

Rules for

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# Materials and Welding

Part 2



January 2022



**RULES FOR**

**MATERIALS AND WELDING**  
**JANUARY 2022**

**PART 2**

**American Bureau of Shipping  
Incorporated by Act of Legislature of  
the State of New York 1862**

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# PART 2

## Foreword (1 July 2021)

For the 1996 edition, the “*Rules for Building and Classing Steel Vessels – Part 2: Materials and Welding*” was re-titled “*Rule Requirements for Materials and Welding (Part 2)*.” The purpose of this generic title was to emphasize the common applicability of the material and welding requirements in “Part 2” to ABS classed vessels, other marine structures and their associated machinery, and thereby make “Part 2” more readily a common “Part” of the various ABS Rules and Guides, as appropriate.

Accordingly, the subject booklet, *Rules for Materials and Welding (Part 2)*, is to be considered, for example, as being applicable and comprising a “Part” of the following ABS Rules and Guides:

- *Rules for Building and Classing Marine Vessels*
- *Rules for Building and Classing Steel Vessels for Service on Rivers and Intracoastal Waterways*
- *Rules for Building and Classing Mobile Offshore Units*
- *Rules for Building and Classing Steel Barges*
- *Rules for Building and Classing High-Speed Craft*
- *Rules for Building and Classing Floating Production Installations*
- *Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels*
- *Guide for Building and Classing Liftboats*
- *Guide for Building and Classing International Naval Ships*
- *Guide for Building and Classing Yachts*

In the 2002 edition, Section 4, “Piping” was added to Part 2, Chapter 4, “Welding and Fabrication”. This Section is applicable only to piping to be installed on vessels to be built in accordance with the *ABS Rules for Building and Classing Marine Vessels*, or the *ABS Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels*.

In the 2004 edition, Part 2 was reorganized to incorporate the new divisions “Rules for Testing and Certification of Materials,” comprised of Chapters 1, 2 and 3 and Appendices 1, 4, 5, 6 and 7, and “Rules for Welding and Fabrication,” comprised of Chapter 4 and Appendices 2 and 3. This reorganization was purely an editorial change intended to clarify the requirements for the materials themselves and for construction, respectively, and does not contain any technical changes.

In the 2018 edition, Part 2 was consolidated to include both the *ABS Rules for Materials and Welding (Part 2)* and the *ABS Rules for Materials and Welding (Part 2) – Aluminum and Fiber Reinforced Plastics (FRP)*.



# PART 2

## Materials and Welding

### CONTENTS

<b>CHAPTER 1</b>	<b>Materials for Hull Construction.....</b>	<b>1</b>
Section 1	General Requirements.....	9
Section 2	Ordinary-strength Hull Structural Steel .....	28
Section 3	Higher-strength Hull Structural Steel .....	39
Section 4	Low Temperature Materials.....	48
Section 5	Hull Steel Castings.....	50
Section 6	Hull Steel Forgings.....	56
Section 7	Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks (2014).....	62
Section 8	Extra High Strength Steel (2018).....	68
<b>CHAPTER 2</b>	<b>Equipment.....</b>	<b>79</b>
Section 1	Anchors .....	83
Section 2	Anchor Chain .....	97
Section 3	Rolled Steel Bars for Chain, Cast and Forged Materials for Accessories and Materials for Studs .....	116
<b>CHAPTER 3</b>	<b>Materials for Machinery, Boilers, Pressure Vessels, and Piping. 121</b>	
Section 1	General Requirements.....	138
Section 2	Steel Plates for Machinery, Boilers and Pressure Vessels.....	149
Section 3	Seamless Forged-steel Drums.....	159
Section 4	Seamless-steel Pressure Vessels.....	160
Section 5	Boiler and Superheater Tubes.....	161
Section 6	Boiler Rivet and Staybolt Steel and Rivets.....	176
Section 7	Steel Machinery Forgings.....	178
Section 8	Hot-rolled Steel Bars for Machinery.....	213
Section 9	Steel Castings for Machinery, Boilers and Pressure Vessels.....	214
Section 10	Ductile (Nodular) Iron Castings (2006) .....	220
Section 11	Gray-iron Castings (2006).....	229

Section 12	Steel Piping.....	235
Section 13	Piping, Valves and Fittings for Low-temperature Service[ Below -18°C (0°F) ] .....	254
Section 14	Bronze Castings.....	257
Section 15	Austenitic Stainless Steel Propeller Castings.....	262
Section 16	Seamless Copper Piping (1998).....	265
Section 17	Seamless Red-brass Piping.....	269
Section 18	Seamless Copper Tube (1998).....	272
Section 19	Condenser and Heat Exchanger Tube (1998).....	276
Section 20	Copper-Nickel Tube and Pipe (1998).....	283
Section 21	Monel Pipe and Tube (1999).....	290
<b>CHAPTER 4</b>	<b>Welding and Fabrication.....</b>	<b>298</b>
Section 1	Hull Construction.....	306
	Appendix 1 - Welding In Way of Water Backing.....	314
Section 2	Boilers, Unfired Pressure Vessels, Piping and Engineering Structures*.....	319
Section 3	Weld Tests.....	344
Section 4	Piping.....	369
Section 5	Aluminum Welding in Hull Construction (2018).....	377
<b>CHAPTER 5</b>	<b>Materials for Hull Construction – Aluminum.....</b>	<b>409</b>
Section 1	General.....	414
Section 2	Standard Test Methods.....	418
Section 3	Chemical Composition.....	419
Section 4	Heat Treatment.....	421
Section 5	Tensile Properties.....	422
Section 6	Corrosion Testing.....	434
Section 7	Sheet, Plate and Rolled Products.....	436
Section 8	Extrusions.....	438
Section 9	Forgings.....	441
Section 10	Castings.....	443
Section 11	Rivets.....	445
Appendix 1	Aluminum/Steel Bi-material Transition Joints (2015).....	446
Appendix 2	Dissimilar Materials (2015).....	453
Appendix 3	List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying (2017).....	454
<b>CHAPTER 6</b>	<b>Materials for Hull Construction – Fiber Reinforced Plastics (FRP).....</b>	<b>456</b>
Section 1	General.....	461
Section 2	Fabrication.....	468
Section 3	Building Process Description.....	470

	Section 4	Quality Control.....	481
	Section 5	Testing.....	488
	Section 6	Repair.....	490
<b>APPENDIX 1</b>		<b>Tests Required for Materials, and Responsibility for Verifying...</b>	<b>504</b>
	Section 1	List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying.	505
<b>APPENDIX 2</b>		<b>Requirements for the Approval of Filler Metals.....</b>	<b>512</b>
	Section 1	General.....	517
	Section 2	Electrodes for Shielded Metal Arc Welding.....	531
	Section 3	Wire-Flux Combinations for Submerged Arc Welding...	538
	Section 4	Wire and Wire Gas Combinations for Gas Metal Arc Welding and Flux Cored Wires for Flux Cored Arc Welding.....	547
	Section 5	Requirements for the Approval of Aluminum Filler Metals (2018).....	555
<b>APPENDIX 3</b>		<b>Application of Filler Metals to ABS Steels.....</b>	<b>561</b>
	Section 1	Application of Filler Metals to ABS Steels (2014).....	562
<b>APPENDIX 4</b>		<b>Procedure for the Approval of Manufacturers of Hull Structural Steel (2003).....</b>	<b>564</b>
	Section 1	Procedure for the Approval of Manufacturers of Semi-Finished Products for Hull Structural Steel (2010).....	566
	Section 2	Procedure for the Approval of Manufacturers of Rolled Hull Structural Steel (2010).....	572
	Section 3	Procedure for the Approval of Manufacturers of Extra High Strength Steels (2018).....	581
<b>APPENDIX 5</b>		<b>Hull Structural Steels Intended for Welding with High Heat Input.....</b>	<b>593</b>
	Section 1	<b>Procedure for the Approval of Manufacturers of Hull Structural Steels Intended for Welding with High Heat Input (2006) .....</b>	<b>594</b>
<b>APPENDIX 6</b>		<b>Nondestructive Examination of Marine Steel Castings (2014)....</b>	<b>598</b>
	Section 1	General .....	600
	Section 2	Surface Inspection .....	601
	Section 3	Volumetric Inspection.....	606
	Annex 1	General Location for the Type of Nondestructive Examinations of Typical Hull Steel Castings.....	609

<b>APPENDIX 7</b>	<b>Nondestructive Examination of Hull and Machinery Steel Forgings (2014).....</b>	<b>614</b>
	Section 1 General .....	616
	Section 2 Surface Inspection .....	617
	Section 3 Volumetric Inspection.....	628
<b>APPENDIX 8</b>	<b>Steel with Enhanced Corrosion Resistance Properties.....</b>	<b>636</b>
	Section 1 Additional Approval Procedure for Steel with Enhanced Corrosion Resistance Properties (2014).....	637
<b>APPENDIX 9</b>	<b>Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014).....</b>	<b>640</b>
	Section 1 General Requirements.....	642
	Annex 1 Location of Charpy V-Notch Impact Test.....	657
	Annex 2 Hardness Test ( <i>Typical examples of hardness test</i> ).....	659
	Annex 3 Welding Positions.....	664
<b>APPENDIX 10</b>	<b>Procedure for the Approval of Aluminum Manufacturers.....</b>	<b>668</b>
	Section 1 Scheme for the Approval of Aluminum Manufacturers..	669
<b>APPENDIX 11</b>	<b>Qualification for Welders and Welding Operators.....</b>	<b>673</b>
	Section 1 General.....	676
	Section 2 Welders Qualification for Hull Structures*.....	677
	Section 3 Welding Operators Qualification.....	693
	Section 4 Certification Process.....	694
	Annex 1 Example of Welder's Qualification Certificate.....	695
<b>APPENDIX 12</b>	<b>Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules.....</b>	<b>697</b>
	Section 1 Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules.....	698

# PART 2

## CHAPTER 1

### Materials for Hull Construction

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General Requirements.....</b>	<b>9</b>
	1	Testing and Inspection .....	9
	1.1	General.....	9
	1.2	Manufacturer Approval (2003).....	9
	1.3	Test and Test Data.....	10
	1.5	Certification on the Basis of the ABS Quality Assurance Program for Rolled Products.....	10
	1.7	Rejection of Previously Accepted Material.....	10
	1.9	Calibrated Testing Machines (2005).....	10
	1.11	Structural Pipe (2016).....	10
	1.13	ASTM References (1998).....	10
	3	Surface Quality.....	11
	3.1	General.....	11
	3.3	Manufacturer Responsibility.....	11
	3.5	Acceptance Criteria.....	11
	3.7	Repair.....	11
	3.9	Bars, Shapes and Tubulars.....	12
	5	Identification of Materials .....	12
	7	Manufacturer's Certificates .....	13
	7.1	Form of Certificate.....	13
	7.2	Electronic Certification System (2017).....	13
	7.3	Other Certificates (2015).....	13
	9	Marking and Retests .....	14
	9.1	Identification of Specimens.....	14
	9.3	Defects in Specimens.....	14
	9.5	Retests.....	14
	9.7	Rejected Material.....	14
	11	Standard Test Specimens .....	14
	11.1	General (2005).....	14
	11.3	Test Specimens Orientation.....	14
	11.5	Tension Test Specimens, Plates and Shapes (1996).....	14



	11.7	Tension Test Specimens for Castings (other than Gray Cast Iron) and Forgings (2006).....	14
	11.9	Bend Test Specimens, Castings and Forgings (2005).....	15
	11.11	Impact Test Specimens (2013).....	15
	11.13	Tolerances (1998).....	15
13		Definition and Determination of Yield Point and Yield Strength ...	15
	13.1	Yield Point (2005).....	15
	13.3	Yield Strength (2005).....	15
	13.5	Tensile Strength (2005).....	16
14		Elongation (2005).....	16
15		Permissible Variations in Dimensions (1994) .....	16
	15.1	Scope (2002).....	16
	15.3	Plates and Wide Flats.....	16
	15.5	Shapes and Bars.....	20
16		Rolled Plates over 100 mm (4 in.) Thick (2016).....	20
17		Steel Plates and Wide Flats with Specified Minimum Through Thickness Properties (“Z” Quality) (2013).....	23
	17.1	Sampling.....	23
	17.3	Number of Tensile Test Specimens.....	24
	17.5	Tensile Test Specimen Dimensions.....	24
	17.7	Tensile Test Results.....	24
	17.9	Retests.....	25
	17.11	Ultrasonic Inspection (2007).....	25
	17.13	Marking.....	25
	17.15	Certification (2013).....	25
19		Formed Materials .....	26
21		Ultrasonic Examination of Plate and Wide Flats .....	26
	21.1	.....	26
	21.3	.....	26
23		Fracture Toughness Testing (2006).....	26
	23.1	.....	26
	23.3	.....	26
	23.5	.....	26
	23.6	(2009).....	27
	23.7	.....	27
	23.9	.....	27
	23.11	.....	27
	23.13	.....	27
	23.15	.....	27
	23.17	.....	27
	TABLE 1	Batch Size Depending Upon Product and Sulfur Content (2005).....	24
	TABLE 2	Reduction of Area Acceptance Values (2005).....	25

FIGURE 1	(1 July 2013).....	18
FIGURE 2	Standard Tension Test Specimen <sup>(1)</sup> (1995).....	20
FIGURE 3	Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length (2008).....	21
FIGURE 4	Charpy V-notch Impact Test Specimens (2015).....	22
FIGURE 5	Plate and Wide Flat Sampling Position (2005).....	24
FIGURE 6	Diagram Showing Acceptance/Rejection and Retest Criteria (2005).....	25

<b>SECTION</b>	<b>2 Ordinary-strength Hull Structural Steel .....</b>	<b>28</b>
1	Ordinary-strength Hull Structural Steel.....	28
3	Process of Manufacture.....	28
3.1	Plates Produced from Coils.....	28
5	Chemical Composition.....	28
5.1	Ladle Analysis.....	28
5.3	Product Analysis.....	28
5.5	Special Compositions.....	29
5.7	Fine Grain Practice.....	29
7	Condition of Supply.....	29
7.1	As Rolled – AR.....	29
7.3	Heat Treatment.....	29
7.5	Controlled Manufacturing Process.....	30
7.7	Quenching and Tempering – QT.....	30
9	Tensile Properties.....	30
9.1	Required Tensile Properties.....	30
9.3	Tension Test Specimens.....	30
9.5	Exceptions.....	31
9.7	<No Text> (2007).....	31
9.9	Omission of Elongation Requirements.....	31
9.11	Retests (1996).....	31
9.13	Unsatisfactory Tests.....	31
11	Impact Properties.....	31
11.1	Impact Tests.....	31
11.3	Impact Test Frequency.....	32
11.5	Initial Test Requirements (2015).....	32
11.7	Retests.....	32
11.9	Unsatisfactory Tests.....	32
11.11	Thin Plates or Tubulars.....	32
13	Marking.....	32
13.1	Stamped or Stenciled Material.....	32
13.3	Coils, Lifts and Bundles.....	33
13.5	Flanging-quality Identification (2015).....	33
13.7	Special Stamping and Marking.....	33
13.9	Special Impact Testing.....	33

13.11	Steel with Improved Through Thickness Properties.....	33
13.13	Steel with Ultrasonic Examination.....	33
13.15	Shipping Procedure.....	33
13.17	Steel at Secondary Sources.....	33
15	Surface Finish.....	34
15.1	Surface Examination (2008).....	34
15.3	Treatment of Surface Defects -Plates.....	34
15.4	Treatment of Surface Defects - Tubulars.....	34
15.5	Treatment of Surface Defects -Shapes.....	34
15.7	Bar-stock Repairs.....	34
15.9	Rivet Steel and Rivets (1996).....	35

TABLE 1	Chemical Properties of Ordinary Strength Hull Structural Steel 150 mm (6.0 in.) and Under.....	35
TABLE 2	Tensile Properties of Ordinary Strength Hull Structural Steel 150 mm (6.0 in.) and Under.....	36
TABLE 3	Elongation Requirements for Alternative B Specimen (1995).....	36
TABLE 4	Impact Properties of Ordinary-Strength Hull Structural Steel 150 mm (6.0 in.) and Under.....	36
TABLE 5	Condition of Supply and Frequency of Impact Tests Ordinary Strength Hull Structural Steel.....	37

**SECTION 3 Higher-strength Hull Structural Steel ..... 39**

1	Higher-strength Hull Structural Steel .....	39
3	General (1996) .....	39
5	Fine Grain Practice (1996) .....	39
7	Additional Requirements of TMCP Steel (1996) .....	40
7.1	Carbon Equivalent.....	40
7.3	Cold Cracking Susceptibility.....	40

TABLE 1	Chemical Properties of Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under.....	40
TABLE 2	Tensile Properties of Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under .....	41
TABLE 3	Elongation Requirements for Alternative B Specimen (1996).....	42
TABLE 4	Impact Properties of Higher-strength Steel 150 mm (6.0 in.) and Under.....	42
TABLE 5	Condition of Supply and Frequency of Impact Tests Higher-strength Hull Structural Steel.....	44
TABLE 6	Carbon Equivalent for Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under Produced by TMCP.....	47

**SECTION 4 Low Temperature Materials..... 48**

1	General .....	48
3	Marking .....	48
5	Toughness Tests .....	48
5.1	Charpy V-notch.....	48
5.3	Drop-weight Test.....	48
7	Service Temperature 0°C (32°F) or Above .....	48
9	Service Temperature at or Above -55°C (-67°F) up to 0°C (32°F) (2018).....	49
11	Service Temperature at or Above -196°C (-320°F) up to -55°C (-67°F) .....	49
13	Service Temperatures below -196°C (-320°F) .....	49
<b>SECTION 5</b>	<b>Hull Steel Castings.....</b>	<b>50</b>
1	Process of Manufacture (2005).....	50
1.1	General (2012).....	50
1.3	Chemical Composition (2006).....	50
3	Marking and Retests (2005).....	51
3.1	Marking.....	51
3.3	Retests.....	51
5	Heat Treatment (2017).....	51
7	Mechanical Properties .....	52
7.1	Ordinary Grade Castings (2006).....	52
7.3	Special Grade Castings (2006).....	52
9	Test Specimens.....	53
9.1	Material Coupons (2016).....	53
9.3	Separately Cast Coupons.....	53
11	Number of Tests (2005).....	53
13	Inspection and Repair (2005).....	54
13.1	General (2008).....	54
13.3	Minor Defects (2006).....	54
13.5	Major Defects.....	54
13.7	Welded Repair (2018).....	54
13.9	Post Weld Repair Heat Treatment.....	55
13.11	Non-destructive Testing.....	55
15	Certification (2005).....	55
<b>SECTION 6</b>	<b>Hull Steel Forgings.....</b>	<b>56</b>
1	Process of Manufacture .....	56
1.1	General (2017).....	56
1.3	Degree of Reduction (2005).....	56
1.5	Discard.....	57
1.7	Chemical Composition (2008).....	57
3	Marking and Retests (2005).....	57
3.1	Marking.....	57

	3.3	Retests.....	57
5		Heat Treatment .....	58
	5.1	General (2017).....	58
	5.3	Cooling Prior to Heat Treatment.....	58
	5.5	Annealing.....	58
	5.7	Normalizing.....	59
	5.9	Tempering (2005).....	59
7		Tensile Properties (2008).....	59
9		Test Specimens .....	59
	9.1	Location and Orientation of Specimens.....	59
	9.3	Hollow-drilled Specimens.....	59
	9.5	Small Forgings.....	59
	9.7	Specimen Identification (2015).....	60
11		Number of Tests .....	60
	11.1	Tension Test.....	60
	11.3	Brinell Hardness Test.....	60
	11.5	Special Situations.....	60
	11.7	Examination (2008).....	60
	11.9	Rectification of Defective Forgings (2018).....	61
13		Certification (2005).....	61

**SECTION 7 Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks (2014).....62**

1		Scope.....	62
	1.1	.....	62
	1.3	.....	62
	1.5	.....	62
	1.7	.....	62
	1.9	.....	63
3		Approval.....	63
	3.1	.....	63
	3.3	.....	63
	3.5	.....	63
5		Method of Manufacture.....	63
	5.1	.....	63
7		Chemical Composition.....	63
	7.1	.....	63
	7.3	.....	63
	7.5	.....	64
	7.7	.....	64
9		Condition of Supply.....	64
	9.1	.....	64
11		Mechanical Properties.....	64
	11.1	.....	64

13	Surface Quality .....	64
15	Tolerances.....	64
	15.1 .....	64
17	Identification of Materials.....	64
	17.1 .....	64
	17.3 .....	64
19	Testing and Inspection.....	64
	19.1 Facilities for Inspection.....	64
	19.3 Testing Procedures.....	65
	19.5 Through Thickness Tensile Tests.....	65
	19.7 Ultrasonic Inspection.....	65
	19.9 Surface Inspection and Dimensions.....	65
21	Test Material.....	65
	21.1 .....	65
23	Test Specimens.....	65
	23.1 Mechanical Test Specimens.....	65
25	Number of Test Specimens.....	65
	25.1 .....	65
27	Retest Procedures.....	65
	27.1 .....	65
29	Marking.....	65
	29.1 .....	65
	29.3 .....	66
	29.5 .....	66
	29.7 .....	66
31	Documentation.....	66
	31.1 .....	66
	31.3 .....	66
	31.5 .....	66
	31.7 .....	66
	31.9 .....	66
	31.11 .....	67
	31.13 .....	67

<b>SECTION 8</b>	<b>Extra High Strength Steel (2018).....</b>	<b>68</b>
1	General.....	68
2	<b>Method of Manufacture .....</b>	<b>68</b>
3	<b>Delivery Condition – Rolling Process and Heat Treatment ...</b>	<b>69</b>
	3.1 Rolling Reduction Ratio.....	69
	3.3 Thickness Limits.....	69
4	<b>Chemical Composition .....</b>	<b>70</b>
5	Mechanical Properties.....	72
	5.1 Tensile Test.....	73

5.3	Impact Test.....	73
5.5	Through Thickness Tensile Test.....	73
5.7	Test Frequency.....	73
5.9	Traceability.....	74
5.11	Re-test.....	74
7	Tolerances.....	76
9	Surface Quality.....	76
9.1	Plate Edge Inspection.....	76
11	Internal Soundness.....	76
11.1	Ultrasonic Examination.....	76
13	Stress Relieving Heat Treatment and Other Heat Treatments.....	76
15	Fabrication & Welding.....	77
17	Facilities for Inspection.....	77
19	Identification of Materials.....	77
21	Marking.....	77
23	Documentation of Inspection Tests.....	77
TABLE 1	Steel Category Based on Minimum Yield Strength (2018)...	68
TABLE 2	Steel Grade Suffix Based on Test Temperature (2018).....	68
TABLE 3	Maximum Thickness Limits.....	70
TABLE 4A	Chemical Composition.....	71
TABLE 4B	Maximum $C_{eq}$ , $CET$ and $P_{cm}$ Values <sup>(1,2)</sup> .....	72
TABLE 5A	Mechanical Properties Requirements (2018).....	74
TABLE 5B	Requirements for Alternative Specimen <sup>(1)</sup> (2018).....	75

## **1 Testing and Inspection**

### **1.1 General**

All materials subject to test and inspection, intended for use in the construction of hulls and equipment of vessels classed or proposed for classification, are to be to the satisfaction of the Surveyor and in accordance with the following requirements or their equivalent. Materials, test specimens and mechanical testing procedures having characteristics differing from those prescribed herein may be approved upon application, due regard being given to established practices in the country in which the material is produced and the purpose for which the material is intended, such as the parts for which it is to be used, the type of vessel and intended service, and the nature of the construction of the vessel.

### **1.2 Manufacturer Approval (2003)**

#### **1.2.1 (2019)**

All products for hull construction are to be manufactured at steel works approved by ABS for the type and grade of steel contemplated. The suitability of the products for welding and assumed forming is to be demonstrated during the initial approval test at the steel works. Approval of the steel works for rolled products is to be in accordance with Part 2, Appendix 4. Refer to 2-1-1/1.11 for structural pipe. Structural pipe for hull construction refers to stanchions, pillars and truss members integral to the hull.

#### **1.2.2 (2006)**

It is the manufacturer's responsibility to assure that effective procedures and production controls are implemented during the production, and that the manufacturing specifications are adhered to. Should any deviation from the procedures and controls occur that could produce an inferior product, the manufacturer is to carry out a thorough investigation to determine the cause of the mishap and establish countermeasures to prevent its recurrence. The complete investigation report is to be submitted to the Surveyor. ABS reserves the right to request a closer survey until the cause is resolved to the satisfaction of the Surveyor. Each affected piece is to be tested to the satisfaction of the attending Surveyor prior to distribution from the steel works. In addition, the frequency of testing for subsequent products may be increased to gain confidence in the quality.

#### **1.2.3**

Where the steel is not produced at the rolling mill, the procedures in 2-1-1/7.3 are to be followed.



#### 1.2.4 (2011)

It is the manufacturer's responsibility to ensure that raw materials used/semi-finished/finished cast or wrought steel products produced are within radioactive contamination limits as permitted by an appropriate regulatory body/agency, as applicable to the place of manufacture. Radiation level and reference to the allowed limits are to be specified and documented in manufacturer's QA/QC procedures.

### 1.3 Test and Test Data

#### 1.3.1 Witnessed Tests

The designation (W) indicates that a Surveyor is to witness the testing unless the plant is enrolled and product is manufactured under ABS's Quality Assurance Program.

#### 1.3.2 Manufacturer's Data

The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

#### 1.3.3 Other Tests

The designation (A) indicates those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with Rule requirements.

See Part 2, Appendix 1 for complete listing of indicated designations for the various tests called out by Part 2, Chapter 1 and Part 2, Chapter 2 of this Part.

### 1.5 Certification on the Basis of the ABS Quality Assurance Program for Rolled Products

Upon application, consideration will be given to the acceptance of plates, shapes and bars without witnessing of mechanical tests by the Surveyor, on the basis of compliance with ABS's Quality Assurance Program.

### 1.7 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing.

### 1.9 Calibrated Testing Machines (2005)

The Surveyor is to be satisfied that the testing machines are maintained in a satisfactory and accurate condition. Additionally, the Surveyor is to keep a record of the dates and by whom the machines were rechecked or calibrated. All tests are to be carried out to a recognized national or international Standard by competent personnel.

### 1.11 Structural Pipe (2016)

Unless otherwise indicated (e.g., 3-1-4/1.1 of the *ABS Rules for Building and Classing Mobile Offshore Units*), pipes intended for structural use are to be tested to the applicable specification or physical requirements of Section 2-3-12, as applicable.

### 1.13 ASTM References (1998)

Frequent references will be found within Part 2, Chapter 1 through Part 2, Chapter 3 to various American Society for Testing and Materials (ASTM) specification designations without year notations. Unless otherwise noted, the current issue of the ASTM specification is to be used.

### 3 Surface Quality (1 July 2018)

#### 3.1 General

The steel is to be free from cracks, injurious surface flaws, injurious laminations and similar defects prejudicial to the use of the material for the intended application.

The finished material is to have a surface quality in accordance with a recognized standard such as EN 10163 Parts 1 (General), 2 (Plates), or ASTM A6 or an equivalent standard accepted by ABS, unless otherwise specified in this Section. In case there is conflict between the requirements, the more stringent requirements are to be followed.

#### 3.3 Manufacturer Responsibility

The responsibility for meeting the surface quality requirements rests with the manufacturer of the material, who is to take the necessary manufacturing precautions and is to inspect the products prior to delivery. At that stage, however, rolling or heat treatment scale may conceal surface discontinuities and defects. If, during the subsequent descaling or working operations, the material is found to be defective, ABS may require materials to be repaired or rejected.

##### 3.3.1

The surface quality inspection method shall be in accordance with recognized national or international standard agreed between purchaser and manufacturer, accepted by ABS.

##### 3.3.2

If agreed by the manufacturer and purchaser, steel may be ordered with improved surface quality over and above these requirements.

#### 3.5 Acceptance Criteria

##### 3.5.1 Imperfections

Imperfections, for example pitting, rolled-in scale, indentations, roll marks, scratches and grooves, regarded as being inherent to the manufacturing process, are permissible irrespective of their number, provided the maximum permissible limits of Class A of EN 10163-2 or limits specified in a recognized equivalent standard accepted by ABS, are not exceeded and the remaining plate or wide flat thickness remains within the average allowable minus thickness tolerances specified in 2-1-1/15. Total affected area with imperfections not exceeding the specified limits are not to exceed 15% of the total surface on each side.

##### 3.5.2 Defects

Affected areas with imperfections with a depth exceeding the limits of Class A of EN10163-2 or the maximum permissible limits specified in a recognized equivalent standard accepted by ABS, shall be repaired irrespective of their number.

Cracks, injurious surface flaws, shells (over lapping material with non-metallic inclusion), sand patches, laminations and sharp edged seams (elongated defects) visually evident on surface and/or edge of plate are considered defects, which would impair the end use of the product and which required rejection or repair, irrespective of their size and number.

#### 3.7 Repair

##### 3.7.1 Grinding Repair

Unless otherwise agreed, grinding may be applied provided all the conditions below are adhered to:

- i) The nominal product thickness will not be reduced by more than 7% or 3 mm (0.12 in.), whichever is the less.

- ii)* Each single ground area below the minimum thickness does not exceed 0.25 m<sup>2</sup> (2.7 ft<sup>2</sup>).
- iii)* All ground areas below the minimum thickness do not exceed 2% of the total surface in question.
- iv)* Ground areas lying in a distance less than their average width to each other are to be regarded as one single area.
- v)* Ground areas lying opposite each other on both surface shall not decrease the product thickness by values exceeding the limits as stated under i.

Defects or unacceptable imperfections are to be completely removed by grinding and the remaining plate or wide flat thickness shall remain within the average allowable thickness tolerance specified in 2-1-1/15. The ground areas are to have a smooth transition to the surrounding surface of the product. Complete elimination of the defect can be verified by visual inspection, Magnetic particle (MT) or liquid penetrant (LT) testing. Note: The NDE technique initially used to detect a defect is to be applied after grinding to verify defect removal. NDE operators are to be qualified to the satisfaction of the attending Surveyor.

NDE can be carried out in accordance with the manufacturer's conformance standard, provided the conformance standard is submitted to ABS Materials for acceptance.

### 3.7.2 Welding Repair

Weld repair procedures and the method for repair are to be reported and be approved by ABS. To confirm defects have been removed prior to weld repair, MP or LP may be required. Repair of defects such as unacceptable imperfections, cracks, shells or seams shall be followed by MP or LP testing.

Local defects which cannot be repaired by grinding as stated in 2-1-1/3.7.1 may be repaired by welding with the agreement of ABS subject to the following conditions:

- i)* Any single welded area shall not exceed 0.125 m<sup>2</sup> (1.35 ft<sup>2</sup>) and the sum of all areas shall not exceed 2% of the surface side in question.
- ii)* The distance between two welded areas shall not be less than their average width.
- iii)* The weld preparation shall not reduce the thickness of the product below 80% of the nominal thickness. For occasional defects with depths exceeding the 80% limit, special consideration at the Surveyor's discretion will be necessary.
- iv)* If weld repair depth exceeds 3 mm, UT may be requested by ABS. If required, UT shall be carried out in accordance with an approved procedure.
- v)* The repair shall be carried out by qualified welders using an approved procedure for the appropriate steel grade. The electrodes shall be of low hydrogen type and shall be dried in accordance with the manufacturer's requirements and protected against re-humidification before and during welding.

### 3.9 Bars, Shapes and Tubulars

The surface quality and condition requirement herein are not applied to products in forms of bars and tubulars, which will be subject to manufacturer's conformance standards.

## 5 Identification of Materials

The manufacturer is to adopt a system for the identification of ingots, slabs, finished plates, shapes, castings and forgings which will enable the material to be traced to its original heat and the Surveyor is to be given every facility for so tracing the material.

## 7 Manufacturer's Certificates

### 7.1 Form of Certificate

Unless requested otherwise, four copies of the certified mill test reports and shipping information (may be separate or combined documents) of all accepted material indicating the grade of material, heat identification numbers, test results and weight shipped are to be furnished to the Surveyor. One copy of the mill test report is to be endorsed by the Surveyor and forwarded to the Purchaser, and three are to be retained for the use of ABS. Before the certified mill tests reports and shipping information are distributed to the local ABS office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been made by an approved process and that it has satisfactorily withstood the prescribed tests. The following form of certificate will be accepted if printed on each certified mill test report with the name of the firm and initialed by the authorized representative of the manufacturer:

“We hereby certify that the material described herein has been made to the applicable specification by the \_\_\_\_\_ process (state process) and tested in accordance with the requirements of \_\_\_\_\_ (the American Bureau of Shipping Rules or state other specification) with satisfactory results.”

At the request of manufacturers, consideration may be given to modifications in the form of the certificate, provided it correspondingly indicates compliance with the requirements of the Rules to no less degree than indicated in the foregoing statement.

### 7.2 Electronic Certification System (2017)

An electronic certification system may be used to issue certified mill test reports, which may be electronically signed and stamped by the attending Surveyor, subject to the following conditions.

- All relevant information regarding the customer order, including the electronic certification request, is to be provided to the attending Surveyor by the manufacturer.
- Procedures are to be established to control handling and distribution of certified mill test reports among the manufacturer, ABS, and the purchaser.
- In order to implement the electronic certification system, the steel mills are to be under mandatory ABS QA program.
- The mills under ABS QA program are to implement security provisions that appropriately control electronic storage and protect unauthorized use of all electronic signatures provided by ABS.
- These provisions are to be assessed at the time of periodic and annual QA audits at the mill.

### 7.3 Other Certificates (2015)

Where steel is not produced in the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor stating the process by which it was manufactured, the name of the manufacturer who supplied it, the number of the heat from which it was made and the ladle analysis. The number of the heat is to be marked on each ingot, bloom, slab or billet for the purpose of identification.

Where the product is not heat treated in the works at which it is rolled, a certificate is to be supplied to the Surveyor by the works at which it is finally heat treated, stating the process by which it was rolled, the name of the manufacturer who supplied it, the heat number from which it was made and the ladle analysis. All heat treatment facilities are to be ABS approved, in association with qualification testing being carried out on the final product after final heat treatment. The heat treatment works should also supply the record of heat treatment, including heat treatment curves, indicating time and temperature, and heating and cooling rates.

## 9 Marking and Retests

### 9.1 Identification of Specimens

Where test specimens are required to be selected by the Surveyor, they are not to be detached until stamped with his identification mark, nor are they to be detached until the material has received its final treatment.

### 9.3 Defects in Specimens

If any test specimen shows defective machining or develops defects, it may be discarded and another specimen substituted, except that for forgings a retest is not allowed if a defect develops during testing which is caused by rupture, cracks or flakes in the steel.

### 9.5 Retests

If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than 19 mm (0.75 in.) from the center of the gauge length of a 50 mm (2 in.) specimen, or is outside the middle half of the gauge length of a 200 mm (8 in.) specimen, as indicated by scribe scratches marked on the specimen before testing, a retest is to be allowed.

### 9.7 Rejected Material

In the event that any set of test specimens fails to meet the requirements, the material from which such specimens have been taken is to be rejected and the required markings withheld or obliterated.

## 11 Standard Test Specimens

### 11.1 General (2005)

The tension test specimens are to be of the full thickness or section of material as rolled, except as otherwise specified. The specimens are to receive no other preparation than that prescribed and are to receive similarly and simultaneously all of the treatment given the material from which they are cut. Straightening of specimens distorted by shearing is to be carried out while the piece is cold. The accuracy of the tensile test machines is to be within  $\pm 1\%$  of the load.

### 11.3 Test Specimens Orientation

Tension test specimens are to be taken longitudinal to the final direction of rolling for plates equal to or less than 600 mm (24 in.) in width and transverse to the final direction of rolling for plates wider than 600 mm (24 in.), except for shapes and bars which are to be taken longitudinal to the final direction of rolling.

### 11.5 Tension Test Specimens, Plates and Shapes (1996)

#### 11.5.1 Flat Specimens

Tension test specimens for rolled plates, shapes and flats are to be cut from the finished material and machined to the form and dimensions referred to in 2-1-1/16 FIGURE 2 or tension test specimens of dimensions other than described may be approved at the request of the manufacturer.

#### 11.5.2 Round Specimens

For material over 19 mm (0.75 in.) in thickness or diameter, tension test specimens may be machined to dimensions referred to in 2-1-1/16 FIGURE 2. The axis of each round specimen is to be located as nearly as practicable midway between the center and the surface of the material. Tension test specimens of dimensions other than described above may be approved at the request of the manufacturer.

### 11.7 Tension Test Specimens for Castings (other than Gray Cast Iron) and Forgings (2006)

Tension test specimens for castings and forgings are to be machined to the form and dimensions shown in for the round specimen alternative C in 2-1-1/16 FIGURE 2 or in accordance with 2-1-1/16 FIGURE 3.

### 11.9 Bend Test Specimens, Castings and Forgings (2005)

When required, bend test specimens for castings and forgings may be machined to 25 mm × 20 mm (1 in. × 0.790 in.) in section. The length is unimportant provided it is enough to perform the bending operation. The edges on the tensile side of the bend test specimens may have the corners rounded to a radius of 1 - 2 mm (0.040 - 0.080 in.).

### 11.11 Impact Test Specimens (2013)

An impact test is to consist of three specimens taken from a single test coupon or test location. Impact test specimens are to be machined to the form, dimensions and tolerances shown in 2-1-1/16 FIGURE 4. Full size standard specimens are to be used unless the section thickness of the product is less than 11 mm ( $\frac{7}{16}$ "") or the absorbed energy is expected to exceed 80% of the test machine full scale capacity. For plates, flats and bars, the specimens are to be located with their edges within 2 mm (0.08 in.) from the surface, except that where the thickness exceeds 40 mm (1.57 in.), the longitudinal axis of the specimen is to be located at a point midway between the surface and the center of the thickness. These test specimens are to be cut with their longitudinal axes either longitudinal or transverse to the final direction of rolling of the material at the option of the steel manufacturer, unless a specific orientation is specified. The length of the notch is to be perpendicular to the original rolled surface. Also see 2-1-2/11.1 and 2-1-4/5.1, as applicable.

### 11.13 Tolerances (1998)

The tolerances of the tension test specimen dimensions are to be in accordance with a recognized national standard.

## 13 Definition and Determination of Yield Point and Yield Strength

### 13.1 Yield Point (2005)

The yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. The value of stress is measured at the commencement of plastic deformation at yield, or the value of stress measured at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield. Yield point may be determined by the halt of the pointer, or autographic diagram. The 0.5% total extension under load method will also be considered acceptable.

The test is to be carried out with an elastic stress within the following limits:

Modulus of Elasticity of the Material (E), N/mm <sup>2</sup>	Rate of Stressing, N/mm <sup>2</sup> -s <sup>-1</sup>	
	Min.	Max.
< 150,000	2	20
≥ 150,000	6	60

### 13.3 Yield Strength (2005)

The yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. When no well-defined yield phenomenon exists, yield strength is to be determined by the 0.2% ( $R_p 0.2$ ) offset method. Alternatively, for material whose stress-strain characteristics are well known from previous tests in which stress-strain diagrams were plotted, the 0.5% extension under load method may be used. When agreed upon between the supplier and purchaser for austenitic and duplex stainless steel products, the 1% proof stress ( $R_p 1$ ) may be determined in addition to  $R_p 0.2$ .

The rate of loading is to be as stated in the limits above.

### 13.5 Tensile Strength (2005)

After reaching the yield or proof load, for ductile material, the machine speed during the tensile test is not to exceed that corresponding to a strain rate of  $0.008 \text{ s}^{-1}$ . For brittle materials, such as gray cast iron, the elastic stress rate is not to exceed  $10 \text{ N/mm}^2$  per second.

## 14 Elongation (2005)

The elongation value is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one-third of the original gauge length. However, the result is valid irrespective of the location of the fracture if the percentage elongation after fracture is equal to or greater than the required value.

Generally, the elongation,  $A_5$ , is determined on a proportional gauge length,  $5.65\sqrt{S_0} = 5d$ , but may also be given for other specified gauge lengths.

If the material is a ferritic steel of low or medium strength and not cold worked, and the elongation is measured on a non-proportional gauge length, the required elongation,  $A_0$ , on that gauge length,  $L_0$ , may after agreement be calculated from the following formula:

$$A_0 = 2A_5 \left( \frac{\sqrt{S_0}}{L_0} \right)^{0.40}$$

## 15 Permissible Variations in Dimensions (1994)

### 15.1 Scope (2002)

The under tolerance specified below represents the minimum material certification requirements and is to be considered as the lower limit of the usual range of variations (plus/minus) from the specified dimension.

The responsibility for meeting the tolerances rests with the manufacturer who is to maintain a procedure acceptable to the Surveyor. Where any tolerance (including over thickness tolerance) to be used is more stringent than the normal commercial tolerance, ABS is to be advised before the steel is presented for acceptance to assure that the thickness measuring procedure is appropriate.

In all cases, the thickness of the steel is to comply with the under tolerance specified below. The steel mill is to consider the effect of mill scale on the resulting measurement.

For classification purposes, including the assessment of deterioration at future thickness gaugings, the thickness indicated on the approved plan is to be used.

### 15.3 Plates and Wide Flats (1 July 2019)

These requirements apply to the tolerance on thickness of steel plates and wide flats with widths of 600 mm (24 in.) or greater (hereinafter referred to as: product or products) with thicknesses of 5 mm (0.2 in.) and over, covering the following steel grades:

- i) Normal and higher strength hull structural steel.
- ii) Extra high strength steel for welded structure according to Section 2-1-8.

The thickness tolerances for products below 5 mm (0.2 in.) are to be in accordance with a national or international standard such as ASTM A6 or Class B of ISO 7452. However, the minus tolerance shall not exceed 0.3 mm (0.012 in.).

**Note:**

Tolerances for length, width, flatness and over thickness may be taken from recognized national or international standards.

Class C of ISO 7452 latest version, or equivalent recognized national or international standards, may be applied in lieu of 15.3.2, in which case the requirements in 15.3.3 and 15.3.4 need not be applied.

Additionally, if Class C ISO 7452 latest version is applied, it is required that the steel mill demonstrate to the satisfaction of ABS that the number of measurements and measurement distribution is appropriate to establish that the mother plates produced are at or above the specified nominal thickness.

