

Table of Contents

	Page No.
<i>Personnel</i>	v
<i>Foreword</i>	xi
<i>List of Tables</i>	xviii
<i>List of Figures</i>	xx
1. General Requirements	1
1.1 Scope	1
1.2 Limitations	1
1.3 Definitions	1
1.4 Responsibilities	2
1.5 Approval	2
1.6 Welding Symbols	3
1.7 Safety Precautions	3
1.8 Standard Units of Measurement	3
1.9 Reference Documents	3
2. Design of Welded Connections	5
2.0 Scope of Section 2	5
Part A—Common Requirements for Design of Welded Connections (Nontubular and Tubular Members)	5
2.1 Scope of Part A	5
2.2 Contract Plans and Specifications	5
2.3 Effective Areas	6
Part B—Specific Requirements for Design of Nontubular Connections (Statically or Cyclically Loaded)	8
2.4 General	8
2.5 Stresses	8
2.6 Joint Configuration and Details	9
2.7 Joint Configuration and Details—Groove Welds	10
2.8 Joint Configuration and Details—Fillet Welded Joints	10
2.9 Joint Configuration and Details—Plug and Slot Welds	11
2.10 Filler Plates	11
2.11 Built-Up Members	11
Part C—Specific Requirements for Design of Nontubular Connections (Cyclically Loaded)	12
2.12 General	12
2.13 Limitations	12
2.14 Calculation of Stresses	12
2.15 Allowable Stresses and Stress Ranges	12
2.16 Detailing, Fabrication, and Erection	14
2.17 Prohibited Joints and Welds	14
2.18 Inspection	15
Part D—Specific Requirements for Design of Tubular Connections (Statically or Cyclically Loaded)	15
2.19 General	15
2.20 Allowable Stresses	15
2.21 Identification	16
2.22 Symbols	16

Page No.

2.23 Weld Design.....	16
2.24 Limitations of the Strength of Welded Connections.....	17
2.25 Thickness Transition	22
2.26 Material Limitations.....	22
3. Prequalification of WPSs.....	57
3.1 Scope.....	57
3.2 Welding Processes	57
3.3 Base Metal/Filler Metal Combinations	57
3.4 Engineer's Approval for Auxiliary Attachments	58
3.5 Minimum Preheat and Interpass Temperature Requirements.....	58
3.6 Limitation of WPS Variables	58
3.7 General WPS Requirements.....	58
3.8 Common Requirements for Parallel Electrode and Multiple Electrode SAW.....	59
3.9 Fillet Weld Requirements	59
3.10 Plug and Slot Weld Requirements	59
3.11 Common Requirements of PJP and CJP Groove Welds.....	59
3.12 PJP Requirements	59
3.13 CJP Groove Weld Requirements	60
3.14 Postweld Heat Treatment	61
4. Qualification	121
4.0 Scope.....	121
Part A—General Requirements	121
4.1 General	121
4.2 Common Requirements for WPS and Welding Personnel Performance Qualification.....	122
Part B—Welding Procedure Specification (WPS).....	122
4.3 Production Welding Positions Qualified.....	122
4.4 Type of Qualification Tests.....	122
4.5 Weld Types for WPS Qualification	122
4.6 Preparation of WPS.....	122
4.7 Essential Variables	123
4.8 Methods of Testing and Acceptance Criteria for WPS Qualification	123
4.9 CJP Groove Welds for Nontubular Connections	125
4.10 PJP Groove Welds for Nontubular Connections.....	125
4.11 Fillet Welds for Tubular and Nontubular Connections.....	125
4.12 CJP Groove Welds for Tubular Connections.....	126
4.13 PJP Tubular T-, Y-, or K-Connections and Butt Joints	127
4.14 Plug and Slot Welds for Tubular and Nontubular Connections.....	127
4.15 Welding Processes Requiring Qualification	127
4.16 WPS Requirement (GTAW)	127
4.17 WPS Requirements (ESW/EGW)	127
Part C—Performance Qualification	128
4.18 General	128
4.19 Type of Qualification Tests Required	128
4.20 Weld Types for Welder and Welding Operator Performance Qualification	128
4.21 Preparation of Performance Qualification Forms	129
4.22 Essential Variables	129
4.23 CJP Groove Welds for Nontubular Connections	129
4.24 PJP Groove Welds for Nontubular Connections	129
4.25 Fillet Welds for Nontubular Connections	129

