS + nsa$$

(f) Strength of plate between rivet holes in the second row plus the crushing strength of the buttstrap in front of one rivet in the outer row

$$F = (p - 2d)tTS + dbc$$

(g) Strength of plate between rivet holes in the third row plus the crushing strength of the buttstrap in front of two rivets in the second row and one rivet in the outer row

$$G = (p - 4d)tTS + ndbc$$

(h) Crushing strength of plate in front of eight rivets plus the crushing strength of the buttstrap in front of three rivets

$$H = Ndtc + ndbc$$

(i) Crushing strength of plate in front of eight rivets plus the shearing strength of two rivets in the second row and one rivet in the outer row in single shear

$$I = Ndtc + nsa$$

Divide the lesser of (b), (c), (d), (e), (f), (g), (h), or (i) by (a) to get the efficiency. Refer to Figures A-6-1 and A-6-2.

BRACED AND STAYED SURFACES (23)

(See Figure A-8.)

A-8

The allowable loads based on the net cross-sectional areas of staybolts with V-threads are computed from the following equations. The use of Whitworth threads with other pitches is permissible.

The equation for the diameter of a staybolt at the bottom of a V-thread is

$$D - (P \times 1.732) = d$$

where

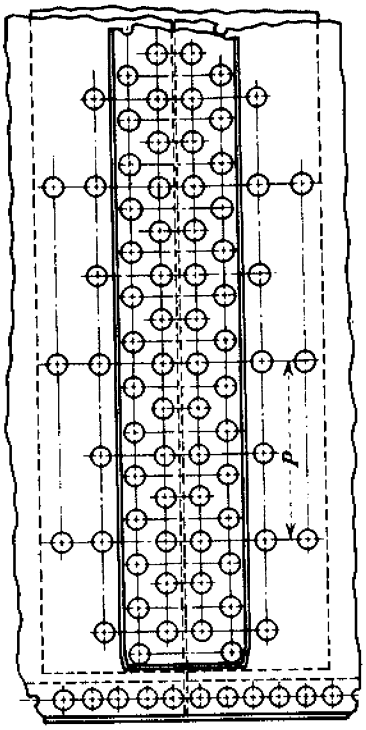
D = diameter of staybolt over the threads
d = diameter of staybolt at bottom of threads
P = pitch of threads
= 1/number of threads/in. (25 mm)
1.732 = a constant

When ASME Standard threads are used, the equation becomes

$$D - (P \times 1.732 \times 0.75) = d$$

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Figure A-6-1
Quadruple-Riveted Buttstrap and Double-Strap Joint



METHOD OF CHECKING PRESSURE RELIEF VALVE CAPACITY BY MEASURING MAXIMUM AMOUNT OF FUEL THAT CAN BE BURNED

A-12

The maximum quantity of fuel C that can be burned per hour at the time of maximum forcing is determined by a test. The maximum number of heat units per hour, or CH, is then determined, using the values of H given in A-17. The weight of steam generated per hour is found by the following equation:

(U.S. Customary Units)

$$W = \frac{C \times H \times 0.75}{1,\ 100}$$

(SI Units)

$$W = \frac{C \times H \times 0.75}{2\,558}$$

where

C = total weight or volume of fuel burned/hr at time of maximum forcing, lbm/hr (kg/h) or ft^3/hr (m^3/h)

H = heat of combustion of fuel, Btu/lbm (kJ/kg) or Btu/ft^3 (kJ/m^3) (see A-17)

W = weight of steam generated per hour, lbm/hr (kg/h)

The sum of the pressure relief valve capacities marked on the valves shall be equal to or greater than W.

A-13 EXAMPLE 1

A boiler at the time of maximum forcing uses 2,150 lbm/hr of Illinois coal with a heating value of 12,100 Btu/lbm. Boiler pressure is 225 psi gage.

$$C \times H = 2,150 \times 12,100 = 26,015,000$$

$$W = \frac{C \times H \times 0.75}{1,100} = 17,740$$

A-14 EXAMPLE 2

Wood shavings of heat of combustion of 6,400 Btu/lbm are burned under a boiler at the maximum rate of 2,000 lbm/hr. Boiler pressure is 100 psi gage.

$$C \times H = 2,000 \times 6,400 = 12,800,000$$

$$W = \frac{C \times H \times 0.75}{1,100} = 8,730$$

A-15 EXAMPLE 3

An oil-fired boiler at maximum forcing uses 1,000 lbm/hr of crude oil (Texas). Boiler pressure is 275 psi gage.

$$C \times H = 1,000 \times 18,500 = 18,500,000$$

$$W = \frac{C \times H \times 0.75}{1,100} = 12,620$$

A-16 EXAMPLE 4

A boiler fired with natural gas consumes 3,000 ft^3/hr. The working pressure is 150 psi gage.

$$C \times H = 3,000 \times 960 = 2,880,000$$

$$W = \frac{C \times H \times 0.75}{1,100} = 1,960$$

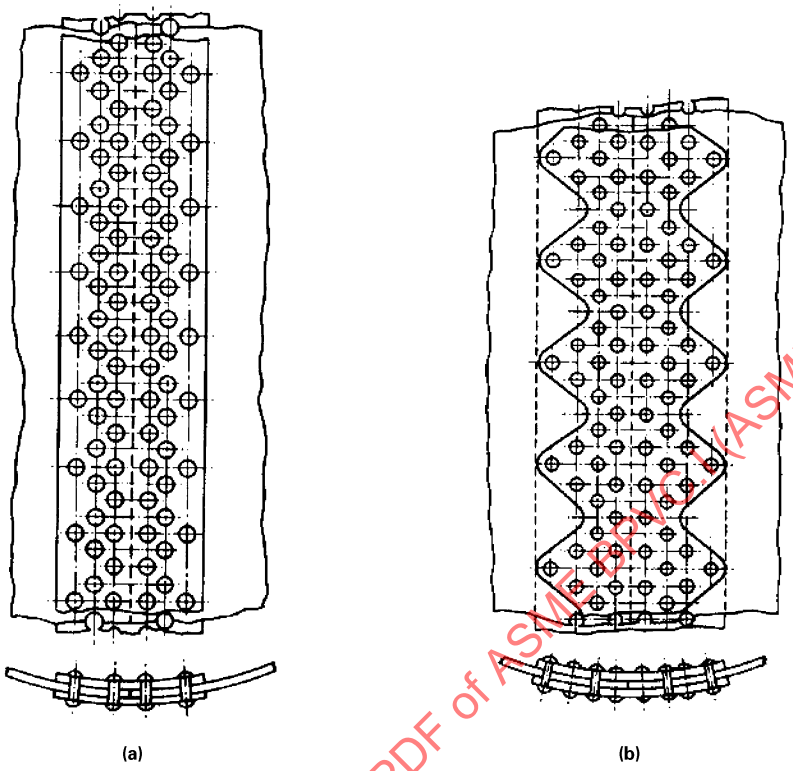
A-17

For the purpose of checking the pressure relief valve capacity as described in A-12, the following values of heats of combustion of various fuels may be used:

Fuel Type	H, Btu/lbm (kJ/kg)
Semibituminous coal	14,500 (34 000)
Anthracite	13,700 (32 000)
Screenings	12,500 (29 000)
Coke	13,500 (31 000)
Wood, hard or soft, kiln dried	7,700 (18 000)
Wood, hard or soft, air dried	6,200 (14 000)
Wood shavings	6,400 (14 400)
Peat, air dried, 25% moisture	7,500 (17 000)

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Figure A-6-2
Joints That May Be Used to Avoid Eccentric Stresses



GENERAL NOTE: Illustration (a), which shows buttstraps of equal length, can have a joint efficiency between 82% and 84%. The sawtooth joint can have a joint efficiency of between 92% and 94%.

Table continued

Fuel Type	H, Btu/lbm (kJ/kg)
Lignite	10,000 (23 300)
Kerosene	20,000 (46 500)
Petroleum, crude oil, Pennsylvania	20,700 (48 000)
Petroleum, crude oil, Texas	18,500 (43 000)

Fuel Type	H, Btu/ft^3 (kJ/m^3)
Natural gas	960 (35 700)
Blast-furnace gas	100 (3 700)
Producer gas	150 (5 600)
Water gas, uncarbureted	290 (11 000)

AUTOMATIC GAGE GLASSES

A-18

Automatic shutoff valves intended to restrict the flow from a damaged gage glass without human intervention shall conform to the requirements of A-18.1 through A-18.6.

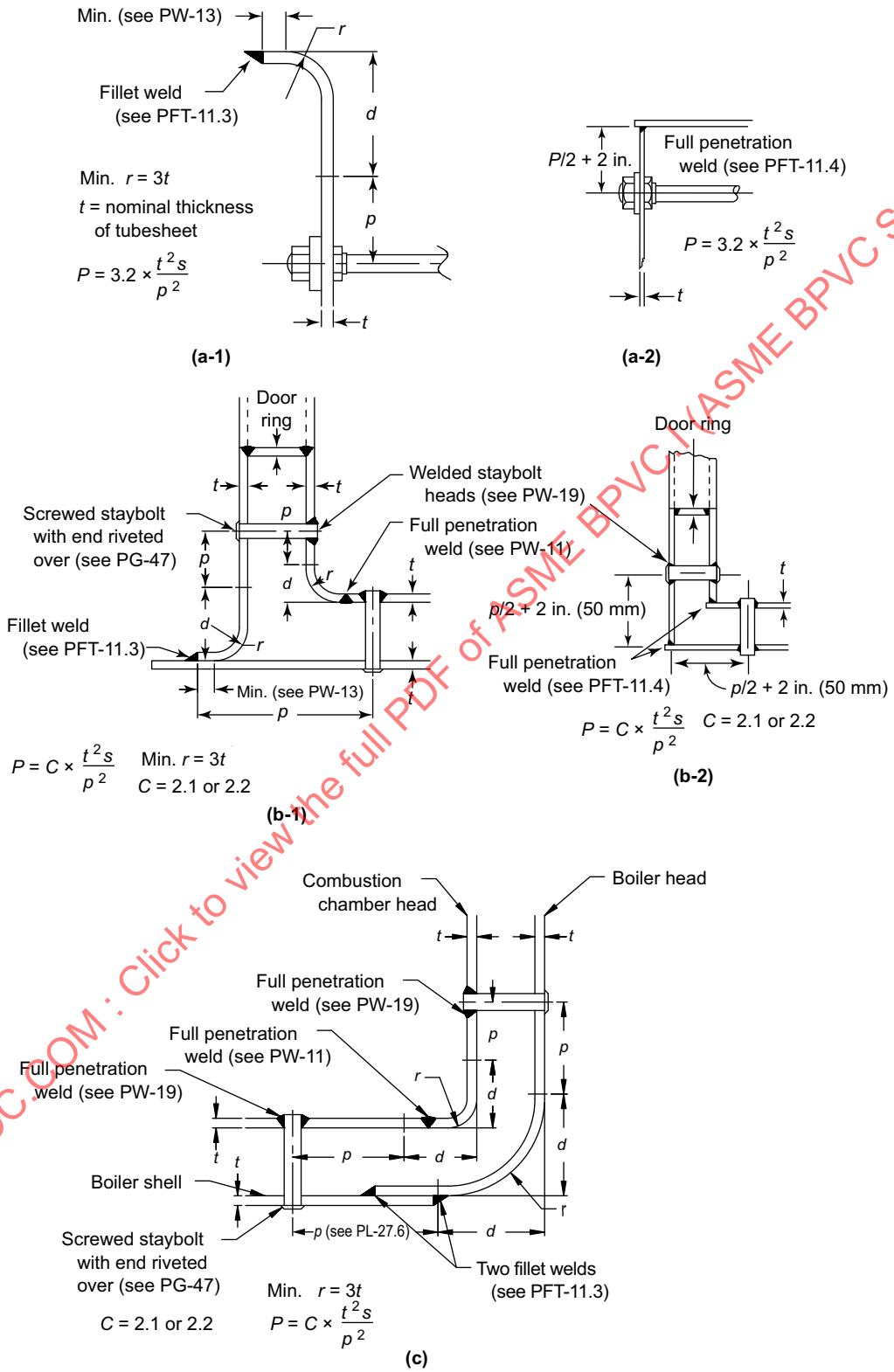
A-18.1 Check valves in upper and lower fittings shall be of solid noncorrosive metal ball type to avoid need for guides.

A-18.2 Ball check valves in upper and lower fittings must open by gravity and the lower ball check valve must rise vertically to its seat.

A-18.3 The check balls must be not smaller than $\frac{1}{2}$ in. (13 mm) in diameter, and the diameter of the circle of contact with the seat must be not greater than two-thirds of the diameter of the check ball. The space around each ball must be not less than $\frac{1}{8}$ in. (3.0

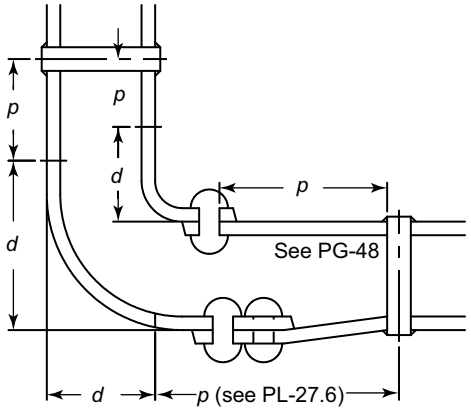
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Figure A-8
Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers (23)

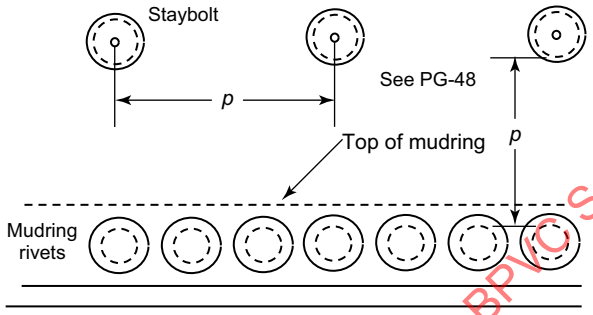


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Figure A-8
Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers (Cont'd)

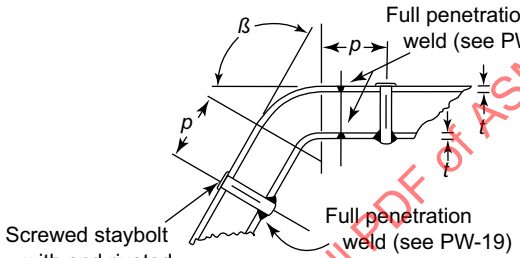


(g-1)



Example where rivets support sheet; not for unsupported lap joint

(g-2)



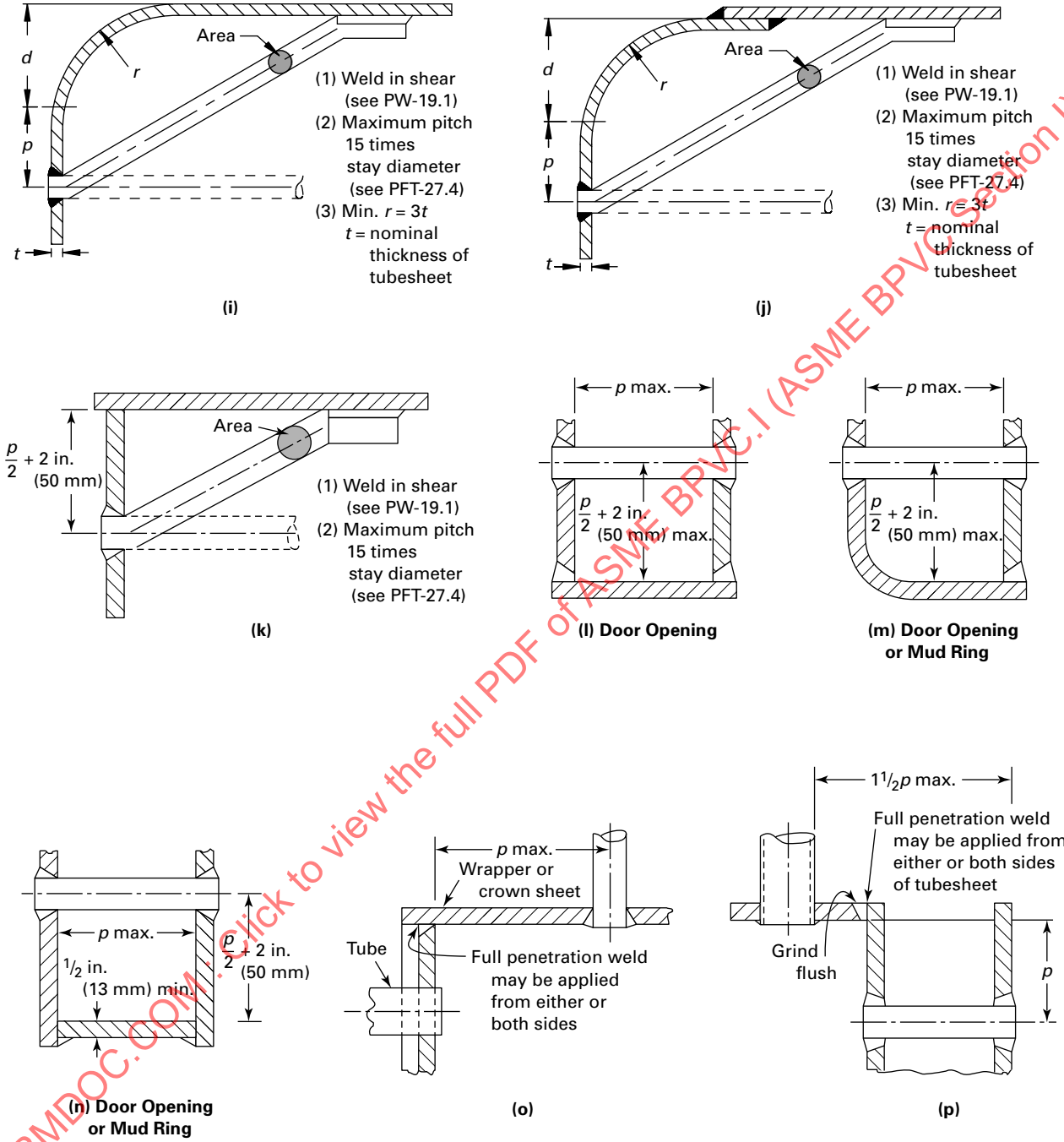
$$P = 2.2 \times \frac{t^2 s}{p^2} \times \left[\frac{90}{ß}\right]^2$$

ß = angularity of tangent lines in degrees

(h)

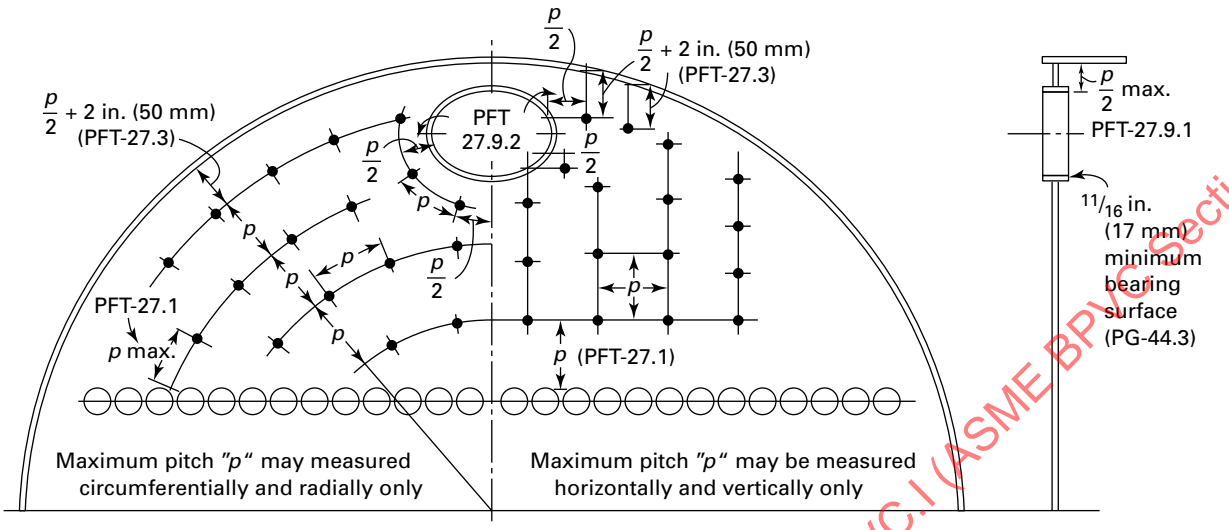
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Figure A-8
Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers (Cont'd)



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Figure A-8
Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers (Cont'd)

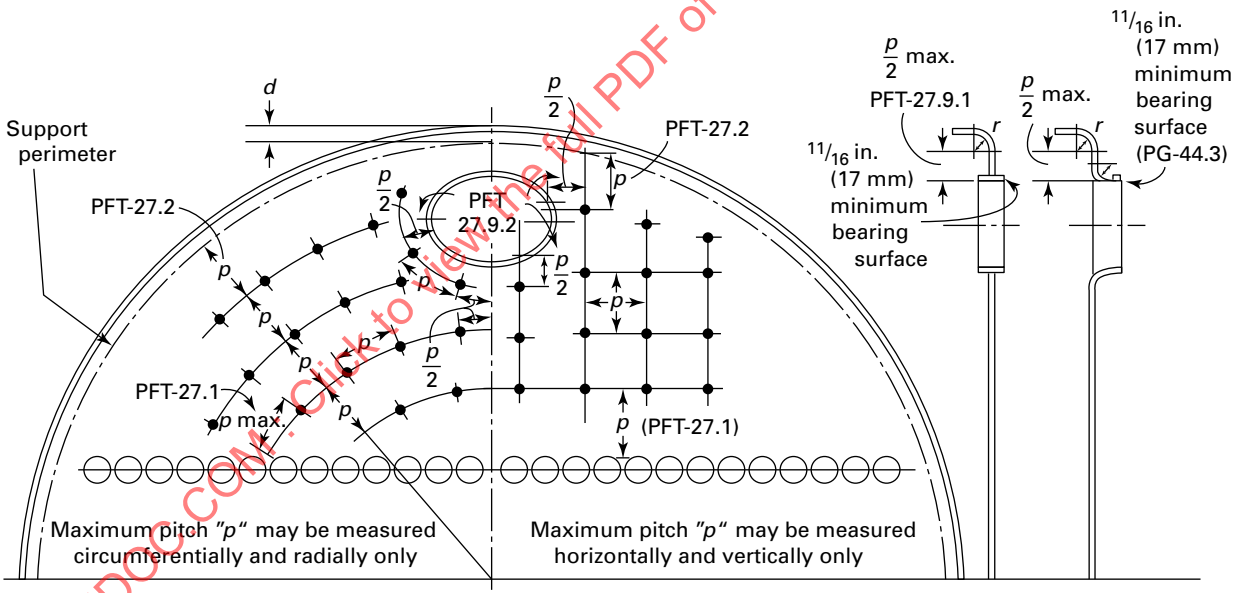


(1) Provide stay cross-sectional area required by PG-49 based upon allowable stresses from Section II, Part D, Subpart 1, Table 1A.