### 15.3.1 Responsibility

The responsibility for verification and maintenance of the production within the required tolerances rests with the manufacturer. The Surveyor may require that he witness some measurements. The responsibility for storage and maintenance of the delivered product(s) with acceptable level of surface conditions rests with the shipyard before the products are used in fabrication.

### 15.3.2 Thickness Tolerances

15.3.2(a) Thickness tolerances of a given products are defined as:

- Minus tolerance is the lower limit of the acceptable range below the nominal thickness.
- Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

*Note:*

Nominal thickness is defined by the purchaser at the time of enquiry and order.

15.3.2(b) The minus tolerance on nominal thickness of products in the scope of 2-1-1/15.3 is 0.3 mm (0.012 in.) irrespective of nominal thickness.

15.3.2(c) Thickness tolerances are not applicable to areas repaired by grinding in accordance with 2-1-1/3.7.1, unless more stringent requirements are specified by the purchaser and agreed by ABS Materials Department.

15.3.2(d) Plus tolerances on nominal thickness are to be in accordance with a recognized national or international standard such as ASTM A6, unless otherwise specified by the purchaser and agreed by ABS Materials Department.

15.3.2(e) Weight tolerance may be specified by purchaser.

### 15.3.3 Average Thickness

15.3.3(a) The average thickness of a product is defined as the arithmetic mean of the measurements made in accordance with the requirements of 2-1-1/15.3.4.

15.3.3(b) The average thickness of the product is not to be less than the nominal thickness.

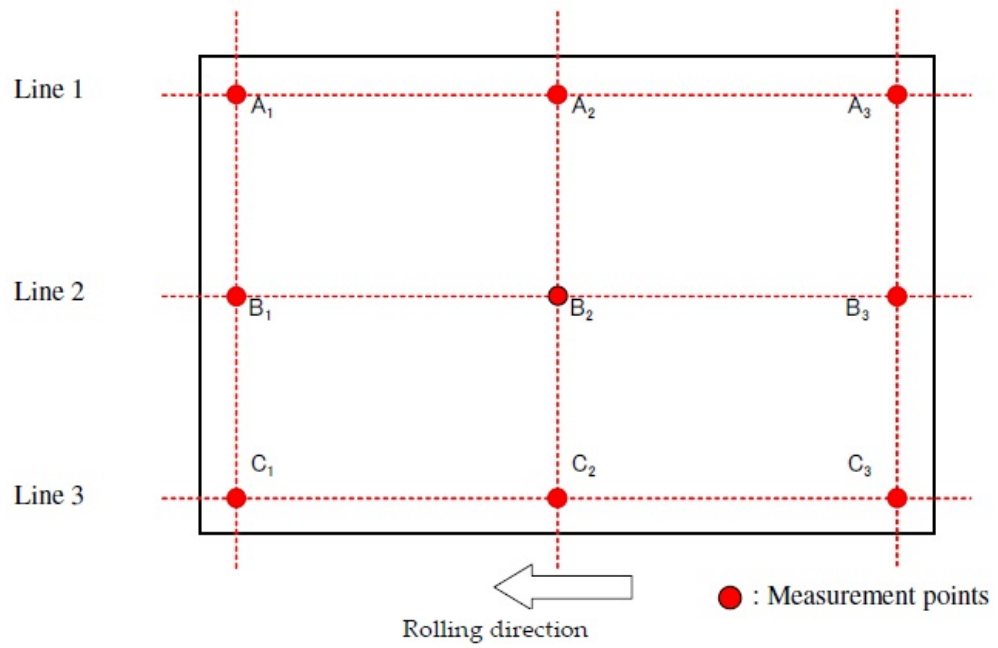
### 15.3.4 Thickness Measurements

15.3.4(a) Thickness is to be measured at locations as defined in 2-1-1/15.3.4 FIGURE 1. Automated or manual measurement methods may be used.

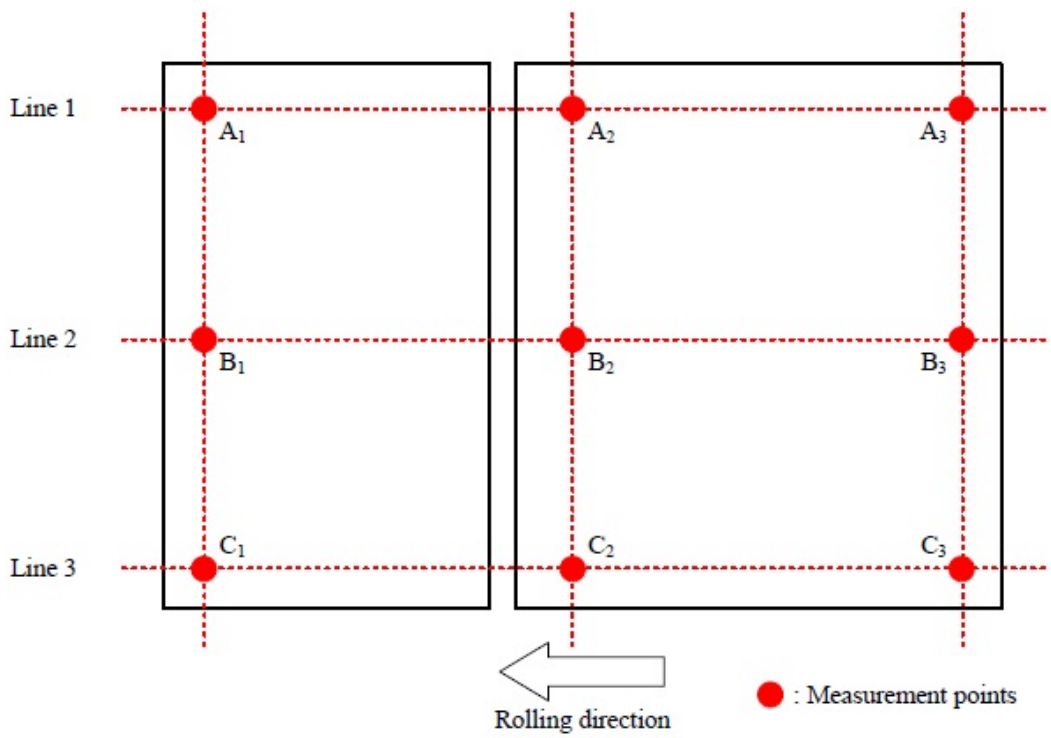
15.3.4(b) The procedure and records of measurements are to be made available to the Surveyor and copies provided on request.

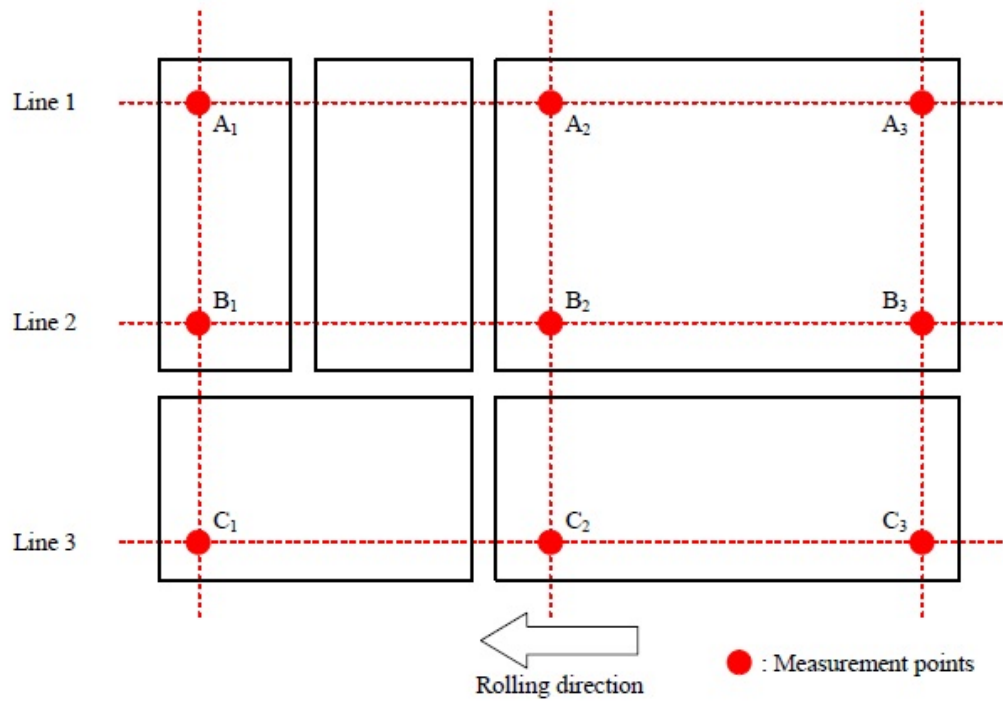
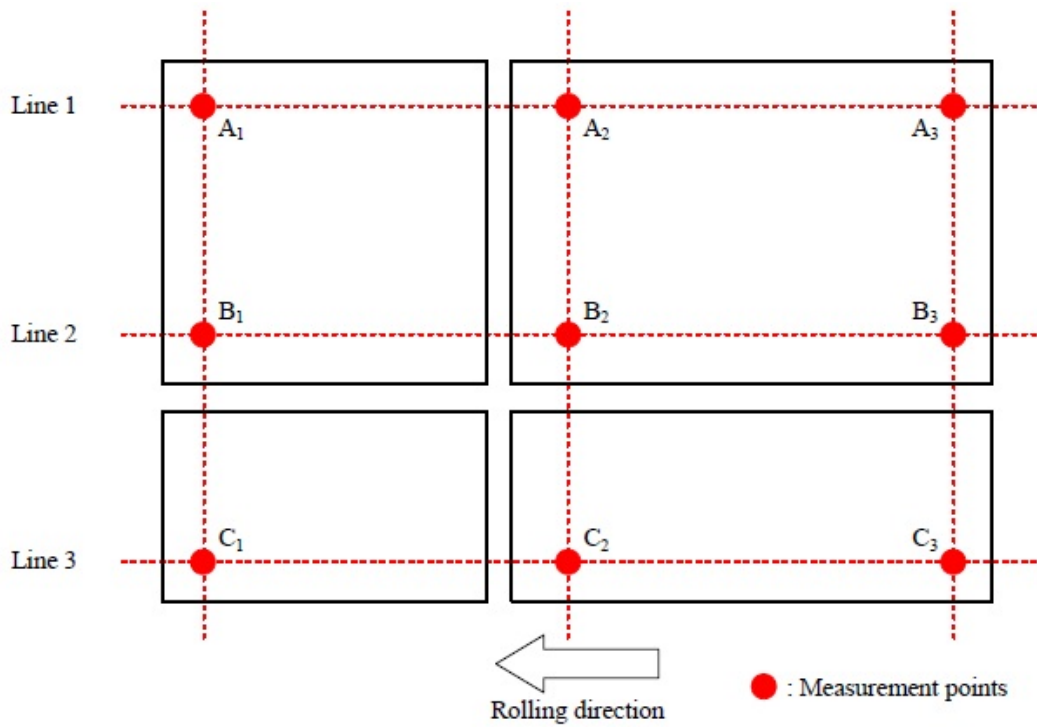


FIGURE 1 (1 July 2013)



a) Locations of Thickness Measuring Points for the Original Steel Plates





b) Locations of Thickness Measuring Points for the Cut Steel Products

*Notes:*

- 1 (1 July 2013) At least two lines are to be selected from Lines 1, 2, or 3 as shown, and at least three points on each selected line are to be selected for thickness measurement. If more than three points are taken on each Line, the number of points on each line is to be the same.  
 The measurement locations apply to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Examples of the original measurements relative to later cut products are shown in 2-1-1/15.3.4 FIGURE 1b). It is to be noted that the examples shown are not representative of all possible cutting scenarios.
- 2 For automated measuring, peripheral points are to be located 10-300 mm (0.375-12.0 in.) from the edge.
- 3 For manual measuring, peripheral points are to be located 10-100 mm (0.375-4.0 in.) from the edge.

### 15.5 Shapes and Bars

The under tolerance of cross sectional dimensions for shapes and bars are based on the ordered dimensions and are to conform to those given in ASTM A6 or other recognized standards as may be specified in the purchase order.

### 16 Rolled Plates over 100 mm (4 in.) Thick (2016)

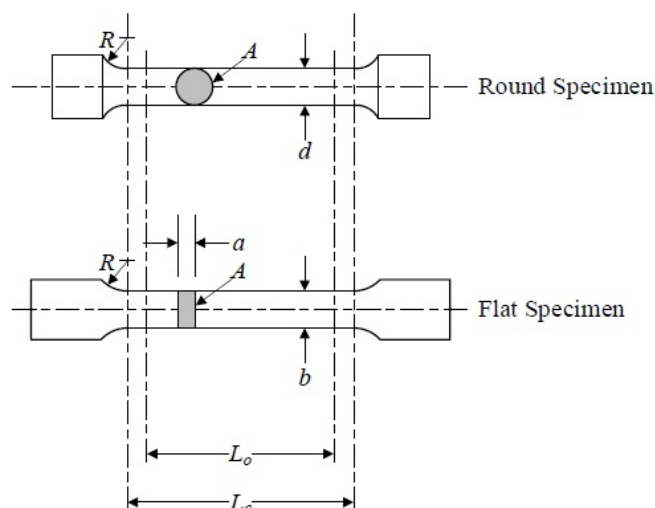
When ABS and non-ABS grade rolled plates of over 100 mm (4 in.) thickness are used for vessel hull structural application, in addition to chemical analysis the following test data is to be obtained at onequarter and mid thickness locations:

- Tensile properties, and
- Impact properties in the longitudinal or transverse directions

Also, each plate is to be UT inspected in accordance with either ASTM A578 Level B or another equivalent recognized standard to evaluate the internal soundness.

**FIGURE 2**  
**Standard Tension Test Specimen<sup>(1)</sup> (1995)**

- $d$  = diameter in mm
- $a$  = thickness in mm
- $b$  = width in mm
- $L_o$  = (2005) original gauge length in mm
- $L_c$  = (2005) parallel length in mm
- $A$  = (2005) original cross sectional area in  $\text{mm}^2$



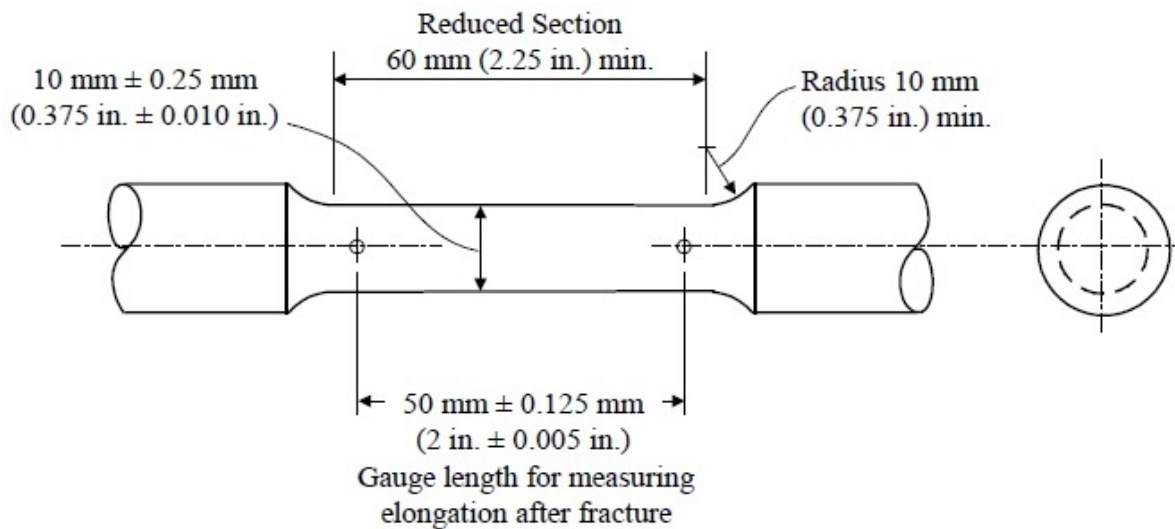
- $R$  = transition radius in mm

	$d$	$a$	$b$	$L_o$	$L_c$	$R$
Flat specimen Alternative A	-	$t^{(2)}$	25	$5.65\sqrt{A}$	$L_o + 2\sqrt{A}$	25
Flat specimen Alternative B	-	$t^{(2)}$	25	200	225	25
Round specimen Alternative C	14	-	-	70	85	10

**Notes:**

- 1 Standard specimen in accordance with ASTM E8/E8M or A370 will also be acceptable in conjunction with the corresponding elongation requirements in 2-1-2/15.9 TABLE 2 or 2-1-3/7.3 TABLE 2.
- 2  $t$  is the full thickness of the material as produced. If the capacity of the testing machine does not allow full thickness specimens to be broken, the thickness may be reduced by machining one surface only.
- 3 (2005)  $L_o$ , the proportional gauge length, is to be greater than 20 mm.

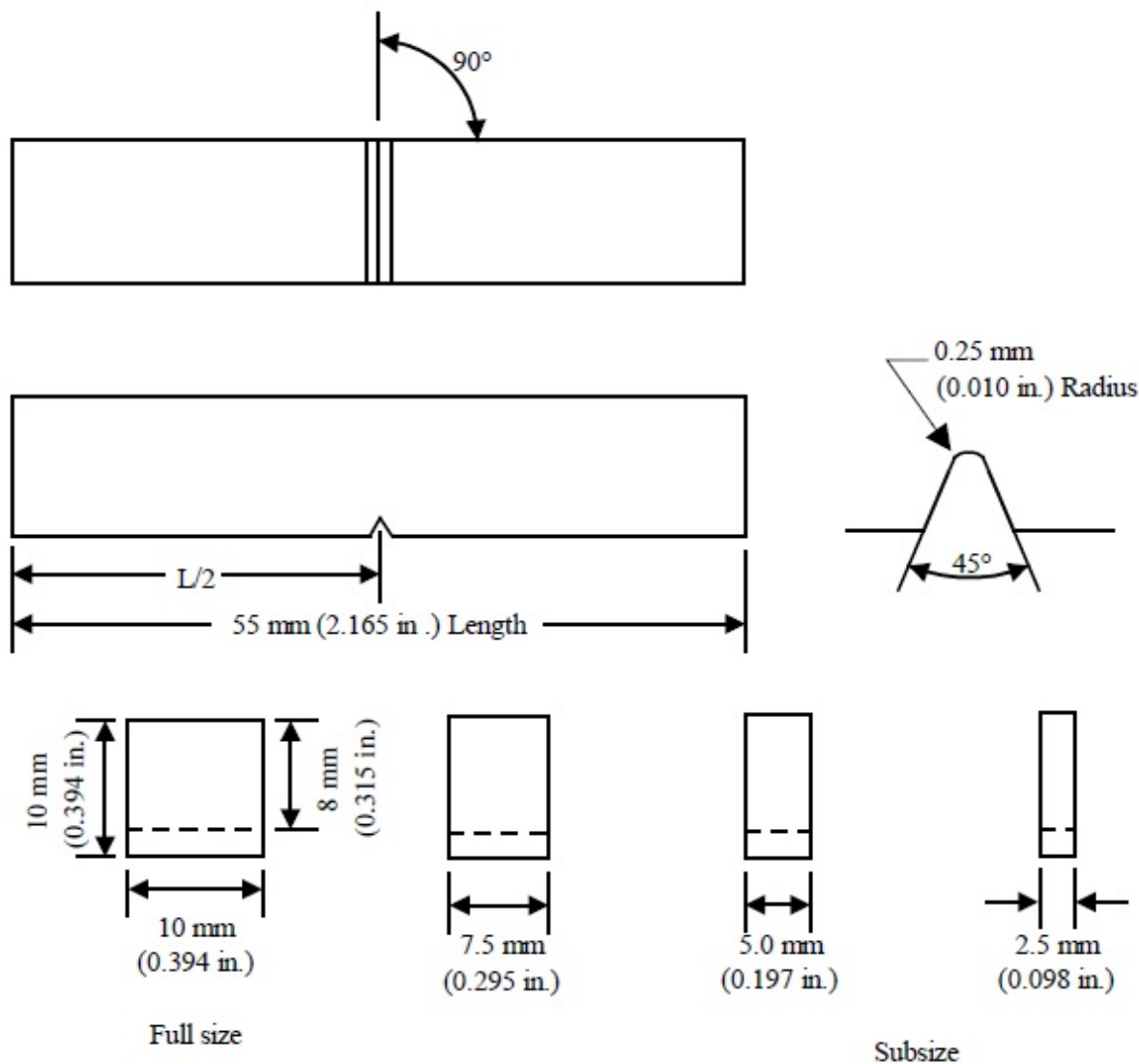
**FIGURE 3**  
**Standard Round Tension Test Specimen**  
**with 50 mm (2 in.) Gauge Length (2008)**



**Note:**

(2008) The gauge length and fillets are to be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load is to be axial. The reduced section may have a gradual taper from the ends towards the center, with the ends not more than 0.13 mm (0.005 in.) larger in diameter than the center.

**FIGURE 4**  
**Charpy V-notch Impact Test Specimens (2015)**



*Notes (2005)*

Adjacent Sides are to be at 90 Deg  $\pm$  10 min.

Width:

- Standard Specimen 10 mm  $\pm$  0.11mm (0.004 in.)
- Subsize Specimen 7.5 mm  $\pm$  0.11 mm (0.004 in.)
- Subsize Specimen 5 mm  $\pm$  0.06 mm (0.0024 in.)
- Subsize Specimen 2.5 mm  $\pm$  0.06 mm (0.0024 in.)

Angle between plane of symmetry of notch and longitudinal axis of test specimen is to be at 90 Deg.  $\pm$  2 Deg.

Centering of notch

Thickness

Angle of Notch

Radius of Notch

$\pm$  1 mm (0.039 in.)

$\pm$  0.06 mm (0.0024 in.)

$\pm$  2 Degs.

$\pm$  0.025 mm (0.001 in.)

Length of specimen	± 0.60 mm (0.024 in.)	Dimension to Bottom of Notch	± 0.06 mm (0.0024 in.)
--------------------	-----------------------	------------------------------	------------------------

Surface Finish Requirements on:

Notched surface and opposite face	2 µm (63 µin.)
Other surfaces	4 µm (125 µin.)

All impact tests are to be carried out on Charpy machines complying with the requirements of ISO 148 or other national and international recognized Standards, and having a striking energy of not less than 150 J.

(2015) Where the test temperature is other than ambient, the temperature of the test specimen at the moment of breaking is to be the specified temperature within ± 2°C (± 3.6°F).

## 17 Steel Plates and Wide Flats with Specified Minimum Through Thickness Properties (“Z” Quality) (2013)

“Z” quality steel is employed in those structural details subject to strains in the through thickness direction in order to minimize the possibility of lamellar tearing during fabrication.

These requirements are intended for material with a thickness greater than or equal to 15 mm (0.60 in.) where a specified minimum ductility in the through thickness or “Z” direction is specified. Products with a thickness less than 15 mm (0.60 in.) may also be included.

Two “Z” quality steels are specified:

**Z25** for normal ship applications

**Z35** for more severe applications.

Through thickness properties are characterized by specified values for reduction of area in a through thickness tension test.

The steel works are to be approved by ABS for the manufacture of “Z” quality steels, in accordance with Part 2, Appendix 4. In addition, the maximum sulfur content is to be 0.008%, determined by ladle analysis.

When steels with improved through thickness properties are specified, special steel-making processes are to be used. The following processes used either singly or in combination would be considered to meet this requirement.

- i) Low sulfur practices
- ii) Additions of elements known to control the shape of nonmetallic inclusions.
- iii) Electroslag or vacuum arc remelting.
- iv) Control of centerline segregation during continuous casting

### 17.1 Sampling

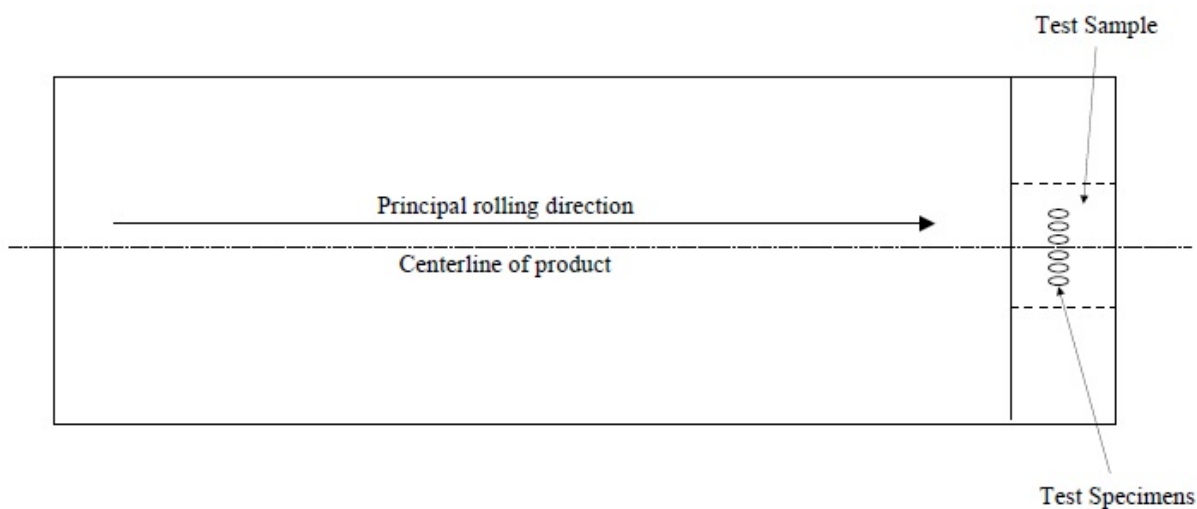
The samples for preparing test specimens for plates and wide flats are to be taken as follows:

One test sample is to be taken close to the longitudinal centerline of one end of each rolled piece representing the batch. See 2-1-1/17.1 TABLE 1 and 2-1-1/17.1 FIGURE 5.

**TABLE 1**  
**Batch Size Depending Upon Product and Sulfur Content (2005)**

<i>Product</i>	<i>Sulfur &gt; 0.005%</i>	<i>Sulfur ≤ 0.005%</i>
Plate	Each piece (parent plate)	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm (1.0 in.)	Maximum 10 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm (1.0 in.)	Maximum 20 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment

**FIGURE 5**  
**Plate and Wide Flat Sampling Position (2005)**



### 17.3 Number of Tensile Test Specimens

The test sample must be large enough to accommodate the preparation of six (6) specimens. Three (3) test specimens are to be prepared while the remaining samples are set aside for possible retest.

### 17.5 Tensile Test Specimen Dimensions

Round test specimens, including built-up type by welding, are to be prepared in accordance with a recognized national standard.

### 17.7 Tensile Test Results

The minimum average value for the reduction of area of at least three (3) tensile test specimens taken in the through thickness direction must be that shown for the appropriate grade given in 2-1-1/17.7 TABLE 2. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade. See 2-1-1/17.9 FIGURE 6.

A value less than the minimum individual value is a cause for rejection

The test is considered invalid and a further replacement test is required if the fracture occurs in the weld or heat-affected zone.

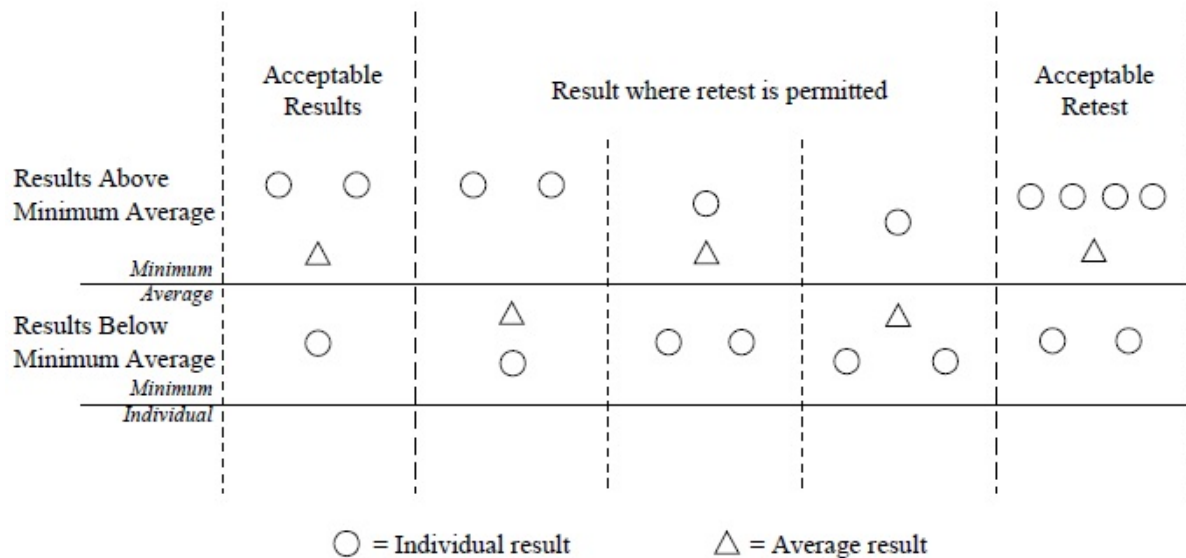
**TABLE 2**  
**Reduction of Area Acceptance Values (2005)**

Grade	Z25	Z35
Minimum Average	25%	35%
Minimum Individual	15%	25%

**17.9 Retests**

2-1-1/17.9 FIGURE 6 shows the three cases where retest is permitted. In these instances, three more tensile tests are to be taken from the remaining test sample. The average of all six (6) tensile tests is to be greater than the required minimum average with no greater than two results below the minimum average. In the case of failure after retest, either the batch represented by the piece is rejected or each piece within the batch is required to be tested.

**FIGURE 6**  
**Diagram Showing Acceptance/Rejection and Retest Criteria (2005)**



**17.11 Ultrasonic Inspection (2007)**

Ultrasonic testing is required and is to be performed in accordance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

Ultrasonic testing should be carried out on each piece in the final supply condition and with a probe frequency of 2.0 or 2.25 MHz. When carrying out UT on material less than 20 mm (<sup>3</sup>/<sub>4</sub>"") thick, frequency up to 5 MHz may be considered acceptable if satisfactorily documented and qualified.

**17.13 Marking**

Products complying with these requirements are to be marked in accordance with the appropriate steel requirement and, in addition, with the notation Z25 or Z35 added to the material grade designation, (e.g., EH36Z25 or EH36Z35).

**17.15 Certification (2013)**

The following information is required to be included on the certificate:



- i) Through thickness reduction in area (%)
- ii) Steel grade with Z25 or Z35 notation.
- iii) Ultrasonic Inspection result of each plate

## 19 Formed Materials

When material is hot or cold formed, confirmatory mechanical tests are to be conducted when required by 2-4-1/3.13.

## 21 Ultrasonic Examination of Plate and Wide Flats (1 July 2018)

### 21.1 (1 July 2018)

If plates and wide flats are ordered with ultrasonic inspection this is to be made in accordance with an accepted standard such as EN10160, ASTM A435 or equivalent, at the discretion of ABS. Acceptance criteria is to be agreed between the purchaser and manufacturer, and accepted by ABS. The products will be specially marked in accordance with 2-1-2/13.3.

Refer to 2-1-8/11.1 for requirements extra high strength steels.

### 21.3 (1 July 2018)

Verification of internal soundness is the responsibility of the manufacturer. The acceptance of internal soundness by the ABS Surveyor shall not absolve the manufacturer from this responsibility.

## 23 Fracture Toughness Testing (2006)

When specified, fracture toughness testing of materials and weldments is to be carried out. Fracture toughness testing may involve tests for properties such as plane strain fracture toughness parameter,  $K_{IC}$ ; elastic-plastic fracture toughness parameter,  $J_{IC}$ ; or critical crack-tip opening displacement (CTOD) parameter, for mode-I type of deformation. Tests are to be carried out as per BS 7448 Parts 1 & 2/ASTM E1820 specification or any other recognized standard. The test is deemed to be valid and acceptable provided post-test data analyses meets all validity criteria of BS 7448 Parts 1 & 2/ASTM E1820 or any other recognized standard, and the fracture toughness value determined is equal to or greater than the minimum specified value in the ABS approved specification. Specific aspects that are to be taken into considerations before testing is initiated are listed below:

### 23.1

Specimen geometry, notch orientation and load type (bend or tension) are to be selected as per the specification and are to be in conformity with BS 7448 Parts 1 & 2/ASTM E 1823 or any other recognized standard.

### 23.3

Cut samples for machining test specimens are to be extracted from test coupons or locations with proper orientation identified as specified in the material specification for plates, and for welds, as given in the manufacturing procedure specification. Orientation mark, heat number, plate number, etc., based on the manufacturer's evolved traceability system are to be transferred onto the samples using a template and paint, local chemical etching or appropriate mechanical means. No plastic deformation or distortions are permitted during this process. This process is to be repeated on the finished, inspected and accepted specimens before the testing program is initiated. A mix-up of specimens without proper identification will call for rejection of the test results.

### 23.5

If straightening of the samples is needed, then it is to be carried out between the platens of a suitable press (mechanical or hydraulic) under the slowest possible loading rate, and the compressive load applied is not

to exceed the compressive yield stress of the material. It is the responsibility of the manufacturer during this operation to ensure complete safety to personnel and the witnessing Surveyor.

### 23.6 (2009)

In the case of weldment testing, the residual stresses are not to be altered in any way by pre-compression crack front straightening method(s), unless specially permitted in the ABS-approved material and product manufacturing procedure specifications.

### 23.7

Dimensions, machined notch root radius, side grooving and other fine details (such as specimen surface finish, centerline offset of loading pins, etc.) in the test specimens are to be as per the approved specimen drawing and in conformity with ASTM E1820 or to any other recognized standard.

### 23.9

Calibration certificates for servo-mechanical/hydraulic universal testing machines, load cells, transducers, and recording equipment used in testing are to be provided to the Surveyor by the testing lab for verification and record. Selection of the loading roller diameter and its alignment with the crack plane of the specimen in the case of bend specimen testing and proper alignment of the clevis for compact tension testing are to be ensured by the Surveyor prior to the beginning of a test.

### 23.11

Crack opening displacement (COD) gauges are to be calibrated once per batch of testing in the presence of the Surveyor.

### 23.13

Fatigue pre-cracking loads and cyclic loading rates (applied stress intensity level/time) are to be as per BS7448/ASTM E1820 or any other recognized standards, and the Surveyor is to witness at least one specimen in a batch of specimens being tested. For the rest, the test lab has to provide the loading history and certify that these were done in accordance with BS 7448/ASTM E1820 or any other recognized standard requirements.

### 23.15

Crack length measurement can be made by compliance or electrical potential technique and may be supplemented by optical means of measurements. The calibration method employed is to be verified by the Surveyor and is to be validated by nine (9) point measurements made on the broken specimen after the test as per BS 7448/ASTM E1820 or to any other recognized standard. Heat tinting/etching or any other suitable method(s) used to reveal the crack front to estimate the final crack length in post-test analysis shall be to the satisfaction of the Surveyor. Photo-macrographs of the broken samples are to be captured and documented along with the valid test report for each specimen tested.

### 23.17

The following acceptance criteria for CTOD tests are to be applied whenever CTOD tests are specified and performed. If the scatter in CTOD ( $\delta_c$ ,  $\delta_u$  or  $\delta_m$ ) data from a set of three tests is such that the minimum value is greater than or equal to 70% of the average value of the set, then the minimum value of the three specimens is to be taken as the characteristic CTOD value for a specified location (base metal, weld metal, or HAZ) and is to be equal to or higher than the specified minimum CTOD value for the material at the location. If the minimum value is less than 70% of the average value of the set, or if the minimum value of the three specimens fails to meet the specified minimum CTOD value, then three additional specimens are to be machined and tested from the same previously tested plate, product, or weldment. The second lowest of all six values is to be reported as the characteristic CTOD value and this has to be equal to or greater than the specified minimum CTOD value as stipulated in the ABS-approved material and fabrication specifications for the specified location.

**1 Ordinary-strength Hull Structural Steel (1 July 2021)**

The requirements in this subsection are intended for products of the following thicknesses.

Plates and Wide Flats	up to and including 150 mm (6.0 in.)
Tubulars (seamless or welded)	up to and including 70 mm (2.75 in.)
Sections and Bars	up to and including 50 mm (2.0 in.)

**3 Process of Manufacture (1 July 2021)**

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen, electricfurnace, vacuum-arc remelt, electro-slag remelt, or such other process as may be specially approved. The steel may be cast in ingots or may be strand (continuous) cast. The ratio of reduction of thickness from a strand (continuous) cast slab to finished plate is to be a minimum of 3 to 1 unless specially approved. Data in support of mechanical properties, weldability and compliance with the Rules in all respects are to be submitted by the steel or pipe manufacturer for review and approval when new or special steels or production methods are proposed or when new steel mills or pipe mills begin production.

**3.1 Plates Produced from Coils**

For coiled plate, the manufacturer or processor is to submit supporting data for review and approval to indicate that the manufacturing, processing, and testing will provide material which is in compliance with the Rules.

**5 Chemical Composition****5.1 Ladle Analysis**

The chemical composition is to be determined by the steel manufacturer on samples taken from each ladle of each heat and is to conform to the applicable chemical requirements of the grades of steel listed in 2-1-2/15.9 TABLE 1.

**5.3 Product Analysis**

When product (check) analysis is required, the chemical tolerances of ASTM A6 or of other nationally recognized standards are to be applied.

## 5.5 Special Compositions

Material differing in chemical composition, deoxidation practice, mechanical properties or heat treatment from that shown in 2-1-2/15.9 TABLE 1 will be subjected to special approval.

## 5.7 Fine Grain Practice

Where steel is required to be made using fine grain practice, the requirement is to be met by adding aluminum, unless some other method is specially approved. The fine grain requirement may be determined by one of the following methods.

### 5.7.1

A McQuaid-Ehn austenite grain size of 5 or finer in accordance with ASTM E112 for each ladle of each heat, or

### 5.7.2

Minimum Acid-soluble Aluminum content of 0.015% or minimum total Aluminum content of 0.020% for each ladle of each heat.

## 7 Condition of Supply (1 July 2018)

The conditions of supply are to be in accordance with the requirements in 2-1-2/15.9 TABLE 5 and the following:

Controlled manufacturing processes require approval for each plant and combination of grade and thickness limit.

The applicable rolling procedures are defined as follows. Reference can also be made to ASTM A941, for cooling definitions.

### 7.1 As Rolled – AR (1 July 2018)

This procedure involves the rolling of steel at high temperature followed by air cooling, as it is rolled, with no further heat treatment. The rolling and finishing temperatures are typically in the austenite recrystallization region and above the normalizing temperature. The strength and toughness properties of steel produced by this process are generally less than steel heat treated after rolling or than steel produced by advanced processes.

## 7.3 Heat Treatment

### 7.3.1 Normalizing Heat Treatment (1 July 2021)

A normalizing heat treatment is to consist of heating plates, tubulars, wide flats, bars or shapes above the critical temperature, AC3, and in the lower end of the austenite recrystallization region for a specific period of time to effect the desired transformation and then individually cooling the material in air. The process improves the mechanical properties of asrolled steel by refining the austenitic grain size and homogenizing the microstructure, provided that the steel is produced to fine austenitic grain size practice. Normalizing heat treatments are usually conducted at the steel manufacturer's plant. Such heat treatment may be carried out at a shipyard or fabricator's plant, provided the Surveyor is satisfied with the heat-treating facilities and procedures. In such cases, the shipyard or fabricator is to indicate on the purchase order that the mill tests are to be made on normalized coupons. Otherwise, tests on the normalized material will be required at the shipyard or fabricator's plant.

### 7.3.2 Special Heat Treatment

Other types of heat treatment are to be specially approved.

## 7.5 Controlled Manufacturing Process

### 7.5.1 Controlled Rolling - CR (Normalized Rolling - NR) (1 July 2018)

Controlled rolling is a procedure in which the final rolling temperature is generally controlled within the range used for normalizing heat treatments so that the austenite completely recrystallizes, allowed to cool in air, resulting in a material condition generally equivalent to that obtained by normalizing.

### 7.5.2 Thermo-mechanical Rolling - TM (Thermo-mechanical Controlled Processing - TMCP) (1 July 2018)

Thermo-mechanical controlled processing involves the strict control of the steel temperature and the rolling reduction. Generally, a high proportion of the rolling reduction is carried out close to or below the Ar<sub>3</sub> transformation temperature and may involve rolling toward the lower end of the temperature range of the intercritical duplex phase region, thus permitting little if any recrystallization of the austenite. Unlike controlled rolling, the properties produced by TM (TMCP) cannot be reproduced by subsequent normalizing or other heat treatment.

The use of accelerated cooling on completion of rolling may also be accepted, subject to the special approval of ABS.

Accelerated cooling (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM (TMCP) operation. Direct quenching is excluded from accelerated cooling.

Where NR (CR) and TM with/without AcC are applied, the programmed rolling schedules are to be verified by ABS at the time of the steel works approval, and are to be made available when required by the attending Surveyor. On the manufacturer's responsibility, the programmed rolling schedules are to be adhered to during the rolling operation. Refer to 2-1-1/1.2.2. To this effect, the actual rolling records are to be reviewed by the manufacturer and occasionally by the Surveyor.

When deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures occurs, the manufacturer shall take the further measures required in 2-1-1/1.2.2 to the Surveyor's satisfaction.

## 7.7 Quenching and Tempering – QT (1 July 2018)

Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the AC<sub>3</sub>, held for a specific period of time, and then cooled with an appropriate coolant for the purpose of hardening the microstructure. Tempering subsequent to quenching is a process in which the steel is reheated to an appropriate temperature not higher than the AC<sub>1</sub>, maintained at that temperature for a specific period of time to restore toughness properties by improving the microstructure and reduce the residual stress caused by the quenching process.

## 9 Tensile Properties

### 9.1 Required Tensile Properties

The material, except as specified in 2-1-2/9.5, is to conform to the requirements of 2-1-2/15.9 TABLE 2 as to tensile properties.