	Page No.
4.26 CJP Groove Welds for Tubular Connections.....	129
4.27 PJP Groove Welds for Tubular Connections	130
4.28 Fillet Welds for Tubular Connections.....	130
4.29 Plug and Slot Welds for Tubular and Nontubular Connections.....	130
4.30 Methods of Testing and Acceptance Criteria for Welder and Welding Operator Qualification	130
4.31 Method of Testing and Acceptance Criteria for Tack Welder Qualification.....	131
4.32 Retest.....	131
 <u>Part D—Requirements for CVN Testing</u>	 131
4.33 General	131
4.34 Test Locations	132
4.35 CVN Tests.....	132
4.36 Test Requirements.....	132
4.37 Retest.....	133
4.38 Reporting.....	133
 5. Fabrication	 189
5.1 Scope.....	189
5.2 Base Metal.....	189
5.3 Welding Consumables and Electrode Requirements	189
5.4 ESW and EGW Processes.....	191
5.5 WPS Variables	191
5.6 Preheat and Interpass Temperatures	191
5.7 Heat Input Control for Quenched and Tempered Steels	192
5.8 Stress-Relief Heat Treatment	192
5.9 Backing, Backing Gas, or Inserts.....	192
5.10 Backing	193
5.11 Welding and Cutting Equipment.....	193
5.12 Welding Environment	193
5.13 Conformance with Design	193
5.14 Minimum Fillet Weld Sizes	193
5.15 Preparation of Base Metal.....	194
5.16 Reentrant Corners	195
5.17 Beam Copes and Weld Access Holes	195
5.18 Temporary and Tack Welds	196
5.19 Camber in Built-Up Members.....	196
5.20 Splices in Cyclically Loaded Structures	196
5.21 Control of Distortion and Shrinkage	196
5.22 Tolerance of Joint Dimensions	197
5.23 Dimensional Tolerance of Welded Structural Members.....	198
5.24 Weld Profiles.....	200
5.25 Technique for Plug and Slot Welds	200
5.26 Repairs	201
5.27 Peening	202
5.28 Caulking	202
5.29 Arc Strikes.....	202
5.30 Weld Cleaning.....	202
5.31 Weld Tabs	202
 6. Inspection	 209
Part A—General Requirements.....	209
6.1 Scope	209
6.2 Inspection of Materials and Equipment	210

	Page No.
6.3 Inspection of WPSs	210
6.4 Inspection of Welder, Welding Operator, and Tack Welder Qualifications.....	210
6.5 Inspection of Work and Records.....	210
 Part B—Contractor Responsibilities	211
6.6 Obligations of the Contractor.....	211
 Part C—Acceptance Criteria	211
6.7 Scope	211
6.8 Engineer’s Approval for Alternate Acceptance Criteria.....	211
6.9 Visual Inspection.....	211
6.10 PT and MT	211
6.11 NDT	212
6.12 RT.....	212
6.13 UT	213
 Part D—NDT Procedures	214
6.14 Procedures	214
6.15 Extent of Testing	215
 Part E—Radiographic Testing (RT).....	215
6.16 RT of Groove Welds in Butt Joints.....	215
6.17 RT Procedures	215
6.18 Supplementary RT Requirements for Tubular Connections.....	217
6.19 Examination, Report, and Disposition of Radiographs.....	218
 Part F—Ultrasonic Testing (UT) of Groove Welds.....	218
6.20 General	218
6.21 Qualification Requirements	218
6.22 UT Equipment.....	218
6.23 Reference Standards.....	219
6.24 Equipment Qualification	219
6.25 Calibration for Testing	220
6.26 Testing Procedures	220
6.27 UT of Tubular T-, Y-, and K-Connections	222
6.28 Preparation and Disposition of Reports	223
6.29 Calibration of the UT Unit with IIW or Other Approved Reference Blocks (Annex H)	223
6.30 Equipment Qualification Procedures	224
6.31 Discontinuity Size Evaluation Procedures	226
6.32 Scanning Patterns	226
6.33 Examples of dB Accuracy Certification	226
 Part G—Other Examination Methods	226
6.34 General Requirements	226
6.35 Radiation Imaging Systems	227
<u>6.36 Advanced Ultrasonic Systems</u>	<u>227</u>
6.37 Additional Requirements	227
 7. Stud Welding	265
7.1 Scope	265
7.2 General Requirements	265
7.3 Mechanical Requirements	266
7.4 Workmanship	266
7.5 Technique	266
7.6 Stud Application Qualification Requirements	267