(2) Provide the number of stays required to not exceed the maximum calculated pitch.

(3) Diagonal stay stresses must not exceed limits computed from PFT-32.

(q)



(1) Provide stay cross-sectional area required by PG-49 based upon allowable stresses from Section II, Part D, Subpart 1, Table 1A.

(2) Provide the number of stays required to not exceed the maximum calculated pitch.

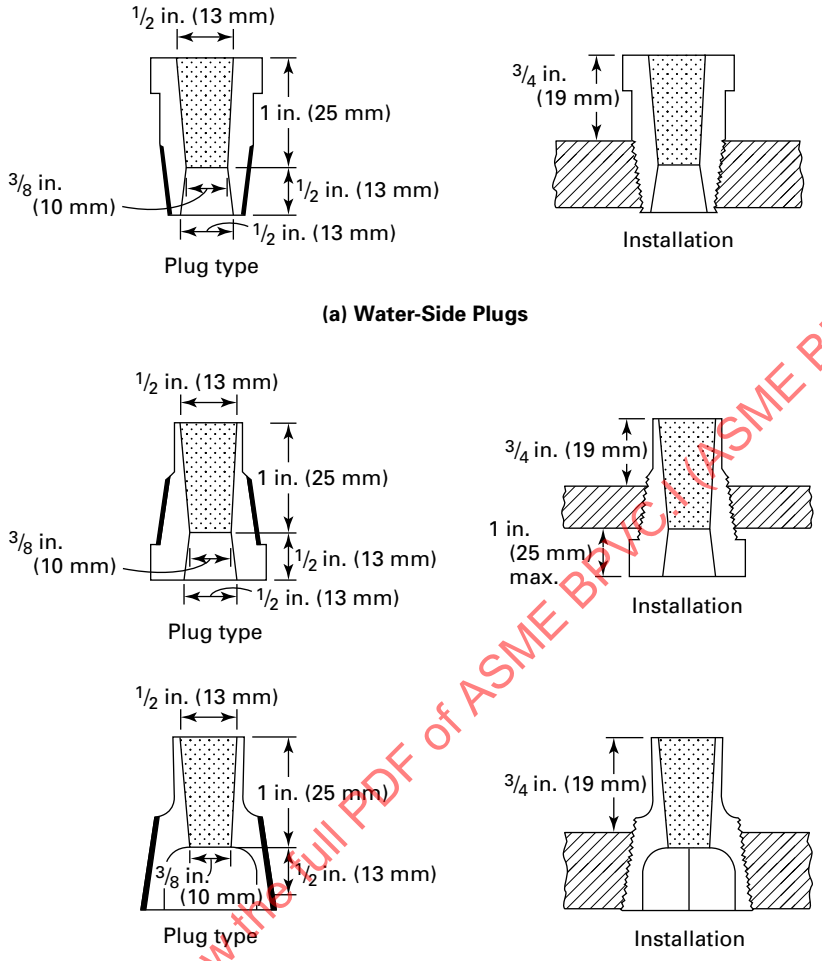
(3) Diagonal stay stresses must not exceed limits computed from PFT-32.

(r)

GENERAL NOTE: "*p*" is same as given in PG-46.

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Figure A-19
Typical Forms of Fusible Plugs



mm), and the travel movement from the normal resting place to the seat must be not less than 1/4 in. (6 mm).

A-18.4 The ball seat in the upper fitting must be a flat seat with either a square or hexagonal opening, or otherwise arranged so that the steam passage can never be completely closed by this valve.

A-18.5 The shutoff valve in the upper fitting must have a projection that holds the ball at least 1/4 in. (6 mm) away from its seat when the shutoff valve is closed.

A-18.6 The balls must be accessible for inspection. Means must be provided for removal and inspection of the lower ball check valve while the boiler is under steam pressure.

These restrictions do not apply to closing the valves by external methods.

FUSIBLE PLUGS

(See Figure A-19.)

A-19

A-19.1 Fire-actuated fusible plugs, if used, except as provided in A-20.9, shall be filled with metal of the following composition, having a melting point between 445°F and 450°F (229°C and 232°C):

Fusible Metal Composition

Pure tin	99.3% min.
Copper	0.5% max.
Lead	0.1% max.
Total allowed impurities	0.7% max.

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A-19.2 The fusible metal shall extend from the water end of the plug to the point of least diameter of the hole and shall be carefully alloyed to the casing. A test shall be made to determine that the fusible metal is not loose in the plug.

A-19.3 Fusible plugs shall be replaced at least once each year. Casings that have been used shall not be refilled.

A-19.4 Fusible plugs filled with metal as specified in A-19.1 shall not be used for pressures and temperatures that will cause the plug to fail while it is submerged in the boiler water.

The fusible metal may be partly replaced by a bronze plug loosely fitted to the hole and of such size that it will pass freely through the hole on the fire side, from which side it must be inserted into the casing. Such plug shall be properly alloyed to the casing with the same fusible metal as required by A-19.1.

A-20

A-20.1 Water-side plugs are fusible plugs that are inserted from the water side of the plate, flue, or tube to which they are attached. Fire-side plugs are fusible plugs inserted from the fire side of the plate, flue, or tube to which they are attached.

A-20.2 The casing of the fusible plugs shall be made of a composition conforming to SB-61 or from phosphor-bronze rods conforming to ASTM B139.

A-20.3 Typical designs of fusible plugs are given in Figure A-19.

A-20.4 The bore of the casing shall be tapered continuously from the water end of the casing for a distance of at least 1 in. to a diameter of not less than $^{3}/_{8}$ in. (10 mm) at a point not less than $^{1}/_{2}$ in. (13 mm) from the fire end. The diameter of the bore at either end shall be not less than $^{1}/_{2}$ in. (13 mm). The hole on the fire end shall be as large as possible and may be of any shape provided the cross-sectional area at all points is greater than the area of the least cross section of the fusible metal.

A-20.5 A fusible plug shall be of such length that when installed it shall project at least $^{3}/_{4}$ in. (19 mm) on the water side of the plate, tube, or flue. It shall extend through the plate, tube, or flue on the fire side as little as possible but not more than 1 in. (25 mm).

A-20.6 A fire-side plug may be designed so as to be inserted by means of a plug-type wrench, so as to reduce the projection on the fire side.

A-20.7 If a fire-actuated fusible plug is inserted in a tube, the tube wall *at the plug* shall not be less than 0.22 in. (5.6 mm) thick, or sufficient to give four full threads.

A-20.8 Fusible plugs that comply with the requirements of A-19 and A-20 must be stamped on the casing with the name of the manufacturer, and on the water end of the fusible metal "ASME Std."

A-20.9 Fusible metal, other than metal as specified in A-19.1, for use under temperatures exceeding 450°F (229°C), may be used and the casing may be made of other material and shape than specified in A-20.2 through A-20.4 if the metal and the casing are approved by the administrative authority. Such plugs shall not be marked as "ASME Std."

A-21

Fire-actuated fusible plugs, if used, shall be located at the lowest permissible water level as determined by the boiler Manufacturer; steam-actuated plugs, if used, shall be so located that they will operate when the water level is at the point where a fire-actuated fusible plug would be located.

PROOF TESTS TO ESTABLISH MAXIMUM ALLOWABLE WORKING PRESSURE

A-22

A-22.1 Scope. The maximum allowable working pressure for pressure parts of boilers for which the strength cannot be computed with a satisfactory assurance of accuracy shall be established in accordance with the requirements of this paragraph, using one of the test procedures applicable to the type of loading and to the material used in its construction.

The tests in these paragraphs may be used only for the purpose of establishing the maximum allowable working pressure of those elements or component parts for which the thickness cannot be determined by means of the design rules given in this Code. The maximum allowable working pressure of all other elements or component parts shall not be greater than that determined by means of the applicable design rules.

A-22.2 Tests.

A-22.2.1 Types. Provision is made for two types of tests for determining the internal maximum allowable working pressure

A-22.2.1.1 Tests based on yielding of the part to be tested. These tests are limited to materials with a ratio of minimum specified yield to minimum specified ultimate strength of 0.625 or less.

A-22.2.1.2 Tests based on bursting of the part.

A-22.2.2 Retests. A retest shall be allowed on a duplicate pressure part if errors or irregularities are obvious in the test results.

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A-22.2.3 Precautions. Safety of testing personnel should be given serious consideration when conducting proof tests, and particular care should be taken during bursting tests in A-22.6.3.

A-22.3 Pressure.

A-22.3.1 Previously Applied. The pressure parts for which the maximum allowable working pressure is to be established shall not previously have been subjected to a pressure greater than $1\frac{1}{2}$ times the desired or anticipated maximum allowable working pressure, adjusted for design temperature as provided in A-22.8.

A-22.3.2 Application. In the procedures given in A-22.6.1 for the Strain Measurement Test, and A-22.6.2 for the Displacement Measurement Test, the hydrostatic pressure in the pressure part shall be increased gradually until approximately one-half the anticipated maximum allowable working pressure is reached. Thereafter, the test pressure shall be increased in steps of approximately one-tenth or less of the anticipated maximum allowable working pressure until the pressure required by the test procedure is reached. The pressure shall be held stationary at the end of each increment for a sufficient time to allow the observations required by the test procedure to be made, and shall be released to zero to permit determination of any permanent strain or displacement after any pressure increment that indicates an increase in strain or displacement over the previous equal pressure increment.

A-22.4 Critical Areas. As a check that the measurements are being taken on the most critical areas, the Inspector may require a brittle coating to be applied on all areas of probable high stress concentrations in the test procedures given in A-22.6.1 and A-22.6.2. The surfaces shall be suitably clean before the coating is applied in order to obtain satisfactory adhesion. The technique shall be suited to the coating material.

NOTE: Strains should be measured as they apply to membrane stresses and to bending stresses within the following range. It is recognized that high localized and secondary bending stresses may exist in pressure parts designed and fabricated in accordance with these rules. Insofar as practical, design rules for details have been written to hold such stresses at a safe level consistent with experience.

A-22.5 Yield Strength and Tensile Strength. For proof tests based on yielding, A-22.6.1 or A-22.6.2, the yield strength (or yield point for those materials which exhibit that type of yield behavior indicated by a "sharp-kneed" portion of the stress–strain diagram) of the material in the part tested, shall be determined in accordance with the method prescribed in the applicable material specification and as described in ASTM E8, Tension Testing of Metallic Materials. For proof tests based on bursting, A-22.6.3, the tensile strength instead of the yield strength of the material in the part tested shall be similarly determined.

Yield or tensile strength so determined shall be the average from three or four specimens cut from the part tested after the test is completed. The specimens shall be cut from a location where the stress during the test has not exceeded the yield strength. The specimens shall not be oxygen cut because this might affect the strength of the material.

When excess stock from the same piece of wrought material is available and has been given the same postweld heat treatment as the pressure part, the test specimens may be cut from this excess stock. The specimens shall not be removed by flame cutting or any other method involving sufficient heat to affect the properties of the specimen.

If yield or tensile strength are not determined by test specimens from the pressure part tested, alternative methods are given in A-22.6.1, A-22.6.2, and A-22.6.3 for evaluation of proof test results to establish the maximum allowable working pressure.

A-22.6 Procedure.

A-22.6.1 Strain Measurement Test.

A-22.6.1.1 Subject to limitations of A-22.2.1.1, this procedure may be used for pressure parts under internal pressure, constructed of any material permitted to be used under the rules of Section I. Strains shall be measured in the direction of the maximum stress at the most highly stressed parts (see A-22.4) by means of strain gages of any type capable of indicating strains to 0.00005 in./in. Pressure shall be applied as provided in A-22.3.2.

A-22.6.1.2 After each increment of pressure has been applied, readings of the strain gages and the hydrostatic pressure shall be taken and recorded. The pressure shall be released and any permanent strain at each gage shall be determined after any pressure increment that indicates an increase in strain for this increment over the previous equal pressure increment. Only one application of each increment of pressure is required.

A-22.6.1.3 Two curves of strain against test pressure shall be plotted for each gage line as the test progresses, one showing the strain under pressure and one showing the permanent strain when the pressure is removed. The test may be discontinued when the test pressure reaches the value H, which will, by the equation, justify the desired working pressure but shall not exceed the pressure at which the plotted points for the most highly strained gage line reaches the value given below for the material used.

A-22.6.1.3.1 0.2% permanent strain for carbon, low-alloy and high-alloy steels.

A-22.6.1.3.2 0.5% strain under pressure for copper-base alloys.

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A-22.6.1.3.3 0.2% permanent strain for nickel alloys.

(23) **A-22.6.1.4** The maximum allowable working pressure P in psi at test temperature for parts tested under this paragraph shall be computed by one of the following equations.

A-22.6.1.4.1 If the average yield strength is determined by A-22.5

$$P = 0.5H\frac{Y_s}{Y_a}$$

A-22.6.1.4.2 If the actual average yield strength is not determined by test specimens

$$P = 0.4H$$

where

H = hydrostatic test pressure, at which the test was stopped in accordance with A-22.6.1.3
Y_a = yield strength — actual average from test specimens
Y_s = yield strength — specified minimum

The maximum allowable working pressure at other temperatures shall be determined as provided in A-22.8.

A-22.6.2 Displacement Measurement Test.

A-22.6.2.1 Subject to the limitations of A-22.2.1.1 this procedure may be used only for pressure parts under internal pressure, constructed of materials having a definitely determinable yield point. Displacement shall be measured at the most highly stressed parts (see A-22.4) by means of measuring devices of any type capable of measuring to 0.001 in. (0.02 mm). This displacement may be measured between two diametrically opposed reference points in a symmetrical structure, or between a reference point and a fixed base point. Pressure shall be applied as provided in A-22.3.2.

A-22.6.2.2 After each increment of pressure has been applied, readings of the displacement and the hydrostatic pressure shall be taken and recorded. The pressure shall be released and any permanent displacement shall be determined after any pressure increment that indicates an increase in measured displacement for this increment over the previous equal pressure increment. Only one application of each increment is required. Care must be taken to assure that the readings represent only displacements of the parts on which measurements are being made and do not include any slip of the measuring devices or any movement of the fixed base points or of the pressure part as a whole.

A-22.6.2.3 Two curves of displacement against test pressure shall be plotted for each reference point as the test progresses, one showing the displacement under pressure, and one showing the permanent displacement when the pressure is removed. The application of pressure shall be stopped when it is evident that the curve through the points representing displacement under pressure has deviated from a straight line.

A-22.6.2.4 The pressure coincident with the (23) proportional limit of the material shall be determined by noting the pressure at which the curve representing displacement under pressure deviates from a straight line. The pressure at the proportional limit may be checked from the curve of permanent displacement by locating the point where the permanent displacement begins to increase regularly with further increases in pressure. Permanent deformation at the beginning of the curve that results from the equalization of stresses and irregularities in the material may be disregarded.

The maximum allowable working pressure P in psi at test temperature for parts tested under this paragraph shall be computed by one of the following equations.

A-22.6.2.4.1 If the average yield strength is determined by A-22.5

$$P = 0.5H\frac{Y_s}{Y_a}$$

A-22.6.2.4.2 In order to eliminate the necessity of cutting tensile specimens and determining the actual yield strength of the material under test, one of the following equations may be used to determine the maximum allowable working pressure.

A-22.6.2.4.2.1 For carbon steel, meeting an acceptable Code specification, with a specified minimum tensile strength of not over 70,000 psi (480 MPa)

(U.S. Customary Units)

$$P = 0.5H\left(\frac{S}{S + 5{,}000}\right)$$

(SI Units)

$$P = 0.5H\left(\frac{S}{S + 34.5}\right)$$

A-22.6.2.4.2.2 For any material listed in Section II, Part D, Subpart 1, Tables 1A and 1B, as acceptable for Section I construction

$$P = 0.4H$$

where

H = hydrostatic test pressure coincident with the proportional limit of the weakest element of the component part tested
S = specified minimum tensile strength

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Y_a = yield strength — actual average from test specimens
Y_s = yield strength — specified minimum

When the equation in A-22.6.2.4.2.1 or A-22.6.2.4.2.2 is used, the material in the pressure part shall have had no appreciable cold working or other treatment that would tend to raise the yield strength above the normal.

The maximum allowable working pressure at other temperatures shall be determined as provided in A-22.8.

A-22.6.3 Bursting Tests.

A-22.6.3.1 This procedure may be used for pressure parts under internal pressure when constructed of any material permitted to be used under the rules of Section I. The maximum allowable working pressure of any component part proof tested by this method shall be established by a hydrostatic test to failure by rupture of a full-size sample of such pressure part. The hydrostatic pressure at which rupture occurs must be determined. Alternatively, the test may be stopped at any pressure before rupture that will satisfy the requirements for the desired maximum allowable working pressure. The item so tested shall not be used for Code construction.

(23) **A-22.6.3.2** The maximum allowable working pressure P in psi at test temperature for parts tested under this paragraph shall be computed by one of the following equations.

A-22.6.3.2.1 Parts constructed of materials other than cast materials

$$P = \frac{B}{4} \times \frac{S}{(S_a \text{ or } S_m)}$$

A-22.6.3.2.2 Parts constructed of cast iron

$$P = \frac{B}{6.67} \times \frac{S}{S_b}$$

A-22.6.3.2.3 Parts constructed of nodular iron

$$P = \frac{Bf}{5} \times \frac{S}{S_b}$$

A-22.6.3.2.4 For parts constructed of cast materials, except cast iron and nodular iron

$$P = \frac{Bf}{4} \times \frac{S}{(S_a \text{ or } S_m)}$$

where

B = bursting test pressure
f = casting quality factor as defined in PG-25
S = specified minimum tensile strength
S_a = average actual tensile strength of test specimens
S_b = minimum tensile strength of test bar
S_m = maximum tensile strength of range of specification

For all materials except cast iron and nodular iron, the maximum allowable working pressure at other temperatures shall be determined as provided in A-22.8.

A-22.7 Parts Subject to Collapse.

A-22.7.1 Parts of the boiler normally subject to collapse for which specified rules are not provided in this Section shall withstand without excessive deformation a hydrostatic test of not less than three times the desired maximum allowable working pressure.

A-22.7.2 The maximum allowable working pressure at other than test temperatures shall be determined as provided in A-22.8.

A-22.8 Higher Temperatures. The maximum allowable working pressure for pressure parts that are designed for temperatures at which the allowable stress value of the material is less than that at the test temperature shall be determined by the following equation:

$$P_o = P_t \frac{S_o}{S_t}$$

where

P_o = maximum allowable working pressure at design temperature
P_t = maximum allowable working pressure at test temperature
S_o = maximum allowable stress value at the design temperature, as given in Section II, Part D, Subpart 1, Table 1A or Table 1B
S_t = maximum allowable stress value at test temperature as given in Section II, Part D, Subpart 1, Table 1A or Table 1B

A-22.9 Duplicate Parts. When the maximum allowable working pressure of a pressure part has been established by a proof test, duplicate parts of the same materials, design and construction need not be proof tested but shall be given the standard hydrostatic test at $1\frac{1}{2}$ times the maximum allowable working pressure. The dimensions and minimum thickness of the structure to be tested should not vary materially from those actually used. A geometrically similar part may be qualified by a series of tests covering the complete size range of the pressure part.

A-22.10 Inspection. Tests to establish the maximum allowable working pressure for pressure parts shall be witnessed and approved by an Authorized Inspector.

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A-22.11 Test Gages.

A-22.11.1 An indicating gage shall be connected directly to the pressure parts. If the indicating gage is not readily visible to the operator controlling the pressure applied, an additional indicating gage shall be provided where it will be visible to the operator throughout the duration of the test. For large pressure parts, it is recommended that a recording gage be used in addition to indicating gages.

A-22.11.2 Pressure gages used in testing shall comply with PG-99.4.

A-22.11.3 All gages used in proof testing shall be calibrated against a standard deadweight tester or a calibrated master gage before the proof test is begun. Gages shall be recalibrated at any time that there is reason to believe they are in error.

A-24 TABLE PG-23.1

See Section II, Part D, Subpart 1, Table 1A.

A-25 TABLE PG-23.2

See Section II, Part D, Subpart 1, Table 1B.

A-26 TABLE PG-23.3

See Section II, Part D, Subpart 1, Table 1B.

A-27 TABLE PG-23.4

See Section II, Part D, Subpart 1, Table Y-1.

A-28 FIGURES G AND CS-1 THROUGH CS-6

See Section II, Part D, Subpart 3, External Pressure Charts.

SUGGESTED RULES COVERING EXISTING INSTALLATIONS

A-30

For existing riveted construction, use suggested rules in the 1971 Edition of Section I.