### 9.3 Tension Test Specimens (1 July 2021)

One tension test is to be made on two different plates, tubulars, shapes or bars from each heat of steel, unless the finished material from a heat is less than 50 tons, when one tension test will be sufficient. If, however, material from one heat differs 9.5 mm (0.375 in.) or more in thickness or diameter, one tension test is to be made from both the thickest and the thinnest material rolled, regardless of the weight represented. One tension test is to be made on each plate as quenched and tempered. For plates from coils, tension tests are to be made from not less than two coils from each heat, except where a single coil is to be

certified in which case tension test specimens from that coil only need be tested. Two tension tests are to be made from each coil tested. One tension test specimen is to be obtained from a location immediately prior to the first plate produced and a second test specimen obtained from the approximate center lap. When the coiled material from one heat differs by 1.6 mm ( $\frac{1}{16}$  in.) or more in thickness, test specimens are to be obtained from both the thinnest and the thickest material rolled.

## 9.5 Exceptions

Shapes less than 645 mm<sup>2</sup> (1 in<sup>2</sup>) in cross section and bars, other than flats, less than 12.5 mm ( $\frac{1}{2}$  in.) in thickness or diameter need not be subject to tension test, but chemistry consistent with the required tensile properties is to be applied.

## 9.7 <No Text> (2007)

## 9.9 Omission of Elongation Requirements

For raised-pattern floor plates not exceeding 12.5 mm (0.50 in.) in thickness, the requirement for elongation is waived.

## 9.11 Retests (1996)

Where the results of the tension test do not comply with the requirements, two further tests may be carried out on specimens taken from the same sample. For elongation retest, 2-1-1/9.5 is to be complied with. For plates from coils the retest specimens are to be taken adjacent to the original specimen.

If the results of both additional tests meet the requirements, the material tested or represented by the test may be accepted.

When the results of one or both additional tests do not meet the requirements, the sample is to be rejected unless the manufacturer elects to resubmit it after heat treatment or reheat treatment, or as another grade. The rest of the material represented by the test may be treated under 2-1-2/9.13.

## 9.13 Unsatisfactory Tests (1 July 2021)

Where the tests under 2-1-2/9.3 and 2-1-2/9.13 fail, the remaining material from the same heat may be accepted, provided satisfactory results are obtained on both of two additional plates, tubulars, shapes or bars selected in accordance with 2-1-2/9.3.

When the results of one or both samples do not meet the requirements, all materials represented by the tests are to be rejected unless the manufacturer elects to submit each piece individually, or to resubmit the lot after heat treatment or reheat treatment or as another grade.

# 11 Impact Properties

## 11.1 Impact Tests (1 July 2021)

Charpy V-notch impact tests are to be carried out in accordance with 2-1-2/15.9 TABLE 4. These same requirements apply for tubulars, flats, rounds, and shapes when specially ordered in these grades unless agreed otherwise. For rolled sections impact tests specimens are to be taken from the flanges of beams, channels, and tees, and from the legs of angles and bulb angles. One set of three impact specimens is to be obtained from the thickest material rolled except when the maximum thickness or diameter of the material represented by the test differs by 9.5 mm (0.375 in.) or more, in which case, one set of impacts is to be made from both the thickest and the thinnest material represented, regardless of their weight. See 2-1-1/11.11.

For plates produced from coils, impact test coupons are to be obtained adjacent to both tension test coupons and a third impact test coupon is to be obtained immediately after the last plate produced to the qualifying grade or specification; in no case, however, is the frequency of impact testing to be less than

that given above for plates, and where additional testing is required, three sets of specimens are to be obtained from each coil tested.

### 11.3 Impact Test Frequency

The frequency of impact testing is to be in accordance with 2-1-2/15.9 TABLE 5.

### 11.5 Initial Test Requirements (2015)

The average value of three specimens is to equal or exceed the required average value indicated in the applicable Rule Tables. Only one individual value may be below the required average, provided it is not less than 70% of the required average value.

Where the subsize specimens in 2-1-1/16 FIGURE 4 are to be used, the modified energy values will apply as follows:

Subsize Specimen Impact Requirements			
Specimen Size	10 × 7.5 mm (0.394 × 0.295 in.)	10 × 5.0 mm (0.394 × 0.197 in.)	10 × 2.5 mm (0.394 × 0.098 in.)
Required Energy	5E/6	2E/3	E/2

*E* = energy required for 10 × 10 mm (0.394 × 0.394 in.) specimen

### 11.7 Retests

When the results fail to meet the above requirements but conditions ii) and iii) below are complied with, three additional specimens may be taken from the location as close to the initial specimens as possible and their test results added to those previously obtained to form a new average. The material represented may be accepted if for the six specimens all of the following conditions are met:

- i) The average is not less than the required average.
- ii) No more than two individual values are below the required average.
- iii) No more than one individual value is below 70% of the required average.

If the results of tests do not meet the above requirements, the material tested is to be rejected unless the manufacturer elects to resubmit it after heat treatment or reheat treatment, or to resubmit as another grade.

### 11.9 Unsatisfactory Tests (1 July 2021)

The remaining material from the heat may be accepted, provided satisfactory impact results are obtained on both of two further plates or tubulars of the same thickness as the rejected plate or tubular in the heat. Alternatively, the manufacturer may qualify material of the same thickness by impact testing each plate or tubular. Plates or tubulars of a lesser thickness in the same heat may be accepted, provided that satisfactory results are obtained on impact specimens taken from the next lower thickness than the rejected plate or tubular.

### 11.11 Thin Plates or Tubulars (1 July 2021)

Generally, impact tests are not required for plates or tubulars less than 6 mm (0.24 in.) in thickness.

## 13 Marking

### 13.1 Stamped or Stenciled Material (1 July 2021)

The ABS markings **AB** and the applicable grades listed in 2-1-2/15.9 TABLE 1 indicating satisfactory compliance with the Rules are to be clearly steel-die-stamped or stenciled by the manufacturer on each

finished plate, tubular, shape and bar to signify that the material has satisfactorily complied with the tests prescribed and that certificates for the material will be furnished to the Surveyor in accordance with 2-1-1/7. Coiled steel which is certified for chemical analysis only, is to be marked **AB** without the grade designation.

### 13.3 Coils, Lifts and Bundles

In special cases, upon application, coils intended for light plate and secured lifts or bundles of light plates, shapes or bars of comparatively small size may be steel-die stamped, stenciled, or labeled on only the top piece or at another approved location, or the markings may be shown on a tag attached to each coil, lift or bundle.

### 13.5 Flanging-quality Identification (2015)

All material intended for cold flanging, when specially approved in accordance with 3-1-2/1.3.3 of the *ABS Rules for Building and Classing Marine Vessels (Marine Vessel Rules)* is to be additionally marked **F** to signify that it is of such quality. Cold flanging is to be carried out in accordance with ASTM A6.

### 13.7 Special Stamping and Marking (1 July 2021)

Material other than those grades listed in 2-1-2/15.9 TABLE 1, is to be marked with both the initials **AB/S** and with either the applicable specification number, or such other markings as may be required for ready identification, to signify that the material has been produced and satisfactorily tested in accordance with the specification. When a specification does not specifically require normalizing but the material is so ordered and so produced, then the plates or tubular are also to be marked with the initial **N** to indicate that the material has been normalized. A shipyard or fabricator who carries out a normalizing heat treatment in accordance with 2-1-2/7 is to also mark such material with the initial **N**.

### 13.9 Special Impact Testing

When steel is impact tested at temperatures other than those specified in 2-1-2/15.9 TABLE 4, the grade marking is to be followed by the test temperature in degrees Celsius. A prefix “0” to the test temperature is to indicate a temperature colder than zero degrees Celsius.

### 13.11 Steel with Improved Through Thickness Properties (1 July 2021)

Steel plates or tubulars meeting the requirements of 2-1-1/17 are to have the letter **Z** marked after the grade designation.

### 13.13 Steel with Ultrasonic Examination

Steels meeting the requirements of 2-1-1/21 are to have the letter **U** marked after the grade designation as a final letter.

### 13.15 Shipping Procedure

No material bearing these markings is to be forwarded from the steel works until the prescribed tests have been satisfactorily carried out in accordance with the Rules.

### 13.17 Steel at Secondary Sources

Secondary sources for ABS Grade Steel are required to assure traceability of steel intended for ABS certification. To retain proper identification, steel may be marked with the information indicated by the manufacturer’s markings to the satisfaction of the Surveyor.



## 15 Surface Finish

### 15.1 Surface Examination (2008)

The material surfaces will be examined by the Surveyor when specially requested by the purchaser. It is to be free from defects and have a workmanlike finish subject to the conditions given in the following subparagraphs.

### 15.3 Treatment of Surface Defects -Plates (1 July 2018)

Refer to 2-1-1/3.

### 15.4 Treatment of Surface Defects - Tubulars (1 July 2021)

Treatment of surface defects in tubulars is to be in accordance with a recognized standard and agreed with ABS during qualification of the mill.

### 15.5 Treatment of Surface Defects -Shapes

Shapes may be conditioned by the manufacturer for the removal of surface defects by grinding or by chipping to sound metal and depositing weld metal, in accordance with the following limitations.

#### 15.5.1 Chipping and Grinding Material Under 9.5 mm (0.375 in.) in Thickness

For material less than 9.5 mm (0.375 in.) thickness, in which the defects are not more than 0.8 mm (0.031 in.) in depth, the defects may be removed by grinding or chipping and grinding with the edges well faired.

#### 15.5.2 Chipping and Grinding Material 9.5 mm (0.375 in.) and Over in Thickness

For material 9.5 mm (0.375 in.) and over in thickness, in which the defects are not more than 1.6 mm (0.063 in.) in depth, the defects may be removed by grinding or chipping and grinding with the edges well faired.

#### 15.5.3 Welding Repairs

Surface defects which are greater in depth than the limits shown above may be removed by chipping or grinding and then depositing weld metal, subject to the following limiting conditions.

*15.5.3(a)* The total area of the chipped or ground surface of any piece is not to exceed 2% of the total surface area of that piece.

*15.5.3(b)* After removal of any defect preparatory to welding, the thickness of the shape is not to be reduced by more than 30% of the nominal thickness, nor is the depth of depression prior to welding to exceed 12.5 mm (0.50 in.) in any case.

*15.5.3(c)* The toes of angles, beams, channels and zees and the stems and toes of tees may be conditioned by grinding or chipping and welding. Prior to welding, the depth of depression, measured from the toe inward, is to be limited to the thickness of the material at the base of the depression, with a maximum depth limit of 12.5 mm (0.50 in.).

*15.5.3(d)* An experienced mill inspector is to inspect and the welding is to be done in accordance with the requirements of 2-1-1/3.7.2.

### 15.7 Bar-stock Repairs

Bars may be conditioned by the manufacturer for the removal of surface defects by grinding, chipping or some other means, provided the conditioned area is well faired and the depth of depression does not extend below the nominal thickness or diameter by more than 1.5%.

### 15.9 Rivet Steel and Rivets (1996)

Material test requirements for rivet steel are to comply with the requirements of Section 25 of the 1969 *Rules for Building and Classing Steel Vessels*.

**TABLE 1**  
**Chemical Properties of Ordinary Strength Hull Structural Steel**  
**150 mm (6.0 in.) and Under (1 July 2021)**

Grade	A	B	D	E
Deoxidation	Killed or semi-killed <sup>(1)</sup> ( <i>t</i> ≤ 50 mm (2.0 in.)) Killed ( <i>t</i> > 50 mm (2.0 in.))	Killed or semi-killed ( <i>t</i> ≤ 50 mm (2.0 in.)) Killed ( <i>t</i> > 50 mm (2.0 in.))	Killed ( <i>t</i> ≤ 25 mm (1.0 in.)) Killed and fine grain ( <i>t</i> > 25 mm (1.0 in.)) <sup>(2)</sup>	Killed and fine grain <sup>(2)</sup>
Chemical Composition (Ladle Analysis), % max. unless specified otherwise. <sup>(8, 10)</sup>				
C	0.21 <sup>(3)</sup>	0.21	0.21	0.18
Mn <sub>min.</sub>	2.5 × C	0.80 <sup>(4)</sup>	0.60	0.70
Si	0.50	0.35	0.10–0.35 <sup>(5)</sup>	0.10–0.35 <sup>(5)</sup>
P	0.035	0.035	0.035	0.035
S <sup>(9)</sup>	0.035	0.035	0.035	0.035
Ni	See Note 6	See Note 6	See Note 6	See Note 6
Cr	See Note 6	See Note 6	See Note 6	See Note 6
Mo	See Note 6	See Note 6	See Note 6	See Note 6
Cu	See Note 6	See Note 6	See Note 6	See Note 6
C + Mn/6	0.40	0.40	0.40	0.40
Marking	AB/A	AB/B	AB/D <sup>(7)</sup>	AB/E

**Notes:**

- 1 For Grade A, rimmed steel sections may be accepted up to and including 12.5 mm (0.5 in).
- 2 Grade D steel over 25 mm and Grade E steel are to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirements. (See 2-1-2/5.7.)
- 3 A maximum carbon content of 0.23% is acceptable for Grade A sections.
- 4 For Grade B steel of cold flanging quality or where fully killed, the lower limit of manganese may be reduced to 0.60%.
- 5 Where the content of soluble aluminum is not less than 0.015%, the minimum required silicon content does not apply.
- 6 The contents of nickel, chromium, molybdenum and copper are to be determined and reported. When the amount does not exceed 0.02%, these elements may be reported as ≤ 0.02%.
- 7 Grade D hull steel which is normalized, thermo-mechanical control processed or control rolled is to be marked AB/DN.
- 8 Intentionally added elements are to be determined and reported.
- 9 (2015) For steels of cold flanging quality, the maximum sulfur content is 0.020%.
- 10 Alternative chemical analysis requirements can be specially agreed with ABS at the time of mill qualification

**TABLE 2**  
**Tensile Properties of Ordinary Strength Hull Structural Steel**  
**150 mm (6.0 in.) and Under (1 July 2021)**

Grade	Tensile Strength N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Yield Point min. N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Elongation <sup>(1, 3, 4)</sup> min. %
A, B, D, E	400-520 <sup>(2)</sup> (41-53, 58-75)	235 (24, 34)	22

**Notes:**

- 1 Based on alternative A flat test specimen or alternative C round specimen in 2-1-1/16 FIGURE 2.
- 2 For Grade A sections, the upper limit of tensile strength may be 550N/mm<sup>2</sup> (56 kgf/mm<sup>2</sup>, 80 ksi).
- 3 Minimum elongation for alternative B flat specimen in 2-1-1/16 FIGURE 2 is to be in accordance with 2-1-2/15.9 TABLE 3.
- 4 (2008) Minimum elongation for ASTM E8M/E8 or A370 specimen is 2-1-2/15.9 TABLE 3 for 200 mm (8 in.) specimen and 22% for 50 mm (2 in.) specimen.
- 5 Steel ordered to cold flanging quality may have tensile strength range of 380-450 N/mm<sup>2</sup> (39-46 kgf/mm<sup>2</sup>, 55-65 ksi) and a yield point of 205 N/mm<sup>2</sup> (21 kgf/mm<sup>2</sup>, 30 ksi) minimum. See also 2-1-2/13.5 and 3-1-2/1.1 of the *Marine Vessel Rules*.

**TABLE 3**  
**Elongation Requirements for Alternative B Specimen (1995)**

	Thickness in mm (in.)							
	5 (0.20)	10 (0.40)	15 (.60)	20 (.80)	25 (1.0)	30 (1.2)	40 (1.6)	50 (2.0)
exceeding								
not exceeding	5 (0.20)	10 (0.40)	15 (.60)	20 (.80)	25 (1.0)	30 (1.2)	40 (1.6)	50 (2.0)
elongation (min. %)	14	16	17	18	19	20	21	22

**TABLE 4**  
**Impact Properties of Ordinary-Strength Hull Structural Steel**  
**150 mm (6.0 in.) and Under (1 July 2021)**

		Average Absorbed Energy <sup>(1)</sup> J (kgf-m, ft-lbf)							
		t ≤ 50 mm (2.0 in.)		50 mm (2.0 in.) < t ≤ 70 mm (2.8 in.)		70 mm (2.8 in.) < t ≤ 100 mm (4.0 in.)		100 mm (4 in.) < t ≤ 150 mm (6.0 in.)	
Grade	Temperature °C (°F)	Long'l <sup>(2)</sup>	Transv <sup>(2)</sup>	Long'l <sup>(2)</sup>	Transv <sup>(2)</sup>	Long'l <sup>(2)</sup>	Transv <sup>(2)</sup>	Long'l <sup>(2)</sup>	Transv <sup>(2)</sup>
A	20 (68)	-	-	34 (3.5, 25) <sup>(3)</sup>	24 (2.4, 17) <sup>(3)</sup>	41 (4.2, 30) <sup>(3)</sup>	27 (2.8, 20) <sup>(3)</sup>	48 (4.9, 35)	32 (3.3, 24)
B <sup>(4)</sup>	0 (32)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	48 (4.9, 35)	32 (3.3, 24)
D	-20 (-4)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	48 (4.9, 35)	32 (3.3, 24)
E	-40 (-40)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	48 (4.9, 35)	32 (3.3, 24)

Notes:

- 1 The energy shown is minimum for full size specimen. See 2-1-2/11.5 for subsize specimen requirements.
- 2 Either direction is acceptable.
- 3 Impact tests for Grade A are not required when the material is produced using a fine grain practice and normalized.
- 4 CVN test requirements for Grade B apply where such test is required by 2-1-2/15.9 TABLE 5.

**TABLE 5**  
**Condition of Supply and Frequency of Impact Tests**  
**Ordinary Strength Hull Structural Steel (1 July 2021)**

Grade	Deoxidation	Products	Condition of Supply (Impact Test Lot Size in Tons)						
			Thickness in mm (in.)						
			exceeding:		12.5 (0.5)	25 (1.0)	35 (1.375)	50 (2.0)	
			not exceeding:	12.5 (0.5)	25 (1.0)	35 (1.375)	50 (2.0)	150 (6.0)	
A	Rimmed	All		A (-)					
	Semi-Killed	All		A (-)					
	Killed	P		N (-) <sup>(4)</sup> TM (-) CR (50) AR (50)					
S									
B	Semi-Killed	ALL		A (-)	A (50)				
	Killed	P		N (50) TM (50) CR (25) AR (25)					
		S							
D	Killed & Fine Grain	P		A (50) N (50)			N (50)TM (50) CR (50)	N (50) TM (50) CR (25)	
		S							
E	Killed & Fine Grain	P		N (P) TM (P)					
		S		N (25) TM (25) CR (15)					

Notes

- 1 Products: P = plate or tubular S = sections
- 2 Conditions of Supply: A = Any Condition N = normalized  
 AR = As Rolled TM = thermomechanical controlled processing  
 CR = Control Rolled
- 3 Frequency of Impact Test (Impact Test Lot Size in Tons):  
 (-) = no impact test required

(P) = each piece

- 4 Impact tests for Grade A are not required when material is produced using a fine grain practice and normalized.

**1 Higher-strength Hull Structural Steel (1 July 2021)**

The requirements in this subsection are intended for products for the following thicknesses:

Plates and Wide Flats

AH32, DH32, EH32, AH36, DH36 and EH36 steels:	up to and including 150 mm (6 in.)
AH40, DH40, EH40, FH32, FH36 and FH40 steels:	up to and including 150 mm (6 in.)
Tubulars (Seamless and Welded)	up to and including 70 mm (2.75 in.)
Sections and Bars	up to and including 50 mm (2 in.)

**3 General (1996)**

The requirements in 2-1-2/3 through 2-1-2/15 are also applicable to higher-strength hull structural steels with the following paragraphs and Tables replaced by the higher-strength requirements as indicated.

2-1-2/15.9 TABLE 1	replaced by 2-1-3/7.3 TABLE 1
2-1-2/15.9 TABLE 2	replaced by 2-1-3/7.3 TABLE 2
2-1-2/15.9 TABLE 3	replaced by 2-1-3/7.3 TABLE 3
2-1-2/15.9 TABLE 4	replaced by 2-1-3/7.3 TABLE 4
2-1-2/15.9 TABLE 5	replaced by 2-1-3/7.3 TABLE 5
2-1-2/5.7	replaced by 2-1-3/5

**5 Fine Grain Practice (1996)**

Where steel is required to be made using fine grain practice, the requirement may be met by one of the following conditions.

- i)* A McQuaid-Ehn austenite grain size of 5 or finer in accordance with ASTM E112 for each ladle of each heat, or
- ii)* Minimum Acid-soluble Aluminum content of 0.015% or minimum total Aluminum content of 0.020% for each ladle of each heat, or

- iii) Minimum Columbium (Niobium) content of 0.020% or minimum Vanadium content of 0.050% for each ladle of each heat, or
- iv) When Vanadium and Aluminum are used in combination, minimum Vanadium content of 0.030% and minimum acid-soluble Aluminum content of 0.010% or minimum total Aluminum content of 0.015%.
- v) When Columbium (Niobium) and Aluminum are used in combination, minimum Columbium (Niobium) content of 0.010% and minimum acid-soluble Aluminum content of 0.010% or minimum total Aluminum content of 0.015%.

## 7 Additional Requirements of TMCP Steel (1996)

### 7.1 Carbon Equivalent

The carbon equivalent  $C_{eq}$  as determined from the ladle analysis in accordance with the following equation is to meet the requirements in 2-1-3/7.3 TABLE 6:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} (\%)$$

### 7.3 Cold Cracking Susceptibility

Unless otherwise specified by the purchaser, the cold cracking susceptibility  $P_{cm}$  may be calculated in accordance with the following equation:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B (\%)$$

Selection of the maximum value for  $P_{cm}$  is a matter to be agreed between the fabricator and the steel mill when the steel is ordered.

**TABLE 1**  
**Chemical Properties of Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under (1 July 2021)**

Grades	AH/DH/EH 32, AH/DH/EH 36 and AH/DH/EH 40	FH 32/36/40
Deoxidation	Killed, Fine Grain Practice <sup>(1)</sup>	
Chemical Composition <sup>(2, 12)</sup>	(Ladle Analysis), % max. unless specified in range	
C	0.18	0.16
Mn	0.90-1.60 <sup>(3)</sup>	0.90-1.60
Si	0.10-0.50 <sup>(4)</sup>	0.10-0.50 <sup>(4)</sup>
P	0.035	0.025
S	0.035	0.025
Al (acid Soluble) min <sup>(5, 6)</sup>	0.015	0.015
Nb <sup>(6, 7)</sup>	0.02-0.05	0.02-0.05
V <sup>(6)(7)</sup>	0.05-0.10	0.05-0.10
Ti <sup>(7)</sup>	0.02	0.02
Cu <sup>(8)</sup>	0.35	0.35
Cr <sup>(8)</sup>	0.20	0.20
Ni <sup>(8)</sup>	0.40	0.80

<i>Grades</i>	<i>AH/DH/EH 32, AH/DH/EH 36 and AH/DH/EH 40</i>	<i>FH 32/36/40</i>
Mo <sup>(8)</sup>	0.08	0.08
Ca <sup>(7)</sup>	0.005	0.005
N	-	0.009 (0.012 if Al present)
Marking <sup>(9)</sup>	AB/XHYY (X = A, D, E or F YY = 32, 36 or 40)	

**Notes:**

- 1 The steel is to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirement (See 2-1-3/5).
- 2 The contents of any other element intentionally added is to be determined and reported.
- 3 AH steel 12.5 mm (0.50 in.) and under in thickness may have a minimum manganese content of 0.70%.
- 4 Where the content of soluble aluminum is not less than 0.015%, the minimum required silicon content does not apply.
- 5 The total aluminum content may be used in lieu of acid soluble content, in accordance with 2-1-3/5.
- 6 The indicated amount of aluminum, niobium and vanadium applies when any such element is used singly. When used in combination, the minimum content in 2-1-3/5 will apply.
- 7 These elements need not be reported on the mill sheet unless intentionally added.
- 8 These elements may be reported as  $\leq 0.02\%$  where the amount present does not exceed 0.02%.
- 9 The marking AB/DHYYN is to be used to denote Grade DHYY plates which have either been normalized, thermo-mechanically control rolled or control rolled in accordance with an approved procedure.
- 10 See 2-1-3/7 for carbon equivalent and cold cracking susceptibility requirements for thermo-mechanically controlled steel.
- 11 For other steels, the carbon equivalent (Ceq) may be calculated from the ladle analysis in accordance with the equation in 2-1-3/7.1. Selection of the maximum value of carbon equivalent for these steels is a matter to be agreed between the fabricator and steel mill when the steel is ordered.
- 12 Alternative chemical analysis requirements can be specially agreed with ABS at the time of mill qualification.

**TABLE 2**  
**Tensile Properties of Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under (1 July 2021)**

<i>Grade</i>	<i>Tensile Strength N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Yield Point min. N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Elongation <sup>(1, 2, 3)</sup> min. %</i>
AH 32 DH 32 EH 32 FH 32	440-590 (45-60, 64-85)	315 (32, 46)	22
AH 36 DH 36 EH 36 FH 36	490-620 (50-63, 71-90)	355 (36, 51)	21
AH 40 DH 40 EH 40 FH 40	510-650 (52-66, 74-94)	390 (40, 57)	20



Notes:

- 1 Based on alternative A flat test specimen or alternative C round specimen in 2-1-1/16 FIGURE 2.
- 2 Minimum elongation for alternative B flat specimen in 2-1-1/16 FIGURE 2 is to be in accordance with 2-1-3/7.3 TABLE 3.
- 3 (2008) Minimum elongation for ASTM E8M/E8 or A370 specimen is 2-1-3/7.3 TABLE 3 for 200 mm (8 in.) specimen and 20% for 50 mm (2 in.) specimen.

**TABLE 3**  
**Elongation Requirements for Alternative B Specimen (1996)**

<i>Thickness in mm (in.)</i>								
<i>exceeding:</i>	5 (.20)	10 (.40)	15 (.60)	20 (.80)	25 (1.00)	30 (1.20)	40 (1.60)	
<i>not exceeding:</i>	5 (.20)	10 (.40)	15 (.60)	20 (.80)	25 (1.00)	30 (1.20)	40 (1.60)	50 (2.00)
Grade Steel	elongation (%)							
XH 32	14	16	17	18	19	20	21	22
XH 36	13	15	16	17	18	19	20	21
XH 40	12	14	15	16	17	18	19	20

Note:

“X” denotes the various material grades, A, D, E and F.

**TABLE 4**  
**Impact Properties of Higher-strength Steel**  
**150 mm (6.0 in.) and Under (1 July 2021)**

Grade	Temp °C (°F)	Average Absorbed Energy <sup>(1)</sup> J (kgf-m, ft-lbf)							
		<i>t ≤ 50 mm (2.0 in.)</i>		<i>50 mm (2.0 in.) &lt; t ≤ 70 mm (2.8 in.)</i>		<i>70 mm (2.8 in.) &lt; t ≤ 100 mm (4.0 in.)</i>		<i>100 mm (4 in.) &lt; t ≤ 150 mm (6.0 in.)</i>	
		<i>Long'l</i> <sup>(2)</sup>	<i>Transv</i> <sup>(2)</sup>	<i>Long'l</i> <sup>(2)</sup>	<i>Transv</i> <sup>(2)</sup>	<i>Long'l</i> <sup>(2)</sup>	<i>Transv</i> <sup>(2)</sup>	<i>Long'l</i> <sup>(2)</sup>	<i>Transv</i> <sup>(2)</sup>
AH 32 AH 36 AH 40	0 (32)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	50 (5.1, 37)	33 (3.4, 25)
		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)	54 (5.5, 40)	36 (3.7, 27)
		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)	58 (5.9, 43)	39 (3.9, 29)
DH 32 DH 36 DH 40	-20 (-4)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	50 (5.1, 37)	33 (3.4, 25)
		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)	54 (5.5, 40)	36 (3.7, 27)
		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)	58 (5.9, 43)	39 (3.9, 29)

Grade	Temp °C (°F)	Average Absorbed Energy <sup>(1)</sup> J (kgf-m, ft-lbf)							
		<i>t</i> ≤ 50 mm (2.0 in.)		50 mm (2.0 in.) < <i>t</i> ≤ 70 mm (2.8 in.)		70 mm (2.8 in.) < <i>t</i> ≤ 100 mm (4.0 in.)		100 mm (4 in.) < <i>t</i> ≤ 150 mm (6.0 in.)	
		Long <sup>l</sup> <sup>(2)</sup>	Transv <sup>(2)</sup>	Long <sup>l</sup> <sup>(2)</sup>	Transv <sup>(2)</sup>	Long <sup>l</sup> <sup>(2)</sup>	Transv <sup>(2)</sup>	Long <sup>l</sup> <sup>(2)</sup>	Transv <sup>(2)</sup>
EH 32 EH 36 EH 40	-40 (-40)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	50 (5.1, 37)	33 (3.4, 25)
		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)	54 (5.5, 40)	36 (3.7, 27)
		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)	58 (5.9, 43)	39 (3.9, 29)
FH 32 FH 36 FH 40	-60 (-76)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	50 (5.1, 37)	33 (3.4, 25)
		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)	54 (5.5, 40)	36 (3.7, 27)
		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)	58 (5.9, 43)	39 (3.9, 29)

**Notes:**

- 1 The energy shown is minimum for full size specimen. See 2-1-2/11.5 for sub size specimen requirement.
- 2 Either direction is acceptable.

**TABLE 5**  
**Condition of Supply and Frequency of Impact Tests Higher-strength Hull Structural Steel (1 July 2021)**

		Condition of Supply impact Test lot Size in Tons								
		Thickness in mm (in.)								
Grade	Deoxidation	Grain Refining Element	Products	Exceeding: ↑ not exceeding: ↑	12.5 (0.5) 20 (0.80)	12.5 (0.5) 20 (0.80)	20 (0.80) 25 (1.0)	25 (1.0) 35 (1.375)	35 (1.375) 50 (2.0)	50 (2.0) 150 (6.0)
AH 32 AH 36	Killed, Fine Grain Practice	Nb V	P		A (50)		N (50*) TM (50) CR (50)			N (50) TM (50) CR (25)
			S		A (50)		N (50*) TM (50) CR (50) AR (25)			N/A
DH 32 DH 36		Al Al+Ti	P		A (50)		AR (25) N (50*) TM (50) CR (50)		N (50*) TM (50) CR (50)	N (50) TM (50) CR (25)
			S		A (50)		N (50*) TM (50) CR (50) AR (25)			N/A
		P		A (50)		N (50) TM (50) CR (50)				N (50) TM (50) CR (25)
		S		A (50)		N (50) TM (50) CR (50)				N/A
EH 32 EH 36		Any	P				AR (25) N (50) TM (50) CR (50)		N (50) TM (50) CR (50)	N (50) TM (50) CR (25)
			S				AR (25) N (50) TM (50) CR (50)		N (50) TM (50) CR (50)	N/A
FH 32 FH 36		Any	P				N (P) TM (P)			N (P) TM (P)
			S				N (25) TM (25) CR (15)			N/A
			P				N (P) TM (P) QT (P)			N (P) TM (P)
			S				N (25) TM (25) QT (25)			N/A

Condition of Supply impact Test Lot Size in Tons										
Grade	Deoxidation	Grain Refining Element	Products	Thickness in mm (in.)						
				12.5 (0.5) 20 (0.80)	12.5 (0.5) 20 (0.80)	20 (0.80) 25 (1.0)	25 (1.0) 35 (1.375)	35 (1.375) 50 (2.0)	50 (2.0) 150 (6.0)	
AH 40		Any	P	A (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)
			S	A (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)
DH 40		Any	P		N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)
			S		N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N (50) TM (50) CR (50)	N/A
EH 40		Any	P		N (P) TM (P) CR (P)	N (P) TM (P) CR (P)	N (P) TM (P) CR (P)	N (P) TM (P) CR (P)	N (P) TM (P) CR (P)	N (P) TM (P) CR (P)
			S		N (25) TM (25) CR (25)	N (25) TM (25) CR (25)	N (25) TM (25) CR (25)	N (25) TM (25) CR (25)	N (25) TM (25) CR (25)	N/A
FH 40		Any	P		N (P) TM (P) QT (P)	N (P) TM (P) QT (P)	N (P) TM (P) QT (P)	N (P) TM (P) QT (P)	N (P) TM (P) QT (P)	N (P) TM (P) QT (P)
			S		N (25) TM (25) CR (25)	N (25) TM (25) CR (25)	N (25) TM (25) CR (25)	N (25) TM (25) CR (25)	N (25) TM (25) CR (25)	N/A

Notes

- Products: P = plate or tubular S = sections
- Conditions of Supply: A = Any Condition N = normalized  
AR = As Rolled TM = thermo-mechanically controlled processing  
CR = Control Rolled QT = quenched and tempered
- Frequency of Impact Test (Impact Test Lot Size in Tons):

(-) = no impact test required (P) = each piece

(\*) = upon application and approval, the impact frequency may be reduced

**TABLE 6**  
**Carbon Equivalent for Higher-strength Hull Structural Steel 150 mm (6.0 in.)**  
**and Under Produced by TMCP (1 July 2021)**

Grade	Carbon Equivalent, Max. (%) <sup>(1)</sup>	
	$t \leq 50 \text{ mm (2.0 in.)}$	$50 \text{ mm (2.0 in.)} < t \leq 100 \text{ mm (4.0 in.)}$
AH 32, DH 32, EH 32, FH 32	0.36	0.38
AH 36, DH 36, EH 36, FH 36	0.38	0.40
AH 40, DH 40, EH 40, FH 40	0.40	0.42

*Notes:*

- 1 It is a matter for the manufacturer and shipbuilder to mutually agree in individual cases as to whether they wish to specify a more stringent carbon equivalent.
- 2 For thicknesses over 100 mm, carbon equivalent is to be agreed with ABS at the time of mill qualification.



# PART 2

## CHAPTER 1 Materials for Hull Construction

### SECTION 4 Low Temperature Materials

#### 1 General

Materials for Liquefied Gas Carriers are also to comply with the requirements of Section 5C-8-6 of the *Marine Vessel Rules*.

#### 3 Marking

In addition to the ABS marking requirements detailed in Part 2, the name or brand of the manufacturer, the letter indicating the grade designation, the manufacturer's identification numbers and for pressure vessel quality material the letters **PV** are to be legibly marked at each end of the finished plate.

Aluminum sheet and plate is to be identified at each end with the manufacturer's name or trade mark, the applicable alloy and temper designation, and in addition for plate, the lot number and the specification number.

#### 5 Toughness Tests

##### 5.1 Charpy V-notch

The specimen is to be transverse to the final direction of rolling for plates and longitudinal to the final direction of rolling for profiles, shapes and bars. Subject to special approval acceptance may be based on a minimum lateral expansion opposite the notch of 0.38 mm (0.015 in.) for transverse specimens and 0.50 mm (0.020 in.) for longitudinal specimens. See 2-1-1/11.11.

##### 5.3 Drop-weight Test

Where drop-weight tests are required, they are to be conducted for no-break performance of two specimens in accordance with ASTM E208, "Conducting Drop-weight Tests to Determine Nil-ductility Transition Temperature of Ferritic Steels." Drop-weight tests are not to be conducted on material of less than 12.5 mm (0.5 in.) thickness. For thickness between 12.5 mm (0.5 in.) and 16 mm (0.63 in.), the E208 specimen P-3 machined to 12.5 mm (0.5 in.) thickness is to be used with a stop distance of 2.29 mm (0.09 in.).

#### 7 Service Temperature 0°C (32°F) or Above

See 5C-8-6/4 of the *Marine Vessel Rules*.

## 9 Service Temperature at or Above -55°C (-67°F) up to 0°C (32°F) (2018)

See 5C-8-6/4 (ABS) of the *Marine Vessel Rules*. Steels intended for this temperature range are normally carbon manganese steels furnished fully killed fine grain normalized.

These steels meeting the requirements in 5C-8-6/4 (ABS) of the *Marine Vessel Rules* may be marked **AB/V-OXX** or **AB/VH32-OXX** or **AB/VH36-OXX** indicating by **XX** the test temperature in Celsius below zero in accordance with 2-1-2/13.9.

## 11 Service Temperature at or Above -196°C (-320°F) up to -55°C (-67°F) (2022)

See 5C-8-6/4 and 5C-8-6/4 of the *Marine Vessel Rules*. Steels intended for this temperature range are normally of the ferritic nickel-alloy type made with fine-grain practice, but austenitic stainless steels or aluminum alloys may be used. In general, the following ASTM grades of material or their equivalents may be used for the temperature listed below. The chemical composition, heat treatment, tensile and impact properties are to conform to the requirements of the applicable approved specification.

A203, 2 <sup>1</sup> / <sub>4</sub> % Ni	-62°C (-80°F)	for Grade A
	-59°C (-75°F)	for Grade B
A203, 3 <sup>1</sup> / <sub>2</sub> % Ni	-90°C (-130°F)	for Grade D
	-79°C (-110°F)	for Grade E
A645, 5% Ni	-105°C (-155°F) <sup>(1)</sup>	
A353, 9% Ni	-196°C (-320°F)	
A553, 9% Ni	-196°C (-320°F)	
Austenitic stainless steels	-196°C (-320°F)	
36% Ni <sup>(2)</sup>	-196°C (-320°F)	
B209, Type 5083, Alum. Alloy	-196°C (-320°F)	

### Notes:

- 1 5% Nickel steel may be used down to -165°C (-265°F) upon special consideration provided that impact tests are conducted at -196°C (-320°F).
- 2 Applicable standard or proprietary specification for 36% Ni can be agreed on a case-by-case basis. In addition, chemistry will be specially considered for lowering the coefficient of expansion.

## 13 Service Temperatures below -196°C (-320°F)

Austenitic low carbon (less than 0.10%) stainless steels and aluminum alloys are to be used for these temperatures. The chemical composition, heat treatment, and tensile properties are to conform to the requirements of the approved specification. Stainless steels types 304, 304L, and 347 and type 5083 aluminum alloy do not require toughness testing for service temperatures above -254°C (-425°F). Toughness tests for -254°C (-425°F) service temperature and below will be subject to special consideration.



*Note:*

In substantial agreement with ASTM A27 Mild to Medium-strength Carbon-steel Castings for General Application. (Grade 60-30 Class I.). In addition, the following requirements are applicable:

**1 Process of Manufacture (2005)****1.1 General (2012)**

The following requirements cover carbon-steel castings intended to be used in hull construction and equipment such as stern frames and rudder frames. These requirements are applicable only to steel castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures. Alternatively, castings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements. This does not preclude the use of alloy steels in accordance with the permissibility expressed in Section 2-1-1. The steel is to be manufactured by a process approved by ABS.

Castings are to be made by a manufacturer approved by ABS. ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection. Thermal cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.

When two or more castings are joined by welding to form a composite component, the proposed welding procedure is to be submitted for approval and welding is to be carried out to the satisfaction of the attending Surveyor.

**1.3 Chemical Composition (2006)**

Castings are to be made from killed steel and the chemical composition is to be appropriate for the type of steel and the mechanical properties specified for the castings. The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

For ordinary grade carbon and carbon-manganese steel castings for welded construction and where welded repair is anticipated, the chemical composition is to comply with the following limits or, where applicable, the requirements of the approved specification.

Carbon	0.23% max
Silicon	0.60% max
Manganese	0.70-1.60%
Sulfur	0.040% max
Phosphorous	0.040% max
Residual elements	0.80% max

*Notes:*

- 1 Grain refining elements such as aluminum may be used at the discretion of the manufacturer. The content of such elements is to be reported.
- 2 Residual elements individual % maximums (Cu = 0.30, Cr = 0.30, Ni = 0.40, Mo = 0.15)
- 3 For non-welded castings, the maximum carbon content is to be 0.40%.

For special grade castings refer to 2-1-5/7.3.

### 3 Marking and Retests (2005)

#### 3.1 Marking

The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the castings when required.

The manufacturer's name or identification mark/pattern number is to be cast on all castings, except those of such small size as to make this type of marking impracticable. The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, is to be stamped on all castings accepted in such location as to be discernible after machining and installation. In addition, identification numbers of the heats used for pouring the castings are to be stamped on all castings individually weighing 227 kg (500 lb) or more.

#### 3.3 Retests

If the results of the physical tests for any casting or any lot of castings do not conform to the requirements specified, the manufacturer may reheat-treat castings or a lot of castings that have failed to meet test requirements. Two additional test samples representative of the casting or casting batch may be taken. If satisfactory results are obtained from both of the additional tests, the casting or batch of castings is acceptable. If one or both retests fail, the casting or batch of castings is to be rejected.

### 5 Heat Treatment (2017)

Heat treatment facilities used in producing ABS certified castings are to be included in the foundry approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities are to be included in the scope of foundry approval.

Heat treatment details are to be included in the approval documentation.

Foundry qualification is to include all of the heat treatment facilities that the foundry uses.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the

specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

Except in cases specifically approved otherwise, all castings are to be either fully annealed, normalized or normalized and tempered in a furnace of ample proportions to bring the whole casting to a uniform temperature above the transformation range on the annealing or normalizing cycle. The furnaces are to be maintained and have adequate means for control and recording temperature. Castings are to be held "soaking" at the proper temperature for at least a length of time equivalent to one hour per 25.5 mm (1 in.) of thickness of the heaviest member for the first 127.5 mm (5.00 in.) plus an additional 15 minutes for each additional 25.5 mm (1.00 in.) over 127.5 mm (5.00 in.) of thickness. No annealed casting is to be removed from the furnace until the temperature of the entire furnace charge has fallen to or below a temperature of 455°C (850°F). A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace can be verified at regular intervals. Tempering is to be carried out at a temperature of not less than 550°C (1022°F).

Local heating or cooling and bending and straightening of annealed castings are not permitted, except with the express sanction of the Surveyor.

The foundry is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

## 7 Mechanical Properties

### 7.1 Ordinary Grade Castings (2006)

Steel castings are to conform to the following requirements as to tensile properties.

Tensile strength min.	415 N/mm <sup>2</sup> (42 kgf/mm <sup>2</sup> , 60000 psi)
Yield point min.	205 N/mm <sup>2</sup> (21 kgf/mm <sup>2</sup> , 30000 psi)
Elongation in 50 mm (2 in.) min.	25%
Reduction of area min.	40%

### 7.3 Special Grade Castings (2006)

Cast stern frames, rudder horns and shoepieces are to be manufactured from special grade material with the following additional mechanical and chemical requirements:

#### 7.3.1 Charpy tests

A set of 3 Charpy v-notch impact tests are to be taken from an extension of the thickest part of the casting and have dimensions that represent the thickest casting section. Charpy tests are to be carried out as indicated in 2-1-1/11.11 and meet 27 J (20 ft-lbs) at 0°C (32°F)

### 7.3.2 Chemical Composition

Carbon	0.23% max
Silicon	0.60% max
Manganese	0.70-1.60%
Sulfur	0.035% max
Phosphorous	0.035% max
Aluminum (acid sol)	0.015-0.080%
or Aluminum (total)	0.020-0.10%
Residual elements	0.80% max

*Note:* For special grade steel castings a ladle and a product analysis is to be made.