	Page No.
7.7 Production Control	268
7.8 Fabrication and Verification Inspection Requirements	269
8. Strengthening and Repairing Existing Structures	273
8.1 General	273
8.2 Base Metal	273
8.3 Design for Strengthening and Repair	273
8.4 Fatigue Life Enhancement	273
8.5 Workmanship and Technique	274
8.6 Quality	274
<i>Annexes</i>	<i>275</i>
<u>Cross Reference for Renumbered Annexes from the 2004 Code to the 2006 Code</u>	<u>276</u>
Annex A (Normative)—Effective Throat	277
Annex B (Normative)—Effective Throats of Fillet Welds in Skewed T-Joints	279
Annex C (Normative)—Weld Quality Requirements for Tension Joints in Cyclically Loaded Structures	281
Annex D (Normative)—Flatness of Girder Webs—Statically Loaded Structures	283
Annex E (Normative)—Flatness of Girder Webs—Cyclically Loaded Structures	287
Annex F (Normative)—Temperature-Moisture Content Charts	293
Annex G (Normative)—Manufacturers' Stud Base Qualification Requirements	297
Annex H (Normative)—Qualification and Calibration of UT Units with Other Approved Reference Blocks	301
Annex I (Normative)—Guideline on Alternative Methods for Determining Preheat	305
Annex J (Normative)—Symbols for Tubular Connection Weld Design	315
Annex K (Informative)—Terms and Definitions	317
Annex L (Informative)—Guide for Specification Writers	325
Annex M (Informative)—UT Equipment Qualification and Inspection Forms	327
Annex N (Informative)—Sample Welding Forms	337
Annex O (Informative)—Guidelines for the Preparation of Technical Inquiries for the Structural Welding Committee	349
Annex P (Informative)—Local Dihedral Angle	351
Annex Q (Informative)—Contents of Prequalified WPS	357
Annex R (Informative)—Safe Practices	359
Annex S (Informative)—UT Examination of Welds by Alternative Techniques	363
Annex T (Informative)—Ovalizing Parameter Alpha	379
Annex U (Informative)—List of Reference Documents	381
Annex V (Informative)—Filler Metal Strength Properties	383
<i>Commentary</i>	<i>389</i>
<i>Foreword</i>	<i>391</i>
Index	491
List of AWS Documents on Structural Welding	503