PRESSURE RELIEF VALVES FOR POWER BOILERS

(23) A-44

The minimum pressure relief valve relieving capacity for other than electric boilers, waste heat boilers, organic fluid vaporizers, and forced-flow steam generators with no fixed steam and waterline, when provided in accordance with PG-67.4.3, may be estimated on the basis of the pound mass of steam generated per hour per square foot (kilogram per hour per square meter) of boiler heating surface and waterwall heating surface, as given in Table A-44.

In many cases, a greater relieving capacity of pressure relief valves will have to be provided than that estimated using Table A-44, in order to meet the requirements of the first paragraph of PG-67.2.

A-45

When boilers of different maximum allowable working pressures with minimum pressure relief valve settings varying more than 6% are so connected that steam can flow toward the lower pressure units, the latter shall be protected by additional pressure relief valve capacity, if necessary, on the lower pressure side of the system. The additional safety valve capacity shall be based upon the maximum amount of steam that can

Table A-44
Guide for Estimating Steaming Capacity Based on Heating Surface (23)

U.S. Customary Units		
	Pound Mass of Steam/(hr ft^2)	
Type of Surface	Firetube Boilers	Watertube Boilers
Boiler heating surface		
Hand fired	5	6
Stoker fired	7	8
Oil, gas, or pulverized fuel fired	8	10
Waterwall heating surface		
Hand fired	8	8
Stoker fired	10	12
Oil, gas, or pulverized fuel fired	14	16

SI Units		
	Kilograms of Steam/(hr m^2)	
Type of Surface	Firetube Boilers	Watertube Boilers
Boiler heating surface		
Hand fired	24	29
Stoker fired	34	39
Oil, gas, or pulverized fuel fired	39	49
Waterwall heating surface		
Hand fired	39	39
Stoker fired	49	59
Oil, gas, or pulverized fuel fired	68	78

GENERAL NOTE: When a boiler is fired only by a gas having a heat value not in excess of 200 Btu/ft^3 (2 000 Whr/m^3), the minimum pressure relief valve relieving capacity may be based on the values given for hand-fired boilers above.

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flow into the lower pressure system. The additional pressure relief valves shall have at least one valve set at a pressure not to exceed the lowest allowable pressure and the other valves shall be set within a range not to exceed 3% above that pressure.

A-46

If the pressure relief valve capacity cannot be determined or if it is desirable to verify the computations, the capacity may be checked in one of the three following ways, and if found insufficient, additional capacity shall be provided.

A-46.1 By making an accumulation test, that is, by shutting off all other steam-discharge outlets from the boiler and forcing the fires to the maximum. The pressure relief valve equipment shall be sufficient to prevent an excess pressure beyond that specified in PG-67.2. This method should not be used on a boiler with a superheater or reheater or on a high-temperature water boiler.

A-46.2 By measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity upon the basis of the heating value of the fuel (see A-12 through A-17).

A-46.3 By determining the maximum evaporative capacity by measuring the feedwater. The sum of the pressure relief valve capacities marked on the valves shall be equal to or greater than the maximum evaporative capacity of the boiler. This method shall not be used on high-temperature water boilers.

A-48

When operating conditions are changed, or additional heating surface such as water screens or waterwalls is connected to the boiler circulation, the pressure relief valve capacity shall be increased, if necessary, to meet the new conditions and be in accordance with PG-67.2. The additional valves required on account of changed conditions may be installed on the piping between the boiler and the main stop valve except when the boiler is equipped with a superheater or other piece of apparatus. In the latter case they may be installed on the piping between the boiler drum and the inlet to the superheater or other apparatus, provided that the piping between the boiler and pressure relief valve (or valves) connection has a cross-sectional area of at least three times the combined areas of the inlet connections to the pressure relief valves applied to it.

A-63

A-63.2 During a hydrostatic test of a boiler, the safety valve or valves shall be removed or each valve disk shall be held to its seat by means of a testing clamp and not by screwing down the compression screw upon the spring.

A-64 REPAIRS TO EXISTING BOILERS

Where repairs are necessary that in any way affect the working pressure or safety of a boiler, a state inspector, municipal inspector, or an inspector employed regularly by an insurance company, which is authorized to do a boiler insurance business in the state in which the boiler is used, shall be called for consultation and advice as to the best method of making such repairs; after such repairs are made they shall be subject to the approval of a state inspector, municipal inspector, or an inspector regularly employed by an insurance company that is authorized to do a boiler insurance business in the state in which the boiler is used.

EXAMPLES OF METHODS OF COMPUTATION OF OPENINGS IN VESSEL SHELLS

Application of the rules in PG-32, PG-33, PG-36 through PG-39, PW-15, and PW-16 are given in the following examples. Common assumptions in all the examples are that the design temperature corresponds to the temperature of saturated steam at the maximum allowable working pressure, that all areas are expressed in terms of equivalent area of the vessel material (see PG-37), that the corrosion/erosion allowance is zero, and that all openings are single openings unless otherwise noted. Subscripts have been provided where necessary to eliminate confusion where an algebraic value has more than one meaning as used in these examples. (S_n denotes allowable stress of the nozzle material, S_v denotes allowable stress of the vessel material, R_n denotes radius of nozzle, etc.) The values t and t_n are assumed to be minimum in these examples.

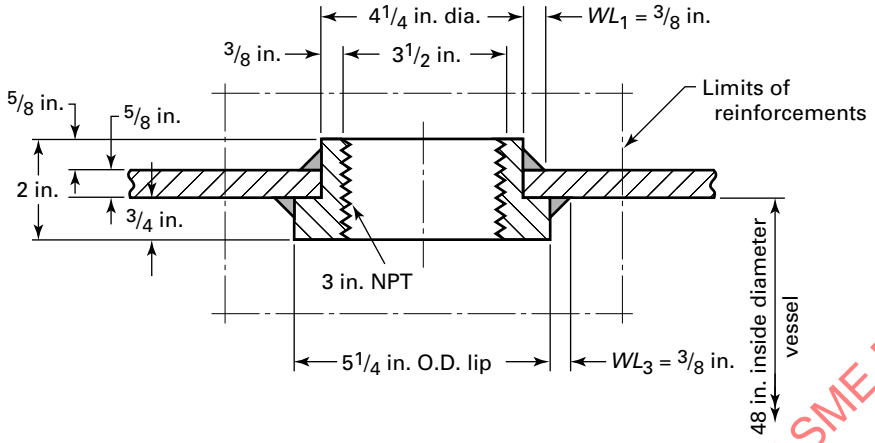
A-65

A boiler shell, designed for 595 psig maximum allowable working pressure, has an inside diameter of 36 in. and is made of $\frac{1}{2}$ in. thick plate. Is it permissible to install an NPS 2 (DN 50) connection by tapping a hole for the pipe directly into the shell?

The NPS 2 (DN 50) connection complies with the pressure-size limitations in PG-39.5.2 and qualifies for the exception provided in PG-32.1.4 permitting the opening without requiring a calculation to determine the availability of compensation in the shell. PG-39.5.1 and Table PG-39, however, require a minimum plate thickness and thread engagement greater than that provided by the shell thickness. Therefore, the connection cannot be made as originally stated; however, either a heavier shell plate or a built-up pad or properly attached plate or fitting could be used to provide the minimum metal thickness and number of threads as required by PG-39 and Table PG-39. Should a plate or fitting, attached by welding, be used, the rules in PG-37, PW-15, and PW-16 shall be met.

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Figure A-66
Example for Typical Nozzle Computations



GENERAL NOTE: This example was performed using computer software. The example was generated by performing the entire calculation without rounding off during each step. Accuracy of the final results beyond three significant figures is not intended or required.

(23) **A-66**

A forged steel fitting as shown in Figure A-66, with a female 3 in. nominal pipe thread over the full fitting depth is to be inserted and welded into a vessel shell. The maximum allowable stress is 15,000 psi for the fitting material and 17,500 psi for the vessel shell material. The maximum allowable working pressure of the vessel is 375 psig. See Figure A-66 for nozzle and vessel dimensions.

The fitting complies with the size, pressure, and thread depth limitations provided in PG-39.5 and Table PG-39. The welded attachment does not qualify for the exception that exempts the design from calculation of the required reinforcement as provided in PG-32 and must, therefore, comply with PG-33 as follows:

Minimum required thickness for reinforcement consideration

$$R_v, \text{ the inside radius of the vessel} = \frac{48}{2} = 24 \text{ in.}$$

$$\text{Shell } t_r = \frac{PR_v}{S_v - (1 - y)P} = \frac{375 \times 24}{17{,}500 - (1 - 0.4) \times 375} = 0.521 \text{ in.}$$

$$\text{Nozzle } t_{rn} = \frac{PR_n}{S_n - (1 - y)P} = \frac{375 \times 1.75}{15{,}000 - (1 - 0.4) \times 375} = 0.044 \text{ in.}$$

Area of reinforcement required (see PG-33.3 and Figure PG-33.1)

$$A = (d + 2t_n)\, t_r F = (3.5 + 2 \times 0.375) \times 0.521 \times 1.0 = 2.214 \text{ in.}^2$$

Area of reinforcement available in vessel wall (see PG-33.3, PG-36.4.1, and Figure PG-33.1) with $w_d = 0$

$$A_1 = (d - 2t_n)(t - Ft_r) = (3.5 - 2 \times 0.375)(0.625 - 1.0 \times 0.521) = 0.286 \text{ in.}^2$$

Area of reinforcement available in the nozzle wall external of the vessel (see PG-33.3, PG-36.4.2, and Figure PG-33.1)

In that the actual nozzle projection is less than that permitted within the limits of reinforcement, modification of the equation provided in PG-33.1 will be required to reflect the actual area available for reinforcement.

$$A_2 = 2(t_n - t_{rn})(\text{actual projection})\,(S_n/S_v) = 2 \times (0.375 - 0.044) \times 0.625 \times (15{,}000/17{,}500) = 0.354 \text{ in.}^2$$

Area of reinforcement available in the nozzle and nozzle lip internal of the vessel (see PG-33.3, PG-36.4.2, and Figure PG-33.1). Due to the nozzle lip, modification of the equation provided in Figure PG-33.1 will be required to reflect the actual area present.

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$$A_3 = 2t_n f_{r1} h + \text{area present in lip}$$
$$= 2 \times 0.375\,(15{,}000/17{,}500)(1.375) + 2 \times 0.5 \times 0.75$$
$$= 1.634 \text{ in.}^2$$

Area of reinforcement available in attachment welds (see PG-36.4.3 and Figure PG-33.1)

$$A_{41} + A_{43} = \left(WL_1{}^2 + WL_3{}^2\right)(S_n/S_v)$$
$$= \left(0.375^2 + 0.375^2\right)(15{,}000/17{,}500)$$
$$= 0.241 \text{ in.}^2$$

Total area of reinforcement available

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 2.515 \text{ in.}^2 \geq A$$

as required for demonstration of compliance with PG-33.

Compliance with PG-37 and PW-15 is demonstrated by the following calculations:

Required minimum strength to be provided by the welds (see PG-37 and PW-15)

$$W = (A - A_1)\, S_v$$
$$= (2.214 - 0.286)\ 17{,}500$$
$$= 33{,}742 \text{ lbf}$$

Strength of the welds (see PG-37 and PW-15)

Internal fillet weld in shear

$$= \tfrac{1}{2}\pi WL_3 \left(\text{O.D. lip} + WL_3\right) \left(\text{factor in PW-15.2}\right) S_n$$
$$= \tfrac{1}{2} \times 3.142 \times 0.375 \times (5.25 + 0.375) \times 0.49 \times 15{,}000$$
$$= 24{,}353 \text{ lbf}$$

External fillet weld in shear

$$= \tfrac{1}{2}\pi WL_1 \left(dl + WL_1\right) (\text{factor in PW-15.2}) S_n$$
$$= 0.5 \times 3.142 \times 0.375 \times (4.25 + 0.375) \times 0.49 \times 15{,}000$$
$$= 20{,}027 \text{ lbf}$$

The combined strength of the welds equals 44,384 lbf ≥ W as required for compliance with PG-37 and PW-15.

Verification of the minimum weld sizing as required by PW-16.1 and Figure PW-16.1, illustration (u-2), is demonstrated by the following:

Required per Figure PW-16.1, illustration (u-2)

$$t_1 + t_2 \geq 1.25 t_{\min}$$
$$t_1 \geq 0.25$$
$$t_2 \geq 0.25$$

Actual per Figure A-66

$$t_1 = WL_1 \sin 45°$$
$$= 0.375 \times 0.7071$$
$$= 0.265 \text{ in.}$$
$$t_2 = WL_3 \sin 45°$$
$$= 0.375 \times 0.7071$$
$$= 0.265 \text{ in.}$$
$$t_{\min} = 0.375 \text{ (based on } t_n)$$

Verification

$$(t_1 + t_2 = 0.530) \geq (1.25 t_{\min} = 0.469)$$
$$(t_1 = 0.265) \geq 0.25$$
$$(t_2 = 0.265) \geq 0.25$$

As verified by the above demonstrations, the design is proved to be in compliance with the requirements of Section I.

A-67 (23)

A vessel shell has a studding outlet connection mounted as shown in Figure A-67. The maximum allowable stress of both the vessel and studding outlet material is 12,500 psi. The maximum allowable working pressure of the design is 325 psig. See Figure A-67 for vessel and studding outlet dimensions.

The studding outlet conforms to the requirements of PG-39.4, both in arrangement and in tapped stud hole requirements. The welded attachment does not qualify for the exception provided in PG-32 and must therefore comply with PG-33 as follows:

Minimum required thickness for reinforcement consideration

$$\text{Shell } t_r = \frac{PR_v}{S_v - (1 - y)\,P}$$
$$= \frac{325 \times 30}{12{,}500 - (1 - 0.4) \times 325}$$
$$= 0.792 \text{ in.}$$

Nozzle t_{rn} = 0.0 [see Figure PG-33.2, illustration (a)]

Area of reinforcement required (see PG-33.2)

$$A = t_r\, Fd$$
$$= 0.79236 \times 1.0 \times 7.5$$
$$= 5.943 \text{ in.}^2$$

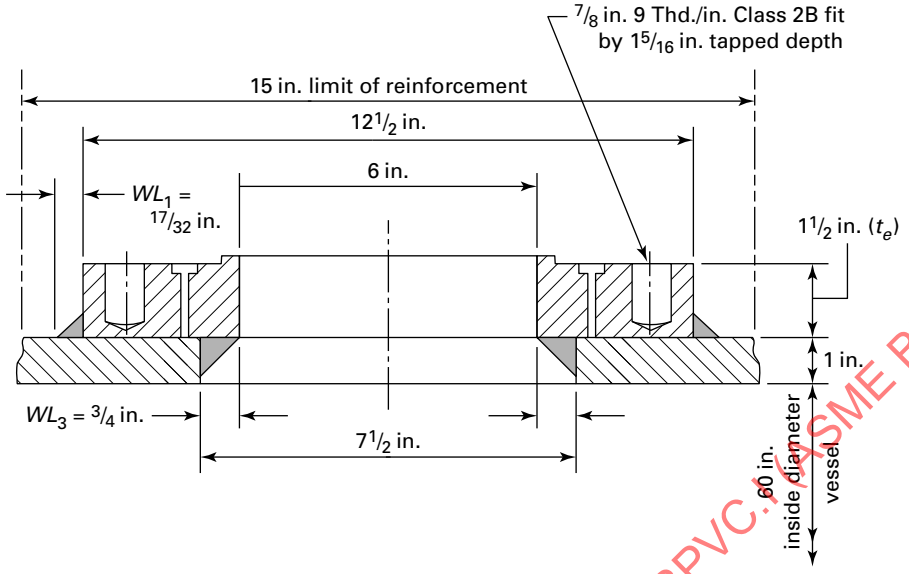
Area of reinforcement available in the vessel wall (see PG-36.4.1)

$$A_1 = (t - Ft_r)\, d$$
$$= (1.0 - 1.0 \times 0.79236) \times 7.5$$
$$= 1.557 \text{ in.}^2$$

Area of reinforcement available in attachment welds (see PG-36.4.3)

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Figure A-67
Example for Typical Nozzle Computations



GENERAL NOTES:
(a) Stud holes are staggered about the line of the longitudinal section and are shown for clarification only.
(b) This example was performed using computer software. The example was generated by performing the entire calculation without rounding off during each step. Accuracy of the final results beyond three significant figures is not intended or required.

$$A_{41} + A_{43} = WL_1^2 + WL_3^2$$
$$= 0.531^2 + 0.75^2$$
$$= 0.845 \text{ in.}^2$$

Area of reinforcement available in pad (see PG-36.4.3)

$$A_5 = \left(\text{O.D.}_{\text{pad}} - \text{I.D.}_{\text{pad}}\right) t_e$$
$$= (12.5 - 6) \times 1.5$$
$$= 9.75 \text{ in.}^2$$

Total area of reinforcement available

$$A_1 + A_{41} + A_{43} + A_5 = 12.152 \text{ in.}^2 \geq A$$

as required for demonstration of compliance with PG-33.

Compliance with PG-37 and PW-15 is demonstrated by the following calculations:

Required minimum strength to be provided by the welds (see PG-37 and PW-15)

$$W = (A - A_1)\, S_v$$
$$= (5.943 - 1.557) \times 12{,}500$$
$$= 54{,}818 \text{ lbf}$$

Strength of the welds (see PG-37 and PW-15)

External fillet weld in shear

$$= \tfrac{1}{2}\pi WL_1 \left(\text{O.D.}_{\text{pad}} + WL_1\right)(\text{factor in PW-15.2})S$$
$$= 0.5 \times 3.14159 \times 0.53125 \times (12.5 + 0.53125) \times 0.49 \times 12{,}500$$
$$= 66{,}606 \text{ lbf}$$

Internal fillet weld in shear

$$= \tfrac{1}{2}\pi WL_3\, (dl - WL_3)(\text{factor in PW-15.2})S$$
$$= 0.5 \times 3.142 \times 0.75 \times (7.5 - 0.75) \times 0.49 \times 12{,}500$$
$$= 48{,}707 \text{ lbf}$$

The combined strength of the welds equals 115,313 lbf ≥ W as required for compliance with PG-37 and PW-15.

Verification of the minimum weld sizing as required by PW-16.1 and Figure PW-16.1, illustration (t) is demonstrated by the following:

Required per Figure PW-16.1, illustration (t)

External fillet weld
throat $\geq {}^1/_2 t_{\min}$

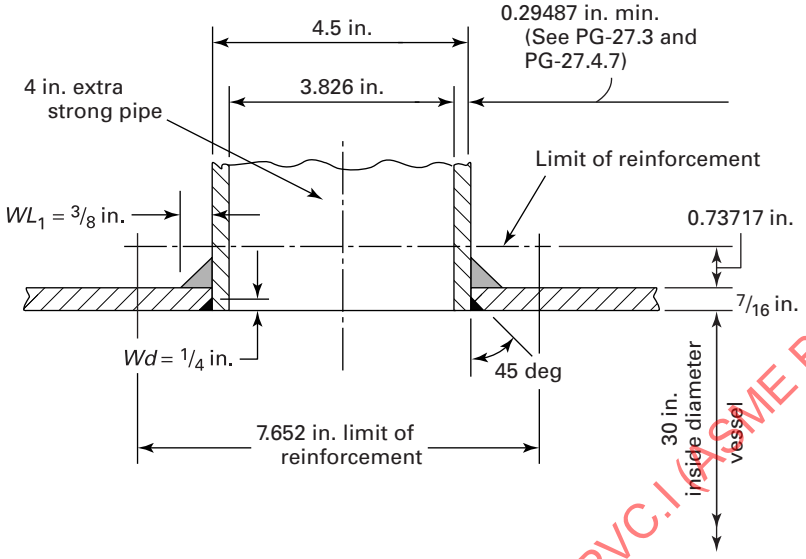
Internal fillet weld
throat $\geq 0.7 t_{\min}$

Actual per Figure A-67

External fillet weld throat

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Figure A-68
Example for Typical Nozzle Computations



$$= WL_1 \sin 45°$$
$$= 0.531 \times 0.707$$
$$= 0.376 \text{ in.}$$

Internal fillet weld throat

$$= WL_3 \sin 45°$$
$$= 0.75 \times 0.707$$
$$= 0.530 \text{ in.}$$
$$t_{min} = 0.75 \text{ (based on PW-16.2)}$$

Verification
(External fillet weld throat = 0.376)

$$\geq \left(\frac{1}{2} t_{min} = 0.375\right)$$

(Internal fillet weld throat = 0.530)

$$\geq (0.7 t_{min} = 0.525)$$

As verified by the above demonstrations, the design is proved to be in compliance with the requirements of Section I.

A-68

A boiler has an NPS 4 extra-strong pipe connection mounted as shown in Figure A-68. The maximum allowable stress is 12,000 psi for the pipe material and 13,700 psi for the boiler shell material. The maximum allowable working pressure of the boiler is 250 psig. See Figure A-68 for pipe and shell dimensions.

Check to determine if the welded attachment qualifies for the exception provided in PG-32.

Per PG-32.1.1

$$K_1 = \text{Lesser of } 0.990 \text{ or } \frac{PD}{1.82St}$$

$$\frac{PD}{1.82St} = \frac{250 \times 30.875}{1.82 \times 13{,}700 \times 0.4375}$$
$$= 0.708 < 0.990$$

$$K_1 = 0.708$$

For a cylindrical shell, $K = K_1$.

$$K = 0.708$$

From PG-32.1.4, determine the maximum size of opening with inherent compensation, which is the larger of PG-32.1.4(a) or PG-32.1.4(b).

Per PG-32.1.4(a)

$$d_{max} = 2.75[Dt(1 - K)]^{1/3}$$
$$= 2.75[30.875 \times 0.4375(1 - 0.708)]^{1/3}$$
$$= 4.34 \text{ in.}$$

Per PG-32.1.4(b),

$$\text{I.D.} = 30 \text{ in.}$$

Smaller of I.D./4(30/4 = 7.5 in.) or 2.375 in., so use 2.375 in.

Per PG-32.1.4, use the larger of PG-32.1.4(a) or PG-32.1.4(b).