## 9 Test Specimens

### 9.1 Material Coupons (2016)

Castings and test material are to be heat treated together in the same furnace, and quenched in the same bath/tank (for Q & T castings).

Test material sufficient for the required number of tests and for possible retest purposes is to be provided for each casting. The physical properties are to be determined from test specimens prepared from coupons which, except as specified in 2-1-5/9.3, are to be cast integral with the casting to be inspected. When this is impracticable, the coupons may be cast with and gated to the casting, and are to have a thickness of not less than the critical controlling cross section thickness of the casting or 30 mm (1.2 in.), whichever is greater. In any case, these coupons are not to be detached until the heat treatment of the castings has been completed, nor until the coupons have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

Where the finished casting mass exceeds 10,000 kg (22,000 lb) or is of complex design, two test samples are to be provided. Where large castings are made from two or more casts which are not from the same pour, two or more test samples are to be provided corresponding to the number of casts involved. The samples are to be integrally cast at locations as widely separated as possible.

*Note:*

The controlling cross section thickness is the diameter of the largest theoretical sphere which can be inscribed within the critical section of the casting.

### 9.3 Separately Cast Coupons

In the case of small castings having an estimated weight of less than 908 kg (2000 lb) each, the coupons may be cast separately, provided the Surveyor is furnished an affidavit by the manufacturer stating that the separately cast coupons were cast from the same heat as the castings represented and that they were heat-treated with the castings.

## 11 Number of Tests (2005)

At least one tension test is to be made from each heat in each heat-treatment charge, except where two or more samples are required, as indicated in 2-1-5/9.1. If the manufacturer's quality-control procedure includes satisfactory automatic chart recording of temperature and time, then one tension test from each heat for castings subject to the same heat-treating procedure may be accepted at the discretion of the attending Surveyor.

## **13 Inspection and Repair (2005)**

### **13.1 General (2008)**

All castings are to be examined by the Surveyor after final heat treatment and thorough cleaning to ensure that the castings are free from defects, in accordance with applicable acceptance criteria. Where applicable, internal surfaces are to be inspected. Surfaces are not to be hammered or peened or treated in any way which may obscure defects.

In the event of a casting proving to be defective during subsequent inspection, machining or testing, it is to be rejected, notwithstanding any previous certification.

The manufacturer is to verify that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer's recorded dimensions.

### **13.3 Minor Defects (2006)**

Defects are to be considered minor when the cavity prepared for welding repair has a depth not greater than 20% of the actual wall thickness, but in no case greater than 25 mm (1 in.), and has no lineal dimension greater than four times the wall thickness nor greater than 150 mm (6 in.). Shallow grooves or depressions resulting from the removal of defects may be accepted, provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth, and complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing. Repairs of minor defects where welding is required are to be treated as weld repairs and repaired in accordance with an approved procedure. Minor defects in critical locations are to be treated as, and repaired in the same manner as, major defects.

### **13.5 Major Defects**

Defects other than minor defects with dimensions greater than those given in 2-1-5/13.3 above, may, with the Surveyor's prior approval, be repaired by welding to the satisfaction of the Surveyor, using an approved procedure. Where major defects are considered numerous or excessive by the Surveyor, an evaluation of the casting is to be made to assess if weld repair is appropriate.

### **13.7 Welded Repair (2018)**

After it has been agreed that a casting can be repaired by welding, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

Weld procedures for all types of welds are to be appropriately qualified to the satisfaction of the attending Surveyor.

Before undertaking the repair welding of castings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work intended.

Removal of defects and weld repair are to be carried out in accordance with Part 2, Appendix 6. The defects are to be removed to sound metal, and before welding the excavation is to be investigated by suitable approved nondestructive examination methods to ensure that the defect has been removed. In the case of repair of major defects on large castings such as rudder horns, stern frames, shoe pieces and rudder stocks, welding is not permitted on unheat-treated castings. Corrective welding is to be associated with the use of preheat.

Temporary welds made for operations such as lifting, handling, staging, etc., are to be carried out to qualified welding procedures and by qualified welders/operators and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

### 13.9 Post Weld Repair Heat Treatment

All welded repairs of defects are to be given a suitable post weld heat treatment, as indicated in 2-1-5/5, or subject to the prior approval of the ABS materials department, consideration may be given to the acceptance of local stress-relieving heat treatment at a temperature of not less than 550°C (1022°F). The heat treatment employed is dependent on the chemical composition of the casting, the casting and defect dimensions, and the position of the repairs.

On completion of heat treatment, the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography may also be required, depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of nondestructive testing used.

The manufacturer is to maintain full records detailing the extent and location of all minor and major repairs made to each casting and details of weld procedures and heat treatments applied. These records are to be available to the Surveyor and copies provided on request.

### 13.11 Non-destructive Testing

Important hull castings, such as cast-steel stern frames and rudder horns, are to be subjected to surface inspection by magnetic particle, dye penetrant or other equivalent means. See Part 2, Appendix 6. Cast-steel stern frames are to be subjected to such inspection over the entire skeg portion of the casting, including the enlarged portion forming the junction to the propeller post, and at such other critical locations as may be indicated on the approved plan of the stern frame. These surfaces are to be clean and free of all substances that will affect the sensitivity of the magnetic-particle test and the degree of magnetization is to produce a satisfactory magnetic potential on the surfaces being tested. In addition to surface inspection, cast-steel rudder horns are to be inspected by radiographic means or, at the discretion of the attending Surveyor, in accordance with an approved ultrasonic procedure at the area just below the connection to the shell, and at such other locations as may be indicated in Part 2, Appendix 6, and on the approved plan. Additional NDE is to be considered at chaplet locations and areas of expected defects. The radiographic acceptance standard for all categories of defects is to be at least equivalent to severity level 4 of ASTM E186, E280 or E446. The ultrasonic acceptance standard is to be at least equivalent to quality level 4 of ASTM A609.

## 15 Certification (2005)

The manufacturer is to provide the required type of inspection certificate, giving the following particulars for each casting or batch of castings which has been accepted:

- i)* Purchaser's name and order number
- ii)* Description of castings, steel quality and weight
- iii)* Identification number
- iv)* Steel making process, cast number and chemical analysis of ladle samples
- v)* Results of mechanical tests
- vi)* Results of nondestructive tests, where applicable
- vii)* Details of heat treatment, including temperatures and holding times
- viii)* Where applicable, test pressure
- ix)* Specification



# PART 2

## CHAPTER 1 Materials for Hull Construction

### SECTION 6 Hull Steel Forgings

*Note:* In substantial agreement with ASTM A668 Carbon-steel Forgings for General Industrial Use (Class B = Grade 2).

## 1 Process of Manufacture

### 1.1 General (2017)

The following requirements cover carbon-steel forgings intended to be used in hull construction and equipment. These requirements are applicable only to steel forgings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary, especially when the forgings are intended for service at low or elevated temperatures. This does not preclude the use of other steels as permitted by Section 2-1-1. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by ABS.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

Raw materials for forging such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS. Steel is to be fully killed and is to be manufactured by a process approved by ABS.

The shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all thermal cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

### 1.3 Degree of Reduction (2005)

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the

average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation. Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where  $L > D$  and 1.5:1 where  $L \leq D$
- For forgings made from rolled products, 4:1 where  $L > D$  and 2:1 where  $L \leq D$
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting
- For rolled bars used in lieu of forgings, 6:1.

$L$  and  $D$  are the length and diameter, respectively, of the part of the forging under consideration.

### 1.5 Discard

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation.

### 1.7 Chemical Composition (2008)

All forgings are to be made from killed steel. The chemical composition is to be reported. Carbon content is not to exceed 0.23% or carbon equivalent (Ceq) is not to exceed 0.41%, unless specially approved. Specially approved grades having more than 0.35% carbon are to have S marked after the grade number.

The maximum sulfur and phosphorus contents are to be 0.035%.

Rudder stocks and pintles are to be of a weldable quality.

The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

## 3 Marking and Retests (2005)

### 3.1 Marking

The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the forgings when required.

In addition to appropriate identification markings of the manufacturer, the ABS markings, indicating satisfactory compliance with the Rule requirements and as furnished by the Surveyor, are to be stamped on all forgings accepted in such location as to be discernible after machining and installation. Grade 2 forgings are to be stamped **AB/2**.

### 3.3 Retests

Test material, sufficient for the required number of tests and for possible retest purposes is to be provided for each forging. If the results of the physical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, but not more than three additional times.



## 5 Heat Treatment

### 5.1 General (2017)

Heat treatment facilities used in producing ABS certified forgings are to be included in the forge approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities are to be included in the scope of forge approval.

Heat treatment details are to be included in the approval documentation.

Forge qualification is to include all of the heat treatment facilities that the forge uses.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

Unless a departure from the following procedures is specifically approved, all forgings are to be annealed, normalized, normalized and tempered or quenched and tempered in a furnace of ample proportions to bring the forgings to a uniform temperature.

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

### 5.3 Cooling Prior to Heat Treatment

After forging and before reheating for heat treatment, the forgings are to be allowed to cool in a manner to prevent injury and to accomplish transformation.

### 5.5 Annealing

The forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

## 5.7 Normalizing

The forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air.

## 5.9 Tempering (2005)

The forgings are to be reheated to and held at the proper temperature, which will be below the transformation range, and are then to be cooled under suitable conditions. The tempering temperature is not to be less than 550°C (1022°F).

## 7 Tensile Properties (2008)

Grade 2 steel forgings are to conform to the following requirements as to tensile properties:

Size		Tensile Strength min. N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , psi)	Yield Point/ Yield Strength min. N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , psi)	Longitudinal Specimens		Transverse Specimens	
Solid Diameter or Thickness				Elongation in Gauging Length % 4d 5d	Reduction of Area, Min. %	Elongation in 50 mm (2 in.) Min. %	Reduction of Area, Min. %
Over	Not over						
305 mm (12 in.)	305 mm (12 in.)	415 (42, 60000)	205 (21, 30000)	25 23	38	20	29
		415 (42, 60000)	205 (21, 30000)	24 22	36	20	29

**Note:** In the case of large forgings requiring two tension tests, the range of tensile strength is not to exceed 70 N/mm<sup>2</sup> (7 kg/mm<sup>2</sup>, 10000 psi).

## 9 Test Specimens

### 9.1 Location and Orientation of Specimens

The mechanical properties are to be determined from test specimens taken from prolongations having a sectional area not less than that of the body of the forging. Specimens may be taken in a direction parallel to the axis of the forgings in the direction in which the metal is most drawn out or may be taken transversely. The axis of longitudinal specimens is to be located at any point midway between the center and the surface of solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings. The axis of transverse specimens may be located close to the surface of the forgings. In the case of carbon steel forgings, test results from other locations may be specially approved, provided appropriate supporting information is presented which indicates that the properties at the specified location will be in conformity with the specified tensile properties.

### 9.3 Hollow-drilled Specimens

In lieu of prolongations, the test specimens may be taken from forgings submitted for each test lot; or if satisfactory to the Surveyor, test specimens may be taken from forgings with a hollow drill.

### 9.5 Small Forgings

In the cases of small forgings weighing less than 114 kg (250 lb) each, where the foregoing procedures are impracticable, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for testing. In such cases, the special forgings are to be subjected to approximately the same amount of working and reduction as the forgings represented and are to be heat-treated with those forgings.

## 9.7 Specimen Identification (2015)

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/tank (for Q & T forgings).

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed nor until the test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacture is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

## 11 Number of Tests

### 11.1 Tension Test

#### 11.1.1 Large Forgings

In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test is to be made from each end of the forging.

#### 11.1.2 Intermediate-sized Forgings

In the case of forgings with rough machined weights less than 3180 kg (7000 lb), except as noted in the following paragraph, at least one tension test is to be made from each forging.

#### 11.1.3 Small Forgings (2005)

In the case of small normalized forgings with rough machined weights less than 1000 kg (2200 lb), and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb), one tension test may be taken from one forging as representative of a lot provided the forgings in each such lot are of similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The total mass of the furnace charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

### 11.3 Brinell Hardness Test

Each forging, except those with rough machined weights less than 113 kg (250 lb), are to be Brinell Hardness tested and are to meet the following requirements.

<i>Grade</i>	<i>Brinell Hardness Number Minimum 10 mm ball, 3000 kg load</i>
2	120

### 11.5 Special Situations

In the cases of a number of pieces cut from a single forging, individual tests need not necessarily be made for each piece, but forgings may be tested in accordance with whichever of the foregoing procedures is applicable to the primary forging involved.

### 11.7 Examination (2008)

All forgings are to be examined by the Surveyor after final heat treatment and they are to be found free from defects. Where applicable, this is to include the examination of internal surfaces and bores.

The manufacturer is to verify that all dimensions meet the specified requirements.

When required by the relevant construction Rules or by the approved procedure for welded composite components, appropriate nondestructive testing is also to be carried out before acceptance and the results

are to be reported by the manufacturer. The extent of testing and acceptance criteria are to be agreed with ABS. Part 2, Appendix 7 is regarded as an example of an acceptable standard.

In the event of any forging proving defective during subsequent machining or testing, it is to be rejected, notwithstanding any previous certification.

### **11.9 Rectification of Defective Forgings (2018)**

Defects may be removed by grinding or chipping and grinding, provided that the component dimensions are acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing.

Repair welding of forgings may be permitted subject to prior approval of ABS. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for the approval.

Weld procedures for all types of welds are to be appropriately qualified to the satisfaction of the attending Surveyor.

Before undertaking the repair welding of forgings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work intended.

The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging repaired. The records are to be presented to the Surveyor upon request.

Temporary welds made for operations such as lifting, handling, staging, etc., are to be carried out to qualified welding procedures and by qualified welders/operators and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

## **13 Certification (2005)**

The manufacturer is to provide the required type of inspection certificate, giving the following particulars for each forging or batch of forgings which has been accepted:

- i)* Purchaser's name and order number
- ii)* Description of forgings and steel quality
- iii)* Identification number
- iv)* Steelmaking process, cast number and chemical analysis of ladle sample
- v)* Results of mechanical tests
- vi)* Results of nondestructive tests, where applicable
- vii)* Details of heat treatment, including temperature and holding times
- viii)* Specification

**Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance  
Properties for Cargo Oil Tanks (2014)****1 Scope****1.1**

These requirements apply to ordinary and higher strength steels with enhanced corrosion resistance properties when such steel is used as the alternative means of corrosion protection for cargo oil tanks as specified in the performance standard MSC 289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention (Corrosion protection of cargo oil tanks of crude oil tankers).

**1.3**

The requirements are primarily intended to apply to steel products with a thickness as follows:

- i)* For steel plates and wide flats:
  - All Grades: Up to 50 mm (2 in.) in thickness
- ii)* For sections and bars:
  - All Grades: Up to 50 mm (2 in.) in thickness

**1.5**

Ordinary and higher strength steels with enhanced corrosion resistance properties as defined within this section, are steels whose corrosion resistance performance in the bottom or top of the internal cargo oil tank is tested and approved to satisfy the requirements in MSC.289(87) in addition to other relevant requirements for ship material, structural strength and construction. It is not intended that such steels be used for corrosion resistant applications in other areas of a vessel that are outside of those specified in the performance standard MSC 289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention.

**1.7**

Since steels with enhanced corrosion resistance properties are similar to the ship steels as specified in Section 2-1-2 for Ordinary-strength Hull Structural Steel and Section 2-1-3 for Higher-strength Hull Structural Steel, the basic requirements of Section 2-1-2 and Section 2-1-3 apply to these steels except where modified by this section.

### 1.9

The weldability of steels with enhanced corrosion resistance properties is similar to those given in Section 2-4-1, therefore welding requirements specified in 2-4-3/3 for Approval of consumables for welding ordinary and higher strength hull structural steels and Welding procedure qualification tests of steels for hull construction and marine structures also apply except as modified by this section.

## 3 Approval

### 3.1

All materials are to be manufactured at works which have been approved by ABS for steel in accordance with Part 2, Appendix 4.

### 3.3

Corrosion tests are to be carried out in accordance with Part 2, Appendix 8. Approval can be given for application in one of the following areas of a cargo oil tank:

- i)* Lower surface of strength deck and surrounding structures;
- ii)* Upper surface of inner bottom plating and surrounding structures;
- iii)* For both strength deck and inner bottom plating

### 3.5

It is the manufacturer's responsibility to assure that effective process and production controls in operation are adhered to within the manufacturing specifications. If the process or production controls are changed in any way, or any product fails to meet specifications, the manufacturer is to issue a report explaining the reasons, and, in the instance of product which fails to meet specifications, the measures to prevent recurrence. The complete report is to be submitted to the Surveyor along with such additional information as the Surveyor may require. Each affected piece is to be tested to the Surveyor's satisfaction. The frequency of testing for subsequent products is at the discretion of ABS.

## 5 Method of Manufacture

### 5.1

Method of manufacture, deoxidation practice and rolling practice is to be in accordance with Part 2, Appendix 4.

## 7 Chemical Composition

### 7.1

The chemical composition of samples taken from each ladle of each cast is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory and is to be in accordance with the requirements 2-1-2/5 for Ordinary-strength Hull Structural Steel and 2-1-3/3 for Higher-strength Hull Structural Steel.

### 7.3

The manufacturer will establish a relationship of all the chemical elements which affect the corrosion resistance, the chemical elements added or controlled to achieve this are to be specifically verified for acceptance. Verification is to be based on the ladle analysis of the steel.

## **7.5**

The manufacturer's declared analysis will be accepted subject to periodic random checks as required by the Surveyor.

## **7.7**

The carbon equivalent is to be in accordance with 2-1-3/7.1.

## **9 Condition of Supply**

### **9.1**

All materials are to be supplied in one of the supply conditions specified in 2-1-2/15.9 TABLE 5 for Ordinary-strength Hull Structural Steel and 2-1-3/7.3 TABLE 5 for Higher-strength Hull Structural steel.

## **11 Mechanical Properties**

### **11.1**

Tensile testing is to be carried out in accordance with 2-1-2/15.9 TABLE 2 for Ordinary-strength Hull Structural Steel and 2-1-3/7.3 TABLE 2 for Higher-strength Hull Structural steel. Charpy V-notch Impact Testing is to be carried out in accordance with 2-1-2/15.9 TABLE 4 for Ordinary-strength Hull Structural Steel and 2-1-3/7.3 TABLE 4 for Higher-strength Hull Structural steel.

## **13 Surface Quality (1 July 2018)**

Please refer to 2-1-1/3.

## **15 Tolerances**

### **15.1**

Unless otherwise agreed or specially required the thickness tolerances in 2-1-1/15, "Permissible Variations in Dimensions" are applicable.

## **17 Identification of Materials**

### **17.1**

The steelmaker is to adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original cast.

### **17.3**

The Surveyor is to be given full facilities for so tracing the material when required.

## **19 Testing and Inspection**

### **19.1 Facilities for Inspection**

The manufacturer is to afford the Surveyor all necessary facilities and access to all relevant parts of the works to enable him to verify that the approved process is adhered to, for the selection of test materials, and the witnessing of tests, as required by the Rules, and for verifying the accuracy of the testing equipment.

### 19.3 Testing Procedures

The prescribed tests and inspections are to be carried out at the place of manufacture before dispatch. The test specimens and procedures are to be in accordance with 2-1-1/11. All the test specimens are to be selected and stamped by the Surveyor and tested in his presence, unless otherwise agreed.

### 19.5 Through Thickness Tensile Tests

If plates and wide flats with thickness of 15 mm (0.60 in.) and over are ordered with through thickness properties, the through thickness tensile test in accordance with 2-1-1/17 is to be carried out.

### 19.7 Ultrasonic Inspection

If plates and wide flats are ordered with ultrasonic inspection, this is to be made in accordance with an accepted standard at the discretion of ABS.

### 19.9 Surface Inspection and Dimensions

Surface inspection and verification of dimensions are the responsibility of the manufacturer. The acceptance by the Surveyor shall not absolve the manufacturer from this responsibility.

## 21 Test Material

### 21.1

Definitions and requirements for test samples are to be in accordance with 2-1-1/11.

## 23 Test Specimens

### 23.1 Mechanical Test Specimens

The dimensions, orientation and location of the tensile and Charp V-notch test specimens within the test samples are to be in accordance with 2-1-1/11.

## 25 Number of Test Specimens

### 25.1

Number of Tensile and Charpy V-notch Impact test specimens are to be in accordance with 2-1-1/11.

## 27 Retest Procedures

### 27.1

To be in accordance with 2-1-1/9.5.

## 29 Marking

### 29.1

Every finished piece is to be clearly stamped or stenciled by the maker in at least one place with the ABS markings and the following particulars:

- i) Unified identification mark for the grade of steel (e.g., [AH 36]).
- ii) Steel plates that have complied with these requirements will be marked with a designation by adding a corrosion designation to the unified identification mark for the grade of steel. Example of designation: AH36 **RCB**



- iii)* The steel with enhanced corrosion resistance properties is to be designated according to its area of application as follows:
- Lower surface of strength deck and surrounding structures: **RCU**
  - Upper surface of inner bottom plating and surrounding structures: **RCB**
  - For both strength deck and inner bottom plating: **RCW**
- iv)* When required by ABS, material supplied in the thermo mechanically controlled process condition is to have the letters “TM” added after the identification mark but before the corrosion designation. (e.g., [EH36 TM RCU Z35).
- v)* Name or initials to identify the steelworks.
- vi)* Cast or other number to identify the piece.
- vii)* If required by the purchaser, his order number or other identification marks.

### 29.3

The above particulars, but excluding the manufacturer's name or trade marks where this is embossed on finished products are to be encircled with paint or otherwise marked so as to be clearly legible.

### 29.5

Where a number of light materials are securely fastened together in bundles the manufacturer may, subject to the agreement of ABS, brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

### 29.7

In the event that any material bearing the ABS brand fails to comply with the test requirements, the brand is to be unmistakably defaced by the manufacturer.

## 31 Documentation

### 31.1

The Surveyor is to verify certificates before the material is accepted by ABS.

### 31.3

The number of copies required are to be specified by ABS.

### 31.5

The certificate is to be supplied in either electronic or paper format as required by ABS.

### 31.7

ABS may require separate documents for each grade of steel.

### 31.9

The certificate is to contain, in addition to the description, dimensions, etc., of the material, at least the following particulars:

- i)* Purchaser's order number and if known the hull number for which the material is intended.
- ii)* Identification of the cast and piece including, where appropriate, the test specimen number.
- iii)* Identification of the steelworks.
- iv)* Identification of the grade of steel [and the manufacturer's brand name].

- v) Ladle analysis (for elements specified in 2-1-2/15.9 TABLE 1 for Ordinary-strength Hull structural steel and 2-1-3/7.3 TABLE 1 for Higher-strength Hull structural steel).
- vi) If the steel is approved in accordance with 2-1-7/7.3, the weight percentage of each element added or intentionally controlled for improving corrosion resistance.
- vii) Condition of supply when other than as rolled (i.e., normalized, controlled rolled or thermo mechanically rolled).
- viii) Test Results

### 31.11

Before the test certificates are signed by the Surveyor, the manufacturer is required to furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor or his authorized deputy. The ABS name is to appear on the test certificate. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and initialled for the makers by an authorized official:

“We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of the American Bureau of Shipping.”

### 31.13

In the case of electronic certification, ABS is to agree upon a procedure with the steel mill to confirm release is authorized by the Surveyor.

# PART 2

## CHAPTER 1 Materials for Hull Construction

### SECTION 8 Extra High Strength Steel (2018)

#### 1 General

The requirements in this Section are intended for product forms, which include plates, wide flats, sections, bars and tubulars.

Specific requirements described in this Section, together with the general requirements in Sections 2-1-1, 2-1-2 and 2-1-3, are applicable to ABS extra high strength steels. Manufacturers are to be approved. Refer to 2-1-1/1.2 and 2-A4-3.

Steels are grouped in eight categories of 43, 47, 51, 56, 63, 70, 91 and 98 based on the level of yield strength (see 2-1-8/1 TABLE 1). Each category is combined with four different alphabetic indicators of AQ, DQ, EQ and FQ according to the Charpy V-notch impact test temperature (see 2-1-8/1 TABLE 2) to designate the steel grades, except for 91 and 98 grade for which FQ grades are specially considered by ABS. For example, Grade AQ43 indicates the steel of yield strength of 420 N/mm<sup>2</sup> (43 kgf/mm<sup>2</sup>, 61 ksi) given the test temperature of 0°C (32°F).

**TABLE 1**  
**Steel Category Based on Minimum Yield Strength (2018)**

<i>Yield Strength\ Category</i>	<i>43</i>	<i>47</i>	<i>51</i>	<i>56</i>	<i>63</i>	<i>70</i>	<i>91</i>	<i>98</i>
<i>N/mm<sup>2</sup></i>	420	460	500	550	620	690	890	960
<i>(kgf/mm<sup>2</sup>, ksi)</i>	(43, 61)	(47, 67)	(51, 73)	(56, 80)	(63, 90)	(70, 100)	(91, 129)	(98, 139)

**TABLE 2**  
**Steel Grade Suffix Based on Test Temperature (2018)**

<i>Test Temperature\ Grade Suffix</i>	<i>AQ</i>	<i>DQ</i>	<i>EQ</i>	<i>FQ</i>
<i>°C (°F)</i>	0 (32)	-20 (-4)	-40 (-40)	-60 (-76)

#### 2 Method of Manufacture

The steel is to be fully killed and manufactured by basic oxygen, basic electric arc furnace or by processes specially approved by ABS.

The steel mill is to have a documented process for control of raw materials.

The steel is to be fine grain treated, and is to have a fine grain structure. The fine grain practice is to be as detailed in the manufacturing specification. The manufacturer is to have the capability to produce a fine grain structure of  $\geq 6$  determined by micrographic examination in accordance with ISO 643 or ASTM E112 or alternative test method. Refer to 2-1-2/5.7 and 2-1-3/5 for fine grain practice.

The steels shall contain Nitrogen binding elements as detailed in the manufacturing specification. Also refer to note 4 in 2-1-8/4 TABLE 4A.

Processes used to control Hydrogen are to be applied. This includes Hydrogen out-gassing methods, such as holding plate at suitable temperatures in controlled conditions. Details of holding environments are to be submitted.

Vacuum degassing is mandatory for steel grades 70, 91 and 98 and for all grades with thickness greater than 50 mm.

### 3 Delivery Condition – Rolling Process and Heat Treatment (2022)

Steel is to be delivered in accordance with the processes approved by the ABS. These processes include:

- Normalized (N)
- Normalized rolling (NR)/Controlled rolled (CR)
- Thermo-mechanical controlled rolled (TM)/with Accelerated cooling (TM+AcC)/with direct quenching followed by tempering (TM+DQ), or
- Quenched and Tempered condition (QT)

The definition of these delivery conditions are defined in 2-1-2/7.

*Note:*

Direct quenching after hot-rolling followed by tempering is considered equivalent to conventional quenching and tempering.

#### 3.1 Rolling Reduction Ratio

The rolling reduction ratio of slab, billet or bloom to the finished product (plate, section or bar) is to be at least 3:1 unless agreed at the time of approval. In such cases, additional information and qualification testing may be required.

The plastic deformation during rolling is to be such as to obtain a uniform wrought structure and satisfactory mechanical properties through the cross section.

When manufacturing rolled products from ingots, slabs, billets or blooms and it cannot be certain that a wrought microstructure can be achieved with a 3:1 reduction ratio, a higher reduction ratio than 3 to 1 will be required. The heat, pressure and rolling technique is to be sufficient to produce a uniform microstructure and close voids, particularly when rolling from ingots. The plastic deformation during rolling is to be such as to obtain a uniform wrought structure and satisfactory mechanical properties through the cross section.

#### 3.3 Thickness Limits

Maximum thickness of plates, sections, bars and tubulars for which a specific delivery condition is applicable are shown in 2-1-8/3.3 TABLE 3.

**TABLE 3**  
**Maximum Thickness Limits (2022)**

Delivery condition	Maximum thickness (mm) <sup>(1)</sup>			
	Plates	Sections	Bars	Tubulars
N	250	50	250	70
NR/CR	150	See Note 2		
TM	150	50	Not Applicable	Not Applicable
QT	250	50	Not Applicable	70

**Notes:**

- 1 Approval for steels with thickness greater than indicated in the above table are subject to the special consideration of ABS.
- 2 The maximum thickness limits of sections, bars and tubulars produced by NR/CR process are to be agreed with ABS. (NR/CR maximum thicknesses are generally less than N maximum thickness.)

## 4 Chemical Composition

Elements used for alloying, deoxidizing, fine grain treatment, nitrogen binding, inclusion shape control and modification, and any residual elements are to be included in the material specification.

Ladle Analysis – The chemical composition is to be determined by the steel manufacturer on samples taken from each heat and is to conform to the applicable requirements of the grade of steel listed in 2-1-8/4 TABLE 4A. The method of sampling is to be in accordance with that carried out for the initial qualification tests. The aim analysis is to be in accordance with the material specification. All elements listed in 2-1-8/4 TABLE 4A are to be reported.

- i) For all steel grades, the carbon equivalent ( $C_{eq}$ ) value is to be calculated from the ladle analysis. Maximum values are specified in 2-1-8/4 TABLE 4B in accordance with the following equation:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \%$$

- ii) For steel grades 47 and higher, carbon equivalent (CET) may be used instead of  $C_{eq}$  at the discretion of the manufacturer, and is to be calculated in accordance to the following equation:

$$CET = C + \frac{(Mn + Mo)}{10} + \frac{(Cr + Cu)}{20} + \frac{Ni}{40} \%$$

**Note:**

The CET is included in the standard EN 1011-2:2001 used as one of the parameters for preheating temperature determination which is necessary for avoiding cold cracking.

- iii) For TM and QT steels with carbon content no more than 0.12%, the cold cracking susceptibility  $P_{cm}$  for evaluating weldability may be used instead of carbon equivalent  $C_{eq}$  or CET at manufacturer's discretion and is to be calculated using the following equation:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B \%$$

**TABLE 4A**  
**Chemical Composition (2022)**

<i>Delivery condition<sup>(1)</sup></i>	<i>N/NR/CR<sup>(6)</sup></i>		<i>TM<sup>(6)</sup></i>		<i>QT</i>	
<i>Steel grade \ Chemical Composition<sup>(2,10)</sup></i>	AQ/DQ 43 AQ/DQ 47	EQ 43 EQ 47	AQ/DQ 43 AQ/DQ 47 AQ/DQ 51 AQ/DQ 56 AQ/DQ 63 AQ/DQ 70 AQ 91	EQ/FQ 43 EQ/FQ 47 EQ/FQ 51 EQ/FQ 56 EQ/FQ 63 EQ/FQ 70 DQ/EQ 91	AQ/DQ 43 AQ/DQ 47 AQ/DQ 51 AQ/DQ 56 AQ/DQ 63 AQ/DQ 70 AQ 91 AQ 98	EQ/FQ 43 EQ/FQ 47 EQ/FQ 51 EQ/FQ 56 EQ/FQ 63 EQ/FQ 70 DQ/EQ 91 DQ/EQ 98
Carbon % max	0.20	0.18	0.16	0.14	0.18 <sup>(5)</sup>	
Manganese %	1.0~1.70		1.0~1.70		1.70 (max)	
Silicon % max	0.60		0.60		0.80	
Phosphorus %max <sup>(3)</sup>	0.030	0.025	0.025	0.020	0.025	0.020
Sulphur % max <sup>(3)</sup>	0.025	0.020	0.015	0.010	0.015	0.010
Aluminum total% min <sup>(4)</sup>	0.02		0.02		0.018	
Niobium % max	0.05		0.05		0.06	
Vanadium % max	0.20		0.12		0.12	
Titanium % max	0.05		0.05		0.05	
Nickel % max	0.80		3.50 <sup>(7)</sup>		3.50 <sup>(7)</sup>	
Copper % max <sup>(11)</sup>	0.55		0.55		0.50	
Chromium %max <sup>(11)</sup>	0.30		0.50		2.00	
Molybdenum %max <sup>(11)</sup>	0.10		0.50		0.70	
Nitrogen % max	0.025		0.025		0.015 <sup>(8)</sup>	
Calcium % max	0.005		0.005		0.005	
Oxygen ppmmax <sup>(9)</sup>	Not applicable		Not applicable	50	Not applicable	30
Boron (maz)	0.005		0.005		0.005	

**Notes:**

- 1 Refer to 2-1-8/3 for delivery conditions.
- 2 The chemical composition is to be determined by ladle analysis and shall meet the approved material specification at the time of approval.
- 3 For sections the P and S content can be 0.005% higher than the value specified in the table.
- 4 The total aluminum to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N ratio do not apply.
- 5 Higher carbon content may be agreed by ABS.
- 6 Total Nb+V+Ti ≤ 0.26% and Mo+Cr ≤ 0.65%, not applicable for QT steels.

- 7 Nickel content to be agreed at time of qualification by ABS.
- 8 Higher nitrogen content may be agreed by ABS.
- 9 The requirement on maximum oxygen content is only applicable to DQ/EQ 91/98.
- 10 The contents of any other elements intentionally added is to be determined and reported.
- 11 Elements may be reported as  $\leq 0.02\%$  where the amount present does not exceed 0.02%.

**TABLE 4B**  
**Maximum  $C_{eq}$ , CET and  $P_{cm}$  Values<sup>(1,2)</sup> (2022)**

Steel Grade	Delivery Condition	Carbon Equivalent (%)								
		$C_{eq}$						CET	$P_{cm}$	
		Plates			Sections	Bars	Tubulars	All	All	
		$t \leq 50$ (mm)	$50 < t \leq 100$ (mm)	$100 < t \leq 250$ 0 (mm)	$t \leq 50$ (mm)	$t \leq 250$ or $d \leq 250$ (mm)	$t \leq 65$ (mm)	All	All	
43	N/NR/CR	0.46	0.48	0.52	0.47	0.53	0.47	N.A		
	TM	0.43	0.45	0.47	0.44	N.A				
	QT	0.45	0.47	0.49	N.A		0.46	N.A		
47	N/NR/CR	0.50	0.52	0.54	0.51	0.55	0.51	0.25	N.A	
	TM	0.45	0.47	0.48	0.46	N.A		0.30	0.23	
	QT	0.47	0.48	0.50	N.A	N.A	0.48	0.32	0.24	
51	TM	0.46	0.48	0.50			N.A	0.32	0.24	
	QT	0.48	0.50	0.54			0.50	0.34	0.25	
56	TM	0.48	0.50	0.54			N.A	0.34	0.25	
	QT	0.56	0.60	0.64			0.56	0.36	0.28	
63	TM	0.50	0.52	N.A			N.A	N.A	0.34	0.26
	QT	0.56	0.60	0.64			0.58	0.38	0.30	
70	TM	0.56	N.A				N.A	N.A	0.36	0.30
	QT	0.64	0.66	0.70			0.68	0.40	0.33	
91	TM	0.60	N.A	N.A			N.A	0.38	0.28	
	QT	0.68	0.75		0.40	N.A				
98	QT	0.75	N.A		0.40					

N.A Not Applicable

**Notes:**

- 1 Alternative limits can be specially agreed with ABS
- 2 Application of which formula is to be applied ( $C_{eq}$ , CET,  $P_{cm}$ ) is subject to agreement between the manufacturer and purchaser.

**5 Mechanical Properties**

Test specimens and test procedures for mechanical properties are in accordance with Sections 2-1-1 and 2-1-2.

## 5.1 Tensile Test

Test specimens are to be cut with their longitudinal axes transverse to the final direction of rolling, except in the case of sections, bars, tubulars and rolled flats with a finished width or diameter of 600 mm or less, where the tensile specimens may be taken in the longitudinal direction. Plates for leg, rack and chord material may be tested in the longitudinal direction.

Full thickness flat tensile specimens are to be prepared. When the capacity of the test machine is exceeded by the use of a full thickness specimen, sub-sized flat tensile specimens representing either the full thickness or half of the product thickness obtained by machining and retaining one of the original surfaces may be used. Alternatively, machined round test specimens as per 2-1-1/11.5.2 may be used. The round specimens are to be located at a position lying at a distance of  $t/4$  from the surface and additionally at  $t/2$  for thickness above 100 mm or as near as possible to these positions.

The results of the tests are to comply with the appropriate requirements of 2-1-8/5.11 TABLE 5A. In the case of product forms other than plates and wide flats where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those transverse requirements as listed in 2-1-8/5.11 TABLE 5B.

## 5.3 Impact Test

The Charpy V-notch impact test specimens are to be taken with their axes longitudinal or transverse to the final rolling direction and the results are to comply with the appropriate requirements of 2-1-8/5.11 TABLE 5A.

Sub-surface test specimens are to be located with their edges not more than 2 mm (0.08 in.) from the rolled surface. For thickness greater than 40 mm (1.57 in.) the impact test specimens are to be taken at quarter thickness ( $t/4$ ) and for products with thickness in excess of 100 mm (4.0 in.), impact tests shall be taken at the quarter thickness ( $t/4$ ) location and mid-thickness ( $t/2$ ). Tests carried out at mid  $t$  and are to achieve at least  $2/3$  of the required Joule value indicated in table 2-1-8/5.11 TABLE 5A. Alternatively, the mid  $t$  test can be carried out at 10°C above the specified CVN test temperature to achieve the same Charpy value specified for the sub-surface specimen.

Impact test for a nominal thickness less than 6 mm are normally not required.

## 5.5 Through Thickness Tensile Test

For steels designated with improved through thickness properties, through thickness tensile tests are to be performed in accordance with 2-1-1/17.

## 5.7 Test Frequency

### 5.7.1 Tensile Test (2022)

For plates and tubulars, tension test specimens are to be taken from each heat treatment batch of the same cast, delivery condition and thickness. In the case of tubulars supplied in QT condition, properties are to be verified from both ends of the product. This may be established by tensile test or hardness test.

For sections and bars, tension test specimens are to be randomly selected from every 25 tonnes or part thereof, from each heat treatment batch of the same cast, delivery condition and thickness.

### 5.7.2 Impact Test (2022)

For plates and tubulars, impact test specimens are to be taken from each heat treatment batch of the same cast, delivery condition and thickness. In the case of tubulars supplied in QT condition, properties are to be verified from both ends of the product during qualification.

For sections and bars, impact test specimens are to be randomly selected from every 25 tonnes or part thereof, from each heat treatment batch of the same cast, delivery condition and thickness.



Notes:

- 1 If the mass of the finished material is greater than 25 tonnes, one set of tests from each 25 tonnes and/or fraction thereof is required. (e.g., for consignment of 60 tonnes would require 3 pieces to be tested).
- 2 For continuous heat treated product special consideration may be given to the number and location of test specimens required by the manufacturer to be agreed by ABS.

5.9 Traceability

Traceability of test material, specimen sampling and test procedures including test equipment with respect to mechanical properties testing, is to be in accordance with 2-1-1/5 and 2-1-1/9.

5.11 Re-test

Re-test procedures for tensile tests and impact tests are to be in accordance with 2-1-1/9.5, 2-1-2/9.11 and 2-1-2/11.7.

**TABLE 5A**  
**Mechanical Properties Requirements (2018)**

Grade of Steel	Tensile Properties <sup>(1,3,8,10)</sup>			Impact Test	
	Yield Strength, ReH <sup>(4)</sup> N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Tensile Strength, Rm N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Elongation % <sup>(5,6)</sup> in 5.65√A <sup>(7)</sup> minimum	Test Temperature °C (°F)	Energy Average J <sup>(1,2)</sup> (kgf-m, ft-lb)
AQ43	420	530/680	18	0 (32)	41 (4.2, 30) <sup>(2)</sup> L
DQ43	(43, 61)	(54/69, 77/98)		-20 (-4)	or
EQ43				-40 (-40)	27 (2.8, 20) <sup>(1)</sup> T
FQ43				-60 (-76)	
AQ47	460	570/720	17	0 (32)	46 (4.7, 34) L
DQ47	(47, 67)	(58/73, 83/104)		-20 (-4)	or
EQ47				-40 (-40)	31 (3.2, 23) T
FQ47				-60 (-76)	
AQ51	500	610/770	16	0 (32)	50 (5.1, 37) L
DQ51	(51, 73)	(62/78, 88/112)		-20 (-4)	or
EQ51				-40 (-40)	33 (3.4, 24) T
FQ51				-60 (-76)	
AQ56	550	670/835	16	0 (32)	55 (5.6, 41) L
DQ56	(56, 80)	(68/85, 97/120)		-20 (-4)	or
EQ56				-40 (-40)	37 (3.8, 27) T
FQ56				-60 (-76)	
AQ63	620	720/890	15	0 (32)	62 (6.3, 46) L
DQ63	(63, 90)	(73/91, 104/129)		-20 (-4)	or
EQ63				-40 (-40)	41 (4.2, 30) T
FQ63				-60 (-76)	
AQ70	690	770/940	14	0 (32)	69 (7.0, 51) L
DQ70	(70, 100)	(78/96, 112/136)		-20 (-4)	or
EQ70				-40 (-40)	46 (4.7, 34) T

Grade of Steel	Tensile Properties <sup>(1,3, 8,10)</sup>			Impact Test	
	Yield Strength, ReH <sup>(4)</sup> N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Tensile Strength, Rm N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Elongation % <sup>(5,6)</sup> in 5.65√A <sup>(7)</sup> minimum	Test Temperature °C (°F)	Energy Average J <sup>(1,2)</sup> (kgf-m, ft-lb)
FQ70				-60 (-76)	
AQ91	890	940/1100	11	0 (32)	69 (7.0, 51) L
DQ91	(91, 129)	(96/112, 136/160)		-20 (-4)	or
EQ91				-40 (-40)	46 (4.7, 34) T
AQ98 <sup>(9)</sup>	960	980/1150	10	0 (32)	69 (7.0, 51) L
DQ98 <sup>(9)</sup>	(98, 139)	(100/117, 142/167)		-20 (-4)	or
EQ98 <sup>(9)</sup>				-40 (-40)	46 (4.7, 34) T

Notes:

- 1 T = Transverse
- 2 L = Longitudinal
- 3 For plates and sections for applications, such as leg, rack and chord in Mobile Offshore Units (MOU), where the design requires that tensile properties are maintained through the thickness, a decrease in the minimum specified tensile properties is not permitted with an increase in the thickness. Materials intended for leg, racks and chords are to have a designation “R” after the Grade (i.e., EQ70-R).
- 4 For tensile test, either the upper yield stress (ReH) or where ReH cannot be determined, the 0.2 percent proof stress (Rp0.2) is to be determined and the material is considered to comply with the requirement if either value meets or exceeds the specified minimum value of yield strength.
- 5 The elongation for alternative B specimen in 2-1-1/16 FIGURE 2 is to be in accordance with 2-1-8/5.11 TABLE 5B.
- 6 The indicated elongations are for specimens taken transverse to the direction of roll. Where longitudinal specimens are specially approved, the minimum elongation values are to be 2% above those shown in 2-1-8/5.11 TABLE 5A and 2-1-8/5.11 TABLE 5B.
- 7 A equals cross-sectional area of test specimen.
- 8 For thickness greater than 100 mm, except as indicated in Note 3, ABS will consider a reduction in tensile properties provided they are accounted for in the design phase. Refer to Note in 3-1-4/1.1 and 3-1-4/3.7 of the MOU Rules.
- 9 Maximum thickness is 50 mm for 98 grades.
- 10 Tensile values that fall between the categories listed in the table will be considered.