List of Tables

Table		Page No.
2.1	Effective Size of Flare-Groove Welds <u>Filled Flush</u>	23
2.2	Z Loss Dimension (Nontubular)	23
2.3	Allowable Stresses	24
2.4	Fatigue Stress Design Parameters	25
2.5	Allowable Stresses in Tubular Connection Welds.....	35
2.6	Stress Categories for Type and Location of Material for Circular Sections	37
2.7	Fatigue Category Limitations on Weld Size or Thickness and Weld Profile (Tubular Connections).....	39
2.8	Z Loss Dimensions for Calculating Prequalified PJP T-, Y-, and K-Tubular Connection Minimum Weld Sizes.....	39
2.9	Terms for Strength of Connections (Circular Sections).....	40
3.1	Prequalified Base Metal—Filler Metal Combinations for Matching Strength	62
3.2	Prequalified Minimum Preheat and Interpass Temperature	66
3.3	Filler Metal Requirements for Exposed Bare Applications of Weathering Steels	69
3.4	Minimum Prequalified PJP Weld Size (E)	69
3.5	Joint Detail Applications for Prequalified CJP T-, Y-, and K-Tubular Connections	69
3.6	Prequalified Joint Dimensions and Groove Angles for CJP Groove Welds in Tubular T-, Y, and K-Connections Made by SMAW, GMAW-S, and FCAW	70
3.7	Prequalified WPS Requirements.....	71
4.1	WPS Qualification—Production Welding Positions Qualified by Plate, Pipe, and Box Tube Tests	134
4.2	WPS Qualification—CJP Groove Welds: Number and Type of Test Specimens and Range of Thickness and Diameter Qualified.....	135
4.3	Number and Type of Test Specimens and Range of Thickness Qualified—WPS Qualification; PJP Groove Welds	137
4.4	Number and Type of Test Specimens and Range of Thickness Qualified—WPS Qualification; Fillet Welds	137
4.5	PQR Essential Variable Changes Requiring WPS Requalification for SMAW, SAW, GMAW, FCAW, and GTAW	138
4.6	PQR Supplementary Essential Variable Changes for CVN Testing Applications Requiring WPS Requalification for SMAW, SAW, GMAW, FCAW, and GTAW	141
4.7	PQR Essential Variable Changes Requiring WPS Requalification for ESW or EGW	142
4.8	<u>Table 3.1, Table 4.9, and Unlisted Steels Qualified by PQR</u>	143
4.9	<u>Code-Approved Base Metals and Filler Metals Requiring Qualification per Section 4</u>	144
4.10	<u>Welder and Welding Operator Qualification—Production Welding Positions Qualified by</u> Plate, Pipe, and Box Tube Tests	145
4.11	<u>Welder and Welding Operator Qualification—Number and Type of Specimens and Range of</u> Thickness and Diameter Qualified.....	146
4.12	<u>Welding Personnel Performance Essential Variable Changes Requiring Requalification</u>	150
4.13	<u>Electrode Classification Groups</u>	150
4.14	<u>CVN Test Requirements</u>	151
4.15	<u>CVN Test Temperature Reduction</u>	151
5.1	Allowable Atmospheric Exposure of Low-Hydrogen Electrodes	203
5.2	Minimum Holding Time	203
5.3	Alternate Stress-Relief Heat Treatment	203
5.4	Limits on Acceptability and Repair of Mill Induced Laminar Discontinuities in Cut Surfaces.....	203
5.5	Tubular Root Opening Tolerances	204