Exemption diameter = MAX |4.34, 2.375| = 4.34 in.

Nominal I.D. of NPS 4 extra strong pipe is

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$$4.5 - 2(0.337) = 3.826 \text{ in.}$$

Since I.D. is less than 4.34 in., no calculation need be made to demonstrate compliance with the compensation requirements of PG-33.

(23) A-69

A vessel has a series of welded connections in a definite pattern as shown in Figure A-69. The maximum allowable stress of all nozzle and vessel material is 17,500 psi. The maximum allowable working pressure of the design is 1,500 psig. See Figure A-69 for all nozzle and vessel dimensions.

The welded attachments do not qualify for the exception provided in PG-32 and must therefore comply with PG-33 as follows:

Minimum required thickness for reinforcement consideration

$$\text{Shell } t_r = \frac{PR_v}{S_v - (1 - y)P} = \frac{1{,}500 \times 30}{17{,}500 - (1 - 0.4) \times 1500} = 2.711 \text{ in.}$$

$$\text{Nozzle } t_{rn} \text{ 1 and 4} = \frac{P\,(0.5\,dl_1 - t_{n1})}{S_n - (1 - y)P} = \frac{1{,}500\,(0.5 \times 4.5 - 0.875)}{17{,}500 - (1 - 0.4) \times 1500} = 0.124 \text{ in.}$$

$$\text{Nozzle } t_{rn} \text{ 2 and 3} = \frac{P\,(0.5\,dl_2 - t_{n2})}{S_n - (1 - y)P} = \frac{1{,}500(0.5 \times 5 - 1.0)}{17{,}500 - (1 - 0.4) \times 1500} = 0.136 \text{ in.}$$

Check for overlapping limits

The sum of the limits of reinforcement on the longitudinal axis between nozzles 1 and 2, as permitted under PG-36.2.2, is

$$= \left(\frac{d_1}{2} + t_{n1} + t\right) + \left(\frac{d_2}{2} + t_{n2} + t\right)$$
$$= \frac{2.75}{2} + 0.875 + 3.25 + \frac{3.0}{2} + 1.0 + 3.25$$
$$= 11.25 \text{ in.} > D_1$$

The sum of the limits of reinforcement on the circumferential axis between nozzles 2 and 3 is

$$= \left(\frac{d_2}{2} + t_{n2} + t\right) + \left(\frac{d_3}{2} + t_{n3} + t\right)$$
$$= \frac{3.0}{2} + 1.0 + 3.25 + \frac{3.0}{2} + 1.0 + 3.25$$
$$= 11.5 \text{ in.} > D_2$$

The sum of the limits of reinforcement on the diagonal between nozzles 3 and 4 is

$$= \left(\frac{d_3}{2} + t_{n3} + t\right) + \left(\frac{d_4}{2} + t_{n4} + t\right)$$
$$= \frac{3.0}{2} + 1.0 + 3.25 + \frac{2.75}{2} + 0.875 + 3.25$$
$$= 11.25 \text{ in.} > D_3$$

Each of the above conditions is greater than the center-to-center distance, for the condition considered, between the openings; therefore, the limits of reinforcement overlap and the rule of PG-38.1 shall apply.

Nozzles 1 and 4 — area of reinforcement required in the longitudinal plane

$$A_{l\,1} = (d_1 + 2t_{n1})\,t_rF = (2.75 + 2 \times 0.875) \times 2.711 \times 1.0 = 12.199 \text{ in.}^2$$

Nozzles 2 and 3 — area of reinforcement required in the longitudinal plane

$$A_{l\,2} = (d_2 + 2\,t_{n2})\,t_rF = (3.0 + 2 \times 1.0) \times 2.711 \times 1.0 = 13.554 \text{ in.}^2$$

Nozzles 2 and 3 — area of reinforcement required in the circumferential plane

$$A_{c2} = (d_2 + 2t_{n2})\,t_rF = (3.0 + 2 \times 1.0) \times 2.711 \times 0.5 = 6.777 \text{ in.}^2$$

Nozzle 3 — area of reinforcement required in the diagonal plane

$$A_{d3} = (d_3 + 2t_{n3})\,t_rF = (3.0 + 2 \times 1.0) \times 2.711 \times 0.88 = 11.928 \text{ in.}^2$$

Nozzle 4 — area of reinforcement required in the diagonal plane

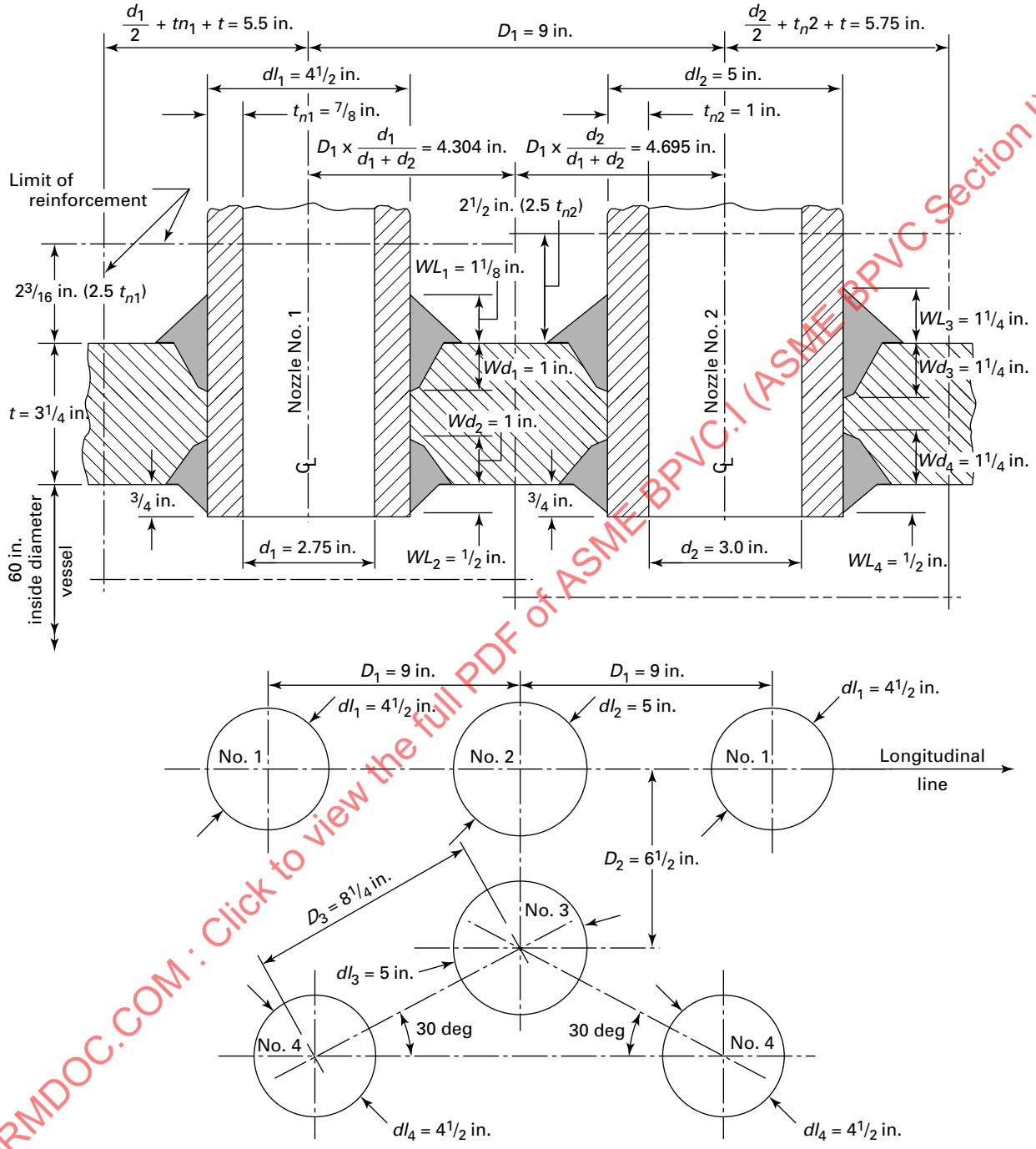
$$A_{d4} = (d_4 + 2t_{n4})\,t_rF = (2.75 + 2 \times 0.875) \times 2.711 \times 0.88 = 10.735 \text{ in.}^2$$

Area of reinforcement provided in nozzle 1 in the longitudinal plane

Since $w_d = 0$ and due to the overlapping limits of reinforcement, the equation for A_1 (given in Figure PG-33.1) will require modification. To prevent any reinforcement available between the nozzles from being counted more than once, the reinforcement limit is reduced such that the available reinforcement in the shell is divided and attributed to either nozzle's compensation in proportion to its relative size. For nozzle 1, this limit is $D_1\,[d_1/(d_1 + d_2)]$. The limit on the other side remains unchanged as $d_1/2 + t_{n1} + t$.

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Figure A-69
Example for Typical Nozzle Computations



GENERAL NOTES:
(a) Nozzles 1 and 4 are identical dimensionally and nozzles 2 and 3 are identical dimensionally.
(b) This example was performed using computer software. The example was generated by performing the entire calculation without rounding off during each step. Accuracy of the final results beyond three significant figures is not intended or required.

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$$A_1 = \left\{ t + D_1 [d_1 / (d_1 + d_2)] - \frac{dl_1}{2} \right\} (t - Ft_r)$$
$$= \{3.25 + 9 [2.75 / (2.75 + 3.0)] - 4.5/2\} \times (3.25 - 1.0 \times 2.711)$$
$$= 2.860 \text{ in.}^2$$
$$A_2 = 2 (t_{n1} - t_{rn1}) 2.5 t_{n1}$$
$$= 2 (0.875 - 0.12424) \times 2.5 \times 0.875$$
$$= 3.285 \text{ in.}^2$$
$$A_3 = 2 t_{n1} h$$
$$= 2 \times 0.875 \times 4.0$$
$$= 7.0 \text{ in.}^2$$
$$A_{41} + A_{43} = WL_1^2 + WL_2^2$$
$$= 1.125^2 + 0.5^2$$
$$= 1.516 \text{ in.}^2$$

Total area of available reinforcement provided by nozzle 1 in the longitudinal plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 14.660 \text{ in.}^2 \geq A_{l1}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided in nozzle 2 in the longitudinal plane

Since nozzle 2 has its limits of reinforcement restricted on both sides by nozzle 1, the reduced limit of $D_1 [d_2/(d_1 + d_2)]$ is applicable to both sides.

$$A_1 = \{2 \times D_1 [d_2 / (d_1 + d_2)] - dl_2\} (t - Ft_r)$$
$$= \{2 \times 9 [3.0 / (2.75 + 3.0)] - 5.0\} \times (3.25 - 1.0 \times 2.711)$$
$$= 2.368 \text{ in.}^2$$
$$A_2 = 2 (t_{n2} - t_{rn2}) 2.5 t_{n2}$$
$$= 2 (1.0 - 0.136) \times 2.5 \times 1.0$$
$$= 4.322 \text{ in.}^2$$
$$A_3 = 2 t_{n2} h$$
$$= 2 \times 1.0 \times 4.0$$
$$= 8.0 \text{ in.}^2$$
$$A_{41} + A_{43} = WL_3^2 + WL_4^2$$
$$= 1.25^2 + 0.5^2$$
$$= 1.812 \text{ in.}^2$$

Total area of available reinforcement provided by nozzle 2 in the longitudinal plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 16.502 \text{ in.}^2 \geq A_{l2}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided in nozzle 2 or 3 in the circumferential plane

$$A_1 = \left\{ t + D_2 [d_2 / (d_2 + d_3)] - \frac{dl_2}{2} \right\} (t - Ft_r)$$
$$= \left\{ 3.25 + 6.5 [3.0 / (3.0 + 3.0)] - \frac{5.0}{2} \right\} \times (3.25 - 0.5 \times 2.711)$$
$$= 7.578 \text{ in.}^2$$
$$A_2 = 2 (t_{n2} - t_{rn2}) 2.5 t_{n2}$$
$$= 2 (1.0 - 0.13554) \times 2.5 \times 1.0$$
$$= 4.3223 \text{ in.}^2$$
$$A_3 = 2 t_{n2} h$$
$$= 2 \times 1.0 \times 4.0$$
$$= 8.0 \text{ in.}^2$$
$$A_{41} + A_{43} = WL_3^2 + WL_4^2$$
$$= 1.25^2 + 0.5^2$$
$$= 1.8125 \text{ in.}^2$$

Total area of available reinforcement provided by nozzle 2 or 3 in the circumferential plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 21.713 \text{ in.}^2 \geq A_{c2}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided by nozzle 3 in the diagonal plane

Although nozzle 1 does not lie exactly in the same plane as nozzles 3 and 4 and is slightly farther away, for simplicity the limit on both sides of nozzle 3 are restricted to the reduced limit between nozzles 3 and 4.

$$A_1 = \{2 \times D_3 \times [d_3/(d_3 + d_4)] - dl_3\} (t - Ft_r)$$
$$= \{2 \times 8.25 \times [3.0/(3.0 + 2.75)] - 5.0\} \times (3.25 - 0.88 \times 2.711)$$
$$= 3.120 \text{ in.}^2$$
$$A_2 = 2 (t_{n3} - t_{rn3}) 2.5 t_{n3}$$
$$= 2 (1.0 - 0.136) \times 2.5 \times 1.0$$
$$= 4.322 \text{ in.}^2$$
$$A_3 = 2 t_{n3} h$$
$$= 2 \times 1.0 \times 4.0$$
$$= 8.0 \text{ in.}^2$$
$$A_{41} + A_{43} = WL_3^2 + WL_4^2$$
$$= 1.25^2 + 0.5^2$$
$$= 1.812 \text{ in.}^2$$

Total area of available reinforcement provided by nozzle 3 in the diagonal plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 17.254 \text{ in.}^2 \geq A_{d3}$$

as required for demonstration of compliance with PG-33.

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Area of reinforcement provided in nozzle 4 in the diagonal plane

$$\begin{aligned} A_1 &= \left\{ t + D_3 \times [d_4 / (d_4 + d_3)] - \frac{dl_4}{2} \right\} \\ &\quad (t - Ft_r) \\ &= \{3.25 + 8.25 \times [2.75 / (2.75 + 3.0)] \\ &\quad - \frac{4.5}{2} \} \times (3.25 - 0.88 \times 2.711) \\ &= 4.275 \text{ in.}^2 \\ A_2 &= 2 (t_{n4} - t_{rn4}) 2.5 t_{n4} \\ &= 2 (0.875 - 0.124) \times 2.5 \times 0.875 \\ &= 3.285 \text{ in.}^2 \\ A_3 &= 2 t_{n4} h \\ &= 2 \times 0.875 \times 4.0 \\ &= 7.0 \text{ in.}^2 \\ A_{41} + A_{43} &= WL_3{}^2 + WL_4{}^2 \\ &= 1.25^2 + 0.5^2 \\ &= 1.516 \text{ in.}^2 \end{aligned}$$

Total area of available reinforcement provided by nozzle 4 in the diagonal plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 16.076 \text{ in.}^2 \geq A_{d4}$$

as required for demonstration of compliance with PG-33.

The rule of PG-38.4 for the minimum required net cross-sectional area between any two finished openings shall apply as follows:

Net area required in longitudinal plane between nozzles 1 and 2

$$\begin{aligned} nar &= 0.7 F t_r D_1 \\ &= 0.7 \times 1.0 \times 2.711 \times 9 \\ &= 17.078 \text{ in.}^2 \end{aligned}$$

Net area provided in vessel wall

$$\begin{aligned} nav &= [D_1 - 0.5(dl_1 + dl_2)]t \\ &= [9 - 0.5 \times (4.5 + 5)] \times 3.25 \\ &= 13.812 \text{ in.}^2 \end{aligned}$$

Net area provided in nozzle wall fused to vessel wall

$$\begin{aligned} nan &= t_{n1} W d_1 + t_{n1} W d_2 + t_{n2} W d_3 + t_{n2} W d_4 \\ &= 0.875 \times 1.0 + 0.875 \times 1.0 + 1.0 \times 1.25 \\ &\quad + 1.0 \times 1.25 \\ &= 4.25 \text{ in.}^2 \end{aligned}$$

Total net area provided in the longitudinal plane between nozzles 1 and 2

$$nav + nan = 18.0625 \text{ in.}^2 \geq nar$$

as required for demonstration of compliance with PG-38.4.

Net area required in the circumferential plane between nozzles 2 and 3

$$\begin{aligned} nar &= 0.7 F t_r D_2 \\ &= 0.7 \times 0.5 \times 2.711 \times 6.5 \\ &= 6.167 \text{ in.}^2 \end{aligned}$$

Net area provided in vessel wall

$$\begin{aligned} nav &= [D_2 - 0.5(dl_2 + dl_3)]t \\ &= [6.5 - 0.5 \times (5 + 5)] \times 3.25 \\ &= 4.875 \text{ in.}^2 \end{aligned}$$

Net area provided in the nozzle wall fused to the vessel wall

$$\begin{aligned} nan &= T t_{n2} W d_3 + t_{n2} W d_4 + t_{n3} W d_3 + t_{n3} W d_4 \\ &= 1.0 \times 1.25 + 1.0 \times 1.25 + 1.0 \times 1.25 \\ &\quad + 1.0 \times 1.25 \\ &= 5 \text{ in.}^2 \end{aligned}$$

Total net area provided in the circumferential plane between nozzles 2 and 3

$$nav + nan = 9.875 \text{ in.}^2 \geq nar$$

as required for demonstration of compliance with PG-38.4.

Net area required in the diagonal plane between nozzles 3 and 4

$$\begin{aligned} nar &= 0.7 F t_r D_3 \\ &= 0.7 \times 0.88 \times 2.711 \times 8.25 \\ &= 13.776 \text{ in.}^2 \end{aligned}$$

Net area provided in vessel wall

$$\begin{aligned} nav &= [D_3 - 0.5(dl_3 + dl_4)]t \\ &= [8.25 - 0.5 \times (5 + 4.5)] \times 3.25 \\ &= 11.375 \text{ in.}^2 \end{aligned}$$

Net area provided in the nozzle wall fused to the vessel wall

$$\begin{aligned} nan &= t_{n3} W d_3 + t_{n3} W d_4 + t_{n4} W d_1 + t_{n4} W d_2 \\ &= 1.0 \times 1.25 + 1.0 \times 1.25 + 0.875 \times 1.0 \\ &\quad + 0.875 \times 1.0 \\ &= 4.25 \text{ in.}^2 \end{aligned}$$

Total net area provided in the diagonal plane between nozzles 3 and 4

$$nav + nan = 15.625 \text{ in.}^2 \geq nar$$

as required for demonstration of compliance with PG-38.4.

Nozzles 1 and 4 — The required minimum strength to be provided by the combined load-carrying elements through each load-carrying path (see PG-37 and PW-15)

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$$W = (A - A_1)S_v$$
$$= (12.199 - 2.860) \times 17{,}500$$
$$= 163{,}431 \text{ lbf}$$

Strength of the welds
Fillet welds in shear

$$= \frac{1}{2}\pi \times (WL_1 + WL_2)dl_1 \text{ (factor in PW-15.2)}S$$
$$= 0.5 \times 3.142 \times (1.125 + 0.5) \times 4.5 \times 0.49 \times 17{,}500$$
$$= 98{,}495 \text{ lbf}$$

Groove welds in tension

$$= \frac{1}{2}\pi(Wd_1 + Wd_2)dl_1(\text{factor in PW-15.2})S$$
$$= 0.5 \times 3.142 \times (1.0 + 1.0) \times 4.5 \times 0.74 \times 17{,}500$$
$$= 183{,}076 \text{ lbf}$$

The combined strength equals 281,571 lb ≥ W as required for demonstration of compliance with PG-37 and PW-15.

Nozzles 2 and 3 — The required minimum strength of the welds (see PG-37 and PW-15)

$$W = (A - A_1)S_v$$
$$= (13.544 - 2.368) \times 17{,}500$$
$$= 195{,}766 \text{ lbf}$$

Strength of the welds
Fillet welds in shear

$$= \frac{1}{2}\pi(WL_3 + WL_4)dl_2(\text{factor in PW-15.2})S$$
$$= 0.5 \times 3.142 \times (1.25 + 0.5) \times 5 \times 0.49 \times 17{,}500$$
$$= 117{,}859 \text{ lbf}$$

Groove welds in tension

$$= \frac{1}{2}\pi(Wd_3 + Wd_4)dl_2(\text{factor in PW-15.2})S$$
$$= 0.5 \times 3.142 \times (1.25 + 1.25) \times 5 \times 0.74 \times 17{,}500$$
$$= 254{,}273 \text{ lbf}$$

The combined strength of path number 3 equals 372,132 lbf ≥ W as required for demonstration of compliance with PG-37 and PW-15.