**TABLE 5B**  
**Requirements for Alternative Specimen<sup>(1)</sup>(2018)**

Grade of Steel	Thickness, mm						
	≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
AQ43 to FQ43	11	13	14	15	16	17	18
AQ47 to FQ47	11	12	13	14	15	16	17
AQ51 to FQ51	10	11	12	13	14	15	16
AQ56 to FQ56	10	11	12	13	14	15	16
AQ63 to FQ63	9	11	12	12	13	14	15
AQ70 to FQ70	9	10	11	11	12	13	14

*Note:*

- 1 91 and 98 specimens which are not included in this table shall be proportional specimens with a gauge length of  $L_0 = 5.65\sqrt{S_0}$ .

## 7 Tolerances

Unless otherwise agreed or specially required, the thickness tolerances are to be in accordance with 2-1-1/15.

## 9 Surface Quality

All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects. The surface quality inspection method shall be in accordance with EN 10163 Parts 1, 2 and 3 or equivalent standards agreed between purchaser and manufacturer and accepted by ABS.

Surface finish requirement shall be in accordance with the relevant requirements in 2-1-2/15.

Surface inspection is the responsibility of the manufacturer. The acceptance by ABS Surveyor of material later found to be defective shall not absolve the manufacturer of this responsibility.

### 9.1 Plate Edge Inspection

Edge of the plate is to be inspected. Any discontinuity greater than 25 mm in length is to be further investigated for depth and extent. Treatment of discontinuity is to be agreed with ABS.

## 11 Internal Soundness

Verification of internal soundness is the responsibility of the manufacturer. The acceptance by the ABS Surveyor shall not absolve the manufacturer of this responsibility.

### 11.1 Ultrasonic Examination (2022)

All steel grades with thickness greater than or equal to 15 mm (0.60 in.) are to be inspected for internal quality at the mill in accordance with EN10160 or ASTM A578 or other recognized standard as agreed with ABS. Acceptance criteria is to be agreed between the purchaser and manufacturer, and accepted by ABS.

Acceptable standards are as follows:

For leg, rack and chord plates in Mobile Offshore Units (MOU), the acceptance criteria shall be a minimum of EN10160 Level S2/E3.

If chords are ordered with ultrasonic inspection in the final formed and heat treated condition, the specification and acceptance criteria is to be agreed between the purchaser and manufacturer, and accepted by ABS

*Note:*

For Z quality steels, ultrasonic examination is to be carried out on products of thickness 15 mm and above (refer to 2-1-1/17).

## 13 Stress Relieving Heat Treatment and Other Heat Treatments

Steels approved by the procedures given in 2-A4-3 are suitable for stress relieving heat treatment such as post-weld heat treatment and stress relieving heat treatment after cold forming (refer to 2-A4-3/5.11.3(e))

*Note:*

Products can be susceptible to deterioration in mechanical strength and toughness if they are subjected to incorrect post-weld heat treatment procedures or other processes involving heating such as flame straightening, rerolling, etc., where the heating temperature and the holding time exceed the limits provided by the manufacturer.

## 15 Fabrication & Welding

Upon request from the fabricator, the steel mill may supply the parameters applied during the weldability tests (carried out in accordance with 2-A4-2/5.13) in order to develop fabrication procedures. Also ABS can populate this information on ABS website with written consent from the steel mill.

## 17 Facilities for Inspection

Testing is to be carried out under the witness of the Surveyor in order to verify that the test results meet the specified requirements.

The manufacturer is to provide access to the steel works to enable the Surveyor to,

- i)* Verify that the approved manufacturing process is followed
- ii)* Select test materials
- iii)* Witness mechanical tests and to verify testing is in accordance with standards
- iv)* Witness/verify NDE inspection, calibration of inspection equipment.

## 19 Identification of Materials

The manufacturer is to adopt a system for the identification of ingots, slabs, billet or bloom and finished products, which will enable the material to be traced to its original cast.

The steel mill is to facilitate the Surveyor to verify traceability of the material.

## 21 Marking

Refer to requirements in 2-1-2/13.

Permanent marking of the grade and delivery condition is to be done on the product in the final delivery condition. Marking of the final designated grade is not permitted on semi-finished products.

Materials intended for leg, racks and chords are to have a designation “R” after the Grade (i.e., EQ70-R).

## 23 Documentation of Inspection Tests

The Surveyor is to be supplied with a copy, of the test certificates or shipping statements for all accepted materials. In addition to the description, dimensions, etc., of the material, the following particulars are to be included:

- i)* Purchaser’s order number
- ii)* Identification of the cast/heat, batch and plate number
- iii)* Manufacturer’s identification
- iv)* Identification of the grade of steel
- v)* Chemical analysis and Ceq, CET or Pcm value
- vi)* Delivery condition with heat treatment temperatures
- vii)* Mechanical properties test results, including traceable test identification
- viii)* Surface quality and inspection results

- ix)* UT report
- x)* Manufacturer's Certificate refer to 2-1-1/7

# PART 2

## CHAPTER 2 Equipment

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Anchors</b> .....	<b>83</b>
	1	General Requirements (2007).....	83
	1.1	Scope.....	83
	1.3	Types of Anchor.....	83
	3	Materials for Anchors (2012).....	84
	3.1	Superior Holding Power (SHP) Anchors for Restricted Service and to a Maximum Weight of 1500 kg (3306 lbs).....	84
	5	Manufacture of Anchors (2007).....	84
	5.1	Tolerance.....	84
	5.3	Welding of Anchors.....	85
	5.5	Heat Treatment (2012).....	85
	5.7	Surface Cleanliness.....	86
	5.9	Repairs (2010).....	86
	5.11	Anchor Assembly.....	86
	7	Testing and Certification (2007).....	86
	7.1	Proof Load Testing of Anchors.....	86
	7.3	Product Tests.....	87
	7.5	Mass and Dimensional Inspection.....	90
	7.7	Retests.....	90
	9	Marking for Anchors .....	90
	9.1	Markings.....	90
	9.3	Provisions for Marks (2005).....	90
	11	Certification (2007).....	91
	13	Painting (2007).....	91
	TABLE 1	Applicable Test Programs for Each Product Form (2010)....	88
	TABLE 2	Product Test Requirements for Program A and B (2010)....	88
	TABLE 3	General NDE for Ordinary and SHP Anchors.....	88
	TABLE 4	General NDE for SHP Anchors for Restricted Service with 4 Times Holding Power of Ordinary Anchors.....	89
	TABLE 5	Extended NDE for Ordinary and all SHP Anchors.....	89

TABLE 6	Proof Tests for Anchors .....	92
FIGURE 1	Allowable Lateral Movement of Shank (2007).....	85
FIGURE 2	Proof Load Application.....	87
FIGURE 3	Stockless Anchor (2008).....	90

<b>SECTION 2</b>	<b>Anchor Chain .....</b>	<b>97</b>
1	Scope.....	97
3	General.....	97
5	Specially Approved Chain.....	97
7	Qualification of Manufacturers .....	97
7.1	General.....	97
7.3	Stud Attachment (2005).....	98
9	Chain Dimensions and Tolerances .....	98
9.1	Shape.....	98
9.3	Dimensions (2005).....	98
9.5	Tolerances (1999).....	99
9.7	Length Over Five Links.....	100
11	Material for Chain.....	100
11.1	General.....	100
13	Material Testing .....	101
13.1	Heat Treatment of Test Specimens.....	101
13.3	Number of Tests.....	101
13.5	Tension Test Specimens (1996).....	101
13.7	Bend Test Specimens.....	101
13.9	Impact Test Specimens.....	101
13.11	Additional Tests before Rejection (1996).....	102
13.13	Manufacturer's Option.....	102
15	Heat Treatment of Chain Lengths.....	102
15.1	Flash Butt-welded Chain.....	102
15.3	Drop-forged, Cast-steel and Extra-high-strength Chain	102
15.5	Sequence of Heat Treatment.....	102
17	Testing and Inspection of Chain Lengths .....	103
17.1	General (1996).....	103
17.3	Chain Identification.....	103
17.5	Testing Precautions.....	103
17.7	Weighing of Tested Chain.....	103
17.9	Testing of Used Chain.....	103
19	Details of Tests on Chain Lengths .....	103
19.1	Breaking Test (2005).....	103
19.3	Proof Test.....	104
19.5	Mechanical Tests on Completed Chain (2005).....	104

	19.7	Mechanical and Breaking Tests on Chain Produced in Long Continuous Lengths.....	104
21		Marking for Chain (2001).....	105
23		Anchor Chain Accessories .....	106
	23.1	Dimensions and Dimensional Tolerances (1996).....	106
	23.2	Locking Pins in Accessories.....	106
	23.3	Material Testing.....	106
	23.5	Cast Accessories.....	106
	23.7	Forged Accessories.....	106
	23.9	Inspection.....	106
	23.11	Hardness Test.....	106
	23.13	Break Test (2001).....	106
	23.15	Proof Tests.....	107
	23.17	Markings.....	107
25		Unstudded Short-link Chain.....	107
	25.1	General.....	107
	25.3	Testing.....	107
	25.5	Marking.....	107
27		Material Hardness for Windlass-Wildcats and Gypsy Wheels....	108
	27.1	Wear and Abrasion.....	108
	27.3	Approximate Hardness Values for Wildcats and Gypsy Wheels.....	108
	27.5	Cladding and Hardfacing.....	109
	TABLE 1	Chain Materials -Mechanical Properties (1999).....	108
	TABLE 2	Stud-link Anchor-chain Proof and Break Tests.....	110
	TABLE 3	Unstudded Short-link Chain.....	115
	FIGURE 1	Location and Orientation of Test Specimens.....	102
	FIGURE 2	Marking for Chain.....	105

**SECTION 3 Rolled Steel Bars for Chain, Cast and Forged Materials for Accessories and Materials for Studs ..... 116**

1		General (2005).....	116
	1.1	Process and Qualification of Manufacture (2012).....	116
	1.3	Deoxidation Practice.....	116
	1.5	Chemical Composition and Heat Treatment (1999).....	116
	1.7	Mechanical Properties (1999).....	116
	1.9	Dimensional properties (1999).....	117
3		Material Testing.....	117
	3.1	Heat Treatment of Test Specimens.....	117
	3.3	Number of Tests.....	117
	3.5	Tension Test Specimens (1996).....	117
	3.7	Bend Test Specimens.....	117



3.9	Impact Test Specimens.....	117
3.11	Additional Tests before Rejection(1996).....	118
3.13	Manufacturer's Option.....	118
3.15	Freedom from Defects (2005).....	118
3.17	Identification of Material (2005).....	118
3.19	Marking (2005).....	118
3.21	Material Certification (2005).....	118
3.23	Forged Steels for Chain Cables and Accessories (2005).....	118
3.25	Cast Steels for Chain Cables and Accessories (2005)..	119
3.27	Materials for Studs (2005).....	119
TABLE 1	Rolled Bars for Chain – Chemical Composition and Intended Chain Condition (2008).....	119
TABLE 2	Rolled Bar for Chain – Dimensional Tolerances (1999).....	119

## **1 General Requirements (2007)**

### **1.1 Scope**

These requirements apply to the materials, manufacture, testing and certification of anchors, shanks and anchor shackles produced from cast or forged steel, or fabricated by welded rolled steel plate and bars.

These manufacturing requirements are applicable to ordinary anchors and superior holding power (SHP) anchors.

### **1.3 Types of Anchor**

#### **1.3.1 Ordinary Anchors (Also see 3-5-1/7)**

Ordinary stockless anchors are to be of an approved design. Any changes or alterations from the approved design are to be approved prior to manufacture.

The mass of the heads of stockless anchors including pins and fittings are not to be less than 60 % of the total mass of the anchor.

#### **1.3.2 Superior Holding Power (SHP) Anchors (Also see 3-5-1/7)**

SHP anchors are to be of an approved design and subject to special approval. Any changes or alterations to the approved design made during manufacture are to have prior approval.

SHP anchors are to be suitable for ship use and are not to require prior adjustment or special placement on the seabed.

SHP anchors are to have at least twice the holding power of ordinary stockless anchors of the same weight.

The mass of each bower anchor can be reduced by up to 25 % of the mass specified in 2-2-1/13 TABLE 6.

Approved manufacturers of SHP anchors are included in a specific directory maintained by ABS.

### 1.3.3 SHP Anchors for Restricted Service and to a Maximum Weight of 1500 kg (3306 lbs)

Special approval can be given to superior holding power anchors with holding powers of at least 4 times the holding power of ordinary anchors. The mass of each bower anchor can be reduced by up to 50% of the mass specified in 2-2-1/13 TABLE 6.

## 3 Materials for Anchors (2012)

All anchors are to be manufactured from materials meeting the requirements of the *ABS Rules for Materials and Welding (Part 2)* and produced by a manufacturer approved by ABS.

Cast steel anchor flukes, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 2-1-5 and comply with the requirements for castings for welded construction. The steel is to be fine grain treated with aluminum.

Cast steel anchor flukes and shanks are to have integrally cast test coupons. The test coupons are not to be detached until the full heat treatment cycle has been completed. The method of detachment is not to physically or metallurgically damage the anchor component. Test coupons are not to be detached until they have been stamped by the Surveyor for identification. Test coupons are to be traceable to the cast components they represent. Test reports are to be traceable to the test coupons.

Two test programs “A” and “B” are permitted in accordance with 2-2-1/7.3.1. Charpy V notch (CVN) impact testing of cast material is required. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

Forged steel anchor pins, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 2-1-6. Shanks, swivels and shackles are to comply with the requirements for carbon and carbon-manganese steels for welded construction. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

Rolled plates and bars for fabricated steel anchors are to be manufactured and tested in accordance with the requirements of Section 2-1-1.

Rolled bars intended for pins, swivels and shackles are to be manufactured and tested in accordance with the requirements of Sections 2-1-1 or 2-3-8.

### 3.1 Superior Holding Power (SHP) Anchors for Restricted Service and to a Maximum Weight of 1500 kg (3306 lbs)

In addition to the above requirements, steel is to be selected in accordance with 3-1-2/3.3 TABLE 1 Class II of the *Marine Vessel Rules*. The welding consumables are to meet the toughness for the base steel grades. Toughness of the anchor shackles is to meet that for Grade 3 anchor chain. The toughness of steel castings is to be not less than a Charpy V-notch energy average of 27 J at 0°C (2.8 kgf-m at 0°C, 20 ft-lbs at 32°F).

## 5 Manufacture of Anchors (2007)

### 5.1 Tolerance

If not otherwise specified in standards or on drawings demonstrated to be appropriate, the following assembly and fitting tolerances are to be applied.

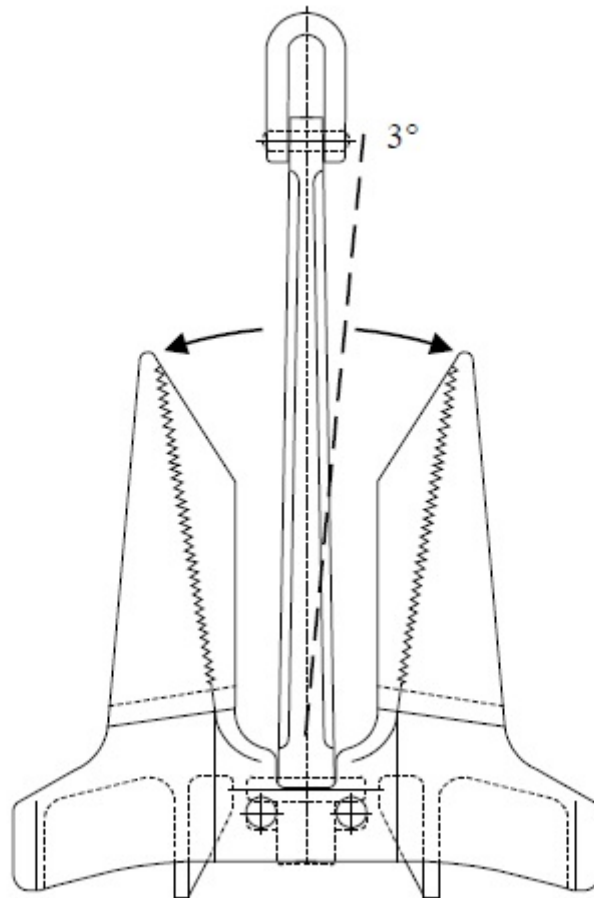
The clearance either side of the shank within the shackle jaws is to be no more than 3 mm (0.12 inch) for small anchors up to 3 tonnes (3.3 tons) weight, 4 mm (0.16 inch) for anchors up to 5 tonnes (5.5 tons) weight, 6 mm (0.24 inch) for anchors up to 7 tonnes (7.7 tons) weight and is not to exceed 12 mm (0.47 inch) for larger anchors. The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle

pin to hole tolerance is to be no more than 0.5 mm (0.02 inch) for pins up to 57 mm (2.24 inch) and 1.0 mm (0.04 inch) for pins of larger diameter.

The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.

The lateral movement of the shank is not to exceed 3 degrees, see 2-2-1/5.1 FIGURE 1.

**FIGURE 1**  
**Allowable Lateral Movement of Shank (2007)**



### 5.3 Welding of Anchors

Welded construction of fabricated anchors is to be in accordance with approved procedures in accordance with Sections 2-4-1 and 2-4-3. NDE is to be carried in accordance with the requirements of 2-2-1/7.3.5 TABLE 3 or 2-2-1/7.3.5 TABLE 4 or 2-2-1/7.3.6 TABLE 5 product tests.

### 5.5 Heat Treatment (2012)

Components for cast or forged anchors are to be properly heat treated; fully annealed; normalized or normalized and tempered in accordance with 2-1-5/5 or 2-1-6/5. Fabricated anchors may require stress relief after welding depending upon weld thickness. Stress relief is to be carried out as indicated in the approved welding procedure. Stress relief temperatures are not to exceed the tempering temperature of the base material.

The foundry or forge is to provide the Surveyor records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The heat treatment temperature and time is to be based on sensors attached to the furnace charge. The time lag between the thermocouples on the furnace charge and wall/interior of the furnace is to be determined in order to assess that the heating and soaking times are sufficient.

Integrally cast or forged coupons are to be of sufficient size to represent the heat transfer experienced in the cast or forged component itself during the complete heat treatment cycle.

## 5.7 Surface Cleanliness

All parts are to have a clean surface consistent with the method of manufacture and intended method of inspection.

## 5.9 Repairs (2010)

Any necessary repairs to forged and cast anchors are to be agreed to by the Surveyor and carried out in accordance with the repair criteria indicated in 2-1-5/13 and 2-1-6/11.9. The restrictions of 2-2-1/7.3.7 - Repair Criteria, also apply.

The manufacturer is to maintain full records detailing the extent and location of all weld repairs made to each casting or forging and details of weld procedures and heat treatments applied. These records are to be available to the Surveyor and copies provided on request.

Repairs to fabricated anchors are to be agreed to by the Surveyor and carried out in accordance with qualified weld procedures, by qualified welders, following the parameters of the welding procedures used in construction.

## 5.11 Anchor Assembly

Assembly and fitting are to be done in accordance with the design details. Securing of the anchor pin, shackle pin or swivel nut, by welding, is to be in accordance with an approved procedure.

# 7 Testing and Certification (2007)

All anchors are to be inspected and tested in the presence of the Surveyor, the proof testing is to be done in a machine recognized for such purposes. The Surveyor is to be satisfied that all testing machines, including material testing machines, are maintained in a satisfactory condition, and is to keep a record of the dates and by whom the machines were rechecked and calibrated.

## 7.1 Proof Load Testing of Anchors

Proof load testing for ordinary and SHP anchors is to be carried out by an approved testing facility.

### 7.1.1 Proof Load Testing of Ordinary Anchors (2014)

Before application of proof test load, the anchors are to be visually examined, and all defects are to be removed, and if necessary repaired by welding, prior to testing. Proof tests are to be carried out on all anchors after being temporarily assembled. The proof tests are to be in accordance with the values given in 2-2-1/13 TABLE 6. The proof load in accordance with 2-2-1/13 TABLE 6 is to be applied on the fluke at a location one third of the distance from the tip of the fluke to the center of the crown as shown in 2-2-1/7.1.1 FIGURE 2.

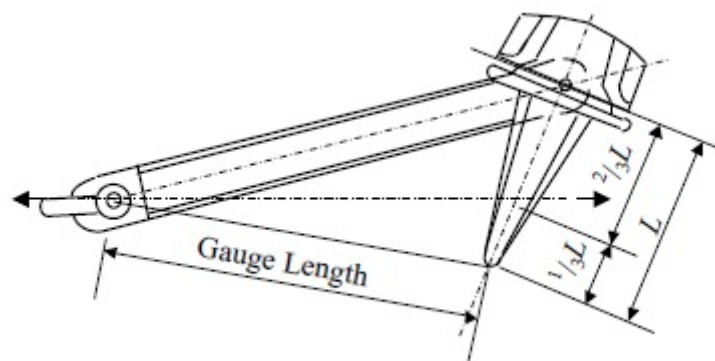
In the case of stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

After proof load testing the anchors are to be examined for cracks and other defects, and for excessive deformation due to seating.

Upon completion of the proof load tests, anchors made in more than one piece are to be examined for free rotation of their heads over the complete angle. The anchor shackle that underwent proof load testing is to be fitted to the anchor before shipping to the customer.

The gauge lengths (see 2-2-1/7.1.1 FIGURE 2) under a load equal to one-tenth of the proof test load are to be determined before and after the application of full proof load on each side. The gauge length after the application of full proof load is to be not more than 1% in excess of the corresponding gauge length before the application of full proof load.

**FIGURE 2**  
**Proof Load Application**



#### 7.1.2 Proof Load Testing of SHP Anchors

SHP anchors are to be proof tested with loads required by 2-2-1/13 TABLE 6 for an anchor mass equal to 1.33 times the actual mass of the SHP anchor. The proof loading procedure and examination procedure for SHP anchors are to comply with those for ordinary anchors, described in 2-2-1/7.1.

#### 7.1.3 Testing of SHP Anchors for Restricted Service with 4 Times Holding Power of Ordinary Anchors

These anchors are to be proof tested with the load required by 2-2-1/13 TABLE 6 for an anchor mass equal to 2 times the actual mass of the SHP anchor. The proof loading procedure and examination procedure for SHP anchors are to comply with those for ordinary anchors, described in 2-2-1/7.1.

#### 7.1.4 SHP Full Scale Anchor Holding Power Tests at Sea

In addition to proof tests SHP anchors are to undergo anchor holding power sea tests on various types of sea bottom, using anchors representative of the full range of anchor size proposed.

### 7.3 Product Tests

#### 7.3.1 Product Test Programs

There are two test programs, which apply to anchor manufacture.

- Program A, or
- Program B.

**TABLE 1**  
**Applicable Test Programs for Each Product Form (2010)**

<i>Product Test</i>	<i>Product Form</i>		
	<i>Cast Components</i>	<i>Forged Components</i>	<i>Fabricated/Welded Components</i>
Program A	Applicable <sup>(1)</sup>	Not Applicable	Not Applicable
Program B	Applicable <sup>(1)</sup>	Applicable <sup>(2)</sup>	Applicable <sup>(2)</sup>

**Notes:**

- 1 CVN impact tests are to be carried out to demonstrate at least 27 J average at 0°C (2.8 kgf-m at 0°C, 20 ft-lbs at 32°F).
- 2 The Drop test requirement in Program B is not applicable for Forged Components or Fabricated/Welded Components.

**TABLE 2**  
**Product Test Requirements for Program A and B (2010)**

<i>Program A</i>	<i>Program B</i>
Drop test	Drop test
Hammering test	---
Visual inspection	Visual inspection
General NDE	General NDE
---	Extended NDE

**7.3.2 Drop Test**

Each anchor fluke and shank is to be individually raised to a height of 4 m (13.1 ft) and dropped on to a steel slab without fracturing. The steel slab is to be suitable to resist the impact of the dropped component.

**7.3.3 Hammering Test**

After the drop test, hammering tests are to be carried out on each anchor fluke and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg (6.6 lbs) mass is to be used.

**7.3.4 Visual Inspection**

After proof loading visual inspection of all accessible surfaces is to be carried out.

**7.3.5 General Nondestructive Examination**

After proof loading, general NDE is to be carried out as indicated in 2-2-1/7.3.5 TABLE 3 and 2-2-1/7.3.5 TABLE 4.

**TABLE 3**  
**General NDE for Ordinary and SHP Anchors**

<i>Location</i>	<i>Method of NDE</i>
In way of feeders of castings	PT or MT
In way of risers of castings	PT or MT

<i>Location</i>	<i>Method of NDE</i>
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Part 2, Appendix 6, “Nondestructive Examination of Marine Steel Castings” is regarded as an example of an acceptable standard for surface and volumetric examination.

**TABLE 4**  
**General NDE for SHP Anchors for Restricted Service with 4 Times Holding Power of Ordinary Anchors**

<i>Location</i>	<i>Method of NDE</i>
In way of feeders of castings	PT or MT and UT
In way of risers of castings	PT or MT and UT
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Part 2, Appendix 6, “Nondestructive Examination of Marine Steel Castings” is regarded as an example of an acceptable standard for surface and volumetric examination.

**7.3.6 Extended Nondestructive Examination**

After proof loading extended NDE is to be carried out as indicated in 2-2-1/7.3.6 TABLE 5.

**TABLE 5**  
**Extended NDE for Ordinary and all SHP Anchors**

<i>Location</i>	<i>Method of NDE</i>
In way of feeders of castings	PT or MT and UT
In way of risers of castings	PT or MT and UT
All surfaces of castings	PT or MT
Random areas of castings	UT
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Part 2, Appendix 6, “Nondestructive Examination of Marine Steel Castings” is regarded as an example of an acceptable standard for surface and volumetric examination.

**7.3.7 Repair Criteria**

If defects are detected by NDE, repairs are to be carried out in accordance with 2-2-1/5.9. For fracture and unsoundness detected in a drop test or hammering test, repairs are not permitted and the component is to be rejected.



### 7.5 Mass and Dimensional Inspection

Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is an integral component.

### 7.7 Retests

Mechanical retest is permitted in accordance with the requirements of 2-1-5/3.3 and 2-1-6/3.3.

## 9 Marking for Anchors

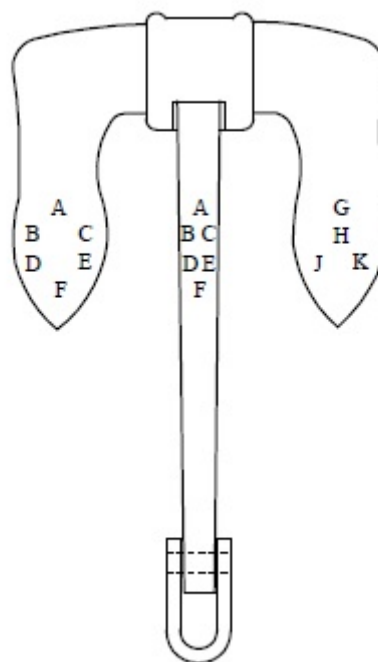
### 9.1 Markings

When anchors have satisfactorily passed the above test requirements, they are to be clearly stamped by the manufacturer as shown in 2-2-1/9.3 FIGURE 3.

### 9.3 Provisions for Marks (2005)

One side of the anchor is to be reserved solely for the above marks and the other side used for the marker's name or other trademarks that may be desired. If the design of the anchor does not admit of the above marks being placed or grouped as indicated, a suitable boss is to be cast on each arm, on which the marks are to be stamped. The Maltese Cross, ☒ is to be stamped at positions "B" & "J" along with the witnessing Surveyor's initials per .

**FIGURE 3**  
**Stockless Anchor (2008)**



A	The number of Certificate. (Furnished by the Surveyor)	00-PA123
B	(2005) The Maltese Cross Stamp and the Initials of the Surveyor who witnesses the Proof Test	☒ X.Y.X.
C	Month and Year of Test	1-00
D	Proof Test applied	34680

E	Signifying that the Testing Machine is recognized by the Committee of the American Bureau of Shipping	AB
F	The Weight of Anchor	1906
G	(2008) Signifying that Anchor Head has been verified by a Surveyor to the American Bureau of Shipping	AB
H	The Weight of Anchor Head	1140
J	(2005) The Maltese Cross Stamp and the Initials of the Surveyor who witnesses the Drop Test	☒ X.Y.X.
K	Month and Year of Drop Test	6-00

## 11 Certification (2007)

Anchors which meet the requirements of this section are to be certified by ABS. The following items that are to be included in the certificate:

- Manufacturer's name
- Type
- Mass
- Fluke and Shank identification numbers
- Grade of materials
- Proof test loads
- Heat treatment
- Markings applied to anchor

## 13 Painting (2007)

All types of anchor are to remain unpainted until all tests and inspections have been completed.

**TABLE 6**  
**Proof Tests for Anchors**

*Note See also 3-5-1/7 of the Marine Vessel Rules*

*SI Units*

Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN
50	23	500	116	2000	349	4500	622	7000	804	15000	1260	38000	2330
55	25	550	125	2100	362	4600	631	7200	818	15500	1270	40000	2410
60	27	600	132	2200	376	4700	638	7400	832	16000	1300	42000	2490
65	29	650	140	2300	388	4800	645	7600	845	16500	1330	44000	2570
70	31	700	149	2400	401	4900	653	7800	861	17000	1360	46000	2650
75	32	750	158	2500	414	5000	661	8000	877	17500	1390	48000	2730
80	34	800	166	2600	427	5100	669	8200	892	18000	1410		
90	36	850	175	2700	438	5200	677	8400	908	18500	1440		
100	39	900	182	2800	450	5300	685	8600	922	19000	1470		
120	44	950	191	2900	462	5400	691	8800	936	19500	1490		
140	49	1000	199	3000	474	5500	699	9000	949	20000	1520		
160	53	1050	208	3100	484	5600	706	9200	961	21000	1570		
180	57	1100	216	3200	495	5700	713	9400	975	22000	1620		
200	61	1150	224	3300	506	5800	721	9600	987	23000	1670		
225	66	1200	231	3400	517	5900	728	9800	998	24000	1720		
250	70	1250	239	3500	528	6000	735	10000	1010	25000	1770		
275	75	1300	247	3600	537	6100	740	10500	1040	26000	1800		

*Note See also 3-5-1/7 of the Marine Vessel Rules*

**SI Units**

Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN
300	80	1350	255	3700	547	6200	747	11000	1070	27000	1850
325	84	1400	262	3800	557	6300	754	11500	1090	28000	1900
350	89	1450	270	3900	567	6400	760	12000	1110	29000	1940
375	93	1500	278	4000	577	6500	767	12500	1130	30000	1990
400	98	1600	292	4100	586	6600	773	13000	1160	31000	2030
425	103	1700	307	4200	595	6700	779	13500	1180	32000	2070
450	107	1800	321	4300	604	6800	786	14000	1210	34000	2160
475	112	1900	335	4400	613	6900	794	14500	1230	36000	2250

*Note See also 3-5-1/7 of the Marine Vessel Rules*

**Metric Units**

Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf
50	2370	500	11800	2000	35600	4500	63400	7000	82000	15000	128000
55	2570	550	12700	2100	36900	4600	64300	7200	83400	15500	130000
60	2760	600	13500	2200	38300	4700	65100	7400	84800	16000	133000
65	2950	650	14300	2300	39600	4800	65800	7600	86200	16500	136000
70	3130	700	15200	2400	40900	4900	66600	7800	87800	17000	139000
75	3300	750	16100	2500	42200	5000	67400	8000	89400	17500	142000
80	3460	800	16900	2600	43500	5100	68200	8200	91000	18000	144000

*Note See also 3-5-1/7 of the Marine Vessel Rules*

*Metric Units*

Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf
90	3700	850	17800	2700	44700	5200	69000	8400	92600	18500	147000				
100	3990	900	18600	2800	45900	5300	69800	8600	94000	19000	150000				
120	4520	950	19500	2900	47100	5400	70500	8800	95400	19500	152000				
140	5000	1000	20300	3000	48300	5500	71300	9000	96800	20000	155000				
160	5430	1050	21200	3100	49400	5600	72000	9200	98000	21000	160000				
180	5850	1100	22000	3200	50500	5700	72700	9400	99400	22000	165000				
200	6250	1150	22800	3300	51600	5800	73500	9600	100600	23000	170000				
225	6710	1200	23600	3400	52700	5900	74200	9800	101800	24000	175000				
250	7180	1250	24400	3500	53800	6000	74900	10000	103000	25000	180000				
275	7640	1300	25200	3600	54800	6100	75500	10500	106000	26000	184000				
300	8110	1350	26000	3700	55800	6200	76200	11000	109000	27000	189000				
325	8580	1400	26700	3800	56800	6300	76900	11500	111000	28000	194000				
350	9050	1450	27500	3900	57800	6400	77500	12000	113000	29000	198000				
375	9520	1500	28300	4000	58800	6500	78200	12500	115000	30000	203000				
400	9980	1600	29800	4100	59800	6600	78800	13000	118000	31000	207000				
425	10500	1700	31300	4200	60700	6700	79400	13500	120000	32000	211000				
450	10900	1800	32700	4300	61600	6800	80200	14000	123000	34000	220000				
475	11400	1900	34200	4400	62500	6900	81000	14500	125000	36000	229000				

*Note See also 3-5-1/7 of the Marine Vessel Rules*

**US Units**

Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb		Proof Test lbf		Mass of Anchor lb		Proof Test lbf		Mass of Anchor lb		Proof Test lbf		Mass of Anchor lb		Proof Test lbf	
		lb	lbf	lb	lbf	lb	lbf	lb	lbf	lb	lbf	lb	lbf	lb	lbf	lb	lbf
100	5000	1000	24100	3000	57700	5000	86500	7000	110500	9000	131500	28000	256000	56000	400000		
125	5900	1100	25900	3100	59200	5100	87800	7100	112000	9500	136000	29000	262000	58000	410000		
150	6800	1200	27700	3200	60700	5200	89100	7200	113000	10000	140500	30000	266000	60000	419000		
175	7600	1300	29500	3300	62200	5300	90400	7300	114000	11000	148500	31000	272000	62000	428000		
200	8300	1400	31200	3400	63700	5400	91700	7400	115000	12000	156000	32000	275000	64000	437000		
250	9700	1500	32900	3500	65200	5500	93000	7500	116000	13000	163500	33000	281000	66000	446000		
300	10900	1600	34600	3600	66700	5600	94300	7600	117000	14000	170500	34000	287000	68000	455000		
350	12000	1700	36300	3700	68200	5700	95500	7700	118000	15000	177000	35000	292000	70000	464000		
400	13000	1800	38000	3800	69700	5800	96700	7800	120000	16000	185000	36000	298000	75000	486000		
450	14000	1900	39700	3900	71200	5900	97900	7900	120500	17000	192000	37000	303000	80000	507000		
500	15000	2000	41400	4000	72600	6000	99100	8000	121500	18000	200000	38000	309000	85000	528000		
550	16000	2100	43100	4100	74100	6100	100500	8100	122500	19000	208000	39000	314000	90000	549000		
600	16900	2200	44700	4200	75500	6200	101500	8200	123500	20000	214000	40000	320000	95000	569000		
650	17800	2300	46400	4300	76900	6300	102500	8300	124500	21000	221000	42000	330000	100000	590000		
700	18700	2400	48000	4400	78300	6400	104000	8400	125500	22000	227000	44000	341000	105000	610000		
750	19600	2500	49700	4500	79700	6500	105000	8500	126500	23000	232000	46000	351000	110000	630000		
800	20500	2600	51300	4600	81100	6600	106500	8600	127500	24000	239000	48000	361000				
850	21400	2700	52900	4700	82500	6700	107500	8700	128500	25000	243000	50000	371000				

*Note See also 3-5-1/7 of the Marine Vessel Rules*

*US Units*

Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb		Proof Test lbf		Mass of Anchor lb		Proof Test lbf		Mass of Anchor lb		Proof Test lbf		Mass of Anchor lb		Proof Test lbf	
		lb	lbf	lb	lbf	lb	lbf	lb	lbf	lb	lbf	lb	lbf	lb	lbf	lb	lbf
900	22300	2800	54500	4800	83800	6800	108500	8800	129500	26000	247000	52000	381000	27000	251000	54000	390000
950	23200	2900	56100	4900	85200	6900	109500	8900	130500	27000	251000	54000	390000				

# PART 2

## CHAPTER 2 Equipment

### SECTION 2 Anchor Chain

#### 1 Scope

Three grades of stud-link anchor chain are covered, and are described as follows:

<i>Strength Level</i>	<i>Grade</i>	<i>Method of Manufacture</i>
Normal Strength	1	Flash Butt-welded
High Strength	2a	Flash Butt-welded or Drop-forged
	2b	Cast Steel
Extra-high Strength	3a	Flash Butt-welded or Drop-forged
	3b	Cast Steel

#### 3 General

All chain is to have a workmanlike finish and be free from injurious defects. There is to be an odd number of links in each shot of anchor chain cable to insure shackles leading over the windlass are in the same position.

#### 5 Specially Approved Chain

Steel chain made by processes or to requirements differing from those shown in 2-2-2/25.5 TABLE 1 and certain types of drop-forged chain will be subject to special consideration.

#### 7 Qualification of Manufacturers (2020)

##### 7.1 General (2020)

Anchor chain and chain accessories are to be produced by manufacturers approved by ABS. For approval purposes, the manufacturer is to submit a manufacturing procedure specification, applicable material grades, and dimensional details of chain/accessories along with a test plan for ABS review. The approval tests, as a minimum, are to include: chemical analyses, proof and break load tests, tensile/impact tests, metallographic examinations, dimensional measurements, visual and non-destructive examinations. Qualification testing is to be carried out on the largest size chain or accessory. The approval tests are to be witnessed by an attending Surveyor and the test-data are to be submitted to ABS Materials, Houston for review and acceptance. The approval is valid for a maximum of 5 years and the renewal process is to be on similar lines as specified in 2-A4-2/11.



### 7.3 Stud Attachment (2005)

Studs are to be securely fastened by press fitting or welding with an approved procedure. When the stud is welded in place, the weld is to be opposite the flash butt weld in the chain. The welding is to be carried out in the horizontal position at least on both faces of the link for a length sufficient to hold the stud securely in place. Any welding of chain subsequent to the approved manufacturing process is to be approved by the attending Surveyor.

Welding of studs is to be in accordance with an approved procedure subject to the following conditions:

- i)* The studs must be of weldable steel.
- ii)* The studs are to be welded at one end only, i.e., opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.
- iii)* The welds, preferably in the horizontal position, shall be executed by qualified welders using suitable welding consumables.
- iv)* All welds must be carried out before the final heat treatment of the chain cable.
- v)* The welds must be free from defects liable to impair the proper use of the chain. Under-cuts, end craters and similar defects are to be ground off, where necessary.

ABS reserves the right to call for a procedure test for the welding of chain studs.

## 9 Chain Dimensions and Tolerances

### 9.1 Shape

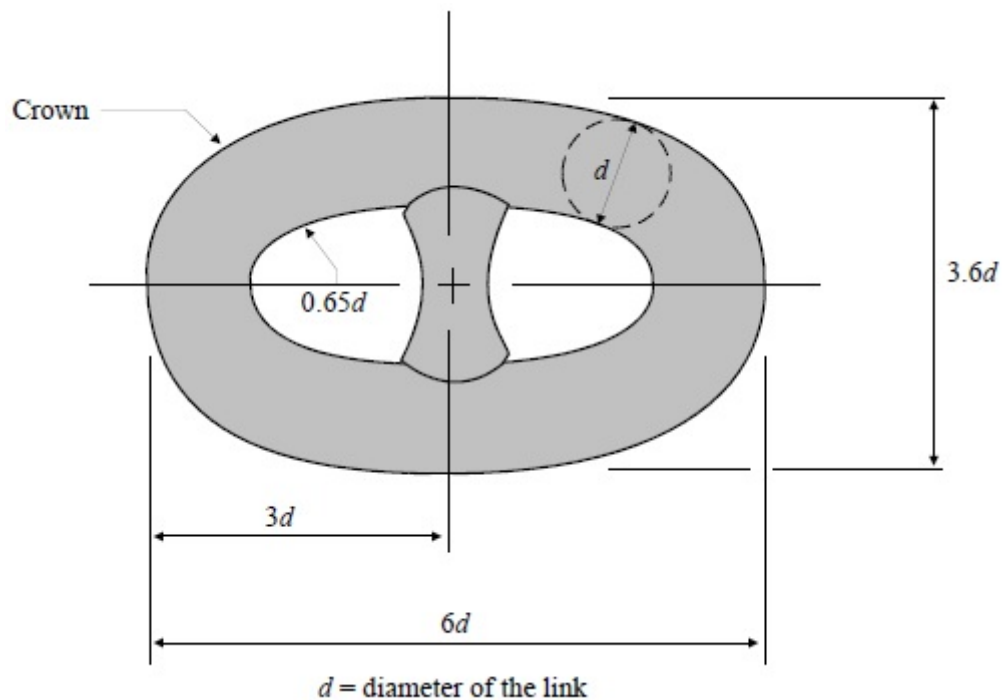
Each link is to be uniform and symmetrical, and is to have smooth internal radii that are to be at least 0.65 times the chain diameter.