Table

	Page No.
5.6 Camber Tolerance for Typical Girder.....	204
5.7 Camber Tolerance for Girders without a Designed Concrete Haunch	204
5.8 Minimum Fillet Weld Sizes	204
6.1 Visual Inspection Acceptance Criteria.....	229
6.2 UT Acceptance-Rejection Criteria (Statically Loaded Nontubular Connections).....	230
6.3 UT Acceptance-Rejection Criteria (Cyclically Loaded Nontubular Connections)	231
6.4 Hole-Type IQI Requirements.....	232
6.5 Wire IQI Requirements	232
6.6 IQI Selection and Placement.....	233
6.7 Testing Angle.....	234
7.1 Mechanical Property Requirements for Studs	270
7.2 Minimum Fillet Weld Size for Small Diameter Studs	270
<u>B.1</u> Equivalent Fillet Weld Leg Size Factors for Skewed T-Joints	280
<u>D.1</u> <u>Intermediate Stiffeners on Both Sides of Web</u>	284
<u>D.2</u> <u>No Intermediate Stiffeners</u>	284
<u>D.3</u> <u>Intermediate Stiffeners on One Side Only of Web</u>	285
<u>E.1</u> <u>Intermediate Stiffness on Both Sides of Web, Interior Girders</u>	288
<u>E.2</u> <u>Intermediate Stiffness on One Side Only of Web, Fascia Girders</u>	289
<u>E.3</u> <u>Intermediate Stiffness on One Side Only of Web, Interior Girders</u>	290
<u>E.4</u> <u>Intermediate Stiffness on Both Sides of Web, Fascia Girders</u>	291
<u>E.5</u> <u>No Intermediate Stiffeners, Interior or Fascia Girders</u>	291
<u>I.1</u> Susceptibility Index Grouping as Function of Hydrogen Level "H" and Composition Parameter P_{cm}	308
<u>I.2</u> Minimum Preheat and Interpass Temperatures for Three Levels of Restraint	308
<u>S.1</u> Acceptance-Rejection Criteria	377

Commentary

C-2.1 Survey of Diameter/Thickness and Flat Width/Thickness Limits for Tubes.....	412
C-2.2 Suggested Design Factors	413
C-2.3 Values of JD.....	413
C-2.4 Structural Steel Plates	414
C-2.5 Structural Steel Pipe and Tubular Shapes	415
C-2.6 Structural Steel Shapes.....	415
C-2.7 Classification Matrix for Applications.....	416
C-2.8 CVN Testing Conditions.....	416
<u>C-3.1</u> Typical Current Ranges for GMAW-S on Steel	429
C-4.1 CVN Test Values	439
C-4.2 HAZ CVN Test Values	439
C-6.1 UT Acceptance Criteria for 2 in. [50 mm] Welding, Using a 70° Probe	467
C-8.1 Guide to Welding Suitability	478
C-8.2 Relationship Between Plate Thickness and Burr Radius	478

List of Figures

Figure	Page No.
2.1 Maximum Fillet Weld Size Along Edges in Lap Joints.....	41
2.2 Transition of Butt Joints in Parts of Unequal Thickness (Nontubular).....	42
2.3 Transition of Widths (Nontubular)	43
2.4 Transversely Loaded Fillet Welds	43
2.5 Minimum Length of Longitudinal Fillet Welds at End of Plate or Flat Bar Members.....	44
2.6 Termination of Welds Near Edges Subject to Tension.....	44
2.7 End Return at Flexible Connections	45
2.8 Fillet Welds on Opposite Sides of a Common Plane	45
2.9 Thin Filler Plates in Splice Joint	46
2.10 Thick Filler Plates in Splice Joint	46
2.11 Allowable Stress Range for Cyclically Applied Load (Fatigue) in Nontubular Connections (Graphical Plot of Table 2.4)	47
2.12 Transition of Width (Cyclically Loaded Nontubular).....	48
2.13 Allowable Fatigue Stress and Strain Ranges for Stress Categories (see Table 2.6), Redundant Tubular Structures for Atmospheric Service	48
2.14 Parts of a Tubular Connection	49
2.15 Fillet Welded Lap Joint (Tubular)	52
2.16 Tubular T-, Y-, and K-Connection Fillet Weld Footprint Radius	52
2.17 Punching Shear Stress	53
2.18 Detail of Overlapping Joint.....	53
2.19 Limitations for Box T-, Y-, and K-Connections.....	54
2.20 Overlapping K-Connections	54
2.21 Transition of Thickness of Butt Joints in Parts of Unequal Thickness (Tubular).....	55
3.1 Weld Bead in which Depth and Width Exceed the Width of the Weld Face	72
3.2 Fillet Welded Prequalified Tubular Joints Made by SMAW, GMAW, and FCAW	72
3.3 Prequalified PJP Groove Welded Joint Details (Dimensions in Millimeters)	74
3.4 Prequalified CJP Groove Welded Joint Details (Dimensions in Inches).....	90
3.5 Prequalified Joint Details for PJP T-, Y-, and K-Tubular Connections.....	112
3.6 Prequalified Joint Details for CJP T-, Y-, and K-Tubular Connections	115
3.7 Definitions and Detailed Selections for Prequalified CJP T-, Y-, and K-Tubular Connections.....	116
3.8 Prequalified Joint Details for CJP Groove Welds in Tubular T-, Y-, and K-Connections— Standard Flat Profiles for Limited Thickness	117
3.9 Prequalified Joint Details for CJP Groove Welds in Tubular T-, Y-, and K-Connections— Profile with Toe Fillet for Intermediate Thickness	118
3.10 Prequalified Joint Details for CJP Groove Welds in Tubular T-, Y-, and K-Connections— Concave Improved Profile for Heavy Sections or Fatigue	119
3.11 Prequalified Skewed T-Joint Details (Nontubular).....	120
4.1 Positions of Groove Welds	152
4.2 Positions of Fillet Welds	153
4.3 Positions of Test Plates for Groove Welds	154
4.4 Positions of Test Pipe or Tubing for Groove Welds	155
4.5 Positions of Test Plate for Fillet Welds	156
4.6 Positions of Test Pipes or Tubing for Fillet Welds	157
4.7 Location of Test Specimens on Welded Test Pipe	158
4.8 Location of Test Specimens for Welded Box Tubing.....	159