Nozzles 1 and 4 — Verification of minimum weld sizing as required by PW-16.1 and Figure PW-16.1, illustration (f)

Required per Figure PW-16.1, illustration (f)

$$t_1 + t_2 \geq 1.25t_{\min}$$
$$t_c \geq 0.25$$
$$t_1 \geq 0.25$$
$$t_2 \geq 0.25$$

Actual per Figure A-69

$$t_c = WL_2 \sin 45°$$
$$= 0.5 \times 0.7071$$
$$= 0.354 \text{ in.}$$
$$t_{\min} = 0.75 \text{ in. (based on PW-16.2)}$$
$$t_1 = WL_1 \sin 45°$$
$$= 1.125 \times 0.707$$
$$= 0.795 \text{ in.}$$
$$t_2 = Wd_1 + Wd_2$$
$$= 1.0 + 1.0$$
$$= 2 \text{ in.}$$

Verification

$$(t_1 + t_2 = 2.795) \geq (1.25t_{\min} = 0.937)$$
$$(t_c = 0.354) \geq 0.25$$
$$(t_1 = 0.795) \geq 0.25$$
$$(t_2 = 2) \geq 0.25$$

Nozzles 2 and 3 — Verification of minimum weld sizing as required by PW-16.1 and Figure PW-16.1, illustration (f)

Required per Figure PW-16.1, illustration (f)

$$t_1 + t_2 \geq 1.25t_{\min}$$
$$t_c \geq 0.25$$
$$t_1 \geq 0.25$$
$$t_2 \geq 0.25$$

Actual per Figure A-69

$$t_c = WL_4 \sin 45°$$
$$= 0.5 \times 0.707$$
$$= 0.354$$
$$t_{\min} = 0.75 \text{ in. (based on PW-16.2)}$$
$$t_1 = WL_3 \sin 45°$$
$$= 1.25 \times 0.7071$$
$$= 0.884 \text{ in.}$$
$$t_2 = Wd_3 + Wd_4$$
$$= 1.25 + 1.25$$
$$= 2.5 \text{ in.}$$

Verification

$$(t_1 + t_2 = 3.384) \geq (1.25t_{\min} = 0.937)$$
$$(t_c = 0.354) \geq 0.25$$
$$(t_1 = 0.884) \geq 0.25$$
$$(t_2 = 2.5) \geq 0.25$$

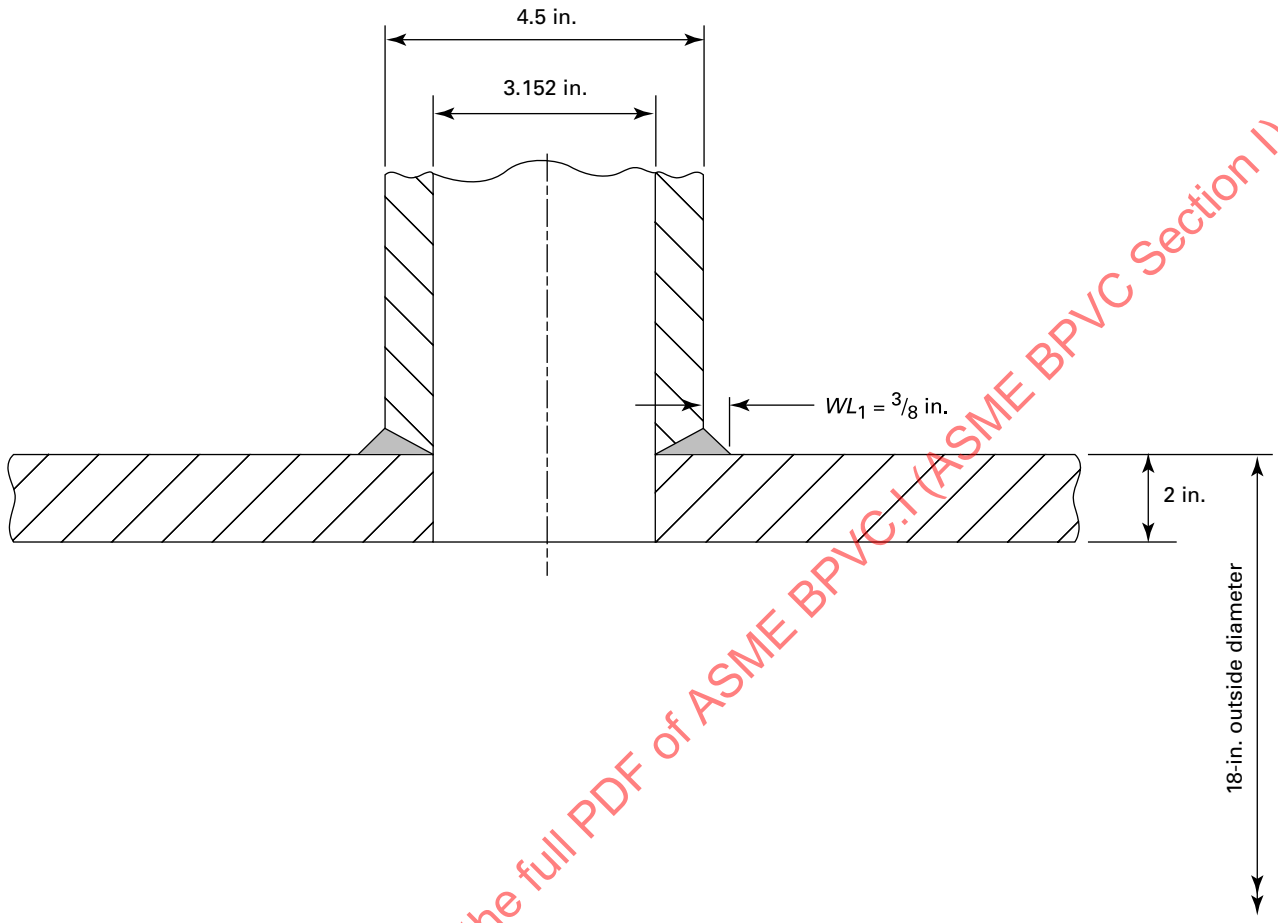
As verified by the above demonstrations, the design is proved to be in compliance with the requirements of Section I.

A-70

A-70.1 A vessel constructed of SA-387 Grade 91 Class 2 plate with a longitudinal weld seam has an SA-335 P91 NPS 4 XXS pipe nozzle attached as shown in Figure A-70.1.

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Figure A-70.1
Example for Typical Nozzle Computations



The maximum allowable working pressure is 1,900 psig at 1,000°F. The maximum allowable stress is 16,300 psi for both the vessel and the pipe connection. The vessel has received subcritical PWHT in accordance with PW-39 after welding.

From Table PG-26, the weld strength reduction factor for CSEF (subcrit.) at 1,000°F is $w = 0.5$. As indicated in PG-27.4.1, $E = w$. From PG-27.4.6, $y = 0.7$. From PG-27.4.3, $C = 0$.

$$\text{Shell } t = \frac{PD}{2SE + 2yP} + C$$
$$= \frac{1{,}900 \times 18}{2 \times 16{,}300 \times 0.5 + 2 \times 0.7 \times 1{,}900} + 0$$
$$= 1.804 \text{ in.}$$

The thickness of the vessel is greater than 1.804 in. and therefore satisfies the requirements of PG-26 and PG-27.

From PG-27.4.1, $E = 1.0$ for seamless cylinders without openings spaced to form ligaments. Inside radius of NPS 4 XXS pipe is (4.5/2) − 0.674 = 1.576 in.

$$\text{Nozzle } t = \frac{PR}{SE - (1 - y)P} + C$$
$$= \frac{1{,}900 \times 1.576}{16{,}300 \times 1 - (1 - 0.7) \times 1{,}900} + 0$$
$$= 0.190 \text{ in.}$$

Considering the 12.5% thinning allowance of pipe in ASME B36.10M per PG-27.4.7, the minimum thickness of the nozzle neck is 0.875 × 0.674 = 0.59 in., and this thickness is greater than 0.190 in. and therefore satisfies the requirements of PG-27.

A-70.1.1 Check to determine if the nozzle opening qualifies for the exception provided in PG-32.1.4.

Per PG-32.1.1

$$K_1 = \text{lesser of } 0.990 \text{ or } \frac{PD}{1.82St}$$

$$\frac{PD}{1.82St} = \frac{1{,}900 \times 18}{1.82 \times 16{,}300 \times 2}$$
$$= 0.576 < 0.990$$

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$$K_1 = 0.576$$

For a cylindrical shell, $K = K_1$.

$$K = 0.576$$

From PG-32.1.4, determine the maximum size of opening with inherent compensation, which is the larger of PG-32.1.4(a) or PG-32.1.4(b).

Per PG-32.1.4(a)

$$\begin{aligned} d_{\max} &= 2.75\,[Dt(1-K)]^{1/3} \\ &= 2.75\,[18 \times 2(1-0.576)]^{1/3} \\ &= 6.82\text{ in.} \end{aligned}$$

Per PG-32.1.4(b)

$$\text{I.D.} = D - 2t = 18 - 2(2) = 14\text{ in.}$$

Smaller of $D/4$ (14/4 = 3.5 in.)or 2.375 in., so use 2.375 in.

Per PG-32.1.4, use the larger of PG-32.1.4(a) or PG-32.1.4(b).

Exemption diameter = MAX|6.82, 2.375| = 6.82 in.

Since the finished opening size, 3.152 in., is less than 6.82 in., no calculation need be made to demonstrate compliance with the compensation requirements of PG-33.

A-70.1.2 Verification of welded connection strength as required by PW-15

Based on PW-15.1.6, the use of Figure PW-16.1, illustration (a) does not require strength calculations for the nozzle attachment weld.

A-70.1.3 Verification of minimum weld size as required by PW-16.1 and Figure PW-16.1, illustration (a)

Required per Figure PW-16.1, illustration (a), t_c must be greater than the smaller of ¼ in. or $0.7t_{\min}$.

$$t_{\min} = 0.674\text{ in.}$$

$$0.7t_{\min} = 0.4718\text{ in.}$$

$$t_c \geq \text{MIN}\ (0.4718,\ 0.25) \geq 0.25\text{ in.}$$

Actual per Figure A-70.1

$$\begin{aligned} t_c &= WL_1 \sin 45\text{ deg} \\ &= 0.375 \times 0.7071 \\ &= 0.265 > 0.25 \end{aligned}$$

therefore the weld size is adequate.

A-70.2 The vessel is the same as provided in A-70.1, except for the following four changes (see Figure A-70.2):

(a) wall thickness of the vessel = 1.25 in.

(b) wall thickness of the nozzle = 0.531 in. (NPS 4 Sch. 160 pipe)

(c) nozzle attachment per Figure PW-16.1, illustration (d), using equal fillet welds with leg sizes ½ in. on inside and outside; nozzle internal projection from the bottom surface of the vessel wall = 1.3275 in.

(d) normalizing + tempering (N + T) PWHT per Table PG-26, Note (10)

A-70.2.1 Check to determine if the welded attachment qualifies for the exception provided in PG-32.

Per PG-32.1.1

$$K_1 = \text{lesser of } 0.990 \text{ or } \frac{PD}{1.82St}$$

$$\begin{aligned} \frac{PD}{1.82St} &= \frac{1{,}900 \times 18}{1.82 \times 16{,}300 \times 1.25} \\ &= 0.922 < 0.990 \end{aligned}$$

$$K_1 = 0.922$$

For a cylindrical shell, $K = K_1$.

$$K = 0.922$$

From PG-32.1.4, determine the maximum size of opening with inherent compensation, which is the larger of PG-32.1.4(a) or PG-32.1.4(b).

Per PG-32.1.4(a)

$$\begin{aligned} d_{\max} &= 2.75\,[Dt(1-K)]^{1/3} \\ &= 2.75\,[18 \times 1.25(1-0.922)]^{1/3} \\ &= 3.317\text{ in.} \end{aligned}$$

Per PG-32.1.4(b)

$$\text{I.D.} = D - 2t = 18 - 2(1.25) = 15.5\text{ in.}$$

Smaller of I.D./4(15.5/4 = 3.875 in.)
or 2.375 in., so use 2.375 in.

Per PG-32.1.4, use the larger of PG-32.1.4(a) or PG-32.1.4(b).

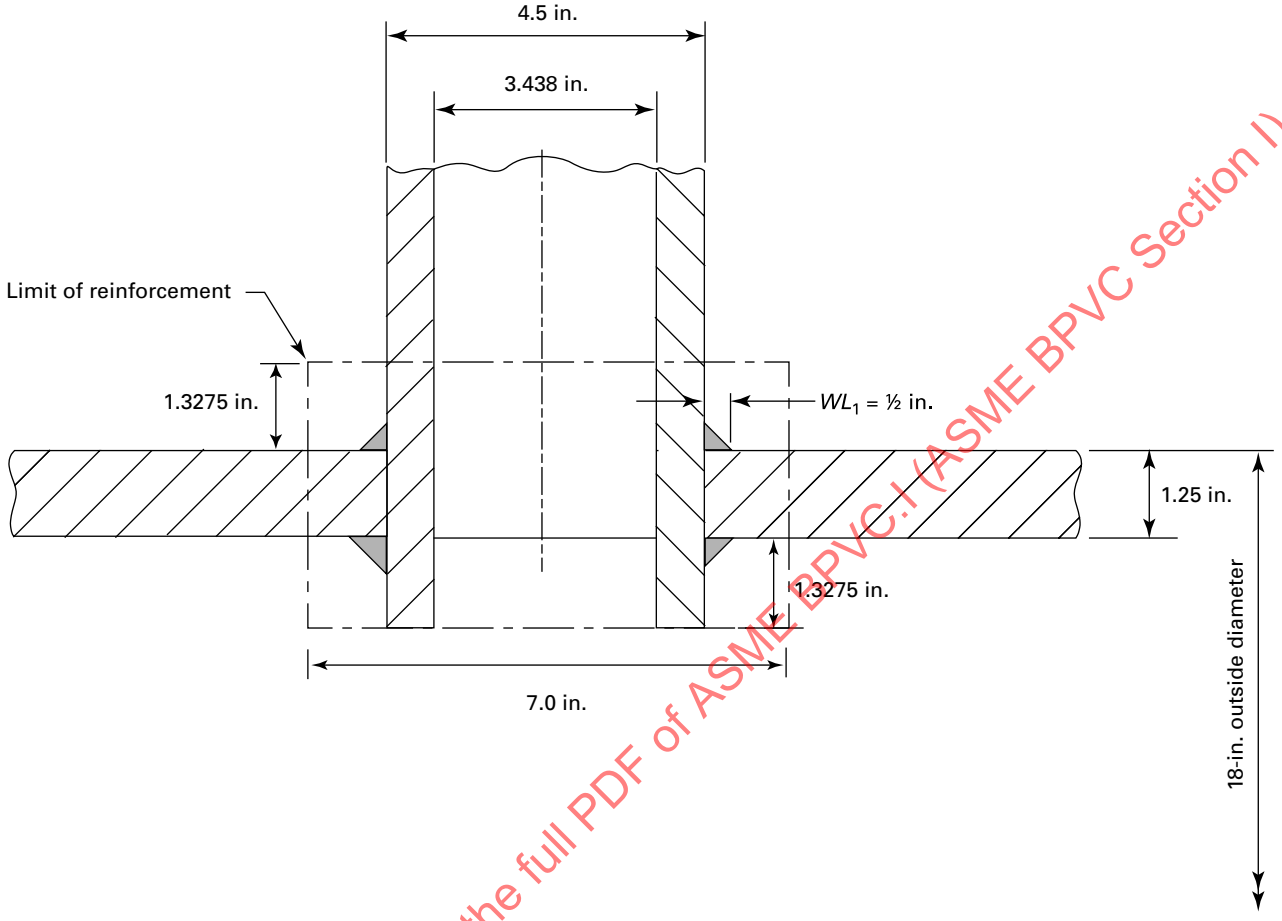
Exemption diameter = MAX|3.317, 2.375| = 3.317 in.

Since the finished opening size, 3.438 in., is greater than 3.317 in., the vessel does not qualify for the exception in PG-32.1.4 and therefore must comply with PG-26, PG-27, and PG-33.

A-70.2.2 From Table PG-26, the weld strength reduction factor for CSEF (N + T) at 1,000°F is w = 0.95. As indicated in PG-27.4.1, $E = w$. From PG-27.4.6, y = 0.7. From PG-27.4.3, C = 0.

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Figure A-70.2
Example for Typical Nozzle Computations



$$\text{Shell } t = \frac{PD}{2SE + 2yP} + C$$
$$= \frac{1{,}900 \times 18}{2 \times 16{,}300 \times 0.95 + 2 \times 0.7 \times 1{,}900} + 0$$
$$= 1.017 \text{ in.}$$

The thickness of the vessel is greater than 1.017 in. and therefore satisfies the requirements of PG-26 and PG-27.

Minimum required thickness for reinforcement consideration

$$\text{Shell } t_r = \frac{PD}{2SE + 2yP} + C$$
$$= \frac{1{,}900 \times 18}{2 \times 16{,}300 \times 1.0 + 2 \times 0.7 \times 1{,}900} + 0$$
$$= 0.970 \text{ in.}$$
$$\text{Nozzle } t_{rn} = \frac{PR}{SE - (1 - y)P} + C$$
$$= \frac{1{,}900 \times 1.719}{16{,}300 \times 1 - (1 - 0.7)\,1{,}900} + 0$$
$$= 0.208 \text{ in.}$$

Considering the 12.5% thinning allowance of pipe in ASME B36.10M per PG-27.4.7, the minimum thickness of the nozzle neck is 0.875 × 0.531 = 0.465 in.; this thickness is greater than 0.208 in. and therefore satisfies the requirements of PG-27.

Area of reinforcement required in the longitudinal plane

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$$A = (d + 2t_n)t_r F$$
$$= (3.438 + 2 \times 0.531) \times 0.970 \times 1$$
$$= 4.365 \text{ in.}^2$$

Limit of reinforcement parallel to the vessel wall is the greater of

$$d \text{ or } R_n + t_n + t = 1.719 + 0.531 + 1.25$$
$$= 3.5 \text{ in.}$$

Limit of reinforcement normal to the vessel wall is the smaller of

$$2\tfrac{1}{2}t \text{ or } 2\tfrac{1}{2}t_n + t_e = 2.5 \times 0.531 + 0$$
$$= 1.3275 \text{ in.}$$

Area of reinforcement available ($f_{r1} = 1$)

$$A_1 = 2t\left(t - Ft_r\right) - 2w_d\left(t - Ft_r\right)\left(1 - f_{r1}\right)$$
$$= 2 \times 1.25(1.25 - 1 \times 0.970) - 0$$
$$= 0.7 \text{ in.}^2$$

$$A_2 = 2\left(t_n - t_{rn}\right)\left(2\tfrac{1}{2}t_n + t_e\right)f_{r1}$$
$$= 2 \times (0.531 - 0.208) \times [2.5 \times (0.531 + 0)] \times 1$$
$$= 0.858 \text{ in.}^2$$

$$A_3 = 2t_n h f_{r1}$$
$$= 2 \times 0.531 \times (1.25 + 1.3275) \times 1$$
$$= 2.737 \text{ in.}^2$$

$$A_{41} = (WL_1)^2 f_{r2}$$
$$= 0.5^2 \times 1$$
$$= 0.25 \text{ in.}^2$$

$$A_{43} = (WL_3)^2 f_{r1}$$
$$= 0.5^2 \times 1$$
$$= 0.25 \text{ in.}^2$$

Total area available for reinforcement

$$= A_1 + A_2 + A_3 + A_{41} + A_{43}$$
$$= 0.7 + 0.858 + 2.737 + 0.25 + 0.25$$
$$= 4.795 \geq 4.365$$

therefore the opening is adequately reinforced.

A-70.2.3 Verification of minimum weld size as required by PW-16.1 and Figure PW-16.1, illustration (d)

Required per Figure PW-16.1, illustration (d), t_c must be greater than the smaller of ¼ in. or $0.7t_{\min}$.

$$t_1 + t_2 \geq 1\frac{1}{4}t_{\min}$$

$$t_{\min} = 0.531 \text{ in.}$$

$$0.7t_{\min} = 0.3717 \text{ in.}$$

$$1.25t_{\min} = 0.664 \text{ in.}$$

$$t_c \geq \text{MIN}\,(0.3717,\ 0.25) \geq 0.25 \text{ in.}$$

Actual weld sizes per Figure A-70.2

$$t_c = WL_1 \sin 45 \text{ deg}$$
$$= 0.5 \times 0.7071$$
$$= 0.354 > 0.25$$

$$0.354 + 0.354 = 0.708 \geq 0.664$$

therefore the weld sizes are adequate.

A-70.2.4 Compliance with PG-37 and PW-15 is demonstrated by the following calculations: (23)

Required minimum strength to be provided by the welds (see PG-37 and PW-15)

$$W = (A - A_1)S_v$$
$$= (4.365 - 0.7) \times 16{,}300$$
$$= 59{,}740 \text{ lbf}$$

Inside and outside fillet welds in shear

$$= WL_1 \text{ in shear} + WL_2 \text{ in shear}$$
$$= 0.49\left(\tfrac{1}{2}\right)WL_1\,\pi\left(d + 2t_n + WL_1\right)S_v f_{r1} + 0.49\left(\tfrac{1}{2}\right)WL_2$$
$$\pi\left(d + 2t_n + WL_2\right)S_v f_{r1}$$
$$= 2[0.49 \times 0.5 \times 0.5 \times 3.14\,(3.438 + 2 \times 0.531 + 0.5)$$
$$\times\ 16{,}300 \times 1]$$
$$= 62{,}730 \text{ lbf}$$

The combined strength of the welds equals 62,730 lbf ≥ W, as required for compliance with PG-37 and PW-15.

EXAMPLES OF COMPUTATION OF ALLOWABLE LOADING ON STRUCTURAL ATTACHMENTS TO TUBES

A-71 (23)

A tube is suspended by a welded attachment with the loads and dimensions as shown in Figure A-71. This is a condition of direct radial loading on the tube.

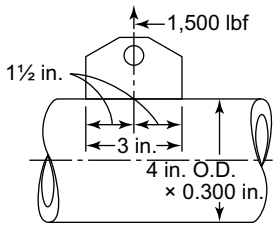
The allowable lug loading is calculated for the following conditions:

$b = 1.0$ in.
$D = 4$ in.
material = SA-213-T22
MAWP = 2258 psi
$T = 800°\text{F}$
$t = 0.30$ in.

¼ in. thick lug

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Figure A-71
Structural Attachment With Radial Load (23)



7 deg attachment angle

$$S = 15{,}000 \text{ psi}$$
$$S_a = 15{,}000 \text{ psi}$$
$$S_t = 2.0\,S_a - S = 15{,}000 \text{ psi}$$

From Table PG-56.2, $K = 1.07$
From Figure PG-56.2, or from PG-56.2, Step 2(a) or PG-56.2, Step 2(b)

$$X = bD / t^2 = 44.4$$

Compression $L_f = 0.0326$
Tension $L_f = 0.0405$

$$L_a = Kb\,(L_f)S_t$$

Compression L_a = (1.07)(0.0326)(15,000)
= 523 lbf/in.
Tension L_a = (1.07)(1.0)(0.0405)(15,000)
= 650 lbf/in.
Actual load

$$W = 1{,}500 \text{ lbf (Tension)}$$
$$L = 1{,}500 \text{ lbf} / 3 \text{ in.} = 500 \text{ lbf/in.} < 650 \text{ lbf/in.}$$

The loading indicated is therefore within the values allowed by the chart in Figure PG-56.2.