### 9.3 Dimensions (2005)

The dimensions, shape and proportions of links and accessories must conform to an approved recognized standard, such as ISO 1704, or the designs are to be specially approved.

After proof testing, measurements are to be taken on at least one link per each 27.5 m (15 fathoms) of chain tested and conform to the dimensions shown below.

### Common Link



### 9.5 Tolerances (1999)

The minus tolerances on the diameter in the plane of the link at the crown are permitted to the extent shown below, provided the cross-sectional area of the link at that point is at least the theoretical area of the nominal diameter:

<i>Chain Diameter in mm (in.)</i>		<i>Crown Minus Tolerance in mm (in.)</i>
<i>Over</i>	<i>Up to</i>	
-	40 (1 <sup>9</sup> / <sub>16</sub> )	1 (1 <sup>1</sup> / <sub>32</sub> )
40 (1 <sup>9</sup> / <sub>16</sub> )	84 (3 <sup>5</sup> / <sub>16</sub> )	2 (1 <sup>1</sup> / <sub>16</sub> )
84 (3 <sup>5</sup> / <sub>16</sub> )	122 (4 <sup>3</sup> / <sub>4</sub> )	3 (1 <sup>1</sup> / <sub>8</sub> )
122 (4 <sup>3</sup> / <sub>4</sub> )	162 (6 <sup>3</sup> / <sub>8</sub> )	4 (5 <sup>1</sup> / <sub>32</sub> )

No minus tolerance on the diameter is allowed at locations other than the crown.

The plus tolerance on the diameter is not to exceed 5% of the nominal diameter. The manufacturer's specification for plus tolerance in way of weld is to be submitted for approval.

Subject to 2-2-2/9.7, the tolerances on other dimensions in 2-2-2/9.3 are not to exceed  $\pm 2.5\%$ .

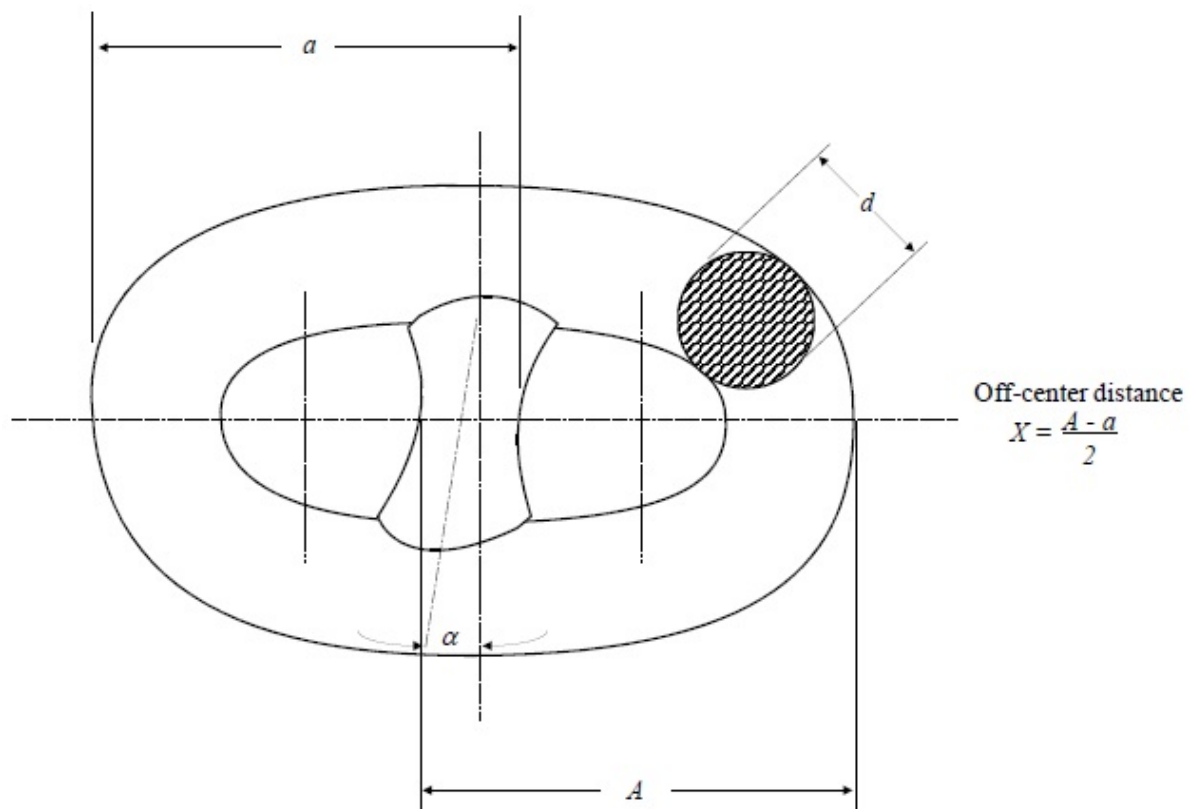
Studs are to be located in the links centrally and at right angles to the sides of the link, except that the studs for the final link at each end of any length may be located off-center to facilitate the insertion of the joining shackle. The following tolerances are acceptable, provided that the stud fits snugly and its ends lie practically flush against the inside of the link.

Maximum off-center distance “X”:  
 Maximum deviation angle “α” from the 90° position :

10% of the nominal diameter, *d*  
 4°

The tolerances are to be measured as follows:

### Final Link



## 9.7 Length Over Five Links

After completion of the proof testing, the length over five links is to be measured while applying a tension of approximately 10% of the applied proof load. The Surveyor is to verify the length over a five link measurement from at least three locations per each 27.5 m (15 fathoms) of chain tested. The allowable tolerance for the length over any five common links is 0.0% of the chain diameter below, and 55% of the chain diameter above the length given in 2-2-2/27 TABLE 2.

## 11 Material for Chain

### 11.1 General

#### 11.1.1 Process of Steel Manufacture and Deoxidation (2020)

Manufacturers of bar, plate, castings, and forgings are to be ABS approved as indicated in 2-2-3/1.1. The steel used for the manufacture of chain is to be made by the open-hearth, basic-oxygen, electric-furnace or such other process as may be specially approved. Refer to 2-2-3/1.1.

Rimmed steel is not acceptable for any grade of chain.

### 11.1.2 Chemical Composition (1996)

The chemical composition of the material for chain manufacture is to be determined by the steelmaker on samples taken from each ladle of each heat and is to comply with the approved specification of the chain manufacturer.

## 13 Material Testing

### 13.1 Heat Treatment of Test Specimens

Test specimens are to be taken from material heat-treated in the same manner as intended for the finished chain, except that in the case of Grades 1 and 2a flash butt-welded chain, test specimens may be taken from material in either the as-rolled or heat-treated condition.

### 13.3 Number of Tests

One set of tests consisting of one tension, and one bend or three impact test specimens as required in 2-2-2/25.5 TABLE 1 are to be taken from the largest casting or drop forging from each lot of 50 tons or fraction thereof from each heat.

### 13.5 Tension Test Specimens (1996)

For cast or drop-forged links, machined type specimens are to be used. They are to be cut and notched as shown in 2-2-2/13.13 FIGURE 1. The tension-test results for stud-link anchor chain materials are to meet the applicable requirements shown in 2-2-2/25.5 TABLE 1.

The required minimum percentage elongation values in 2-2-2/25.5 TABLE 1 are based on specimens having gauge lengths equal to 5 times the diameter. For specimens having other gauge lengths the equivalent elongation value is to be calculated by the following equation:

$$n = 2E(\sqrt{A}/L)^{0.4}$$

where

- $n$  = equivalent minimum elongation
- $A$  = actual cross-sectional area of the specimen
- $L$  = actual gauge length
- $E$  = specified minimum percentage elongation for specimens having a gauge length of 5 times the diameter

The above equation is not applicable to quenched and tempered steel, for which the specimen is to have a gauge length of 5 times the specimen diameters.

### 13.7 Bend Test Specimens

For cast or drop-forged links, machined type specimens are to be used. Each specimen is to withstand, without fracture, cold bending around a mandril diameter and through the angle specified in 2-2-2/25.5 TABLE 1.

### 13.9 Impact Test Specimens

Impact test specimens are to be in accordance with 2-1-1/11.11. They are to be cut and notched as shown in 2-2-2/13.13 FIGURE 1. The average value of 3 specimens is to comply with the requirements of 2-2-2/25.5 TABLE 1.

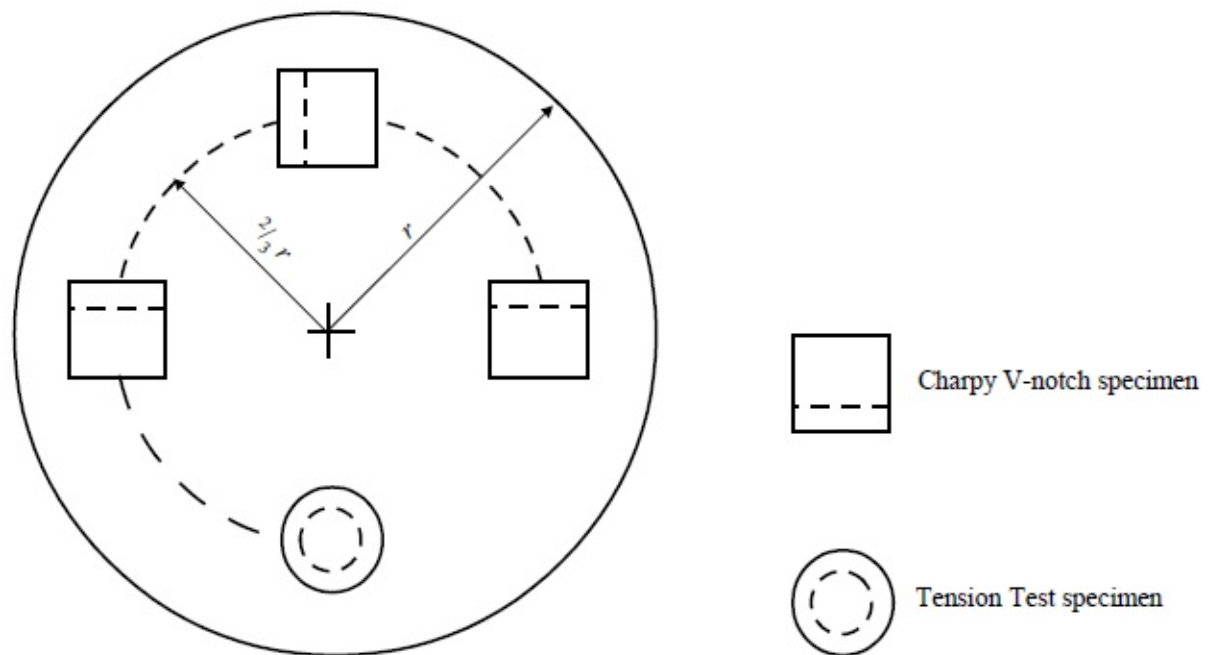
### 13.11 Additional Tests before Rejection (1996)

When a specimen fails to meet the requirements of 2-2-2/25.5 TABLE 1 retest in accordance with 2-1-2/9.11, 2-1-2/9.13, 2-1-2/11.7 and 2-1-2/11.9 may be permitted, as applicable.

### 13.13 Manufacturer's Option

At the option of the chain manufacturer, the above material tests (normally conducted prior to chain fabrication) may be waived, provided the required test specimens representative of each heat are taken from finished links after final heat treatment, if any, and in the same proportion of number of tests to tonnage as outlined in 2-2-2/13.3.

**FIGURE 1**  
**Location and Orientation of Test Specimens**



## 15 Heat Treatment of Chain Lengths

### 15.1 Flash Butt-welded Chain

Grades 1 and 2a flash butt-welded chain may be supplied in either the as-welded or normalized condition.

### 15.3 Drop-forged, Cast-steel and Extra-high-strength Chain

Grade 2a drop-forged chain, Grade 2b cast-steel chain and Grades 3a and 3b extra-high-strength chain are to be normalized, normalized and tempered or quenched and tempered in accordance with the manufacturer's approved specification.

### 15.5 Sequence of Heat Treatment

Heat treatment is to be completed prior to the proof and breaking tests.

## 17 Testing and Inspection of Chain Lengths

### 17.1 General (1996)

All anchor chain is to be subjected to breaking and proof tests in the presence of a Surveyor. The Surveyor is to satisfy himself that the testing machines are maintained in a satisfactory and accurate condition and is to keep a record of the dates and by whom the machines were rechecked or calibrated. Prior to test and inspection, the chain is to be free from paint or other coating which would tend to conceal defects. After proof testing, links are to be carefully examined for workmanship, concentricity, distortion, stud attachment, test grip damage, surface appearance and alignment of butt welds.

Provided their depth is not greater than 5% of the link diameter, surface discontinuities may be removed by grinding and blending to a smooth contour. The cross sectional area in way of the grinding is to be not less than the theoretical area of nominal chain diameter. Links repaired by grinding are to be subjected to magnetic particle or dye penetrant inspection.

### 17.3 Chain Identification

Each shot is to be stamped with a distinctive mark in order to identify it through the several processes of gauging, testing, measuring, examining, repairing and weighing, and in the event of the Surveyor being in attendance at the works while forged chains are being fabricated, which will ultimately be submitted for testing, the break test specimens will be selected as far as possible during the process of fabrication.

### 17.5 Testing Precautions

Care is to be taken that arrangements are made for each link to be tested at least once. The gripping arrangements are to be such that they do not put any stress on the end links of the portion under test, except such stress as is equally applied to every link tested.

### 17.7 Weighing of Tested Chain

When chains have satisfactorily passed the requirements, they are to be weighed, together with the shackles forming the outfit, and this actual weight will be given on the certificate of test.

### 17.9 Testing of Used Chain

When a chain, which has been in use, is submitted for testing or retesting, the size for testing purposes is to be the original chain diameter. The certificate issued for such chain will include for descriptive purposes the original chain diameter as well as the mean diameter of the part most worn, and will be marked, "This chain is not new, and has been previously used".

## 19 Details of Tests on Chain Lengths

### 19.1 Breaking Test (2005)

A break-test specimen consisting of at least three links is to be taken from the chain or produced at the same time and the same way as the chain. Where produced separately, the specimen is to be securely attached to the chain during any heat treatment. One specimen is to be taken from each four 27.5 m (15 fathoms) lengths or less of flash butt-welded or drop-forged chain and one from each heat treatment batch with a minimum of one from each four 27.5 m (15 fathoms) lengths or less of cast-steel chain. Each specimen is to be subjected to the applicable breaking load given in 2-2-2/27 TABLE 2 (stud-link chain). The breaking load test is to be carried out in the presence of the Surveyor and is to be maintained for a minimum of 30 seconds. A specimen will be considered to have successfully passed the test if there is no sign of fracture after application of the required load. Special attention is to be given to the visual inspection of the flash butt weld. Where the first test is not satisfactory, one more specimen may be cut out and subjected to the breaking load. If this test fails, the shot is to be rejected, and additional specimens are to be cut from each of the three remaining shots of 27.5 m (15 fathoms) or less and subjected to the breaking load. In such cases, each shot from which the satisfactory break specimens have been taken is to

be rejoined and may be accepted, provided it passes the required proof test. All breaking test specimens are to be subsequently discarded.

Alternative test procedures to the required breaking test of chain of Grades 2a, 2b, 3a, and 3b may be accepted. This alternative procedure consists of additional mechanical tests and the preparation of macro sections on a two or three link sample of chain taken from every four lengths of 27.5 m (15 fathoms) or less of completed chain. In the case of Grade 3a or 3b chain, the two or three link sample is not to be taken from the same length of chain as that length from which the link to be mechanically tested, according to 2-2-2/19.5 is taken.

### 19.3 Proof Test

Each shot of chain of 27.5 m (15 fathoms) length or less and the entire length of chain when produced in lengths longer than 27.5 m (15 fathoms) is to withstand the applicable proof load indicated in 2-2-2/27 TABLE 2 (stud-link chain). Upon special request and when approved by ABS, detachable links may be subjected to a greater proof load than required for the chain. After the proof test, the length of chain is to be ascertained and the chain carefully examined. Any link showing surface defects or excessive deformation is to be taken out and the chain repaired, after which the proof test is again to be applied and the chain re-examined. If one link breaks under the proof test, a joining link is to be inserted and the proof test again applied; if a second link breaks, the shot or length under test is to be rejected. For chain produced in long continuous lengths, if more than one link breaks under proof test, the entire length is to be rejected unless approved otherwise.

### 19.5 Mechanical Tests on Completed Chain (2005)

One link from every four lengths of 27.5 m (15 fathoms) or less of

Grade 2a flash butt welded chain delivered in as welded condition, and

Grades 3a or 3b chain

is to be subjected to a set of mechanical tests consisting of one tension and three impact tests. The mechanical tests are to be carried out in the presence of the Surveyor.

In the case of a welded chain, the above mentioned test specimens are to be taken from the base metal of the link opposite to the weldment and, additionally, three impact specimens are to be taken with notches at the weld center. The results of the tests are to comply with the requirements given in 2-2-2/25.5 TABLE 1. When the results of the original tests fail to meet the requirements, retests in accordance with 2-1-2/9.11 and 2-1-2/11.7 may be permitted, as applicable.

### 19.7 Mechanical and Breaking Tests on Chain Produced in Long Continuous Lengths

When chain is produced in lengths longer than 27.5 m (15 fathoms), the test frequency for the mechanical and breaking tests required in 2-2-2/19.1 and 2-2-2/19.5 are to be based on tests at regular intervals according to the following table:

<i>Nominal Chain Size</i>		<i>Maximum Specified Length to Obtain Samples</i>	
<i>mm</i>	<i>in.</i>	<i>m</i>	<i>ft</i>
Min to 48	Min to 1 <sup>7</sup> / <sub>8</sub>	91	300
50 to 60	2 to 2 <sup>3</sup> / <sub>8</sub>	110	360
64 to 73	2 <sup>1</sup> / <sub>2</sub> to 2 <sup>7</sup> / <sub>8</sub>	131	430
76 to 85	3 to 3 <sup>3</sup> / <sub>8</sub>	152	500

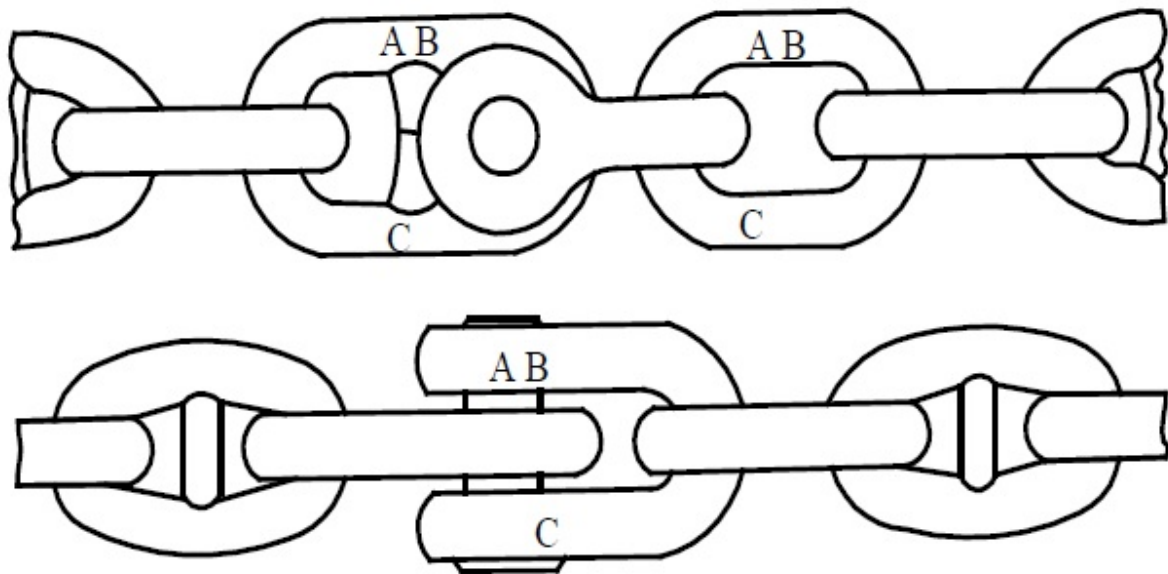
<i>Nominal Chain Size</i>		<i>Maximum Specified Length to Obtain Samples</i>	
87 to 98	$3\frac{1}{2}$ to $3\frac{7}{8}$	175	575
102 to 111	4 to $4\frac{3}{8}$	198	650

If an order or a fraction of an order is less than the specified length, that length is to be subject to all tests required for a full length.

## 21 Marking for Chain (2001)

The shackles and the end links of each length and one link in every 27.5 m (15 fathoms) of stud-link chain, made in a continuous length without joining shackles, are to be clearly stamped by the manufacturer as shown in 2-2-2/21 FIGURE 2 in location A, B and C. When Kenter shackles are used, the marking is to be clearly stamped on the Kenter shackle and on both adjoining common links. Any accessory tested to a break load for a lower grade chain, as permitted in 2-2-2/23.13, is to be marked with the grade of the chain to which it is tested.

**FIGURE 2**  
**Marking for Chain**



- A The Number of the Certificate (Furnished by the Surveyor) 78 PT1234
- B Signifying that the Chain has been satisfactorily tested to the ABS Requirements and the Grade as Applicable AB/1, AB/2 or AB/3
- C Nominal Chain Diameter in mm or in. (When chain manufacturers emboss the chain diameter in a permanent manner by some suitable means such as forging or casting, marking of the chain diameter in location C may be omitted.)



## 23 Anchor Chain Accessories

### 23.1 Dimensions and Dimensional Tolerances (1996)

The dimensions of anchor chain accessories are to be in accordance with a recognized standard such as ISO 1704. The following tolerances are applicable to anchor chain accessories.

nominal diameter : +5%, -0%

other dimensions :  $\pm 2.5\%$

### 23.2 Locking Pins in Accessories (2020)

Locking pins in detachable connecting links are to have taper contact at both top and bottom in the link halves. Acceptable material is to be used for plugging the locking pin hole, which is to contain an appropriate undercut recess or equivalent arrangement to secure the plug.

### 23.3 Material Testing

Test specimens are to be taken either from finished accessories, or from special test bars indicated in 2-2-2/23.5 and 2-2-2/23.7. In all cases the specimens are to be taken from pieces representing the largest diameter accessory in the lot. A lot is defined as the accessories of the same grade, made from the same heat of steel and heat treated in the same furnace charge where the diameter does not differ by more than 25 mm (1 in.). Test results are to comply with 2-2-2/25.5 TABLE 1 or such other specification as may be specially approved. When the results of original tests fail to meet the requirements, retests in accordance with 2-1-2/9.11 and 2-1-2/11.7 may be permitted, as applicable.

### 23.5 Cast Accessories

Test specimens may be taken from integrally or separately cast test blocks, heat-treated together with the accessories represented.

### 23.7 Forged Accessories

Test specimens may be taken from a special forging, representative of the accessories in the lot. In such cases, the special forging is to be subjected to approximately the same amount of working and reduction as the forging represented, and is to be heat-treated with the forgings represented.

### 23.9 Inspection

All accessories are to be inspected by magnetic particle or other suitable method to assure freedom from injurious surface defects. Special attention is to be given to welds.

### 23.11 Hardness Test

All accessories are to be subjected to a Brinell hardness test to meet the following:

<i>Grade</i>	<i>Brinell Hardness Number Minimum 10 mm ball, 3000 kg load</i>
1	120
2	145
3	207

### 23.13 Break Test (2001)

Break tests are to be made on 1 out of 25 accessories (or 1 out of 50 in the case of Kenter shackles), representative of the same type, grade and heat treatment procedure, but not necessarily representative of each heat of steel, heat treatment charge or individual purchase order. When the range of Brinell hardness readings of these accessories in the batch exceed 30 Brinell hardness numbers, the accessories represented

by the lowest and highest Brinell hardness readings are to be tested. This requirement may be waived when the range of properties represented by the Brinell hardness numbers is established to the satisfaction of the Surveyor. For accessories from the same lot (see 2-2-2/23.3), the Surveyor may reduce the number of break tests to a minimum of two per lot. All parts of the accessory subjected to a break test required by this subparagraph are to be subsequently discarded, except where further use is permitted by 2-2-2/23.13.1 below.

#### 23.13.1 Use of Break Tested Parts (2001)

Where it is demonstrated by either one of the following methods that the accessories can withstand at least 140% of the breaking test load prescribed in 2-2-2/27 TABLE 2 for the chain in which they are intended, such accessories may be used in service provided:

23.13.1(a) the material of the accessories is of higher grade than the chain (e.g., grade 3 accessories of grade 2 size in grade 2 chain), or

23.13.1(b) where an accessory of increased dimension is specially approved for the particular application and a procedure test is completed at 140% of the 2-2-2/27 TABLE 2 break test load. All parts of the accessories used in this procedure test are to be subsequently discarded.

In either case, each accessory requiring a break test is to be tested to 100% of the 2-2-2/27 TABLE 2 break load for the chain in which it is intended to be used.

#### 23.15 Proof Tests

Each accessory is to be subjected to a proof test in accordance with 2-2-2/19.3.

#### 23.17 Markings

The certificate number, **AB/Chain Grade**, and nominal chain diameter are to be steel die stamped on each accessory. The stamping of the nominal chain diameter may be omitted provided the nominal chain diameter is cast or forged into the accessory. Markings are to be located in such a manner as to be readily visible when completely assembled together with the chain.

### 25 Unstudded Short-link Chain

#### 25.1 General

Unstudded short-link chain is to meet the requirements specified in 2-2-2/3 and 2-2-2/11. Material is to be in accordance with the manufacturer's specification which is to be the equivalent of normal strength Grade 1 requirements of 2-2-2/25.5 TABLE 1.

#### 25.3 Testing

Breaking and proof testing are to be in accordance with 2-2-2/19 and subjected to the applicable testing loads as given in 2-2-2/27 TABLE 3.

#### 25.5 Marking

One link including the end link in every 4.5 m (2.5 fathoms) is to be steel die stamped as prescribed in locations A, B and C by the manufacturer as shown in 2-2-2/13.13 FIGURE 1. In special cases, shots of comparatively small size may be marked or stenciled in lieu of die stamping or the markings may be shown on a metal tag attached at every 4.5 m (2.5 fathoms).

**TABLE 1**  
**Chain Materials -Mechanical Properties (1999)**

<i>Chain Grade</i>	<i>Grade 1</i>	<i>Grade 2</i>	<i>Grade 3</i>
<i>Yield Point</i> <i>N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	–	295 (30, 42.8)	410 (42, 60)
<i>Tensile Range</i> <i>N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	370 – 490 (38-51, 53.7-71.1)	490-690 (50-70, 71.1-99.6)	690 min. (70, 99.6) min.
<i>Elongation (5D), min %</i>	25	22	17
<i>Reduction of Area, min %</i>	–	–	40
<i>Average Impact Value @ 0°C (32°F), J (kgf-m, ft-lbf)</i>			
<i>base metal</i>	–	27 <sup>(1)</sup> (2.8, 20)	60 (6, 43)
<i>at weld center</i>	–	27 <sup>(1)</sup> (2.8, 20)	50 (5, 36)
<i>Bend Test</i>			
<i>mandrel dia.<sup>(2)</sup></i>	2T	3T	
<i>Angle (degree)</i>	180	180	

**Notes:**

- 1 Impact test for Grade 2 chain material is required for flash butt welded chain to be delivered in as-welded condition.
- 2 T = diameter or thickness of test specimen.

**27 Material Hardness for Windlass-Wildcats and Gypsy Wheels (2022)**

All materials (castings, forgings, rolled bars or rolled plate) entered into the construction of torque-transmitting and load-bearing parts of windlasses are to be tested in the presence of, inspected and certified by the Surveyor in accordance with Part 2, Chapter 3 as required per 4-5-1/3.1 of the *Marine Vessel Rules*.

**27.1 Wear and Abrasion**

For wear and abrasion considerations, the type of material used for windlass-wildcats and gypsy wheels will depend upon the grade of chain used in the system. Refer to ASTM F765, Standard Specification for Wildcats, Ship Anchor Chain and to API 2S Design of Windlass Wildcats for Floating Offshore Structures. These construction Standards contain a number of types of wildcats or gypsy wheels, from Type I, II, III, IV.

**27.3 Approximate Hardness Values for Wildcats and Gypsy Wheels**

<i>ASTM Type</i>	<i>Steel Grade</i>	<i>Brinell Hardness (approx.)</i>
I and III	Medium Strength (ASTM A27)	150 HB
II and IV	High Strength (ASTM A148)	300 HB

Selection of the correct material type has to be made in accordance with the chain grade applied.

Actual chain hardness is typically in the following ranges.

<i>Chain Grade</i>	<i>Brinell Hardness</i>
1	120 – 140
2	130 - 150
3	210 - 250

Typical hardness values of chain Grade 3 are in the range of 210 – 250 Brinell. Accordingly, Types II and IV are to be selected to avoid accelerated wear of the wildcat or gypsy wheel.

### 27.5 Cladding and Hardfacing

Weld cladding or hardfacing may be carried out to build up chain contact surfaces, if the chain fit is offset or wear has occurred during service. The carbon content and carbon equivalent influences the weldability of the material. Weld build-up procedures are to be properly qualified on material with similar weldability to the wildcat or gypsy wheel to be welded. Weld procedures are to be properly qualified and welding is to be carried out under controlled conditions, to the satisfaction of the attending Surveyor.

The aim hardness of weld build-up should be the same as the material base metal. A higher, build-up hardness, may be acceptable subject to the following restriction:

<i>ASTM Type</i>	<i>Weld Build-up Maximum Increase in Brinell Hardness (approx.)</i>
I and III	150 + 25HB
II and IV	300 + 50 HB

**TABLE 2**  
**Stud-link Anchor-chain Proof and Break Tests**

SI Units

Chain Diameter	Length of Five Links	Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		Mass kilograms per 27.5 meters
		Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load	
mm	mm	kN	kN	kN	kN	kN	kN	kg
12.5	275	46.1	65.7	65.7	92.2	92.2	132.4	110
14	308	57.9	82.4	82.4	115.7	115.7	164.8	130
16	352	75.5	106.9	106.9	150.0	150.0	215.7	170
17.5	385	89.3	127.5	127.5	179.5	179.5	260.8	180
19	418	104.9	150.0	150.9	210.8	210.8	301.1	220
20.5	451	122.6	174.6	174.6	244.2	244.2	349.1	260
22	484	140.2	200.1	200.1	280.5	280.5	401.1	300
24	528	166.7	237.3	237.3	332.4	332.4	475.6	340
26	572	194.2	277.5	277.5	389.3	389.3	556.0	420
28	616	224.6	320.7	320.7	449.1	449.1	642.3	480
30	660	256.9	367.7	367.7	513.9	513.9	734.5	550
32	704	291.3	416.8	416.8	582.5	582.5	832.6	610
34	748	327.5	467.8	467.8	655.1	655.1	936.5	700
36	792	365.8	522.7	522.7	731.6	731.6	1049.3	790
38	836	406.0	580.6	580.6	812.0	812.0	1157.2	880
40	880	448.2	640.4	640.4	896.3	896.3	1284.7	970
42	924	492.3	703.1	703.1	980.7	980.7	1402.3	1070
44	968	538.4	768.8	768.8	1078.7	1078.7	1539.6	1170
46	1012	585.5	836.5	836.5	1167.0	1167.0	1676.9	1270
48	1056	635.5	908.1	908.1	1274.9	1274.9	1814.2	1380
50	1100	686.5	980.7	980.7	1372.9	1372.9	1961.3	1480
52	1144	739.4	1059.1	1059.1	1480.8	1480.8	2108.4	1600
54	1188	794.3	1137.6	1137.6	1588.7	1588.7	2265.3	1720
56	1232	851.2	1216.0	1216.0	1706.4	1706.4	2432.0	1850
58	1276	909.1	1294.5	1294.5	1814.2	1814.2	2598.8	1990
60	1320	968.9	1382.7	1382.7	1941.7	1941.7	2765.5	2120
62	1364	1029.7	1471.0	1471.0	2059.4	2059.4	2942.0	2250
64	1408	1098.3	1559.3	1559.3	2186.9	2186.9	3128.3	2440
66	1452	1157.2	1657.3	1657.3	2314.4	2314.4	3304.8	2590
68	1496	1225.8	1745.6	1745.6	2451.7	2451.7	3501.0	2750

Chain Diameter	Length of Five Links	Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		Mass kilograms per 27.5 meters
		Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load	
mm	mm	kN	kN	kN	kN	kN	kN	kg
70	1540	1294.5	1843.7	1843.7	2579.1	2579.1	3687.3	2910
73	1606	1392.5	1990.7	1990.7	2794.9	2794.9	3991.3	3180
76	1672	1500.4	2147.6	2147.6	3010.6	3010.6	4295.3	3470
78	1716	1578.9	2255.5	2255.5	3157.7	3157.7	4501.3	3650
81	1782	1686.7	2412.4	2412.4	3383.3	3383.3	4824.9	3930
84	1848	1804.4	2579.1	2579.1	3608.8	3608.8	5158.3	4250
87	1914	1922.1	2745.9	2745.9	3854.0	3854.0	5501.5	4560
90	1980	2049.6	2922.4	2922.4	4089.4	4089.4	5844.8	4860
92	2024	2128.0	3040.1	3040.1	4256.1	4256.1	6080.1	5100
95	2090	2255.5	3226.4	3226.4	4511.0	4511.0	6443.0	5400
97	2134	2343.8	3344.1	3344.1	4677.8	4677.8	6688.1	5670
98	2156	2383.0	3402.9	3402.9	4766.0	4766.0	6815.6	5750
100	2200	2471.3	3530.4	3530.4	4942.6	4942.6	7060.8	6010
102	2244	2559.5	3657.9	3657.9	5119.1	5119.1	7315.8	6250
105	2310	2696.8	3854.0	3854.0	5393.7	5393.7	7698.2	6600
107	2354	2785.1	3981.5	3981.5	5570.2	5570.2	7963.0	6820
108	2376	2834.1	4040.3	4040.3	5658.4	5658.4	8090.4	6950
111	2442	2971.4	4246.3	4246.3	5942.8	5942.8	8482.8	7290
114	2508	3108.7	4442.4	4442.4	6227.2	6227.2	8894.6	7640
117	2574	3255.8	4648.4	4648.4	6511.6	6511.6	9296.7	7980
120	2640	3492.9	4854.3	4854.3	6805.8	6805.8	9718.4	8310
122	2684	3501.0	5001.4	5001.4	7001.9	7001.9	9993.0	8620
124	2728	3599.0	5138.7	5138.7	7198.1	7198.1	10277.4	8920
127	2794	3746.1	5354.4	5354.4	7492.3	7492.3	10708.9	9380
130	2860	3903.0	5570.2	5570.2	7796.3	7796.3	11140.4	9840
132	2904	4001.1	5717.3	5717.3	8002.2	8002.2	11424.7	10140
137	3014	4256.1	6080.1	6080.1	8512.2	8512.2	12160.2	10910
142	3124	4520.9	6452.8	6452.8	9031.9	9031.9	12905.6	11670
147	3234	4785.6	6835.2	6835.2	9561.5	9561.5	13660.7	12440
152	3344	5050.4	7217.7	7217.7	10100.8	10100.8	14425.6	13200
157	3454	5325.0	7600.2	7600.2	10640.2	10640.2	15200.3	14000
162	3564	5599.6	8002.2	8002.2	11199.2	11199.2	15994.6	14700

**MKS Units**

Chain Diameter	Length of Five Links	Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		Mass kilograms per 27.5 meters
		Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load	
mm	mm	kgf	kgf	kgf	kgf	kgf	kgf	kg
12.5	275	4700	6700	6700	9400	9400	13500	110
14	308	5900	8400	8400	11800	11800	16800	130
16	352	7700	10900	10900	15300	15300	22000	170
17.5	385	9100	13000	13000	18300	18300	26100	180
19	418	10700	15300	15300	21500	21500	30700	220
20.5	451	12500	17800	17800	24900	24900	35600	260
22	484	14300	20400	20400	28600	28600	40900	300
24	528	17000	24200	24200	33900	33900	48500	340
26	572	19800	28300	28300	39700	39700	56700	420
28	6126	22900	32700	32700	45800	45800	65500	480
30	660	26200	37500	37500	52400	52400	74900	550
32	704	29700	42500	42500	59400	59400	84900	610
34	748	33400	47700	47700	66800	66800	95500	700
36	792	37300	53300	53300	74600	74600	107000	790
38	836	41400	59200	59200	82800	82800	118000	880
40	880	45700	65300	65300	91400	91400	131000	970
42	924	50200	71700	71700	100000	100000	143000	1070
44	968	54900	78400	78400	110000	110000	157000	1170
46	1012	59700	85300	85300	119000	119000	171000	1270
48	1056	64800	92600	92600	130000	130000	185000	1380
50	1100	70000	100000	100000	140000	140000	200000	1480
52	1144	75400	108000	108000	151000	151000	215000	1600
54	1188	81000	116000	116000	162000	162000	231000	1720
56	1232	86800	124000	124000	174000	174000	248000	1850
58	1276	92700	132000	132000	185000	185000	265000	1990
60	1320	98800	141000	141000	198000	198000	282000	2120
62	1364	105000	150000	150000	210000	210000	300000	2250
64	1408	112000	159000	159000	223000	223000	319000	2440
66	1452	118000	169000	169000	236000	236000	337000	2590
68	1496	125000	178000	178000	250000	250000	357000	2750

Chain Diameter	Length of Five Links	Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		Mass kilograms per 27.5 meters
		Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load	
mm	mm	kgf	kgf	kgf	kgf	kgf	kgf	kg
70	1540	132000	188000	188000	263000	263000	376000	2910
73	1606	142000	203000	203000	285000	285000	407000	3180
76	1672	153000	219000	219000	307000	307000	438000	3470
78	1716	161000	230000	230000	322000	322000	459000	3650
81	1782	172000	246000	246000	345000	345000	492000	3930
84	1848	184000	263000	263000	368000	368000	526000	4250
87	1914	196000	280000	280000	393000	393000	561000	4560
90	1980	209000	298000	298000	417000	417000	596000	4860
92	2024	217000	310000	310000	434000	434000	620000	5100
95	2090	230000	329000	329000	460000	460000	657000	5400
97	2134	239000	341000	341000	477000	477000	682000	5670
98	2156	243000	347000	347000	486000	486000	695000	5750
100	2200	252000	360000	360000	504000	504000	720000	6010
102	2244	261000	373000	373000	522000	522000	746000	6250
105	2310	275000	393000	393000	550000	550000	785000	6600
107	2354	284000	406000	406000	568000	568000	812000	6820
108	2376	289000	412000	412000	577000	577000	825000	6950
111	2442	303000	433000	433000	606000	606000	865000	7290
114	2508	317000	453000	453000	635000	635000	907000	7640
117	2574	332000	474000	474000	664000	664000	948000	7980
120	2640	347000	495000	495000	694000	694000	991000	8310
122	2684	357000	510000	510000	714000	714000	1019000	8620
124	2728	367000	524000	524000	734000	734000	1048000	8920
127	2794	382000	546000	546000	764000	764000	1092000	9380
130	2860	398000	568000	568000	795000	795000	1136000	9840
132	2904	408000	583000	583000	816000	816000	1165000	10140
137	3014	434000	620000	620000	868000	868000	1240000	10910
142	3124	461000	658000	658000	921000	921000	1316000	11670
147	3234	488000	697000	697000	975000	975000	1393000	12440
152	3344	515000	736000	736000	1030000	1030000	1471000	13200
157	3454	543000	775000	775000	1085000	1085000	1550000	14000
162	3564	571000	816000	816000	1142000	1142000	1631000	14700



US Units

Chain Dia meter	Length of Five Links		Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		Mass pounds per 15 fathoms lb
	in.	ft	Proof Load lbf	Breaking Load lbf	Proof Load lbf	Breaking Load lbf	Proof Load lbf	Breaking Load lbf	
1/2	-	11	10700	15300	15300	21400	21400	30600	230
9/16	1	0 3/8	13500	19300	19300	27000	27000	38600	290
5/8	1	1 3/4	16600	23700	23700	33200	33200	47500	370
11/16	1	3 1/8	20100	28600	28600	40100	40100	57300	410
3/4	1	4 1/2	23800	34000	34000	47600	47600	68000	480
13/16	1	5 7/8	27800	39800	39800	55700	55700	79500	570
7/8	1	7 1/4	32200	46000	46000	64400	64400	91800	660
15/16	1	8 5/8	36800	52600	52600	73700	73700	105000	760
1	1	10	41800	59700	59700	83600	83600	119500	860
1 1/16	1	11 3/8	47000	67200	67200	94100	94100	135000	970
1 1/8	2	0 3/4	52600	75000	75000	105000	105000	150000	1080
1 3/16	2	2 1/8	58400	83400	83400	116500	116500	167000	1220
1 1/4	2	3 1/2	64500	92200	92200	129000	129000	184000	1350
1 5/16	2	4 7/8	70900	101500	101500	142000	142000	203000	1490
1 3/8	2	6 1/4	77500	111000	111000	155000	155000	222000	1630
1 7/16	2	7 5/8	84500	120500	120500	169000	169000	241000	1780
1 1/2	2	9	91700	131000	131000	183500	183500	262000	1940
1 9/16	2	10 3/8	99200	142000	142000	198500	198500	284000	2090
1 5/8	2	11 3/4	108000	153000	153000	214000	214000	306000	2240
1 11/16	3	1 1/8	115000	166500	166500	229000	229000	327000	2410
1 3/4	3	2 1/2	123500	176000	176000	247000	247000	352000	2590
1 13/16	3	3 7/8	132000	188500	188500	264000	264000	377000	2790
1 7/8	3	5 1/4	140500	201000	201000	281000	281000	402000	2980
1 15/16	3	6 5/8	149500	214000	214000	299000	299000	427000	3180
2	3	8	159000	227000	227000	318000	318000	454000	3360
2 1/16	3	9 3/8	168500	241000	241000	337000	337000	482000	3570
2 1/8	3	10 3/4	178500	255000	255000	357000	357000	510000	3790
2 3/16	4	0 1/8	188500	269000	269000	377000	377000	538000	4020
2 1/4	4	1 1/2	198500	284000	284000	396000	396000	570000	4250
2 5/16	4	2 7/8	209000	299000	299000	418000	418000	598000	4490
2 3/8	4	4 1/4	212000	314000	314000	440000	440000	628000	4730
2 7/16	4	5 5/8	231000	330000	330000	462000	462000	660000	4960
2 1/2	4	7	242000	346000	346000	484000	484000	692000	5270
2 9/16	4	8 3/8	254000	363000	363000	507000	507000	726000	5540
2 5/8	4	9 3/4	265000	379000	379000	530000	530000	758000	5820

**Note:**

See also 2-2-2/9.