Figure	Page No.
4.9 Location of Test Specimens on Welded Test Plates—ESW and EGW—WPS Qualification	160
4.10 Location of Test Specimens on Welded Test Plate Over 3/8 in. [10 mm] Thick—WPS Qualification ...	161
4.11 Location of Test Specimens on Welded Test Plate 3/8 in. [10 mm] Thick and Under— WPS Qualification	162
4.12 Face and Root Bend Specimens.....	163
4.13 Side Bend Specimens.....	164
4.14 Reduced-Section Tension Specimens	165
4.15 Guided Bend Test Jig	166
4.16 Alternative Wraparound Guided Bend Test Jig	167
4.17 Alternative Roller-Equipped Guided Bend Test Jig for Bottom Ejection of Test Specimen	167
4.18 All-Weld-Metal Tension Specimen	168
4.19 Fillet Weld Soundness Tests for WPS Qualification	169
4.20 Pipe Fillet Weld Soundness Test—WPS Qualification	170
4.21 Test Plate for Unlimited Thickness—Welder Qualification	171
4.22 Test Plate for Unlimited Thickness—Welding Operator Qualification.....	171
4.23 Location of Test Specimen on Welded Test Plate 1 in. [25 mm] Thick—Consumables Verification for Fillet Weld WPS Qualification	172
4.24 Tubular Butt Joint—Welder or WPS Qualification—without Backing	173
4.25 Tubular Butt Joint—WPS Qualification with and without Backing	173
4.26 Acute Angle Heel Test (Restraints not Shown)	174
4.27 Test Joint for T-, Y-, and K-Connections without Backing on Pipe or Box Tubing—Welder and WPS Qualification	175
<u>4.28 Test Joint for T-, Y-, and K-Connections without Backing on Pipe or Box Tubing (<4 in. [100 mm] O.D.)—Welder and WPS Qualification</u>	<u>176</u>
4.29 Corner Macroetch Test Joint for T-, Y-, and K-Connections without Backing on Box Tubing for CJP Groove Welds—Welder and WPS Qualification.....	177
4.30 Optional Test Plate for Unlimited Thickness—Horizontal Position—Welder Qualification	178
4.31 Test Plate for Limited Thickness—All Positions—Welder Qualification	179
4.32 Optional Test Plate for Limited Thickness—Horizontal Position—Welder Qualification.....	180
4.33 Fillet Weld Root Bend Test Plate—Welder or Welding Operator Qualification—Option 2	181
4.34 Location of Test Specimens on Welded Test Pipe and Box Tubing—Welder Qualification	182
4.35 Method of Rupturing Specimen—Tack Welder Qualification	183
4.36 Butt Joint for Welding Operator Qualification—ESW and EGW	183
4.37 Fillet Weld Break and Macroetch Test Plate—Welder or Welding Operator Qualification— Option 1.....	184
4.38 Plug Weld Macroetch Test Plate—Welding Operator or Welder Qualification.....	185
4.39 Fillet Weld Break Specimen—Tack Welder Qualification.....	186
<u>4.40 CVN Test Specimen Locations.....</u>	<u>187</u>
5.1 Edge Discontinuities in Cut Material.....	205
5.2 Weld Access Hole Geometry	206
5.3 Workmanship Tolerances in Assembly of Groove Welded Joints	207
5.4 Acceptable and Unacceptable Weld Profiles	208
6.1 Weld Quality Requirements for Elongated Discontinuities as Determined by RT for Statically Loaded Nontubular Structures	237
6.2 Maximum Acceptable RT Images per 6.12.3.1	238
6.3 For RT of Tubular Joints 1-1/8 in. [30 mm] and Greater, Typical of Random Acceptable Discontinuities	239
6.4 Weld Quality Requirements for Discontinuities Occurring in Cyclically Loaded Nontubular Tension Welds (Limitations of Porosity and Fusion Discontinuities).....	240
6.5 Weld Quality Requirements for Discontinuities Occurring in Cyclically Loaded Nontubular Compression Welds (Limitations of Porosity or Fusion-Type Discontinuities).....	241
6.6 Weld Quality Requirements for Elongated Discontinuities as Determined by RT of Tubular Joints	242
6.7 Class R Indications.....	247