Figure A-72
Structural Attachment With Eccentric Load (23)

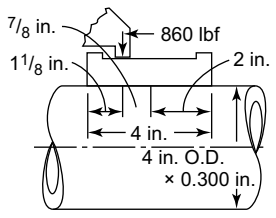


Figure A-73
Structural Attachment With Moment Load (23)

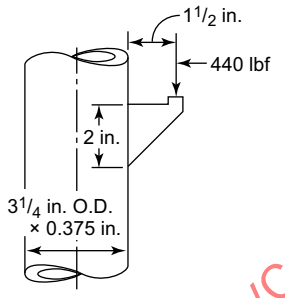
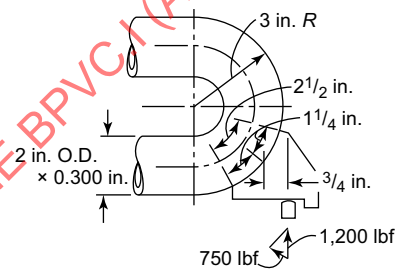


Figure A-74
Structural Attachment on Tube Bend (23)



A-72 (23)

A load is supported on a rubbing strip welded to a tube, as shown in Figure A-72. This problem illustrates a condition where the load is not applied on the center of welded attachment.

The allowable lug loading is calculated for the same conditions given in example A-71
Compression L_a = (1.07)(1.0)(0.0326)(15,000)
= 523 lbf/in.
Tension L_a = (1.07)(1.0)(0.0405)(15,000)
= 650 lbf/in.
Actual unit load

$$W = 860 \text{ lbf}$$
$$L = \frac{860}{4} \pm \frac{(6 \times 860 \times 0.875)}{4^2} = 215 \pm 282.19$$
$$= 497.19 \text{ lbf/in. compression; } 67.19 \text{ lbf/in. tension}$$

The actual loading does not exceed values of allowable loading.

A-73 (23)

A-73.1 A load is supported from a vertical tube with a welded bracket attachment as shown in Figure A-73. This example illustrates a condition of eccentric loading where the direct loading is not additive.

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The allowable lug loading is calculated for the following conditions:

b = 1.0 in.
D = 3.25 in.
material = SA-213-T22
MAWP = 3722 psi
T = 800°F
t = 0.375 in.

¼ in. thick lug
10 deg attachment angle

S = 15,000 psi
S_a = 15,000 psi
$S_t = 2.0\,S_a - S$ = 15,000 psi

From Table PG-56.2, K = 1.108
From Figure PG-56.2, or from PG-56.2, Step 2(a) or PG-56.2, Step 2(b)

$$X = bD / t^2 = 23.11$$

Compression L_f = 0.0637
Tension L_f = 0.090

$$L_a = Kb\left(L_f\right)S$$

Compression L_a = (1.108)(1.0)(0.0637)(15,000) = 1,058 lbf/in.
Tension L_a = (1.108)(1.0)(0.090)(15,000) = 1,495 lbf/in.
Actual

$$W = 440 \text{ lbf}$$
$$L = \frac{6 \times 440 \times 1.5}{2^2} = 990 \text{ lbf/in. compression or tension}$$

The actual loading does not exceed values of allowable loading.

A-73.2 To determine the maximum allowable loading on structural attachments to tubes, a test may be conducted on a full-size section of tube with attachment. The test may be considered as meeting the Code requirements provided

A-73.2.1 The loading applied to the test specimen is at least equivalent to the design loading, and at the same time the tube is subjected to a hydrostatic pressure corresponding to design conditions.

A-73.2.2 The test is conducted in accordance with the requirements of A-22 with the exception that the hydrostatic pressure shall be held at expected design pressure, and the loading on the support shall be increased until permanent set occurs.

A-73.2.3 The maximum load P, allowed on the attachment at or below the pressure corresponding to the hydrostatic pressure, is given by the following equation:

$$P = \frac{HS}{E}$$

where

E = average proportional limit of the tube material, psi
H = test load at the proportional limit of the structure, lbf
P = maximum allowable load on attachment, lbf
S = working stress permitted in Section II, Part D, Subpart 1, Table 1A, for the tube material at the design temperature that in no case shall be taken at less than 700°F, psi

A-74 (23)

A superheater section is supported by welded attachment to the short-radius return bend section as shown in Figure A-74. This example illustrates a condition where a direct and eccentric load is applied to a bent tube section.

The allowable lug loading is calculated for the following conditions:

b = 1.0 in.
D = 2.0 in.
material = SA-213-T22
MAWP = 5,087 psi
T = 700°F
t = 0.30 in.

¼ in. thick lug
15 deg attachment angle

S = 15,000 psi
S_a = 15,000 psi
$S_t = 2.0\,S_a - S$ = 15,000 psi

From Table PG-56.2, K = 1.16
From Figure PG-56.2, or from PG-56.2, Step 2(a) or PG-56.2, Step 2(b)

$$X = bD / t^2 = 22.2$$

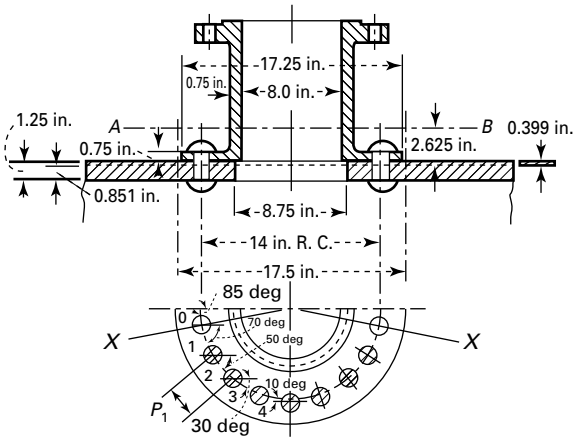
Compression L_f = 0.0664
Tension L_f = 0.0948
For bend

$$X = b(\text{Bend dia}) / t^2 = (1.0)6 / 0.3^2 = 66.6$$

From Figure PG-56.2, or from PG-56.2, Step 2(a) or PG-56.2, Step 2(b)
Compression L_f = 0.0215
Tension L_f = 0.0257

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Figure A-75-1
Example of Nozzle Attached by Riveting



$$L_a = Kb\left(\Sigma L_f\right) S_t$$

Compression L_a = (1.16)(1.0)(0.0664 + 0.0215)(15,000)
= 1,529 lbf/in.
Tension L_a = (1.16)(1.0)(0.0948 + 0.0257)(15,000)
= 2,096 lbf/in.
Actual unit load

$$P = \frac{750}{2.5} \pm \frac{6 \times 1{,}200 \times 0.75}{2.5^2}$$

$$= 300 \pm 864 = 1{,}164 \text{ lbf/ in. compression; } 564 \text{ lbf/in. tension}$$

The actual applied load is less than the values allowed by the chart in Figure PG-56.2.

COMPUTATIONS OF TYPICAL NOZZLE FITTINGS ATTACHED BY RIVETS

(23) ### A-75 EXAMPLE

An 8 in. (200 mm) nozzle is located on a shell as shown in Figure A-75-1. The shell data are as follows:
- inside diameter: 54 in. (1400 mm)
- material thickness: 1.25 in. (32 mm)
- design pressure 340 psi (2.3 MPa)
- design temperature: 440°F (230°C)
- efficiency of riveted longitudinal joint of shell: 80%
- boiler designed with no corrosion allowance

The shell material is SA-516 Grade 70 and the nozzle material is SA-105.

For the purpose of this example, assume the following:
- opening in shell: 8.75 in. (225 mm) to provide space for caulking
- nozzle inside diameter: 8 in. (200 mm)
- nozzle wall thickness: 0.75 in. (19 mm)
- nozzle riveting flange thickness: 0.75 in. (19 mm)
- nozzle riveting flange outside diameter: 17.25 in. (440 mm)
- quantity of attaching rivets: 18
- size of attaching rivets: 1.25 in. (32 mm)
- diameter of rivet circle: 14 in. (350 mm)
- diameter of rivet holes: 1.28 in. (33 mm)

The weakest section will be along a line making an angle of 10 deg with the longitudinal axis passing through the center of each of the two rivets nearest to and straddling the centerline of the nozzle as shown in Figure A-75-1.

The excess metal in the neck of the nozzle may be considered as reinforcement for a distance of 2.5 times its thickness measured from the back of the riveting flange. Therefore, the distance of line A–B in Figure A-75-1 from the outside of the shell is

(U.S. Customary Units)

$$(2.5 \times 0.75) + 0.75 = 2.625 \text{ in.}$$

(SI Units)

$$(2.5 \times 19) + 19 = 66.5 \text{ mm}$$

Minimum thickness for riveted shell (from PG-27.2.2 and PR-8.2.1)

$$t = \frac{PR}{0.7SE - (1 - y)P} + C$$

(U.S. Customary Units)

$$\text{Shell } t_r = \frac{340 \times 27}{(0.7 \times 20{,}000 \times 0.8) - (1 - 0.4) \times 340}$$

$$\text{Shell } t_r = 0.83 \text{ in.}$$

(SI Units)

$$\text{Shell } t_r = \frac{2.3 \times 700}{(0.7 \times 138 \times 0.8) - (1 - 0.4) \times 2.3}$$

$$\text{Shell } t_r = 21.2 \text{ mm}$$

Minimum thickness for seamless nozzle

(U.S. Customary Units)

$$\text{Nozzle } t_{rn} = \frac{340 \times 4}{(20{,}000 \times 1) - (1 - 0.4) \times 340}$$

$$\text{Nozzle } t_{rn} = 0.069 \text{ in.}$$

(SI Units)

$$\text{Nozzle } t_{rn} = \frac{2.3 \times 100}{(138 \times 1) - (1 - 0.4) \times 2.3}$$

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$$\text{Nozzle } t_{rn} = 1.68 \text{ mm}$$

Area of reinforcement required (from PG-33)

$$A = (d + 2t_n)t_r F$$

(U.S. Customary Units)

$$A = (8.75 + 2 \times 0.75) \times 0.581 \times 1$$

$$A = 5.96 \text{ in.}^2$$

(SI Units)

$$A = (225 + 2 \times 19) \times 14.7 \times 1$$

$$A = 3\,870 \text{ mm}^2$$

Area of reinforcement available in shell
Use larger value of

$$A_1 = (d - 2t_n)(t - Ft_r)$$

$$A_1 = 2t(t - Ft_r)$$

(U.S. Customary Units)

$$A_1 = (8.75 - 2 \times 0.75)(1.25 - 1 \times 0.581) = 4.85 \text{ in.}^2$$

$$A_1 = 2 \times 1.25(1.25 - 1 \times 0.581) = 1.67 \text{ in.}^2$$

$$A_1 = 4.85 \text{ in.}^2$$

(SI Units)

$$A_1 = (225 - 2 \times 19)(32 - 1 \times 14.7) = 3\,235 \text{ mm}^2$$

$$A_1 = 2 \times 32(32 - 1 \times 14.7) = 1\,110 \text{ mm}^2$$

$$A_1 = 3\,235 \text{ mm}^2$$

Area of reinforcement available in nozzle
Use smaller value of

$$A_2 = 2(t_n - t_{rn})(2.5\,tf_{r1})$$

$$A_2 = 2(t_n - t_{rn})(2.5\,t_n + t_e)f_{r1}$$

(U.S. Customary Units)

$$A_2 = (0.75 - 0.069)(2.5 \times 1.25 \times 1) = 2.128 \text{ in.}^2$$

$$A_2 = 2(0.75 - 0.069)(2.5 \times 0.75 + 0) \times 1 = 2.55 \text{ in.}^2$$

$$A_2 = 2.128 \text{ in.}^2$$

(SI Units)

$$A_2 = (19 - 1.68)(2.5 \times 32 \times 1) = 1\,385 \text{ mm}^2$$

$$A_2 = 2(19 - 1.68)(2.5 \times 19 + 0) \times 1 = 1\,645 \text{ mm}^2$$

$$A_2 = 1\,385 \text{ mm}^2$$

Failure can occur by shearing of the rivets on one side of Section X-X in Figure A-75-1. The allowable stress of the rivets in single shear is 8,800 psi (60 MPa). The allowable stress of the shell material is 20,000 psi (138 MPa), and the allowable stress of the nozzle material is 20,000 psi (138 MPa). The total cross-sectional area of the rivets, after driving, on one side of the section is

(U.S. Customary Units)

$$\pi \times 0.64^2 \times 8 = 10.3 \text{ in.}^2$$

(SI Units)

$$\pi \times 16.5^2 \times 8 = 6\,845 \text{ mm}^2$$

Strength of rivets in shear

(U.S. Customary Units) driving

$$10.3 \times 8{,}800 = 90{,}640 \text{ lbf}$$

(SI Units)

$$6\,845 \times 60 = 410\,700 \text{ N}$$

Strength of the nozzle

(U.S. Customary Units)

$$2.128 \times 20{,}000 = 42{,}560 \text{ lbf}$$

(SI Units)

$$1\,385 \times 138 = 191\,130 \text{ N}$$

Strength of cross section of area $(A - A_1)$

(U.S. Customary Units)

$$(5.96 - 4.85) \times 20{,}000 = 22{,}200 \text{ lbf}$$

(SI Units)

$$(3\,870 - 3\,235) \times 138 = 87\,630 \text{ N}$$

Internal pressure can also cause the rivets to fail under tension. The strength of the rivets in tension is 9,000 psi (62 MPa). The total cross-sectional area of the rivets, after driving, is

(U.S. Customary Units)

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$$\pi \times 0.64^2 \times 18 = 23.2 \text{ in.}^2$$

(SI Units)

$$\pi \times 16.5^2 \times 18 = 15\,400 \text{ mm}^2$$

Strength of rivets in tension

(U.S. Customary Units)

$$23.2 \times 9{,}000 = 208{,}800 \text{ lbf}$$

(SI Units)

$$15\,400 \times 62 = 954\,800 \text{ N}$$

Required strength due to internal pressure acting on the 8.75 in. (225 mm) caulking circle

(U.S. Customary Units)

$$\pi \times 4.38^2 \times 340 = 20{,}490 \text{ lbf}$$

(SI Units)

$$\pi \times 113^2 \times 2.3 = 92\,270 \text{ N}$$

If the riveting flange is also to be caulked on the outside, then the required strength due to internal pressure acting on 17.25 in. (440 mm) caulking circle is

(U.S. Customary Units)

$$\pi \times 8.63^2 \times 340 = 79{,}550 \text{ lbf}$$

(SI Units)

$$\pi \times 220^2 \times 2.3 = 349\,720 \text{ N}$$

The shell plate may fail by tearing around through the rivet holes. Find the relative force across each ligament as the value of F in Figure PG-33.3. Multiply this by cos θ to find the effective component in the direction of the greatest stress on the connection.

(U.S. Customary Units)

$$P_1 = 2 \times (\sin 10 \text{ deg}) \times 7 = 2.432 \text{ in.}$$

(SI Units)

$$P_1 = 50 \times (\sin 10 \text{ deg}) \times 180 = 62 \text{ mm}$$

Net section between holes

(U.S. Customary Units)

$$P_1 - D = 2.432 - 1.282 = 1.15 \text{ in.}$$

(SI Units)

$$P_1 - D = 62 - 32 = 30 \text{ mm}$$

Effective length of net section to carry load in the direction of highest stress is

(U.S. Customary Units)

$$2 \times 2.391 \times 1.15 = 5.5 \text{ in.}$$

(SI Units)

$$2 \times 2.391 \times 30 = 144 \text{ mm}$$

Effective area to carry stress is

(U.S. Customary Units)

$$5.5 \times 1.25 = 6.875 \text{in.}^2$$

(SI Units)

$$144 \times 32 = 4\,600 \text{ mm}^2$$

This is less than the area of 7.165 in.^{2} (4 620 mm^2) in the nozzle, so the net section between the rivets is not adequate.

A-76 EXAMPLES OF METHODS TO DETERMINE LIGAMENT EFFICIENCY (23)

The following are examples of the applications of the rules in PG-53. PG-53.2.1 and PG-53.2.2 shall be used to determine the efficiency of ligaments in groups of 3 or more openings not forming a definite pattern. The variables used in the examples are those defined in PG-52.1.

The examples shown may be used to clarify understanding of the typical applications of PG-53, which include the determination of ligament efficiency when a misdrilled hole results in a ligament smaller than that used to set MAWP and in the intentional design of irregularly spaced openings not forming a definite pattern. The examples in (a) and (b) show an evaluation of acceptable efficiency based on the rules in PG-53.2.1 and

Table A-75-1

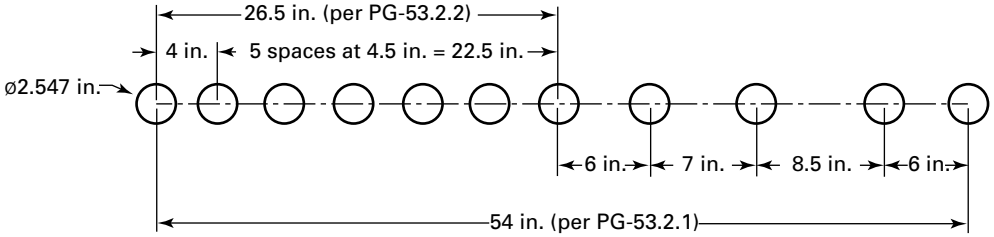
Ligament (Figure A-75-1)	θ, deg	cos θ	F From Figure PG-33.3	F cos θ
0	85	0.087	0.51	0.022 (1)
1	70	0.342	0.55	0.188
2	50	0.643	0.7	0.453
3	30	0.866	0.88	0.76
4	10	0.985	0.98	0.968
			Total:	2.391

NOTE: (1) Multiplied by 0.5 because of half-length ligament.

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(23)

Figure A-76-1
Example of Determining Ligament Efficiency per PG-53.2.1 and PG-53.2.2



PG-53.2.2, respectively. These explanations are to be used with the rules in PG-53.2.1, PG-53.2.2, Figure A-76-1, and the equations as shown in (a) and (b).

Example: A 54-in. I.D. drum has multiple rows of openings. The pitch between holes in the condition used to set MAWP is 4.5 in.

$$E = \frac{p - d}{p} = \frac{4.5 - 2.547}{4.5} = 0.434$$

A second row of holes is drilled in the pattern shown in Figure A-76-1 introducing a 4-in. space.

(a) Efficiency Per PG-53.2.1. Determine the center-to-center dimension between the first and last hole over a distance less than or equal to the I.D. of the drum that produces the lowest average efficiency. In this example, the area under consideration consists of 10 ligaments with a center-to-center distance of 54 in. between the first and last hole. The ligament efficiency is established as follows:

$$\frac{p_1 - nd}{p_1} = \frac{54 - 10(2.547)}{54} = 0.528$$

$$0.528 > 0.434$$

(b) Efficiency Per PG-53.2.2. Determine the center-to-center dimension between the first and last hole over a distance less than or equal to the inside radius of the drum.

In this example, the area under consideration consists of 6 ligaments with a center-to-center distance of 26.5 in. between the first hole and last. The ligament efficiency is established as follows:

$$\frac{p_1 - nd}{p_1} = \frac{26.5 - 6(2.547)}{26.5} = 0.432$$

$$0.434(0.80) = 0.347$$

$$0.423 > 0.347$$

PREHEATING

A-101 HEATING AND COOLING RATES FOR POSTWELD HEAT TREATMENT

A-101.1 Heating and cooling rates for weldments and materials should be established by the Manufacturer. These rates should be sufficient to avoid inducing distortion, residual stresses, cracking, and other detrimental effects into the weldment during postweld heat treatment. Heating and cooling rates should be established based, in part, upon successful past practice for specific materials and thicknesses, by using other Codes and Standards as a guide, or by engineering analysis.

A-101.2 For thicknesses of 2 in. (50 mm) or greater, the following rates of heating and cooling should be applied; however, these rates should not be applied to P-No. 7 and P-No. 10I welded base materials:

(a) Above 800°F (425°C), the heating rate should not exceed 600°F/hr (335°C/h) divided by the thickness in inches (in millimeters, the thickness divided by 25 shall be used), but in no case should it be more than 600°F/hr (335°C/h).

(b) Above 800°F (425°C), the cooling rate should not exceed 600°F/hr (335°C/h) divided by the thickness in inches (in millimeters, the thickness divided by 25 shall be used), but in no case should it be more than 600°F/hr (335°C/h).

(c) The rates of heating and cooling need not be less than 100°F/hr (55°C/h).

From 800°F (425°C) or below, the pressure part should be cooled in still air.

ROUNDED INDICATION CHARTS

A-250 ACCEPTANCE STANDARD FOR RADIOGRAPHICALLY DETERMINED ROUNDED INDICATIONS IN WELDS

A-250.1 Applicability of These Standards. These standards are applicable to ferritic, austenitic, and nonferrous materials.