The weight of chain is not to be more than 2 1/2% under the weight specified.

**TABLE 3**  
**Unstudded Short-link Chain**

SI Units (MKS Units)					US Units		
Diameter of Common Links	Breaking Test		Proof Test		Diameter of Common Links	Breaking Test	Proof Test
	<i>kN</i>	<i>kgf</i>	<i>kN</i>	<i>kgf</i>			
6	11.6	1180	5.8	590	<sup>5</sup> / <sub>16</sub>	5040	2520
8	22.6	2300	11.3	1150	<sup>3</sup> / <sub>8</sub>	7280	3640
10	35.9	3660	17.9	1830	<sup>7</sup> / <sub>16</sub>	10080	5040
12	52.8	5380	26.4	2690	<sup>1</sup> / <sub>2</sub>	13440	6720
14	71.5	7290	35.8	3650	<sup>9</sup> / <sub>16</sub>	16800	8400
16	93.6	9540	46.8	4770	<sup>5</sup> / <sub>8</sub>	20720	10360
18	119.2	12150	59.9	6110	<sup>11</sup> / <sub>16</sub>	25200	12600
20	147.7	15060	74.4	7590	<sup>3</sup> / <sub>4</sub>	30240	15120
22	178.6	18210	89.7	9150	<sup>13</sup> / <sub>16</sub>	35392	17696
24	212.5	21670	106.5	10860	<sup>7</sup> / <sub>8</sub>	40880	20440
26	249.9	25480	125.0	12750	<sup>15</sup> / <sub>16</sub>	47040	23520
28	288.9	29460	144.5	14730	1	53760	26880
30	332.6	33920	166.8	16960	<sup>11</sup> / <sub>16</sub>	60480	30240
32	379.6	38710	189.5	19320	<sup>11</sup> / <sub>8</sub>	67760	33880
34	427.5	43590	213.6	21780	<sup>13</sup> / <sub>16</sub>	75712	37856
36	477.2	48660	239.3	24400	<sup>11</sup> / <sub>4</sub>	84000	42000
38	534.1	54460	267.1	27240	<sup>15</sup> / <sub>16</sub>	92400	46200
					<sup>13</sup> / <sub>8</sub>	101360	50680
					<sup>17</sup> / <sub>16</sub>	110880	55440
					<sup>11</sup> / <sub>2</sub>	120960	60480

**Rolled Steel Bars for Chain, Cast and Forged Materials for Accessories  
and Materials for Studs****1 General (2005)**

Rolled steel bars Grades U1, U2 or U3 for Grade 1, 2 or 3 chains, cast and forged materials for accessories and materials for studs are to be in accordance with this section. Bars for offshore mooring chains are to be in accordance with the *ABS Guide for the Certification of Offshore Mooring Chain*.

These Rules are not intended to replace or modify any part of a chain manufacturer's specification approved by ABS.

**1.1 Process and Qualification of Manufacture (2012)**

The manufacturers of materials for anchor chain and accessories are to be approved. Approval is not required for Grade 1 bars. The bar manufacturers are to submit the manufacturing specifications and the details of the manufacturing procedure. The approval tests are to be carried out in accordance with Section 2-A4-2, the scope of which is to be agreed with ABS.

The steel is to be made by the open-hearth, basic oxygen, vacuum-arc remelt, electro-slag remelt electric-furnace or such other process as may be specially approved.

Unless otherwise stipulated, the steel bars are to be supplied in the as rolled condition.

**1.3 Deoxidation Practice**

Bars are to be fully killed and, in addition, Grade U2 or U3 bars are to be produced to a fine grain practice.

**1.5 Chemical Composition and Heat Treatment (1999)**

The chemical composition and heat treatment are to be in accordance with the manufacturer's specification that is to be approved by ABS. In general, they are to conform to 2-2-3/3 TABLE 1.

**1.7 Mechanical Properties (1999)**

Mechanical tests are to be carried out in accordance with 2-2-3/3 and the results are to meet the requirements in 2-2-2/25.5 TABLE 1.

### 1.9 Dimensional properties (1999)

Unless otherwise approved, the tolerances on diameter and roundness ( $d_{\max} - d_{\min}$ ) are to be within the limits listed in 2-2-3/3 TABLE 2, where  $d_{\max}$  and  $d_{\min}$  are the maximum and minimum diameter measured at the section under consideration.

## 3 Material Testing

### 3.1 Heat Treatment of Test Specimens

Test specimens are to be taken from material heat-treated in the same manner as intended for the finished chain.

### 3.3 Number of Tests

One tensile and three impact test specimens are to be taken from two different bars of steel from each heat unless the material from a heat is less than 50 metric tons (49.21 long tons), in which case, tests from one bar will be sufficient. If, however, the material from one heat differs 9.5 mm (0.375 in.) or more in diameter, one set of tests is to be taken from the thinnest and thickest material rolled.

### 3.5 Tension Test Specimens (1996)

Tension test specimens for bar material are to be taken at  $2/3r$  as shown in 2-2-2/13.13 FIGURE 1 or as close thereto as possible and machined to 2-1-1/16 FIGURE 2 or appropriate national standard specimen.

The required minimum percentage elongation values in 2-2-2/25.5 TABLE 1 are based on specimens having gauge lengths equal to 5 times the diameter. For specimens having other gauge lengths the equivalent elongation value is to be calculated by the following equation:

$$n = 2E(\sqrt{A}/L)^{0.4}$$

where

$n$  = equivalent minimum elongation

$A$  = actual cross-sectional area of the specimen

$L$  = actual gauge length

$E$  = specified minimum percentage elongation for specimens having a gauge length of 5 times the diameter

The above equation is not applicable to quenched and tempered steel, for which the specimen is to have a gauge length of five (5) times the specimen diameter.

### 3.7 Bend Test Specimens

Bend test specimens may be either the full section of the bar or may be machined at the option of the manufacturer to a 25 mm (1 in.) diameter or to a rectangular cross section of 25 mm × 12.5 mm (1 in. × 0.5 in.), but not less than 12.5 mm × 12.5 mm (0.5 in. × 0.5 in.). Each specimen is to withstand, without fracture, cold bending around a mandrel diameter and through the angle specified in 2-2-2/25.5 TABLE 1.

### 3.9 Impact Test Specimens

Impact test specimens are to be in accordance with 2-1-1/11.11. They are to be cut and notched as shown in 2-2-2/13.13 FIGURE 1. The average value of 3 specimens is to comply with the requirements of 2-2-2/25.5 TABLE 1.

### **3.11 Additional Tests before Rejection(1996)**

When a specimen fails to meet the requirements of 2-2-2/25.5 TABLE 1 retests in accordance with 2-1-2/9.11, 2-1-2/9.13, 2-1-2/11.7 and 2-1-2/11.9 may be permitted, as applicable.

### **3.13 Manufacturer's Option**

At the option of the chain manufacturer, the above material tests (normally conducted prior to chain fabrication) may be waived, provided the required test specimens representative of each heat are taken from finished links after final heat treatment, if any, and in the same proportion of number of tests to tonnage as outlined in 2-2-2/13.3.

### **3.15 Freedom from Defects (2005)**

The materials are to be free from internal and surface defects that might impair proper workability and use. Surface defects may be repaired by grinding, provided the admissible tolerance is not exceeded.

### **3.17 Identification of Material (2005)**

Manufacturers are to effectively operate an identification system ensuring traceability of the material to the original cast.

### **3.19 Marking (2005)**

The minimum markings required for the steel bars are the manufacturer's brandmark, the steel grade and an abbreviated symbol of the heat. Steel bars having diameters up to and including 40 mm (1.6 in.) and combined into bundles may be marked on permanently affixed labels.

### **3.21 Material Certification (2005)**

Bar material for Grade 2 or Grade 3 is to be certified by ABS. For each consignment, manufacturers shall forward to the Surveyor a certificate containing at least the following data:

- Manufacturer's name and/or purchaser's order No.
- Number and dimensions of bars and weight of consignment
- Steel specification and chain grade
- Heat number
- Manufacturing procedure
- Chemical composition
- Details of heat treatment of the test sample (where applicable)
- Results of mechanical tests (where applicable)
- Number of test specimens (where applicable)

### **3.23 Forged Steels for Chain Cables and Accessories (2005)**

Forged steels used for the manufacture of chain cables and accessories are to be in compliance with Section 2-1-6 "Hull Steel Forgings", unless otherwise specified in the following paragraphs.

The chemical composition is to comply with the specification approved by ABS. The steel manufacturer must determine and certify the chemical composition of every heat of material.

The stock material may be supplied in the as-rolled condition. Finished forgings are to be properly heat treated, i.e., normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant grade of chain.

### 3.25 Cast Steels for Chain Cables and Accessories (2005)

Cast steels used for the manufacture of chain cables and accessories are to be in compliance with Section 2-1-5 “Hull Steel Castings”, unless otherwise specified in the following paragraphs.

The chemical composition is to comply with the specification approved by ABS. The foundry is to determine and certify the chemical composition of every heat.

All castings must be properly heat treated (i.e., normalized, normalized and tempered or quenched and tempered), whichever is specified for the relevant grade of chain.

### 3.27 Materials for Studs (2005)

The studs are to be made of steel corresponding to that of the chain cable or from rolled, cast or forged mild steels. The use of other materials (e.g., gray or nodular cast iron) is not permitted.

**TABLE 1**  
**Rolled Bars for Chain – Chemical Composition and Intended Chain Condition (2008)**

<i>Bar Stock Grade</i>	<i>U1</i>	<i>U2</i>	<i>U3</i>
<i>Intended Chain Grade</i>	<i>Grade 1</i>	<i>Grade 2</i>	<i>Grade 3</i>
<i>Deoxidation</i>	fully killed	fully killed, fine grain	fully killed, fine grain
<i>Intended Chain Condition</i>	as rolled	as rolled or normalized <sup>(4)</sup>	normalized, normalized and tempered or quenched and tempered
<i>Chemical Composition<sup>(1)</sup>, (Ladle Analysis) - % max unless specified otherwise</i>			
C	0.20	0.24	0.36
Si	0.15 - 0.35	0.15 - 0.55	0.15 - 0.55
Mn	0.40 min.	1.00 - 1.60	1.00 - 1.90
P	0.040	0.035	0.035
S	0.040	0.035	0.035
Al <sup>(2)</sup> (total) min.	-	0.020	0.020
Bar Stock Marking	AB/U1	AB/U2 <sup>(3), (4)</sup>	AB/U3

**Notes:**

- 1 Other intentionally added elements are to be reported on the mill sheet.
- 2 Specified aluminum contents may be partly replaced by other grain refining elements. See 2-1-3/5.
- 3 Bars impact tested in accordance with Note 1 to 2-2-2/25.5 TABLE 1 to be marked AB/U2AW.
- 4 Normalized bars for Grade 2 chains are to be marked AB/U2N.

**TABLE 2**  
**Rolled Bar for Chain – Dimensional Tolerances (1999)**

<i>Specified Bar Diameter, mm (in.)</i>		<i>Tolerance on Diameter,</i>	<i>Tolerance on (d<sub>max</sub> - d<sub>min</sub>)</i>
<i>over</i>	<i>up to</i>	<i>mm (in.)</i>	<i>mm (in.)</i>
less than 25 (1.0)		- 0, + 1.0 (0.04)	0.6 (0.02)
25 (1.0) or above	35 (1.37)	- 0, + 1.2 (0.05)	0.8 (0.03)
35 (1.37)	50 (2.0)	- 0, + 1.6 (0.06)	1.1 (0.04)

50 (2.0)	80 (3.12)	- 0, + 2.0 (0.08)	1.50 (0.06)
80 (3.12)	100 (4.0)	- 0, + 2.6 (0.10)	1.95 (0.08)
100 (4.0)	120 (4.75)	- 0, + 3.0 (0.12)	2.25 (0.09)
120 (4.75)	160 (6.25)	- 0, + 4.0 (0.16)	3.00 (0.12)

### Materials for Machinery, Boilers, Pressure Vessels, and Piping

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General Requirements.....</b>	<b>138</b>
	1	Testing and Inspection.....	138
	1.1	General (2007).....	138
	1.3	Test and Test Data.....	138
	1.5	Rejection of Previously Accepted Material.....	138
	1.7	Calibrated Testing Machines (2005).....	139
	1.9	ASTM References.....	139
	3	Defects.....	139
	5	Identification of Materials.....	139
	7	Manufacturer's Certificates.....	139
	7.1	Form of Certificate.....	139
	7.3	Other Certificates.....	139
	9	Marking and Retests.....	140
	9.1	Identification of Test Specimens.....	140
	9.3	Defects in Specimens.....	140
	9.5	Retests (2005).....	140
	9.7	Rejected Material.....	140
	11	Standard Test Specimens.....	140
	11.1	General.....	140
	11.3	Test Specimens (2005).....	140
	11.5	Tension Test Specimens for Plates and Shapes.....	140
	11.7	Tension Test Specimens for Castings (Other than Gray Cast Iron) and Forgings (2006).....	141
	11.9	Tension Test Specimens (for Gray Cast Iron) (2006).....	141
	11.11	Transverse or Flexure Test Specimens for Gray Cast Iron (2006).....	141
	11.13	Bend Test Specimens for Steel Castings and Forgings (2005).....	141
	13	Definition and Determination of Yield Point and Yield Strength..	143
	13.1	Yield Point (2005).....	143
	13.3	Yield Strength (2005).....	143
	13.5	Tensile Strength (2005).....	143



15	Permissible Variations in Dimensions (1994).....	144
15.1	Scope.....	144
15.3	Plates.....	144
FIGURE 1	Standard Tension Test Specimen <sup>(1)</sup> (2006).....	141
FIGURE 2	Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length (2008).....	142
FIGURE 3	Tension Test Specimen Machined from Transverse or Flexure Test Bars for Gray Cast Iron (2006).....	143
FIGURE 4	Locations for Checking Thickness Tolerance and Average Thickness <sup>(1,2,3)</sup> (2014).....	146

**SECTION 2 Steel Plates for Machinery, Boilers and Pressure Vessels..... 149**

1	General Requirements for All Grades of Steel Plates for Machinery, Boilers, and Pressure Vessels .....	149
1.1	General.....	149
1.2	Manufacturer Approval.....	149
1.3	Marking.....	149
1.5	Process of Manufacture.....	150
1.7	Chemical Composition.....	150
1.9	Test Specimens.....	150
1.11	Tensile Properties.....	151
1.13	Retests.....	151
1.15	Thickness Variation.....	152
1.17	Finish.....	152
1.19	Weldability.....	152
3	Steel Plates for Intermediate-temperature Service .....	152
3.1	Scope.....	152
3.3	General.....	152
3.5	Chemical Composition.....	152
3.7	Specimen Preparation.....	153
3.9	Tensile Properties.....	153
5	Steel Plates for Intermediate- and Higher-temperature Service	153
5.1	Scope.....	153
5.3	General.....	153
5.5	Heat Treatment.....	153
5.7	Chemical Composition.....	154
5.9	Test Specimens.....	154
5.11	Tensile Properties.....	154
7	Steel Plates for Intermediate- and Lower-temperature Service	154
7.1	Scope.....	154
7.3	General.....	154
7.5	Heat Treatment.....	154
7.7	Chemical Composition.....	155

	7.9	Test Specimens.....	155
	7.11	Tensile Properties.....	155
9		Materials for Low Temperature Service [Below - 18°C (0°F)] ....	155
	TABLE 1	Chemical Composition for Plate Grades MD, ME, MF, MG, H, I, J.....	155
	TABLE 2	Tensile Properties for Plate Grades MD, ME, MF, MG, H, I, J.....	156
	TABLE 3	Chemical Composition for Plate Grades K, L, M, N.....	157
	TABLE 4	Tensile Properties for Plate Grades K, L, M, N.....	158
<b>SECTION</b>	<b>3</b>	<b>Seamless Forged-steel Drums.....</b>	<b>159</b>
	1	Tests and Inspections .....	159
	3	Heat Treatment .....	159
<b>SECTION</b>	<b>4</b>	<b>Seamless-steel Pressure Vessels.....</b>	<b>160</b>
	1	General .....	160
	3	Tension Test .....	160
	5	Flattening Test .....	160
	7	Hydrostatic Test .....	160
	9	Inspection .....	160
	11	Marking .....	160
<b>SECTION</b>	<b>5</b>	<b>Boiler and Superheater Tubes.....</b>	<b>161</b>
	1	Scope (1998) .....	161
	3	General .....	161
	3.1	Grades D and F.....	161
	3.3	Grade G.....	161
	3.5	Grade H.....	161
	3.7	Grade J.....	161
	3.9	Grades K, L and M.....	161
	3.11	Grades N, O and P.....	161
	3.13	Grades R and S (1998).....	161
	3.15	ASTM Designation (1998).....	162
	5	Process of Manufacture .....	162
	5.1	Grades D, F, and G.....	162
	5.3	Grades H, J, K, L, and M (1998).....	162
	5.5	Grades N, O, and P (1998).....	162
	5.7	Grades R and S (1998).....	163
	7	Marking (1998).....	163
	9	Chemical Composition - Ladle Analysis .....	163
	11	Check Analysis .....	163
	11.1	General (1998).....	163

	11.3	Samples.....	163
	11.5	Grades D, F, G, and H.....	163
	11.7	Grades J, K, L, M, N, O, P, R, and S (1998).....	164
	11.9	Retests for Seamless Tubes (1998).....	164
	11.11	Retests for Electric-resistance-welded Tubes.....	164
13		Mechanical Tests Required .....	164
15		Test Specimens .....	164
	15.1	Selection of Specimens (1998).....	164
	15.3	Tension Test Specimens.....	164
	15.5	Testing Temperature.....	164
17		Tensile Properties .....	164
19		Flattening Test .....	164
	19.1	Seamless and Electric-resistance-welded Tubes (1998).....	164
	19.3	Electric-resistance-welded Tubes.....	165
21		Reverse Flattening Test .....	165
23		Flange Test .....	165
25		Flaring Test (1998) .....	166
27		Crush Test .....	166
29		Hardness Tests .....	166
	29.1	Type of Test (1998).....	166
	29.3	Brinell Hardness Test.....	166
	29.5	Rockwell Hardness Test.....	167
	29.7	Tubes with Formed Ends.....	167
	29.9	Maximum Permissible Hardness (1998).....	167
31		Hydrostatic Test .....	167
	31.1	General.....	167
	31.3	Maximum Hydrostatic Test Pressure.....	167
	31.5	Duration of Test.....	168
	31.7	Alternate Tests.....	168
	31.9	Rejection.....	168
33		Nondestructive Electric Test (NDET) (1998).....	168
	33.1	General.....	168
	33.3	Ultrasonic Calibration Standards.....	168
	33.5	Eddy-current Calibration Standards.....	168
	33.7	Flux Leakage Calibration Standards.....	169
	33.9	Rejection.....	169
	33.11	Affidavits.....	169
35		Retests (1998).....	169
37		Finish (2008).....	169
39		Permissible Variations in Dimensions (1998).....	170
	39.1	Wall Thickness.....	170
	39.3	Outside Diameter.....	170

	TABLE 1	Chemical Composition for Tubes (1998).....	171
	TABLE 2	Mechanical Tests (1998).....	172
	TABLE 3	Tensile Properties of Tubes (1998).....	173
	TABLE 4	Permissible Variations in Outside Diameter for Tubes <sup>(1)</sup> ...	174
<b>SECTION</b>	<b>6</b>	<b>Boiler Rivet and Staybolt Steel and Rivets.....</b>	<b>176</b>
	1	Process of Manufacture (2008).....	176
	3	Marking and Retests.....	176
	3.1	Manufacturer's Markings.....	176
	3.3	ABS Markings.....	176
	3.5	Retests.....	176
	5	Tensile Properties.....	176
	7	Bending Properties.....	177
	9	Test Specimens.....	177
	11	Number of Tests.....	177
	13	Tests of Finished Rivets.....	177
	13.1	Bending Properties.....	177
	13.3	Flattening Tests.....	177
	13.5	Number of Tests.....	177
<b>SECTION</b>	<b>7</b>	<b>Steel Machinery Forgings.....</b>	<b>178</b>
	1	Carbon Steel Machinery Forgings (2000).....	178
	1.1	Process of Manufacture.....	178
	1.3	Marking, Retests and Rejection.....	179
	1.5	Heat treatment.....	180
	1.7	Tensile Properties.....	181
	1.9	Test Specimens.....	181
	1.11	Number and Location of Tests.....	182
	1.13	Examination (2008).....	186
	1.15	Rectification of Defective Forgings (2018).....	186
	1.17	Certification (2005).....	187
	3	Alloy Steel Gear Assembly Forgings (2000).....	187
	3.1	Process of Manufacture.....	187
	3.3	Marking, Retests and Rejection.....	189
	3.5	Heat Treatment.....	189
	3.7	Mechanical Properties.....	191
	3.9	Test Specimens.....	191
	3.11	Examination (2008).....	194
	3.13	Rectification of Defective Forgings (2005).....	194
	3.15	Certification (2005).....	194
	5	Alloy Steel Shaft and Stock Forgings (2000).....	194
	5.1	Process of Manufacture.....	194
	5.3	Marking, Retests and Rejection.....	196

5.5	Heat Treatment.....	196
5.7	Mechanical Properties.....	198
5.9	Test Specimens.....	198
5.11	Examination (2008).....	200
5.13	Rectification of Defective Forgings (2005).....	200
5.15	Certification (2005).....	200
7	General Shipboard Alloy Steel Forgings (2000).....	200
7.1	Process of Manufacture.....	200
7.3	Marking, Retests and Rejection.....	201
7.5	Heat Treatment.....	202
7.7	Mechanical Properties.....	203
7.9	Mechanical Testing.....	204
7.11	Number and Location of Tests.....	204
7.13	Examination (2008).....	205
7.15	Rectification of Defective Forgings (2005).....	205
7.17	Certification (2005).....	205
TABLE 1	Chemical Composition Requirements for Carbon Steel Machinery Forgings <sup>(1)</sup> , in percent (2013).....	205
TABLE 2	Tensile Property Requirements <sup>(1)</sup> for Carbon-steel Machinery Forgings (2013).....	206
TABLE 3	Chemical Composition Requirements for Alloy Steel Gear Assembly Forgings <sup>(1)</sup> , in percent.....	207
TABLE 4	Tensile Property Requirements for Alloy Steel Gear Assembly Forgings <sup>(1)</sup> (2008).....	208
TABLE 5	Chemical Composition Requirements for Alloy Steel Shaft and Stock Forgings <sup>(1)</sup> , in percent.....	209
TABLE 6	Tensile Property Requirements for Alloy Steel Shaft and Stock Forgings <sup>(1)</sup> (2008).....	210
TABLE 7	Chemical Composition Requirements for General Shipboard Alloy Steel Forgings <sup>(1)</sup> , in percent.....	210
TABLE 8	Tensile Property Requirements for General Shipboard Alloy Steel Forgings <sup>(1)</sup> (2008).....	211
FIGURE 1	Gear Ring Forgings - Test Specimen Locations and Orientations (2017).....	183
FIGURE 2	Pinion or Gear Forging - Test Specimen Locations and Orientations (2017).....	184
FIGURE 3	Gear Shaft Forging - Test Specimen Locations and Orientations (2017).....	184
FIGURE 4	Pinion or Gear Forging - Test Specimen Locations and Orientations (2017).....	192
FIGURE 5	Gear Shaft Forging - Test Specimen Locations and Orientations (2017).....	193

**SECTION 8 Hot-rolled Steel Bars for Machinery.....213**

	1	Hot-rolled Steel Bars (2018).....	213
	3	Number of Tests.....	213
<b>SECTION</b>	<b>9</b>	<b>Steel Castings for Machinery, Boilers and Pressure Vessels.....</b>	<b>214</b>
	1	General.....	214
	1.1	Process of Manufacture (2012).....	214
	1.3	ASTM Designations (2005).....	214
	3	Marking and Retests.....	215
	3.1	Marking (2005).....	215
	3.3	Retests (2005).....	215
	5	Heat Treatment (2017).....	215
	7	Tensile Properties (2008).....	216
	9	Application.....	216
	9.1	General and High-temperature Applications.....	216
	9.3	Propeller and Forging Applications.....	216
	9.5	Alloy Steels or Special Carbon Steels.....	216
	11	Test Specimens.....	217
	11.1	Material Coupons (2016).....	217
	11.3	Separately Cast Coupons.....	217
	13	Number of Tests.....	217
	13.1	Machinery Castings (2005).....	217
	13.3	Steel Propeller Castings.....	217
	15	Inspection and Repair.....	217
	15.1	General (2008).....	217
	15.3	Minor Defects (2006).....	218
	15.5	Major Defects.....	218
	15.7	Welded Repair (2018).....	218
	15.9	Postweld-repair Heat Treatment (2012).....	218
	15.11	Crankshaft Castings (2005).....	219
	17	Nondestructive Testing (2005).....	219
	19	Certification (2005).....	219
<b>SECTION</b>	<b>10</b>	<b>Ductile (Nodular) Iron Castings (2006) .....</b>	<b>220</b>
	1	Scope.....	220
	1.1	.....	220
	1.3	.....	220
	1.5	.....	220
	1.7	.....	220
	3	Manufacture.....	220
	3.1	(2012).....	220
	3.3	.....	221
	3.5	.....	221
	5	Quality of Casting.....	221

7	Chemical Composition.....	221
9	Heat Treatment.....	221
	9.1 .....	221
	9.3 .....	221
	9.5 .....	221
	9.7 (2018).....	221
	9.9 (2018).....	221
	9.11 (2018).....	221
	9.13 (2018).....	221
	9.15 (2018).....	222
	9.17 (2018).....	222
	9.19 (2018).....	222
11	Mechanical Tests.....	222
	11.1 .....	222
	11.3 .....	222
	11.5 .....	224
	11.7 .....	224
	11.9 (2016).....	224
	11.11 .....	224
	11.13 .....	224
	11.15 .....	224
	11.17 .....	224
	11.19 .....	224
	11.21 .....	225
13	Mechanical Properties.....	225
	13.1 .....	225
	13.3 .....	225
	13.5 .....	225
	13.7 .....	225
15	Inspection.....	226
	15.1 .....	226
	15.3 .....	226
	15.5 .....	226
	15.7 .....	226
	15.9 .....	226
	15.11 .....	226
17	Metallographic Examination.....	227
	17.1 .....	227
	17.3 .....	227
	17.5 .....	227
19	Rectification of Defective Castings.....	227
	19.1 .....	227
	19.3 .....	227
	19.5 .....	227

21	Identification of Castings.....	227
21.1	.....	227
21.3	.....	227
21.5	.....	228
23	Certification.....	228
23.1	.....	228
TABLE 1	Mechanical Properties for Spheroidal or Nodular Cast Iron.....	225
TABLE 2	Mechanical Properties for Spheroidal or Nodular Cast Iron with Additional Charpy Requirements.....	226
FIGURE 1	Type A Test Samples (U-type).....	222
FIGURE 2	Type B Test Samples (Double U-type).....	223
FIGURE 3	Type C Test Samples (Y-type).....	223

<b>SECTION</b>	<b>11 Gray-iron Castings (2006).....</b>	<b>229</b>
1	Scope.....	229
1.1	.....	229
1.3	.....	229
1.5	.....	229
3	Process of Manufacture.....	229
3.1	(2012).....	229
3.3	.....	229
3.5	.....	230
5	Quality of Castings.....	230
7	Chemical Composition.....	230
9	Heat Treatment.....	230
9.1	.....	230
9.3	.....	230
9.5	(2018).....	230
9.7	(2018).....	230
9.9	(2018).....	230
9.11	(2018).....	230
9.13	(2018).....	230
9.15	(2018).....	230
9.17	(2018).....	231
11	Mechanical Tests.....	231
11.1	.....	231
11.3	.....	231
11.5	.....	231
11.7	.....	231
11.9	.....	231
11.11	.....	231



	11.13	.....	231
	11.15	.....	231
	11.17	.....	231
	11.19	.....	232
	11.21	.....	232
13	Mechanical Properties.....		232
	13.1 Tensile Strength.....		232
15	Inspection.....		232
	15.1	.....	232
	15.3	.....	232
	15.5	.....	232
	15.7	.....	232
	15.9	.....	233
17	Rectification of Defective Casting.....		233
	17.1	.....	233
	17.3	.....	233
	17.5	.....	233
19	Identification of Castings.....		233
	19.1	.....	233
	19.3	.....	233
	19.5	.....	233
21	Certification.....		233

<b>SECTION</b>	<b>12 Steel Piping.....</b>		<b>235</b>
	1 Scope (1998).....		235
	3 General .....		235
	3.1 Grades 1, 2 and 3.....		235
	3.3 Grades 4 and 5.....		235
	3.5 Grade 6.....		235
	3.7 Grades 7, 11, 12, 13 and 14 (1998).....		235
	3.9 Grades 8 and 9.....		236
	3.11 ASTM Designations (2006).....		236
	5 Process of Manufacture .....		236
	5.1 Grades 1, 2 and 3.....		236
	5.3 Grades 4 and 5.....		236
	5.5 Grades 6 and 7.....		236
	5.7 Grades 8 and 9.....		237
	5.9 Grades 11, 12, 13 and 14 (1998).....		237
	7 Marking (1998).....		237
	9 Chemical Composition.....		237
	11 Ladle Analysis (1998).....		237
	13 Check Analysis .....		238
	13.1 General.....		238

	13.3	Samples.....	238
	13.5	Grades 1, 2 and 3.....	238
	13.7	Grades 4 and 5.....	238
	13.9	Grades 6, 7, 11, 12, 13 and 14 (1998).....	238
	13.11	Grades 8 and 9.....	238
	13.13	Retests for Grades 1, 2, 3, 4 and 5.....	238
	13.15	Retests for Grades 6, 7, 11, 12, 13 and 14 (1998).....	238
	13.17	Retests for Grades 8 and 9.....	238
15		Mechanical Tests Required (1998).....	239
17		Tension Test Specimens .....	239
	17.1	Grades 1, 2 and 3.....	239
	17.3	Grades 4, 5, 6, 7, 11, 12, 13 and 14 (1998).....	239
	17.5	Grades 8 and 9.....	239
19		Bend and Flattening Test Specimens.....	239
21		Testing Temperature.....	240
23		Tensile Properties.....	240
25		Bend Test.....	240
	25.1	General.....	240
	25.3	Details of Test.....	240
27		Flattening Test .....	240
	27.1	General.....	240
	27.3	Furnace-welded Pipe.....	240
	27.5	Electric-resistance-welded Pipe.....	241
	27.7	Seamless Pipe (1998).....	241
29		Hydrostatic Test .....	242
	29.1	General (1998).....	242
	29.3	Grades 1, 2 and 3 (1999).....	242
	29.5	Grades 4, 5, 6, 7, 11, 12, 13 and 14 (1999).....	242
	29.7	Grades 8 and 9.....	242
	29.9	Test Pressures (1999).....	242
	29.11	Exceptions (1999).....	243
31		Nondestructive Electric Test (NDET) for Seamless Pipe (1998).....	243
	31.1	General.....	243
	31.3	Ultrasonic Calibration Standards.....	243
	31.5	Eddy-Current Calibration Standards.....	243
	31.7	Flux Leakage Calibration Standards.....	244
	31.9	Rejection.....	244
	31.11	Affidavits.....	244
33		Retests .....	244
	33.1	General (1998).....	244
	33.3	Grades 1, 2, 3, 8 and 9.....	244
	33.5	Grades 4 and 5.....	244
	33.7	Grades 6, 7, 11, 12, 13 and 14 (1998).....	244
35		Pipe Testing and Inspection .....	245

35.1	Group I Piping (2008).....	245
35.3	Group I and II Piping (1998).....	245
37	Permissible Variation in Wall Thickness (1998).....	245
39	Permissible Variations in Outside Diameter .....	245
39.1	Grades 1, 2, 3.....	245
39.3	Grades 4, 5, 6, 7, 11, 12, 13 and 14 (1998).....	245
39.5	Grades 8 and 9.....	245
39.7	Inspection (1998).....	245
TABLE 1	Maxima or Permissible Range of Chemical Composition in Percent for Pipe (1998).....	246
TABLE 2	Lot Sizes for Pipe Grades 6, 7, 11, 12, 13 and 14 (1998)..	246
TABLE 3	Mechanical Tests for Pipe (1998).....	247
TABLE 4	Tensile Requirements for Pipe (1998).....	248
TABLE 5	Hydrostatic-test Pressure for Welded and Seamless Plain-end Steel Pipe.....	250
TABLE 6	Out-of-roundness Variation (1998).....	253

<b>SECTION</b>	<b>13 Piping, Valves and Fittings for Low-temperature Service[ Below -18°C (0°F) ] .....</b>	<b>254</b>
1	Scope.....	254
3	Designation (2013).....	254
5	Manufacture.....	254
7	Heat Treatment.....	254
9	Marking.....	255
11	Chemical Composition.....	255
13	Mechanical Tests.....	255
15	Impact Properties.....	255
17	Steels for Service Temperatures Between -18°C (0°F) and -196°C (-320°F) .....	255
19	Steels for Service Temperatures Below -196°C (-320°F).....	255
21	Materials for Nuts and Bolts.....	255
23	Toughness.....	255
25	Impact Test Temperature.....	256
27	Witnessed Tests (2006).....	256
29	Retests.....	256
31	Welding.....	256

<b>SECTION</b>	<b>14 Bronze Castings.....</b>	<b>257</b>
1	For General Purposes .....	257
1.1	Tensile Properties.....	257
1.3	Number of Tests (2012).....	257
3	Propellers and Propeller Blades .....	257
3.1	Foundry Approval (2006).....	257

	3.2	Castings.....	258
	3.3	Chemical Composition (1 July 2013).....	258
	3.5	Zinc Equivalent.....	258
	3.7	Alternative Zinc Equivalent.....	258
	3.9	Tensile Properties (2012).....	259
	3.11	Test Specimens (2008).....	259
	3.13	Separately Cast Coupons (1996).....	259
	3.15	Integrally Cast Coupons.....	260
	3.17	Number of Tests.....	260
	3.19	Special Compositions.....	260
	3.21	Inspection and Repair (2014).....	260
	3.23	Marking.....	261
		FIGURE 1 Test Coupons (1996).....	260
<b>SECTION</b>	<b>15</b>	<b>Austenitic Stainless Steel Propeller Castings.....</b>	<b>262</b>
	1	Process of Manufacture and Foundry Approval (2006).....	262
	1.1	Process of Manufacture.....	262
	1.3	Foundry Approval (2012).....	262
	1.5	Scope of the Approval Test.....	262
	1.7	Quality Control.....	263
	3	Inspection and Repair.....	263
	5	Chemical Composition.....	263
	7	Tensile Properties.....	263
	9	Tests and Marking .....	263
	9.1	Test Specimens.....	263
	9.3	Separately Cast Coupons (2006).....	264
	9.5	Integral Coupons (2006).....	264
	9.7	Number of Tests.....	264
	9.9	Special Compositions.....	264
	9.11	Marking.....	264
<b>SECTION</b>	<b>16</b>	<b>Seamless Copper Piping (1998).....</b>	<b>265</b>
	1	Scope.....	265
	3	General.....	265
	3.1	Grades C1, C2, C3, C4, C5, C6 and C7.....	265
	3.3	ASTM Designation.....	265
	5	Process of Manufacture (2009).....	266
	7	Marking .....	266
	7.1	Manufacturer's Marking.....	266
	7.3	ABS Markings.....	266
	9	Chemical Composition.....	266
	11	Tension Test .....	266

	11.1	Tension Test Specimens.....	266
	11.3	Tensile Properties.....	266
13		Expansion Test.....	266
15		Flattening Test.....	266
17		Hydrostatic Test .....	267
	17.1	Limiting Test Pressures.....	267
	17.3	Affidavits of Tests.....	267
19		Number of Tests.....	267
21		Retests.....	267
23		Permissible Variations in Dimensions.....	268

TABLE 1 Chemical Composition for Copper Pipe and Tube (1998). 268

TABLE 2 Tensile Properties for Copper Pipe and Tube (1998)..... 268

**SECTION 17 Seamless Red-brass Piping..... 269**

	1	Process of Manufacture (2009).....	269
	3	Marking .....	269
	3.1	Manufacturer's Marking.....	269
	3.3	ABS Marking.....	269
	5	Scope.....	269
	7	Chemical Composition.....	269
	9	Expansion Test.....	270
	11	Flattening Test.....	270
	13	Mercurous Nitrate Test.....	270
	15	Bend Test.....	270
	17	Hydrostatic Test .....	270
	17.1	Limiting Test Pressures.....	270
	17.3	Affidavits of Tests.....	271
	19	Number of Tests.....	271
	21	Retests.....	271
	23	Permissible Variations in Dimensions.....	271

**SECTION 18 Seamless Copper Tube (1998)..... 272**

	1	Scope.....	272
	3	General .....	272
	3.1	Grades CA, CB, CC, CD, CE, CF and CG.....	272
	3.3	ASTM Designation.....	272
	5	Process of Manufacture (2009).....	273
	7	Marking .....	273
	7.1	Manufacturer's Marking.....	273
	7.3	ABS Markings.....	273
	9	Chemical Composition.....	273
	11	Tension Test .....	273

	11.1	Tension Test Specimens.....	273
	11.3	Tensile Properties.....	273
13		Expansion Test.....	273
15		Flattening Test.....	273
17		Hydrostatic Test .....	274
	17.1	Limiting Test Pressures.....	274
	17.3	Affidavits of Tests.....	274
19		Number of Tests.....	274
21		Retests.....	274
23		Permissible Variations in Dimensions.....	275
<b>SECTION</b>	<b>19</b>	<b>Condenser and Heat Exchanger Tube (1998).....</b>	<b>276</b>
	1	Scope.....	276
	3	General .....	276
	3.1	Grades CNA and CNB.....	276
	3.3	ASTM Designation.....	276
	5	Process of Manufacture .....	276
	5.1	Grade CNA.....	276
	5.3	Grade CNB.....	276
	7	Marking.....	277
	9	Chemical Composition .....	277
	9.1	Chemical Requirements.....	277
	9.3	Chemical Analysis Sampling.....	277
	11	Tension Test .....	277
	11.1	Tension Test Specimens.....	277
	11.3	Tensile Properties.....	277
	13	Expansion Test.....	277
	15	Flattening Test.....	277
	17	Nondestructive Electric Test (NDET).....	278
	19	Hydrostatic Test .....	278
	19.1	Limiting Test Pressures.....	278
	19.3	Affidavits of Tests.....	279
	21	Number of Tests.....	279
	23	Retests.....	279
	25	Finish.....	279
	27	Dimensions and Tolerances.....	279
	27.1	Diameter.....	279
	27.3	Wall Thickness Tolerances.....	280
	27.5	Length.....	281
	27.7	Squareness of Cut.....	281
	TABLE 1	Chemical Composition for Copper Nickel Pipe and Tube (1998).....	282

TABLE 2	Tensile Properties for Seamless Copper Nickel Pipe and Tube (1998).....	282
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<b>SECTION</b>	<b>20 Copper-Nickel Tube and Pipe (1998).....</b>	<b>283</b>
1	Scope.....	283
3	General .....	283
3.1	Grades CN1 and CN2.....	283
3.3	Grades CN3 and CN4.....	283
3.5	ASTM Designation.....	283
5	Process of Manufacture.....	284
5.1	Grades CN1 and CN2.....	284
5.3	Grades CN3 and CN4.....	284
7	Marking.....	284
9	Chemical Composition .....	284
9.1	Chemical Requirements.....	284
9.3	Chemical Analysis Sampling.....	284
11	Tension Test .....	284
11.1	Tension Test Specimens.....	284
11.3	Seamless Tensile Properties.....	284
11.5	Welded (WO61) Tensile Properties.....	285
11.7	Welded (WO50) Tensile Properties.....	285
13	Expansion Test.....	285
13.1	Grades CN1 and CN2.....	285
13.3	Grades CN3 and CN4.....	285
15	Flattening Test.....	285
17	Nondestructive Examination .....	286
17.1	Nondestructive Electric Test (NDET).....	286
17.3	Radiographic Examination.....	286
19	Hydrostatic Test .....	286
19.1	Limiting Test Pressures.....	286
19.3	Affidavits of Tests.....	286
21	Number of Tests.....	286
23	Retests.....	287
25	Finish.....	287
27	Dimensions and Tolerances.....	287
27.1	Diameter.....	287
27.3	Roundness.....	288
27.5	Wall Thickness Tolerances.....	288
27.7	Length.....	288
27.9	Squareness of Cut.....	288
27.11	Straightness Tolerances.....	289
<b>SECTION</b>	<b>21 Monel Pipe and Tube (1999).....</b>	<b>290</b>

1	Scope .....	290
3	General.....	290
	3.1 Grades M1 and M2.....	290
	3.3 Grades M3 and M4.....	290
	3.5 ASTM Designation.....	290
5	Process of Manufacture .....	291
	5.1 Grades M1 and M2.....	291
	5.3 Grades M3 and M4.....	291
7	Marking .....	291
9	Chemical Composition .....	291
	9.1 Ladle Analysis.....	291
	9.3 Chemical Composition -Check Analysis.....	292
11	Tension Test .....	292
	11.1 Tension Test Specimens.....	292
	11.3 Annealed Tensile Properties.....	292
	11.5 Stress Relieved Tensile Properties.....	292
13	Flattening Test .....	292
15	Flare Test .....	292
17	Flange Test .....	293
19	Number of Tests .....	293
	19.1 Chemical Analysis.....	293
	19.3 Other Tests.....	293
21	Hydrostatic Test.....	293
	21.1 Limiting Test Pressures.....	293
	21.3 Exceeding Limiting Test Pressures.....	294
	21.5 Affidavits of Tests.....	294
23	Nondestructive Electric Test (NDET) .....	294
	23.1 General.....	294
	23.3 Ultrasonic Calibration Standards.....	294
	23.5 Eddy-Current Calibration Standards.....	294
	23.7 Rejection.....	295
	23.9 Affidavits.....	295
25	Retests .....	295
27	Finish .....	295
29	Dimensions and Tolerances .....	295
	29.1 Diameter.....	295
	29.3 Wall Thickness -Seamless.....	296
	29.5 Wall Thickness -Welded.....	296
	29.7 Cut Ends.....	296
	29.9 Straightness.....	297



## **1 Testing and Inspection**

### **1.1 General (2007)**

All materials subject to test and inspection, intended for use in boilers, pressure vessels, piping and machinery of vessels classed or proposed for classification, are to be verified by the Surveyor in accordance with the following requirements or their equivalent. Materials, test specimens, and testing procedures having characteristics differing from those prescribed herein require special approval for each application of such materials and the physical tests may be modified to suit conditions as approved in connection with the design.