Figure	Page No.
6.8 Class X Indications	249
6.9 Hole-Type IQI.....	250
6.10 Wire IQI	251
6.11 RT Identification and Hole-Type or Wire IQI Locations on Approximately Equal Thickness Joints 10 in. [250 mm] and Greater in Length	252
6.12 RT Identification and Hole-Type or Wire IQI Locations on Approximately Equal Thickness Joints Less than 10 in. [250 mm] in Length.....	253
6.13 RT Identification and Hole-Type or Wire IQI Locations on Transition Joints 10 in. [250 mm] and Greater in Length	254
6.14 RT Identification and Hole-Type or Wire IQI Locations on Transition Joints Less than 10 in. [250 mm] in Length	255
6.15 RT Edge Blocks	255
6.16 Single-Wall Exposure—Single-Wall View.....	256
6.17 Double-Wall Exposure—Single-Wall View	256
6.18 Double-Wall Exposure—Double-Wall (Elliptical) View, Minimum Two Exposures	257
6.19 Double-Wall Exposure—Double-Wall View, Minimum Three Exposures	257
6.20 Transducer Crystal	258
6.21 Qualification Procedure of Search Unit Using IIW Reference Block	258
6.22 International Institute of Welding (IIW) UT Reference Blocks	259
6.23 Qualification Blocks	260
6.24 Plan View of UT Scanning Patterns	262
6.25 Scanning Techniques	263
6.26 Transducer Positions (Typical)	264
7.1 Dimension and Tolerances of Standard-Type Shear Connectors	271
7.2 Typical Tension Test Fixture	271
7.3 Torque Testing Arrangement and Table of Testing Torques.....	272
<u>F.1</u> Temperature-Moisture Content Chart to be Used in Conjunction with Testing Program to Determine Extended Atmospheric Exposure Time of Low-Hydrogen SMAW Electrodes	294
<u>F.2</u> Application of Temperature-Moisture Content Chart in Determining Atmospheric Exposure Time of Low-Hydrogen SMAW Electrodes	295
<u>G.1</u> Bend Testing Device	299
<u>G.2</u> Suggested Type of Device for Qualification Testing of Small Studs	299
<u>H.1</u> Other Approved Blocks and Typical Transducer Position	303
<u>I.1</u> Zone Classification of Steels.....	310
<u>I.2</u> Critical Cooling Rate for 350 VH and 400 VH	310
<u>I.3</u> Graphs to Determine Cooling Rates for Single-Pass SAW Fillet Welds	311
<u>I.4</u> Relation Between Fillet Weld Size and Energy Input	314
<u>S.1</u> Standard Reference Reflector	368
<u>S.2</u> Recommended Calibration Block	368
<u>S.3</u> Typical Standard Reflector (Located in Weld Mock-Ups and Production Welds)	369
<u>S.4</u> Transfer Correction	370
<u>S.5</u> Compression Wave Depth (Horizontal Sweep Calibration).....	370
<u>S.6</u> Compression Wave Sensitivity Calibration	371
<u>S.7</u> Shear Wave Distance and Sensitivity Calibration	371
<u>S.8</u> Scanning Methods.....	372
<u>S.9</u> Spherical Discontinuity Characteristics	373
<u>S.10</u> Cylindrical Discontinuity Characteristics	373
<u>S.11</u> Planar Discontinuity Characteristics	374
<u>S.12</u> Discontinuity Height Dimension	374
<u>S.13</u> Discontinuity Length Dimension	375
<u>S.14</u> Display Screen Marking.....	375
<u>S.15</u> Report of UT (Alternative Procedure).....	376
<u>T.1</u> Definition of Terms for Computed Alpha.....	379