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Table A-250.3.2
Maximum Permissible Size of Rounded Indication (Examples Only)

U.S. Customary Units

Thickness t, in.	Maximum Size of Acceptable Rounded Indication, in.		Maximum Size of Nonrevelant Indication, in.
	Random	Isolated	
Less than 1/8	1/4t	1/3t	1/10t
1/8	0.031	0.042	0.015
3/16	0.047	0.063	0.015
1/4	0.063	0.083	0.015
5/16	0.078	0.104	0.031
3/8	0.091	0.125	0.031
7/16	0.109	0.146	0.031
1/2	0.125	0.168	0.031
9/16	0.142	0.188	0.031
5/8	0.156	0.210	0.031
11/16	0.156	0.230	0.031
3/4 to 2 incl.	0.156	0.250	0.031
Over 2	0.156	0.375	0.063

SI Units

Thickness t, mm	Maximum Size of Acceptable Rounded Indication, mm		Maximum Size of Nonrevelant Indication, mm
	Random	Isolated	
Less than 3	1/4t	1/3t	1/10t
3	0.79	1.07	0.38
5	1.19	1.60	0.38
6	1.60	2.11	0.38
8	1.98	2.64	0.79
10	2.31	3.18	0.79
11	2.77	3.71	0.79
13	3.18	4.27	0.79
14	3.61	4.78	0.79
16	3.96	5.33	0.79
17	3.96	5.84	0.79
19 to 50 incl.	3.96	6.35	0.79
Over 50	3.96	9.53	1.60

A-250.2 Terminology.

A-250.2.1 Rounded Indications. Indications with a maximum length of three times the width or less on the radiograph are defined as rounded indications. These indications may be circular, elliptical, conical, or irregular in shape and may have tails. When evaluating the size of an indication, the tail shall be included. The indication may be from any imperfection in the weld, such as porosity, slag, or tungsten.

A-250.2.2 Aligned Indications. A sequence of four or more rounded indications shall be considered to be aligned when they touch a line parallel to the length of the weld drawn through the center of the two outer rounded indications.

A-250.2.3 Thickness t. t is the thickness of the weld, excluding any allowable reinforcement. For a butt weld joining two parts having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the fillet weld throat shall be included in t.

A-250.3 Acceptance Criteria.

A-250.3.1 Image Density. Density within the image of the indication may vary and is not a criterion for acceptance or rejection.

A-250.3.2 Relevant Indications (See Table A-250.3.2 for Examples). Only those rounded indications which exceed the following dimensions shall be considered relevant:

(*a*) 1/10t for t less than 1/8 in. (3 mm)
(*b*) 1/64 in. (0.4 mm) for t 1/8 in. to 1/4 in. (6 mm), inclusive
(*c*) 1/32 in. (0.8 mm) for t 1/4 in. (6 mm) to 2 in. (50 mm), inclusive
(*d*) 1/16 in. (1.6 mm) for t greater than 2 in. (50 mm)

A-250.3.3 Maximum Size of Rounded Indication (See Table A-250.3.2 for Examples). The maximum permissible size of any indication shall be 1/4t, or 5/32 in. (4 mm), whichever is smaller; except that an isolated indication separated from an adjacent indication by 1 in. (25 mm) or more may be 1/3t, or 1/4 in. (6 mm), whichever is less. For t greater than 2 in. (50 mm) the maximum permissible size of an isolated indication shall be increased to 3/8 in. (10 mm).

A-250.3.4 Aligned Rounded Indications. Aligned rounded indications are acceptable when the summation of the diameters of the indications is less than t in a length of 12t (see Figure A-250.3.4-1). The length of groups of aligned rounded indications and the spacing between the groups shall meet the requirements of Figure A-250.3.4-2.

A-250.3.5 Spacing. The distance between adjacent rounded indications is not a factor in determining acceptance or rejection, except as required for isolated indications or groups of aligned indications.

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A-250.3.6 Rounded Indication Charts. The rounded indications characterized as imperfections shall not exceed that shown in the charts.

The charts in Figures A-250.3.6-1 through A-250.3.6-6 illustrate various types of assorted, randomly dispersed, and clustered rounded indications for different weld thicknesses greater than $\frac{1}{8}$ in. (3 mm). These charts represent the maximum acceptable concentration limits for rounded indications.

The chart for each thickness range represents full-scale 6 in. (150 mm) radiographs, and shall not be enlarged or reduced. The distributions shown are not necessarily the patterns that may appear on the radiograph, but are typical of the concentration and size of indications permitted.

A-250.3.7 Weld Thickness *t* Less Than $\frac{1}{8}$ in. (3 mm). For t less than $\frac{1}{8}$ in. (3 mm), the maximum number of rounded indications shall not exceed 12 in a 6 in. (150 mm) length of weld. A proportionally fewer number of indications shall be permitted in welds less than 6 in. (150 mm) in length.

A-250.3.8 Clustered Indications. The illustrations for clustered indications show up to four times as many indications in a local area, as that shown in the illustrations for random indications. The length of an acceptable cluster shall not exceed the lesser of 1 in. (25 mm) or 2t. Where more than one cluster is present, the sum of the lengths of the clusters shall not exceed 1 in. (25 mm) in a 6 in. (150 mm) length of weld.

(23) METHODS FOR MAGNETIC PARTICLE EXAMINATION (MT)

NOTE: The satisfactory application of this examination method requires special skills in technique application and results interpretation. The examinations addressed in this Appendix shall be performed by suitably experienced personnel.

A-260

A-260.1 Scope. The requirements of this Appendix shall be followed whenever magnetic particle examination is required by PG-93. The detailed examination method of Section V, Article 7 shall be used with the acceptance criteria specified in this Appendix.

Magnetic particle examination shall be performed in accordance with a written procedure that has been demonstrated to the satisfaction of the Inspector, and certified by the Manufacturer to be in accordance with the requirements of Section V, Subsection A, Article 1, T-150(a) or T-150(b).

A-260.2 Certification of Personnel. The Manufacturer shall certify that each magnetic particle examiner meets the following requirements:

(a) The examiner has vision, corrected as necessary, to enable reading a Jaeger Type No. 2 Standard Chart at a distance of not less than 12 in. (300 mm). The examiner shall be capable of distinguishing and differentiating contrast between the colors used for the examinations. These capabilities shall be checked annually.

(b) The examiner is competent in the magnetic particle examination method for which they are certified, including performing the examination and interpreting and evaluating the results. Where the examination method consists of more than one operation, they may be certified as being qualified only for one or more of these operations.

A-260.3 Evaluation of Indications. Indications are revealed by the retention of magnetic particles. All such indications are not necessarily imperfections. Excessive surface roughness, magnetic permeability variations (such as at the edge of heat-affected zones), etc., may produce similar indications that are not imperfections.

While the indication of an imperfection may be larger than the imperfection, the size of the indication is the basis for acceptance evaluation. Any questionable or doubtful indications shall be reexamined to determine if they are relevant.

A-260.4 Definitions. For use with A-260, the following definitions apply:

linear indication: an indication having a length greater than 3 times the width.

relevant indication: an indication with any dimension greater than $\frac{1}{16}$ in. (1.5 mm).

rounded indication: an indication of circular or elliptical shape with a length equal to or less than 3 times its width.

A-260.5 Acceptance Standards. All surfaces to be examined shall be free of the following:

(a) relevant linear indications

(b) relevant rounded indications greater than $\frac{3}{16}$ in. (5 mm)

(c) four or more relevant rounded indications in a line separated by $\frac{1}{16}$ in. (1.5 mm) or less, edge to edge

METHODS FOR LIQUID PENETRANT EXAMINATION (PT) (23)

NOTE: The satisfactory application of this examination method requires special skills in technique application and results interpretation. The examinations addressed in this Appendix shall be performed by suitably experienced personnel.

A-270

A-270.1 Scope. The requirements of this Appendix shall be followed whenever liquid penetrant examination is required by PG-93. The detailed examination method of Section V, Article 6 shall be used with the acceptance criteria specified in this Appendix.

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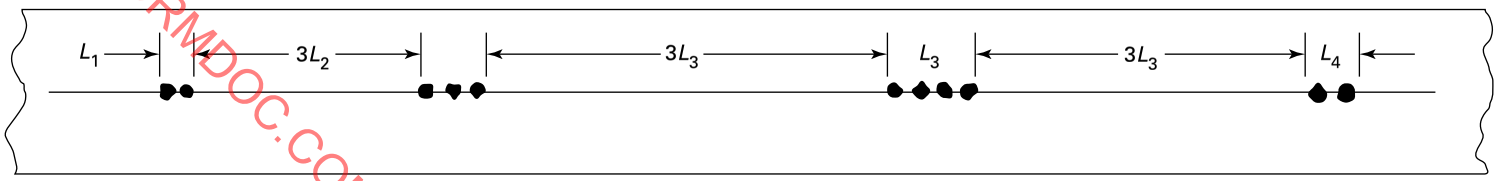
Figure A-250.3.4-1
Aligned Rounded Indications

GENERAL NOTE: Sum of L_1 to L_x shall be less than t in a length of $12t$.

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Figure A-250.3.4-2
Groups of Aligned Rounded Indications

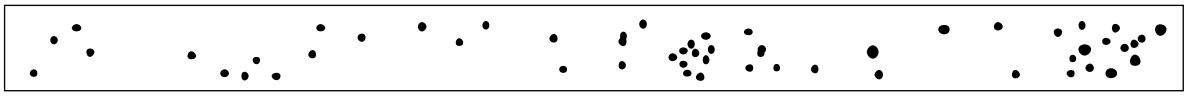


Maximum Group Length
$L = 1/4$ in. (6 mm) for t less than $3/4$ in. (19 mm)
$L = 1/3\ t$ for t $3/4$ in. (19 mm) to $2\,1/4$ in. (57 mm)
$L = 3/4$ in. (19 mm) for t greater than $2\,1/4$ in. (57 mm)

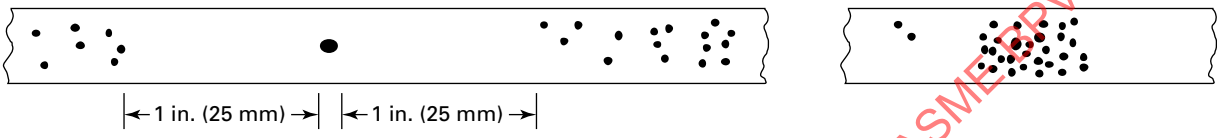
Minimum Group Spacing
$3L$ where L is the length of the longest adjacent group being evaluated.

GENERAL NOTE: Sum of the group lengths shall be less than t in a length of $12t$.

Figure A-250.3.6-1
Charts for t $\frac{1}{8}$ in. (3 mm) to $\frac{1}{4}$ in. (6 mm), Inclusive



(a) Random Rounded Indications [Note (1)]

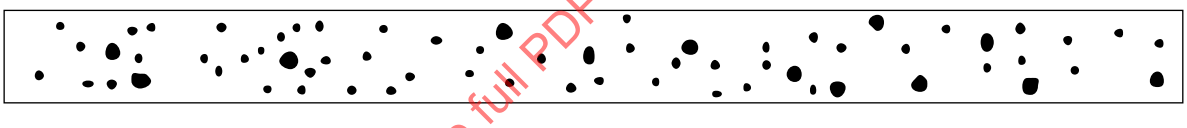


(b) Isolated Indication [Note (2)]

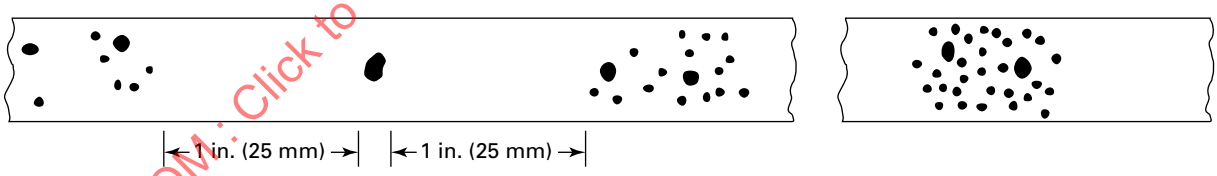
(c) Cluster

NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Maximum size per Table A-250.3.2.

Figure A-250.3.6-2
Charts for t Over $\frac{1}{4}$ in. (6 mm) to $\frac{3}{8}$ in. (10 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



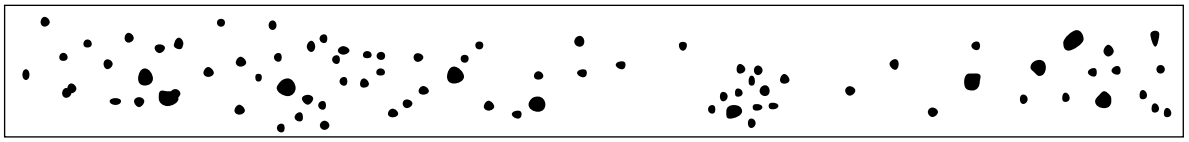
(b) Isolated Indication [Note (2)]

(c) Cluster

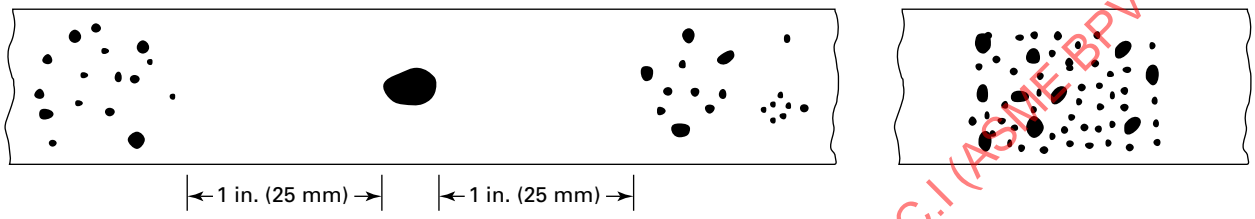
NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Minimum size per Table A-250.3.2.

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Figure A-250.3.6-3
Charts for t Over $^3/_8$ in. (10 mm) to $^3/_4$ in. (19 mm), Inclusive



(a) Random Rounded Indications [Note (1)]

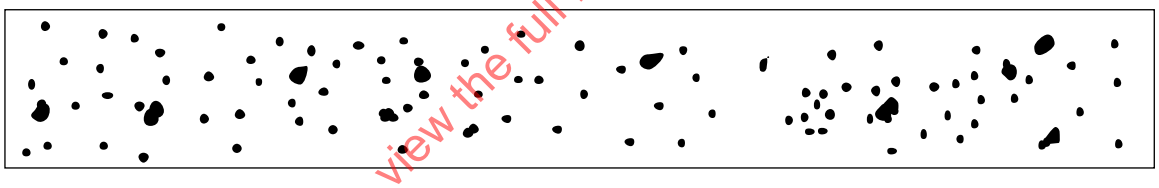


(b) Isolated Indication [Note (2)]

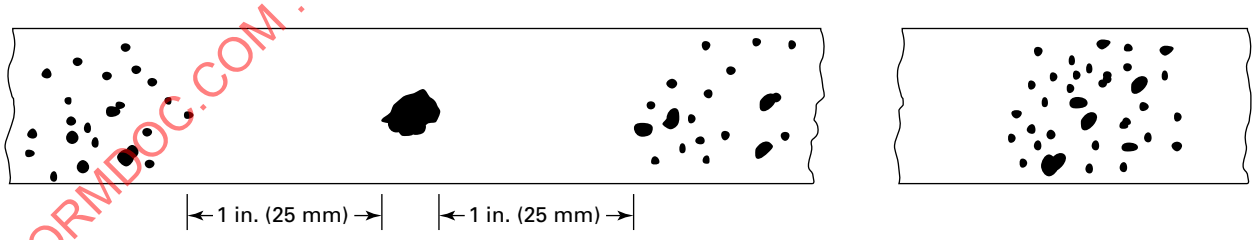
(c) Cluster

NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Minimum size per Table A-250.3.2.

Figure A-250.3.6-4
Charts for t Over $^3/_4$ in. (19 mm) to 2 in. (50 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



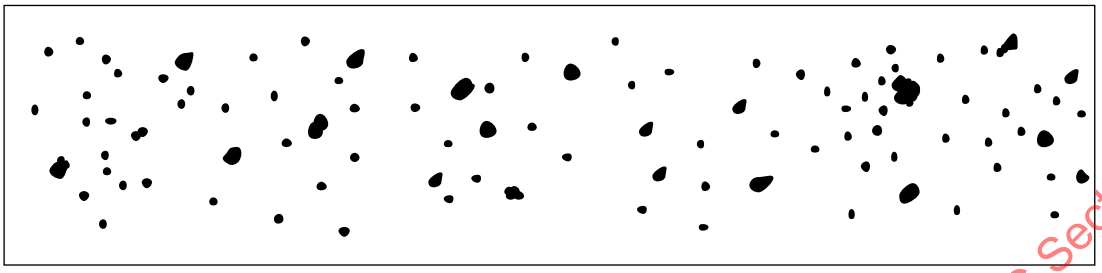
(b) Isolated Indication [Note (2)]

(c) Cluster

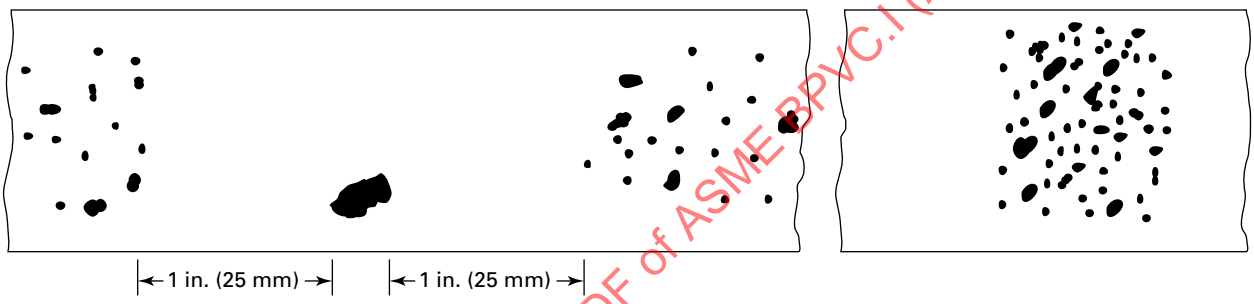
NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Minimum size per Table A-250.3.2.

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Figure A-250.3.6-5
Charts for *t* Over 2 in. (50 mm) to 4 in. (100 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



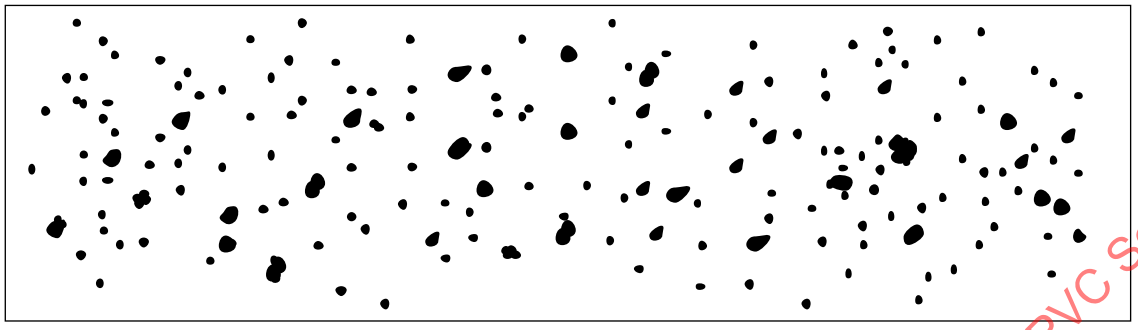
(b) Isolated Indication [Note (2)]

(c) Cluster

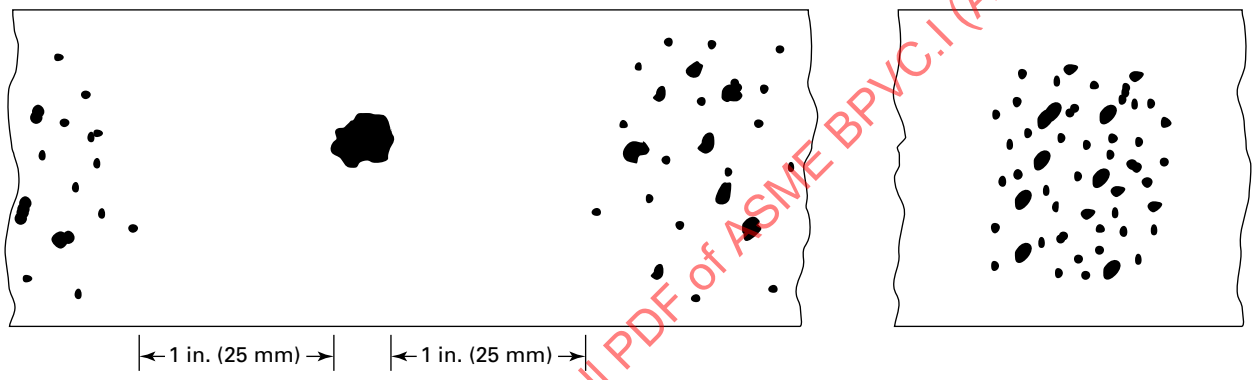
NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Minimum size per Table A-250.3.2.

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Figure A-250.3.6-6
Charts for *t* Over 4 in. (100 mm)



(a) Random Rounded Indications [Note (1)]



(b) Isolated Indication [Note (2)]

(c) Cluster

NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Minimum size per Table A-250.3.2.

Liquid penetrant examination shall be performed in accordance with a written procedure that has been demonstrated to the satisfaction of the Inspector and certified by the Manufacturer to be in accordance with the requirements of Section V, Subsection A, Article 1, T-150(a) or T-150(b).

A-270.2 Certification of Personnel. The Manufacturer shall certify that each liquid penetrant examiner meets the following requirements:

(a) The examiner has vision, corrected as necessary, to enable reading a Jaeger Type No. 2 Standard Chart at a distance of not less than 12 in. (300 mm). The examiner shall be capable of distinguishing and differentiating contrast between the colors used for the examinations. These capabilities shall be checked annually.

(b) The examiner is competent in the techniques of the liquid penetrant examination method for which they are certified, including performing the examination and interpreting and evaluating the results. Where examination method consists of more than one operation, they may be certified as being qualified only for one or more of these operations.

A-270.3 Evaluation of Indications. While the indication of an imperfection may be larger than the imperfection, the size of the indication is the basis for acceptance evaluation.

Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

A-270.4 Definitions. For use with A-270, the following definitions apply:

linear indication: an indication having a length greater than 3 times the width.

relevant indication: an indication that have any dimension greater than $^{1}/_{16}$ in. (1.5 mm).

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rounded indication: an indication of circular or elliptical shape with a length equal to or less than 3 times its width.

A-270.5 Acceptance Standards. All surfaces to be examined shall be free of the following:

(a) relevant linear indications

(b) relevant rounded indications greater than $^{3}/_{16}$ in. (5 mm)

(c) four or more relevant rounded indications in a line separated by $^{1}/_{16}$ in. (1.5 mm) or less, edge to edge

QUALITY CONTROL SYSTEM

A-301 GENERAL

A-301.1 Quality Control System. The Manufacturer or assembler shall have and maintain a quality control system which will establish that all Code requirements, including material, design, fabrication, examination (by the Manufacturer) and inspection of boilers and boiler parts (by the Authorized Inspector), will be met. The quality control systems of electric boiler Manufacturers, pressure relief valve manufacturers or assemblers shall include duties of a Certified Individual when required by this Section. The Certified Individual authorized to provide oversight may also serve as the Certificate Holder's authorized representative responsible for signing data reports or certificates of conformance.

Provided that Code requirements are suitably identified, the system may include provisions for satisfying any requirements by the Manufacturer or user which exceed minimum Code requirements and may include provisions for quality control of non-Code work. In such systems, the Manufacturer may make changes in parts of the system which do not affect the Code requirements without securing acceptance by the Authorized Inspector. Before implementation, revisions to quality control systems of Manufacturers and Assemblers of pressure relief valves shall have been found acceptable to an ASME designee if such revisions affect Code requirements.

The system that the Manufacturer or assembler uses to meet the requirements of this Section must be one suitable for their own circumstances. The necessary scope and detail of the system shall depend on the complexity of the work performed and on the size and complexity of the Manufacturer's (or assembler's) organization. A written description of the system the Manufacturer or assembler will use to produce a Code item shall be available for review. Depending upon the circumstances, the description may be brief or voluminous.

The written description may contain information of proprietary nature relating to the Manufacturer's (or assembler's) processes. Therefore, the Code does not require any distribution of this information, except for the Authorized Inspector or ASME designee.

It is intended that information learned about the system in connection with evaluation will be treated as confidential and that all loaned descriptions will be returned to the Manufacturer upon completion of the evaluation.

A-302 OUTLINE OF FEATURES TO BE INCLUDED IN THE WRITTEN DESCRIPTION OF THE QUALITY CONTROL SYSTEM

The following is a guide to some of the features that should be covered in the written description of the quality control system and that is equally applicable to both shop and field work.

A-302.1 Authority and Responsibility. The authority and responsibility of those in charge of the quality control system shall be clearly established. Persons performing quality control functions shall have sufficient and well-defined responsibility, the authority, and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

A-302.2 Organization. An organization chart showing the relationship between management and engineering, purchasing, manufacturing, field assembling, inspection, and quality control, is required to reflect the actual organization. The purpose of this chart is to identify and associate the various organizational groups with the particular function for which they are responsible. The Code does not intend to encroach on the Manufacturer's right to establish, and from time to time to alter, whatever form of organization the Manufacturer considers appropriate for its Code work.

A-302.3 Drawings, Design Calculations, and Specification Control. The Manufacturer's or assembler's quality control system shall provide procedures which will assure that the latest applicable drawings, design calculations, specifications and instructions, required by the Code, as well as authorized changes, are used for manufacture, assembly, examination, inspection, and testing.

For manufacturers of parts who do not perform or assume any design responsibility for the parts they manufacture, the quality control system need only describe how the design documents, including specifications, drawings, and sketches, that are received from the purchaser of the part are controlled, and how the parts are controlled while in the custody of the parts manufacturer.

A-302.4 Material Control. The Manufacturer or assembler shall include a system of receiving control that will ensure that the material received is properly identified, has the correct documentation, including required material certifications or material test reports, and satisfies Code requirements as ordered. The material control system shall ensure that only the intended material is used in Code construction.

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A-302.5 Examination and Inspection Program. The Manufacturer's quality control system shall describe the fabrication operations, including examinations, sufficiently to permit the Authorized Inspector to determine at what stages specific inspections are to be performed.

A-302.6 Correction of Nonconformities. There shall be a system agreed upon with the Authorized Inspector for correction of nonconformities. A nonconformity is any condition that does not comply with the applicable rules of this Section. Nonconformities must be corrected or eliminated in some way before the completed component can be considered to comply with this Section.

A-302.7 Welding. The quality control system shall include provisions for indicating that welding conforms to requirements of Section IX as supplemented by this Section. Manufacturers intending to use AWS Standard Welding Procedures shall describe control measures used to assure that the welding meets the requirements of this Section (see PW-1.2) and Section IX.

A-302.8 Nondestructive Examination. The quality control system shall include provisions for identifying nondestructive examination procedures the Manufacturer will apply to conform with requirements of this Section.

A-302.9 Heat Treatment. The quality control system shall provide controls to assure that heat treatments as required by the rules of this Section are applied. Means shall be indicated by which the Authorized Inspector can satisfy themselves that these Code heat treatment requirements are met. This may be by review of furnace time–temperature records or by other methods as appropriate.

A-302.10 Calibration of Measurement and Test Equipment. The Manufacturer or assembler shall have a system for the calibration of examination, measuring, and test equipment used in fulfillment of requirements of this Section.

(23) **A-302.11 Records Retention.** The Manufacturer or Assembler shall have a system for the maintenance of radiographs (PW-51.5), UT reports (PW-52.2), Manufacturer's Data Reports (PG-113.3), and qualification maintenance records for welders and welding operators (PW-28.4) and brazers and brazing operators (PB-29.3) as required by this Section.

A-302.12 Sample Forms. The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description shall make necessary references to these forms.

A-302.13 Inspection of Boilers and Boiler Parts.

A-302.13.1 Inspection of boilers and boiler parts shall be by the Authorized Inspector described in PG-91.

A-302.13.2 The written description of the quality control system shall include reference to the Authorized Inspector and when required, the Certified Individual.

A-302.13.2.1 The Manufacturer (or assembler) shall make available to the Authorized Inspector at the Manufacturer's plant (or construction site) a current copy of the written description or the applicable quality control system.

A-302.13.2.2 The Manufacturer's quality control system shall provide for the Authorized Inspector at the Manufacturer's plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the Inspector to perform their duties in accordance with this Section. The Manufacturer may provide such access either to their own files of such documents or by providing copies to the Inspector.

A-302.14 Inspection of Pressure Relief Valves.

A-302.14.1 Inspection of pressure relief valves shall be by designated representative of the ASME, as described in PG-73.4.

A-302.14.2 The written description of the quality control system shall include reference to the CI and the ASME designee.

A-302.14.2.1 The valve Manufacturer (or assembler) shall make available to the ASME designee at the Manufacturer's plant a current copy of the written description of the applicable quality control system.

A-302.14.2.2 The valve Manufacturer's (or assembler's) quality control system shall provide for the ASME designee to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the designee to perform their duties in accordance with this Section. The Manufacturer may provide such access either to their own files of such documents or by providing copies to the designee.

A-302.15 Certifications. Methods other than written signature may be used for indicating certifications, authorizations, and approvals where allowed and as described elsewhere in this Section. Where other methods are employed, controls and safeguards shall be provided and described to ensure the integrity of the certification, authorization, and approval.

A-311 LABORATORY, PERSONNEL, AND TEST REQUIREMENTS FOR CAPACITY CERTIFICATION (23)

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A-317 CYLINDRICAL COMPONENTS UNDER INTERNAL PRESSURE

(23) **A-317.1 General.** The requirements of this Appendix may be used in place of the requirements of PG-27 to determine the minimum required thickness or the maximum allowable working pressure of piping, tubes, drums, shells, and headers for temperatures not exceeding those given for the various materials listed in Section II, Part D, Subpart 1, Tables 1A and 1B. The calculated and ordered thickness of material must include the requirements of PG-16.3, PG-16.4, and PG-16.5. Design calculations must include the loadings as defined in PG-22. When required by the provisions of this Code, allowance must be provided in material thickness for threading and minimum structural stability (see PWT-9.2 and A-317.3, Notes 3 and 5).

A-317.2 Equation for Calculation.

A-317.2.1 Equations (Based on the Strength of the Weakest Course). The minimum required thickness shall be calculated from

$$t = D\left(1 - e^{(-P/SE)}\right)/2 + C + f$$

or

$$t = D_i\left(e^{(P/SE)} - 1\right)/2 + C + f$$

For the maximum allowable pressure, this becomes

$$P = SE \log_e\{D / [D - 2(t - C - f)]\}$$

or

$$P = SE \log_e \{[D_i + 2(t - C - f)] / D_i\}$$

where

C = minimum allowance for threading and structural stability (see A-317.3, Note 3)
D = outside diameter of cylinder, less any portion of C that might pertain to the O.D.
D_i = inside diameter of cylinder, plus any portion of C that might pertain to the I.D.
E = efficiency (see A-317.3, Note 1)
e = the base of natural logarithms
f = thickness factor for expanded tube ends (see A-317.3, Note 4)
P = maximum allowable working pressure (see PG-21)
S = maximum allowable stress value at the design temperature of the metal, as listed in the tables specified in PG-23 (see A-317.3, Note 2)
t = minimum required thickness (see A-317.3, Note 6)
w = weld joint strength reduction factor per PG-26

A-317.2.1.1

A-317.2.1.2 The wall thickness of the ends of tubes strength-welded to headers or drums need not be made greater than the run of the tube as determined by this equation.

A-317.2.1.3 A tube in which a fusible plug is to be installed shall be not less than 0.22 in. (5.6 mm) in thickness at the plug in order to secure four full threads for the plug (see also A-20).

A-317.2.1.4 Bimetallic sections meeting the requirements of PG-9.4 shall use as an outside diameter D, in the equation given in A-317.2.1, not less than the calculated outside diameter of the core material. The outside diameter of the core material shall be determined by subtracting the minimum thickness of the cladding from the outside diameter of the bimetallic section, including the maximum plus tolerance. The minimum required thickness t should apply only to the core material.

A-317.3 Notes. Notes applicable to the equation given in A-317.2.1 are as follows:

(a) Note 1

E = 1.0 for seamless cylinders without openings spaced to form ligaments
= ligament efficiency per PG-52 or PG-53 for seamless cylinders with ligaments
= w, the weld joint strength reduction factor per PG-26 for longitudinally welded cylinders without ligaments

For longitudinally welded cylinders with ligaments located such that no part of the longitudinal weld seam is penetrated by the openings forming the ligament, E shall be taken as the lesser of w or the ligament efficiency from PG-52 or PG-53. If any part of the longitudinal seam weld is penetrated by the openings that form the ligaments, E shall be taken as the product of w times the ligament efficiency.

(b) Note 2. The temperature of the metal to be used in selecting the S value shall be not less than the maximum expected mean wall temperature, i.e., the sum of the outside and inside surface temperatures divided by 2. For situations where there is no heat absorption, the metal temperature may be taken as the temperature of the fluid being transported, but not less than the saturation temperature.

(c) Note 3. Any additive thickness represented by the general term C may be considered to be applied on the outside, the inside, or both. It is the responsibility of the designer using these equations to make the appropriate selection of diameter or radius to correspond to the intended location and magnitude of this added thickness. The pressure- or stress-related terms in the equation should be evaluated using the diameter (or radius) and the remaining thickness which would exist if the "additive"

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thickness had not been applied or is imagined to have been entirely removed.

The values of C below are mandatory allowances for threading. They do not include any allowance for corrosion and/or erosion, and additional thickness should be provided where they are applicable.

Threaded Sections, in. (mm)	Value of C, in. (mm)
$\frac{3}{4}$ (19) nominal, and smaller	0.065 (1.65)
1 (25) nominal, and larger	depth of thread h

(1) Steel or nonferrous pipe lighter than Schedule 40 of ASME B36.10M, *Welded and Seamless Wrought Steel Pipe*, shall not be threaded.

(2) The values of C stipulated above are such that the actual stress due to internal pressure in the wall of the pipe is not greater than the values of S, given in Section II, Part D, Subpart 1, Table 1A, as applicable in the equations.

(3) The depth of thread h in inches may be determined from the equation $h = 0.8/n$, where n is the number of threads per inch.

(d) Note 4

f = 0.04 in. (1.0 mm) over a length at least equal to the length of the seat plus 1 in. (25 mm) for tubes expanded into tube seats, except

= 0 for tubes expanded into tube seats, provided the thickness of the tube ends over a length of the seat plus 1 in. (25 mm) is not less than the following:

(a) 0.095 in. (2.41 mm) for tubes $1\frac{1}{4}$ in. (32 mm) O.D. and smaller

(b) 0.105 in. (2.67 mm) for tubes above $1\frac{1}{4}$ in. (32 mm) O.D. and up to 2 in. (50 mm) O.D.

(c) 0.120 in. (3.05 mm) for tubes above 2 in. (50 mm) O.D. and up to 3 in. (75 mm) O.D.

(d) 0.135 in. (3.43 mm) for tubes above 3 in. (75 mm) O.D. and up to 4 in. (100 mm) O.D.

(e) 0.150 in. (3.81 mm) for tubes above 4 in. (100 mm) O.D. and up to 5 in. (125 mm) O.D.

= 0 for butt welds and for tubes strength-welded to tubesheets, headers, and drums. Strength-welded tubes shall comply with the minimum weld sizes of PW-16.

(e) Note 5. While the thickness given by the equation is theoretically ample to take care of both bursting pressure and material removed in threading, when steel pipe is threaded and used for steam pressures of 250 psi (1 720 kPa) and over, it shall be seamless and of a weight at least equal to Schedule 80 in order to furnish added mechanical strength.

(f) Note 6. If pipe is ordered by its nominal wall thickness, as is customary in trade practice, the manufacturing tolerance on wall thickness shall be taken into account. After the minimum pipe wall thickness t is determined by the equation, this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance allowed in the applicable pipe specification. The next heavier commercial wall thickness may then be selected from Standard thickness schedules as contained in ASME B36.10M. The manufacturing tolerances are given in the several pipe specifications listed in PG-9.

(g) Note 7. When computing the allowable pressure for a section of a definite minimum wall thickness, the value obtained by the equations may be rounded out to the next higher unit of 10.

DATA REPORT FORMS AND GUIDES

A-350 GUIDES FOR COMPLETING MANUFACTURERS' DATA REPORT FORMS

Immediately following each of the included Data Report Forms (P-2, P-2A, P-2B, P-3, P-3A, P-4, P-4A, P-5, P-7, P-8, and PL-1) is a guide for completing that form. The explanations included in the guides are keyed to the Data Report Forms in the following manner:

Circled numbers on each of the forms refer to the items listed on the applicable guide. The parenthesized numbers in the guides correspond to circled numbers on the forms.

Numbers without circles appearing in the guides identify specific line or item numbers of the forms.

No guide is provided for completing Form P-6, Manufacturer's Data Report Supplementary Sheet.

Table A-357 is a guide for determining the Data Report Forms required for Section I construction.

Any quantity to which units apply shall be entered on the Manufacturer's Data Report with the chosen units.

A-350.1 Data Report Forms may be preprinted or computer generated. Forms shall be identical in size, arrangement, and content as shown in this Appendix, except that additional lines may be added as necessary.

When using forms that result in multiple pages, each page shall be marked to be traceable to the first page of the form. For Forms P-2, P-2A, P-3, P-3A, and P-5, each page shall contain, at the top of the page as a minimum, the Manufacturer's name, Manufacturer's serial number, CRN, and National Board number, as shown on the first page. For Forms P-4, P-4A, P-7, and P-8, each page shall contain, at the top of the page as a minimum, the Manufacturer's name and the Form ID number, as shown on the first page.

Additionally, on all forms each sheet shall contain the page number of that page and the total number of pages that comprise the complete form.

These requirements do not apply to Form P-6, Manufacturer's Data Report Supplementary Sheet, since this form is intended to be a single-page form attached to another form (see PG-112.2.7).

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(23)

FORM P-2 MANUFACTURER'S DATA REPORT FOR ALL TYPES OF BOILERS EXCEPT WATERTUBE AND ELECTRIC

As Required by the Provisions of the ASME Code Rules, Section I

Page ____ of ____

1. Manufactured by ____ (1) (Name and address of manufacturer)
2. Manufactured for ____ (2) (Name and address of purchaser)
3. Location of Installation ____ (3) (Name and address)
4. Type ____ (4) (HRT, etc.) Boiler No. ____ (5) (Mfr's. Serial No.) ____ (5) (CRN) ____ (5) (Drawing No.) ____ (5) (Nat'l Board No.) Year Built ____ (6)
5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design conforms to Section I of the ASME BOILER AND PRESSURE VESSEL CODE ____ (7) (Year),

   Addenda to ____ (8) (Date) (if applicable), and Code Cases ____ (Numbers)

   Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors are attached for the following items of this report:

   ____ (9) ____
   (Name of part, item number, mfr's. name and identifying Certification Mark)

6. Shells or drums ____ (10) (no.) ____ (11) (mat'l. spec. gr.) ____ (thickness) ____ [diameter (ID)] ____ (length, inside) ____ [diameter (ID)] ____ (length, inside)
7. Joints ____ (12) [long (seamless, welded)] ____ (13) [efficiency (as compared with seamless)] ____ (14) [girth (seamless, welded)] ____ (no. of shell courses)
8. Heads ____ (Material Specification No.: Thickness — Flat, Dished, Ellipsoidal — Radius of Dish)
9. Tubesheet ____ (11) (Mat'l. Spec., Grade, Thickness) Tube Holes ____ (Diameter)
10. Boiler Tubes: No. ____ ____ (11) (Mat'l. Spec., Grade) (Straight or Bent)

    Diameter ____ (If various, give max. & min.) Length ____ Gage ____ (or thickness)
11. Furnace No. ____ (15) Size ____ (O.D. or WxH) Length, each section ____ (16) Total ____ (16)

    Type ____ (17) (Plain Adamson, Ring Reinforced, Corrugated, Combined, or Stayed)

    ____ (11) (Mat'l. Spec., Grade, Thickness) Seams: Type ____ (12) (Seamless, Welded)
12. Staybolts: No. ____ Size ____ (18) (11) (19) (Diameter, Mat'l. Spec., Grade, Size Telltale, Net Area)

    Pitch ____ (Horizontal and Vertical) MAWP ____ (20) psi.
13. Stays or braces

Location	Material Spec. No.	Type	No. and Size	Maximum Pitch	Fig. PFT-32 L/l	Dist. Tubes to Shell	MAWP
(a) F.H. above tubes	(11)	(21)			(23)	(23)	(23)
(b) R.H. above tubes							
(c) F.H. below tubes							
(d) R.H. below tubes							
(e) Through stays							
(f) Dome braces							

14. Other Parts. 1. ____ (24) 2. ____ 3. ____
    (Brief Description — i.e., Dome, Boiler Piping, etc.)

    1. ____ (25) (11)
    2. ____
    3. ____
    (Mat'l. Spec., Grade, Size, Material Thickness, MAWP)

(07/15)

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FORM P-2

Manufactured by (1) Page ____ of ____

Mfr's. Serial No. (5) CRN (5) National Board No. (5)

15. Openings: (a) Steam (26) (No., Size, and Type) (b) Pressure Relief Valve (No., Size, and Type)

(c) Blowoff (No., Size, Type, and Location) (d) Feed (No., Size, Type, and Location)

(e) Manholes: No. Size Location

(f) Handholes: No. Size Location

16. Fusible Plug (if used) (No., Diameter, Location, and Mfr's. Certification Mark)

17. Boiler Supports: No. Type (Saddles, Legs, or Lugs) Attachment (Bolted or Welded)

18. MAWP (27) Based On (28) (Code Para. and/or Formula) Heating Surface (29) (Total)

19. Shop Hydrostatic Test (30) 20. Maximum Designed Steaming Capacity

21. Remarks

(31) **CERTIFICATE OF SHOP COMPLIANCE**

We certify that the statements made in this data report are correct and that all details of design, material, construction, and workmanship of this boiler conform to Section I of the ASME BOILER AND PRESSURE VESSEL CODE.

Our Certificate of Authorization no. to use the (S) Designator expires (32)

Date Signed (Authorized Representative) Name (Manufacturer)

(33) **CERTIFICATE OF SHOP INSPECTION**

Boiler constructed by at .

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by

have inspected parts of this boiler referred to as data items (34) and have examined Manufacturer's Partial Data Reports for items (35) and state that, to the best of my knowledge and belief, the manufacturer has constructed this boiler in accordance with Section I of the ASME BOILER AND PRESSURE VESSEL CODE.

By signing this certificate, neither the Inspector nor the Inspector's employer makes any warranty, expressed or implied, concerning the boiler described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor the Inspector's employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date Signed (Authorized Inspector) Commission (36) [National Board Authorized Inspector Commission Number]

(37) **CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE**

We certify that the field assembly construction of all parts of this boiler conforms with the requirements of Section I of the ASME BOILER AND PRESSURE VESSEL CODE.

Our Certificate of Authorization no. (38) to use the (A) or (S) (38) Designator expires (38)

Date Signed (Authorized Representative) Name (Assembler)

(39) **CERTIFICATE OF FIELD ASSEMBLY INSPECTION**

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by

have compared statements in this Manufacturer's Data Report with the described boiler and state that the parts referred to as data items (40), not included in the certificate of shop inspection, have been inspected by me and that, to the best of my knowledge and belief, the manufacturer and/or the assembler has constructed and assembled this boiler in accordance with the applicable sections of the ASME BOILER AND PRESSURE VESSEL CODE. The described boiler was inspected and subjected to a hydrostatic test of (38).

By signing this certificate, neither the Inspector nor the Inspector's employer makes any warranty, expressed or implied, concerning the boiler described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor the Inspector's employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date Signed (Authorized Inspector) Commission (36) [National Board Authorized Inspector Commission Number]

(07/23)

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