Figure	Page No.
<i>Commentary</i>	
C-2.1	Balancing of Fillet Welds About a Neutral Axis 417
C-2.2	Shear Planes for Fillet and Groove Welds 417
C-2.3	Eccentric Loading 418
C-2.4	Load Deformation Relationship for Welds 418
C-2.5	Single Fillet Welded Lap Joints 418
C-2.6	Illustrations of Branch Member Stresses Corresponding to Mode of Loading 418
C-2.7	Improved Weld Profile Requirements 419
C-2.8	Simplified Concept of Punching Shear 419
C-2.9	Reliability of Punching Shear Criteria Using Computed Alpha 420
C-2.10	Transition Between Gap and Overlap Connections 421
C-2.11	Upper Bound Theorem 421
C-2.12	Yield Line Patterns 422
<u>C-3.1</u>	<u>Oscillograms and Sketches of GMAW-S Metal Transfer</u> 429
<u>C-3.2</u>	<u>Examples of Centerline Cracking</u> 430
<u>C-3.3</u>	<u>Details of Alternative Groove Preparations for Prequalified Corner Joints</u> 430
C-4.1	Type of Welding on Pipe That Does Not Require Pipe Qualification 439
C-5.1	Examples of Unacceptable Reentrant Corners 449
C-5.2	Examples of Good Practice for Cutting Copes 449
C-5.3	Permissible Offset in Abutting Members 450
C-5.4	Correction of Misaligned Members 450
C-5.5	Typical Method to Determine Variations in Girder Web Flatness 451
C-5.6	Illustration Showing Camber Measurement Methods 452
C-5.7	Measurement of Flange Warpage and Tilt 453
C-5.8	Tolerances at Bearing Points 454
C-6.1	90° T- or Corner Joints with Steel Backing 468
C-6.2	Skewed T- or Corner Joints 468
C-6.3	Butt Joints with Separation Between Backing and Joint 469
C-6.4	Effect of Root Opening on Butt Joints with Steel Backing 469
C-6.5	Scanning with Seal Welded Steel Backing 470
C-6.6	Resolutions for Scanning with Seal Welded Steel Backing 470
C-8.1	Microscopic Intrusions 479
C-8.2	Fatigue Life 479
C-8.3	Toe Dressing with Burr Grinder 480
C-8.4	Toe Dressing Normal to Stress 480
C-8.5	Effective Toe Grinding 481
C-8.6	End Grinding 481
C-8.7	Hammer Peening 482
C-8.8	Toe Remelting 483