### **1.3 Test and Test Data**

#### **1.3.1 Witnessed Tests**

The designation (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved under ABS's Quality Assurance Program.

#### **1.3.2 Manufacturer's Data**

The designation (M) indicated that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

#### **1.3.3 Other Tests**

The designation (A) indicates those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with Rule requirements.

See Part 2, Appendix 1 for complete listing of indicated designations for the various tests called out by Part 2, Chapter 3.

### **1.5 Rejection of Previously Accepted Material**

In the event of any material proving unsatisfactory in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing.

### 1.7 Calibrated Testing Machines (2005)

The Surveyor is to be satisfied that the testing machines are maintained in a satisfactory and accurate condition and is to keep a record of the dates and by whom the machines were rechecked or calibrated. All tests are to be carried out to a recognized national or international Standard by competent personnel.

### 1.9 ASTM References

For identification of ASTM references, see Section 2-1-1.

## 3 Defects

All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects. Except as indicated for specific materials, welding or dressing for the purpose of remedying defects is not permitted unless and until sanctioned by the Surveyor. In such cases, where sanction is required for materials to be so treated, the Surveyor may prescribe further probing and necessary heat treatment; then, if found satisfactory, the part treated is to be stamped with the Surveyor's identification mark and surrounded by a ring of paint.

## 5 Identification of Materials

The manufacturer is to adopt a system of marking ingots, slabs, finished plates, shapes, castings and forgings which will enable the material to be traced to its original heat; and the Surveyor is to be given every facility for so tracing material.

## 7 Manufacturer's Certificates

### 7.1 Form of Certificate

Unless requested otherwise, four copies of the certified mill test reports and shipping information (may be separate or combined documents) of all accepted material indicating the grade of steel, heat identification numbers, test results and weight shipped are to be furnished to the Surveyor. One copy of the mill test report is to be endorsed by the Surveyor and forwarded to the Purchaser, and three are to be retained for the use of ABS. Before the certified mill test reports and shipping information are distributed to the local ABS office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been made by an approved process and that it has satisfactorily withstood the prescribed tests. The following form of certificate will be accepted if printed on each certified mill test report with the name of the firm and initialed by the authorized representative of the manufacturer:

“We hereby certify that the material described herein has been made to the applicable specification by the \_\_\_\_\_ process (state process) and tested in accordance with the requirements of \_\_\_\_\_ (the American Bureau of Shipping Rules or state other specification) with satisfactory results.”

At the request of manufacturers, consideration may be given to modifications in the form of the certificate, provided it correspondingly indicates compliance with the requirements of the Rules to no less degree than indicated in the foregoing statement.

### 7.3 Other Certificates

Where steel is not produced in the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor stating the process by which it was manufactured, the name of the manufacturer who supplied it and the number of the heat from which it was made. The number of the heat is to be marked on each plate or bar for the purpose of identification.

## 9 Marking and Retests

### 9.1 Identification of Test Specimens

Where test specimens are required to be selected by the Surveyor, they are not to be detached until stamped with his identification mark; but in no case, except as otherwise specified, are they to be detached until the material has received its final treatment. Satisfactory ABS-tested material is to be stamped **AB**, or as specified for a particular material, to indicate compliance with the requirements.

### 9.3 Defects in Specimens

If any test specimen shows defective machining or develops defects, it may be discarded and another specimen substituted, except that for forgings, a retest is not allowed if a defect develops during testing which is caused by rupture, cracks, or flakes in the steel.

### 9.5 Retests (2005)

The elongation value is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one-third of the original gauge length. However, the result is valid irrespective of the location of the fracture if the percentage elongation after fracture is equal to or greater than the required value.

Generally, elongation,  $A_5$ , is determined on a proportional gauge length,  $5.65\sqrt{S_0} = 5d$ , but may also be given for other specified gauge lengths.

If the material is a ferritic steel of low or medium strength and not cold worked, and the elongation is measured on a non-proportional gauge length, the required elongation,  $A_0$ , on that gauge length,  $L_0$ , may after agreement be calculated from the following formula:

$$A_0 = 2A_5 \left( \frac{\sqrt{S_0}}{L_0} \right)^{0.40}$$

### 9.7 Rejected Material

In the event that any set of test specimens fails to meet the requirements, the material from which such specimens have been taken are to be rejected and the required markings withheld or obliterated.

## 11 Standard Test Specimens

### 11.1 General

Test specimens are to be taken longitudinally and of the full thickness or section of material as rolled, except as otherwise specified.

### 11.3 Test Specimens (2005)

Test specimens are to receive no other preparation than that prescribed and are to similarly and simultaneously receive all of the treatment given the material from which they are cut, except as otherwise specified. Straightening of specimens distorted by shearing is to be carried out while the piece is cold. The accuracy of the tensile test machines is to be within  $\pm 1\%$  of the load.

### 11.5 Tension Test Specimens for Plates and Shapes

Tension test specimens for rolled plates, shapes and flats are to be cut from the finished material and machined to the form and dimensions shown in 2-3-1/11.13 FIGURE 1, or they may be prepared with both edges parallel throughout their length. Alternatives to the foregoing are indicated under specific materials.

**11.7 Tension Test Specimens for Castings (Other than Gray Cast Iron) and Forgings (2006)**

Tension test specimens for castings (other than gray cast iron) and forgings are to be machined to the form and dimensions shown for the round specimen alternative C in 2-3-1/11.13 FIGURE 1 or in accordance with 2-3-1/11.13 FIGURE 2.

**11.9 Tension Test Specimens (for Gray Cast Iron) (2006)**

Tension test specimens for gray cast iron are, unless otherwise approved, to be machined to the form and dimensions shown in 2-3-1/11.13 FIGURE 3 from test bars cast separately from the casting represented. Such test bars are to be poured from ladles of iron used to pour the castings and under the same sand conditions, and they are to receive the same thermal treatment as the castings they represent.

**11.11 Transverse or Flexure Test Specimens for Gray Cast Iron (2006)**

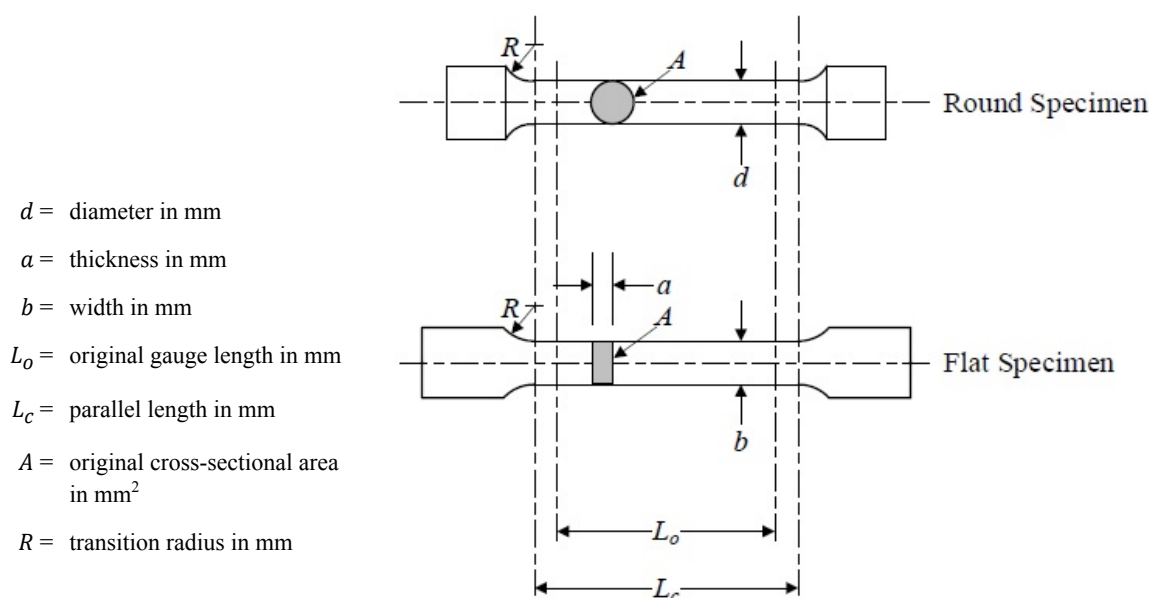
Transverse or flexure test specimens for gray cast iron are, unless otherwise approved, to be a test bar as cast with a 50 mm (2 in.) diameter and 700 mm (27 in.) length. Such test bars are to be cast under the same conditions as described in 2-3-1/11.9.

**11.13 Bend Test Specimens for Steel Castings and Forgings (2005)**

When required, bend test specimens for steel castings and forgings may be machined to 25 mm × 20 mm (1 in. × 0.790 in.) in section. The length is unimportant, provided that it is enough to perform the bending operation.

The edges on the tensile side of the bend test specimens may have the corners rounded to a radius of 1–2 mm (0.040–0.080 in.).

**FIGURE 1  
 Standard Tension Test Specimen <sup>(1)</sup>(2006)**



- $d$  = diameter in mm
- $a$  = thickness in mm
- $b$  = width in mm
- $L_o$  = original gauge length in mm
- $L_c$  = parallel length in mm
- $A$  = original cross-sectional area in  $\text{mm}^2$
- $R$  = transition radius in mm

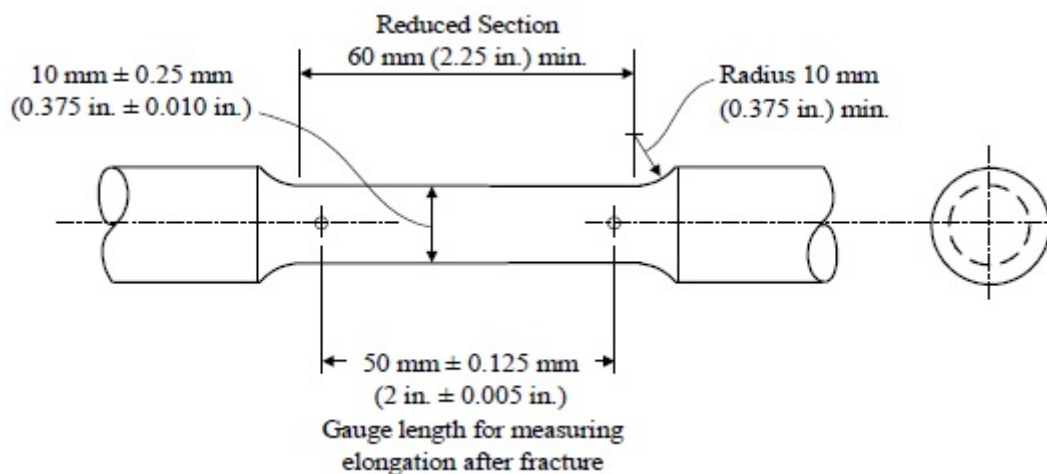
	$d$	$a$	$b$	$L_o$	$L_c$	$R$
Flat specimen Alternative A	-	$t^{(2)}$	25	$5.65\sqrt{A}$	$L_o + 2\sqrt{A}$	25

Flat specimen Alternative B	-	$t^{(2)}$	25	200	225	25
Round specimen Alternative C	14	-	-	70	85	10

**Notes:**

- 1 Standard specimen in accordance with ASTM E8/E8M or A370 will also be acceptable in conjunction with the corresponding elongation requirements in 2-1-2/15.9 TABLE 2 or 2-1-3/7.3 TABLE 2
- 2  $t$  is the full thickness of the material as produced. If the capacity of the testing machine does not allow full thickness specimens to be broken, the thickness may be reduced by machining one surface only.
- 3  $L_o$ , the proportional gauge length, is to be greater than 20 mm.

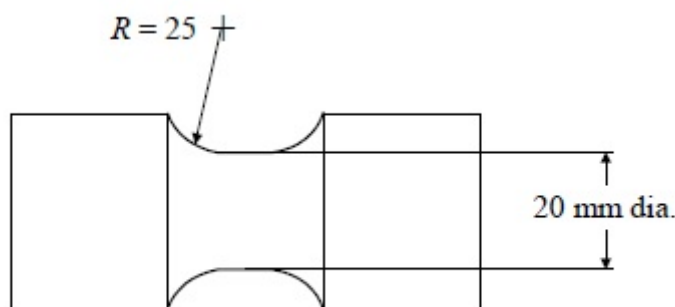
**FIGURE 2**  
**Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length**  
**(2008)**



**Note:**

(2008) The gauge length and fillets are to be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load is to be axial. The reduced section may have a gradual taper from the ends towards the center, with the ends not more than 0.13 mm (0.005 in.) larger in diameter than the center.

**FIGURE 3**  
**Tension Test Specimen Machined from Transverse**  
**or Flexure Test Bars for Gray Cast Iron (2006)**



## 13 Definition and Determination of Yield Point and Yield Strength

### 13.1 Yield Point (2005)

The yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. The value of stress is measured at the commencement of plastic deformation at yield, or the value of stress measured at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield. Yield point may be determined by the halt of the pointer or autographic diagram. The 0.5% total extension under load method will also be considered acceptable.

The test is to be carried out with an elastic stress within the following limits:

Modulus of Elasticity of the Material ( <i>E</i> ), N/mm <sup>2</sup>	Rate of Stressing, N/mm <sup>2</sup> -s <sup>-1</sup>	
	Min.	Max.
< 150,000	2	20
≥150,000	6	60

### 13.3 Yield Strength (2005)

The yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. When no well-defined yield phenomenon exists, yield strength is to be determined by the 0.2% (*R<sub>p</sub> 0.2*) offset method. Alternatively, for material whose stress-strain characteristics are well known from previous tests in which stress-strain diagrams were plotted, the 0.5% extension under load method may be used. When agreed upon between the supplier and purchaser for austenitic and duplex stainless steel products, the 1% proof stress (*R<sub>p</sub> 1*) may be determined in addition to *R<sub>p</sub> 0.2*.

The rate of loading is to be as stated in the limits above.

### 13.5 Tensile Strength (2005)

After reaching the yield or proof load, for ductile material, the machine speed during the tensile test is not to exceed that corresponding to a strain rate of 0.008 s<sup>-1</sup>. For brittle materials, such as gray cast iron, the elastic stress rate is not to exceed 10 N/mm<sup>2</sup> per second.

## 15 Permissible Variations in Dimensions (1994)

### 15.1 Scope

The under tolerance specified below represents the minimum material certification requirements and is to be considered as the lower limit of usual range of variations (plus/minus) from the specified dimension.

The responsibility for meeting the specified tolerances rests with the manufacturer who is to maintain a procedure acceptable to the Surveyor.

### 15.3 Plates (1 July 2019)

The maximum permissible under thickness tolerance for plates and wide flats for construction of machinery, excluding boilers, pressure vessels and independent tanks for liquefied gases and chemicals (see 2-3-2/1.15), is to be in accordance with the following:

These requirements apply to the tolerance on thickness of steel plates and wide flats with widths of 600 mm (24 in.) or greater (hereinafter referred to as products).

*Note:*

Tolerances for length, width, flatness and over thickness may be taken from recognized national or international standards.

Class C of ISO 7452 latest version may be applied in lieu of 2-3-1/15.3.2, in which case the requirements in 2-3-1/15.3.3 and 2-3-1/15.3.4 need not be applied.

Additionally, if ISO 7452 is applied, it is required that the steel mill demonstrate to the satisfaction of ABS that the number of measurements and measurement distribution is appropriate to establish that the mother plates produced are at or above the specified nominal thickness.

#### 15.3.1 Responsibility

Responsibility for verification and maintenance of production within the required tolerances rests with the manufacturer. The Surveyor may require witnessing of some measurements. Responsibility for storage and maintenance of the delivered plates with acceptable level of surface conditions, before the products are used in fabrication, rests with the shipyard.

#### 15.3.2 Thickness Tolerances (1 July 2019)

15.3.2(a) Thickness tolerances of a given product are defined as:

- Minus tolerance is the lower limit of the acceptable range below the nominal thickness.
- Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

*Note:*

Nominal thickness is defined by the purchaser at the time of enquiry and order.

15.3.2(b) The minus tolerances are to be in accordance with the following table.

<i>Nominal Thickness, t, mm (in.)</i>	<i>Tolerance, mm (in.)</i>
$3 \leq t < 5$ ( $0.12 \leq t < 0.20$ )	0.3 (0.012)
$5 \leq t < 8$ ( $0.20 \leq t < 0.32$ )	0.4 (0.016)
$8 \leq t < 15$ ( $0.32 \leq t < 0.59$ )	0.5 (0.02)
$15 \leq t < 25$ ( $0.59 \leq t < 0.98$ )	0.6 (0.024)
$25 \leq t < 40$ ( $0.98 \leq t < 1.57$ )	0.7 (0.027)
$40 \leq t < 80$ ( $1.57 \leq t < 3.15$ )	0.9 (0.035)
$80 \leq t < 150$ ( $3.15 \leq t < 5.91$ )	1.1 (0.043)
$150 \leq t < 250$ ( $5.91 \leq t < 9.84$ )	1.2 (0.047)
$t \geq 250$ ( $t \geq 9.84$ )	1.3 (0.051)

15.3.2(c) Thickness tolerances are not applicable to areas repaired by grinding in accordance with 2-1-1/3.7.1, unless more stringent requirements are specified by the purchaser and agreed by ABS Materials Department.

15.3.2(d) Plus tolerances on nominal thickness are to be in accordance with a recognized national or international standard such as ASTM A20, unless otherwise specified by the purchaser and agreed by ABS Materials Department.

### 15.3.3 Average Thickness

15.3.3(a) The average thickness of a product is defined as the arithmetic mean of the measurements made in accordance with the requirements of 2-3-1/15.3.4.

15.3.3(b) The average thickness is not to be less than the nominal thickness.

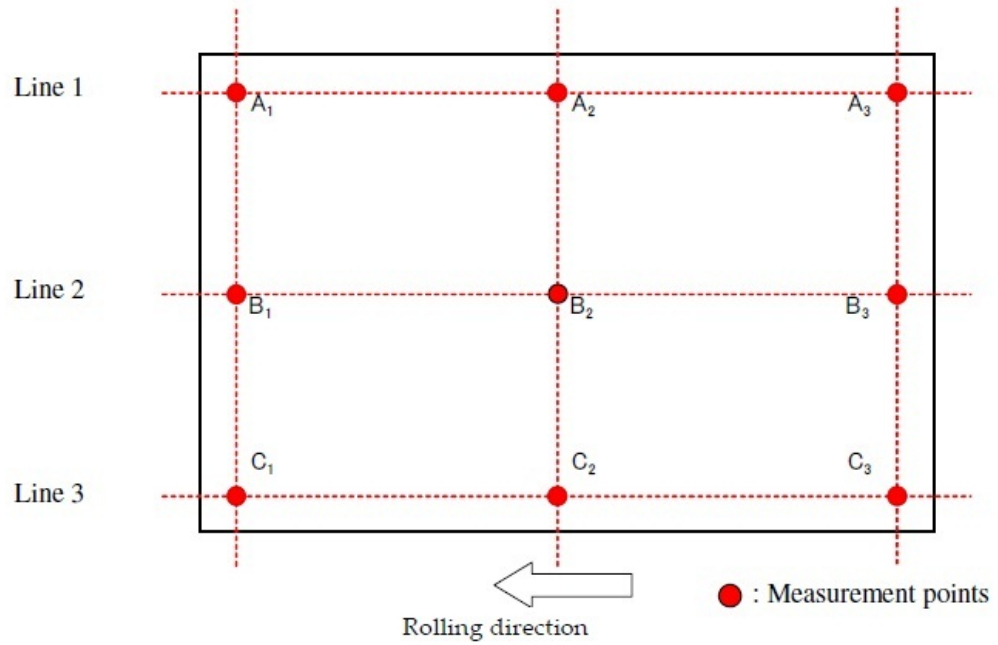
### 15.3.4 Thickness Measurements

15.3.4(a) Thickness is to be measured at locations as defined in 2-3-1/15.3.4 FIGURE 4. Automated or manual measurement methods may be used.

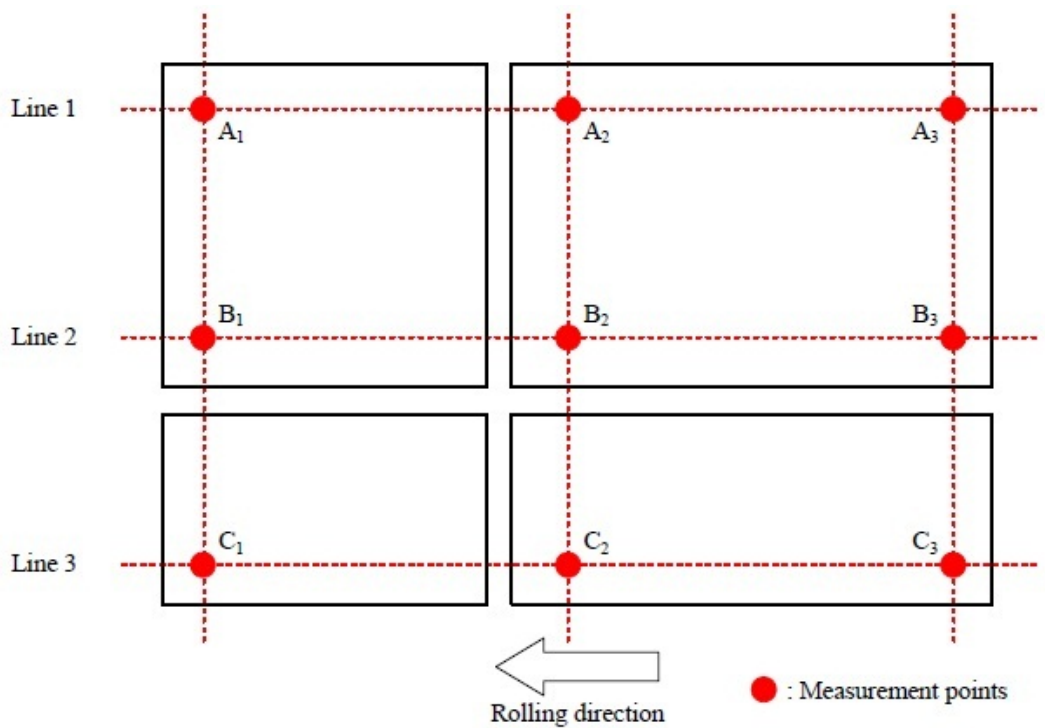
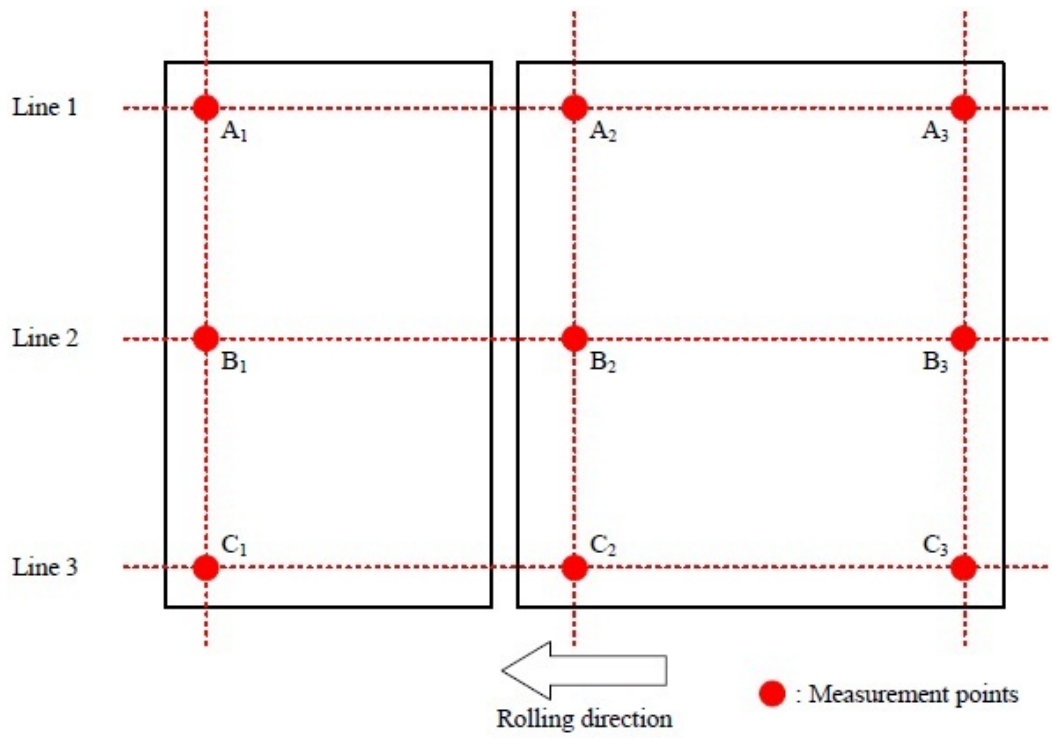
15.3.4(b) The procedure and records of measurements are to be made available to the Surveyor and copies provided on request.

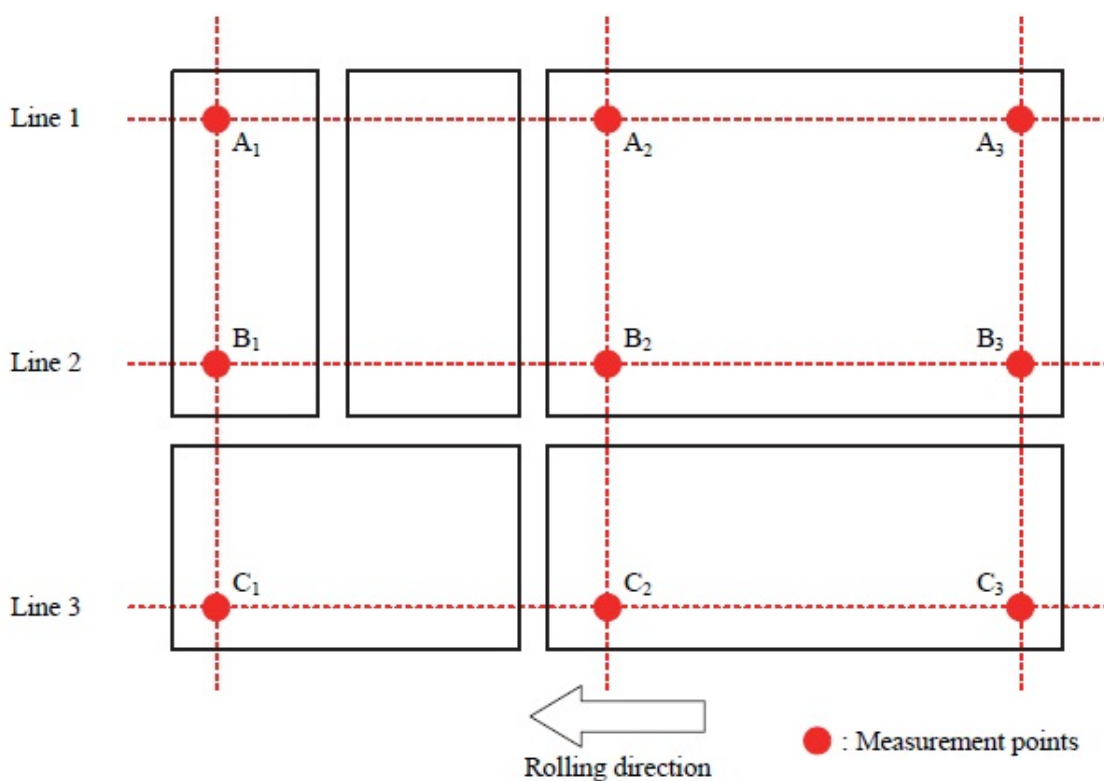


**FIGURE 4**  
**Locations for Checking Thickness Tolerance and Average Thickness** <sup>(1,2,3)</sup>  
**(2014)**



a) Locations of Thickness Measuring Points for the Original Steel Plates





b) Locations of Thickness Measuring Points for the Cut Steel Products

*Notes:*

- 1 (2014) At least two lines are to be selected from Lines 1, 2, or 3, as shown, and at least three points on each selected line. If more than three points are taken on each line, the number of points on each line is to be the same.  
 The measurement locations apply to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Examples of the original measurements relative to later cut products are shown in 2-3-1/15.3.4 FIGURE 4b). It is to be noted that the examples shown are not representative of all possible cutting scenarios.
- 2 For automated measuring, peripheral points are to be located 10-300 mm (0.375-12.0 in.) from the edge.
- 3 For manual measuring, peripheral points are to be located 10-100 mm (0.375-4.0 in.) from the edge.

**1 General Requirements for All Grades of Steel Plates for Machinery, Boilers, and Pressure Vessels****1.1 General (2022)****1.1.1 Examination at Mills (2022)**

The grades of steel covered in 2-3-2/3, 2-3-2/5 and 2-3-2/7 are rolled plates intended for use in machinery, boilers and other pressure vessels. All tests are to be conducted in the presence of the Surveyor at the place of manufacture prior to shipping, unless the plant is approved under ABS's Quality Assurance Program for Rolled Products. The material surfaces will be examined by the Surveyor when specially requested by the purchaser. Plates are to be free from defects and have a workmanlike finish, subject to the conditions given under 2-3-2/1.7. Refer to 4-4-1/Table 3 of the *Marine Vessel Rules* for certification requirements for boiler and pressure vessels.

**1.2 Manufacturer Approval (2022)**

All grades of steel plates for Group I boiler and pressure vessels are to be manufactured at steel works approved by ABS for the type and grade of steel contemplated. The suitability of the steel plates for welding and assumed forming is to be demonstrated during the initial approval test at the steel works. Approval of the steel works for steel plates is to be in accordance with Part 2, Appendix 4.

Approval can be requested for grades of steel covered in 2-3-2/3, 2-3-2/5 and 2-3-2/7 or other grades as approved in design.

Refer to 2-1-1/1.5 for the certification on the basis of the ABS Quality Assurance Program for Rolled Products.

**1.3 Marking****1.3.1 Plates and Test Specimens**

The name or brand of the manufacturer, the letter indicating the grade of steel, the manufacturer's identification numbers and the letters **PV** to indicate pressure-vessel quality are to be legibly stamped (except as specified in 2-3-2/1.3.4) on each finished plate in two places, not less than 300 mm (12 in.) from the edges. Plates, the maximum lengthwise and crosswise dimensions of which do not exceed 1800 mm (72 in.), are to have the marking stamped in one place approximately midway between the center and an edge. The manufacturer's test identification number is to be

legibly stamped on each test specimen. All test specimens are to be ring-stamped, match-marked or otherwise suitably identified to the satisfaction of the attending Surveyor before being detached.

### 1.3.2 Heat-treatment Marking

When the heat treatment is to be carried out by the fabricator as covered in 2-3-2/5.5 and 2-3-2/7.5, the letter **G** is to also be stamped on each plate by the steel producer to indicate that the material is in the unheat-treated (green) condition. After heat treatment at the fabricator's plant, the letter **T** is to be stamped following the letter **G**.

### 1.3.3 ABS Markings

ABS markings **AB**, indicating satisfactory compliance with the Rule requirements and other markings as furnished by the Surveyor, are to be stamped on all plates near the marking specified in 2-3-2/1.3.1 to signify that the material has satisfactorily complied with the test prescribed, and that certificates for the material will be furnished to the Surveyor in accordance with 2-3-1/7. For coiled steel which is certified for chemical analysis only, the marking **AB** without grade designation is to be marked on the outer wrap of each coil shipped.

### 1.3.4 Thin Plates

Plates under 6.4 mm (0.25 in.) in thickness are to be legibly stenciled with the markings specified in 2-3-2/1.3.1 and 2-3-2/1.3.2 instead of stamped.

### 1.3.5 Special Impact Testing

When steel is impact tested in accordance with 2-3-2/9 the grade marking is to be followed by the test temperature in degrees Celsius. A prefix "0" to the test temperature is to indicate a temperature colder than zero degrees Celsius.

## 1.5 Process of Manufacture

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. The steel may be cast in ingots or may be strand (continuous) cast. The ratio of reduction of thickness from strand (continuous) cast slab to finished plate is to be a minimum of 3 to 1 unless specially approved.

### 1.5.1 Plates Produced from Coils

For coiled plate, the manufacturer or processor is to submit supporting data for review and approval to indicate that the manufacturing, processing and testing will provide material which is in compliance with the Rules.

## 1.7 Chemical Composition

### 1.7.1 Ladle Analysis

An analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. This analysis is to be made from a test sample taken during pouring of the heat. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements as specified for each grade in 2-3-2/3.5, 2-3-2/5.7 or 2-3-2/7.7.

### 1.7.2 Check Analysis

The chemical composition determined by check analysis is to conform to the requirements as specified for each Grade in 2-3-2/3.5, 2-3-2/5.7, and 2-3-2/7.7.

## 1.9 Test Specimens

### 1.9.1 Selection of Specimens

One tension test specimen is to be taken from each plate as rolled in such manner that the longitudinal axis of the specimen is transverse to the final direction of rolling of the plate. The

tension test specimen is to be taken from a corner of the plate. If the final rolling direction of the plate is parallel to the original longitudinal ingot axis, the tension test specimen is to be taken from the “bottom” end of the plate. If the final direction of rolling of the plate is transverse to the original longitudinal ingot axis, or if the relationship of final rolling direction and original ingot axis is unknown, the tension test specimen may be taken from either end. For plates produced from coils, two tension test specimens are to be made from each coil. One tension test specimen is to be obtained from a location immediately prior to the first plate produced and a second test specimen obtained from the approximate center lap. When required, impact tests are to be obtained adjacent to both tension test coupons and a third coupon is to be obtained immediately after the last plate produced to the qualifying grade or specification.

### 1.9.2 Specimens from Plates 19 mm (0.75 in.) and Under in Thickness

For plates 19 mm (0.75 in.) and under in thickness, tension test specimens are to be the full thickness of the material and are to be machined to the form and dimensions shown in 2-3-1/11.13 FIGURE 1 or with both edges parallel.

### 1.9.3 Specimens from Plates Over 19 mm (0.75 in.) Thickness

For plates over 19 mm (0.75 in.) in thickness, tension test specimens may be machined to the form and dimensions shown in 2-3-1/11.13 FIGURE 2, and the axis of each such specimen is to be located as nearly as practicable midway between the center and the surface of the plate, or for plates up to 101.6 mm (4 in.) inclusive in thickness, they may be the full thickness of the material and of the form shown in 2-3-1/11.13 FIGURE 1 when adequate testing-machine capacity is available.

### 1.9.4 Stress Relieving

When required, test specimens are to be stress-relieved by gradually and uniformly heating them to 590–650°C (1100–1200°F), holding at temperature for at least 1 hour per 25 mm (1 in.) thickness and cooling in still atmosphere to a temperature not exceeding 315°C (600°F). If applicable, in the case of plates which are to be heat-treated and subsequently stress-relieved, the test specimens for such plates are to, before testing, be stress-relieved following the heat treatment.

## 1.11 Tensile Properties

### 1.11.1 Tensile Requirements

The material is to conform to the tensile requirements as specified for each grade in 2-3-2/3.9, 2-3-2/5.11 or 2-3-2/7.11.

### 1.11.2 Elongation Deduction for Material Under 7.9 mm (0.313 in.) Thick

For material under 7.9 mm (0.313 in.) in thickness, a deduction from the specified percentage of elongation in 200 mm (8 in.) of 1.25% is to be made for each decrease of 0.8 mm (0.031 in.) of the specified thickness below 7.9 mm (0.313 in.).

### 1.11.3 Elongation Deduction for Material Over 88.9 mm (3.50 in.) Thick

For material over 88.9 mm (3.50 in.) in thickness, a deduction from the specified percentage of elongation in 50 mm (2 in.) of 0.50% is to be made for each increase of 12.7 mm (0.50 in.) of the specified thickness above 88.9 mm (3.50 in.). This deduction is not to exceed 3%.

## 1.13 Retests

### 1.13.1 For All Thicknesses

When the result of any of the physical tests specified for any of the material does not conform to the requirements, two additional specimens may, at the request of the manufacturer, be taken from the same plate and tested in the manner specified, but in such case, both of the specimens are to conform to the requirements (see 2-3-1/9.5).

### 1.13.2 For Heat-treated Material (2008)

If any heat-treated material fails to meet the mechanical requirements, the material may be reheat-treated, and all physical tests are to be repeated. Where plates are specially ordered requiring surface inspection, the Surveyor is to reexamine the plate surfaces following any additional heat treatment.

### 1.15 Thickness Variation

No plate is to vary more than 0.25 mm (0.01 in.) or 6% under the thickness specified, whichever is the lesser (See 4-4-1-A1/1.7 of the *Marine Vessel Rules*).

### 1.17 Finish

Except when ordered for riveted construction, plates may be conditioned by the manufacturer, for the removal of surface defects on either surface by grinding, provided the ground area is well faired and grinding does not reduce the thickness of the plate below the permissible minimum thickness.

### 1.19 Weldability

All of the grades covered in 2-3-2/3, 2-3-2/5 and 2-3-2/7 are intended for fusion welding, but welding technique is of fundamental importance and welding procedure is to be in accordance with approved methods. See Part 2, Chapter 4.

## 3 Steel Plates for Intermediate-temperature Service

### 3.1 Scope

Three grades of low and intermediate-tensile-strength carbon-steel plates designated MA, MB, and MC are covered.

### 3.3 General

The various grades are in substantial agreement with ASTM designations as follows.

ASTM -A285 Grades A, B, C

ABS -Grades MA, MB, MC

The maximum thickness of these grades is to be 50.8 mm (2.0 in.).

### 3.5 Chemical Composition

The steel is to conform to the following requirements as to chemical composition.

	<i>Grade MA</i>	<i>Grade MB</i>	<i>Grade MC</i>
Carbon, max., %	0.17	0.22	0.28
Manganese, max., %	0.90	0.90	0.90
Phosphorus, max., %	0.035	0.035	0.035
Sulfur, max., %	0.045	0.045	0.045
Copper *, when Copper Steel is specified			
Ladle Analysis	0.20/0.35	0.20/0.35	0.20/0.35
Check Analysis	0.18/0.37	0.18/0.37	0.18/0.37

**Note:**

See 2-3-2/1.7.

\* When specified, the maximum incidental copper content is to be 0.25%.

### 3.7 Specimen Preparation

Test specimens are to be prepared for testing from material in its rolled condition.

### 3.9 Tensile Properties

The material is to conform to the following requirements as to tensile properties.

	<i>Grade MA</i>	<i>Grade MB</i>	<i>Grade MC</i>
Tensile Strength N/mm <sup>2</sup> (kgf/mm <sup>2</sup> ) (psi)	310-450 (31.5-46) (45000-65000)	345-485 (35-49) (50000-70000)	380-515 (39-53) (55000-75000)
Yield Strength, min., N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , psi)	165 (17, 24000)	185 (19, 27000)	205 (21, 30000)
Elongation in 200 mm (8 in.) min., % *	27	25	23
Elongation in 50 mm (2 in.) min., %	30	28	27

\* See 2-3-2/1.11.2 and 2-3-2/1.11.3.

## 5 Steel Plates for Intermediate- and Higher-temperature Service

### 5.1 Scope

Seven grades of steel plates designated MD, ME, MF, MG, H, I and J are covered. Grades MD, ME, MF and MG cover intermediate and higher-tensile-strength ranges in carbon-silicon steel plates; Grades H, I and J cover three high-tensile-strength ranges in carbon-molybdenum steel plates.

### 5.3 General

The various grades are in substantial agreement with ASTM designations as follows:

ASTM - A515 Grades 55, 60, 65, 70      ABS - Grades MD, ME, MF, MG  
 ASTM - A204 Grades A, B, C              ABS - Grades H, I, J

Plates are limited in thickness as follows: Grade MD to 304.8 mm (12.0 in.); Grades ME, MF and MG to 203.2 mm (8.0 in.); Grades H and I to 152.4 mm (6.0 in.) and Grade J to 101.6 mm (4 in.).

### 5.5 Heat Treatment

#### 5.5.1 Treatment

Plates of Grades MD, ME, MF and MG over 50.8 mm (2.0 in.) and Grades H, I and J over 38.1 mm (1.5 in.) in thickness are to be treated either by normalizing or heating uniformly for hot forming. If the required treatment is to be obtained in conjunction with the hot-forming operation, the temperature to which the plates are heated for hot forming is to be equivalent to and is not to significantly exceed the normalizing temperature. If this treatment is not done at the rolling mill, the testing is to be carried out in accordance with 2-3-2/5.5.3.

#### 5.5.2 Heat-treatment Instructions on Orders

Orders to the plate manufacturer or the fabricator are to specify when plates are to be heat-treated and any special requirement that the test specimens be stress-relieved, so that proper provision may be made for the heat treatment of the test specimens. The purchaser is to also indicate in the orders to the mill whether the rolling mill or the fabricator is to perform the required heat treatment of the plates.



### 5.5.3 Responsibility for Heat Treatment

When a fabricator is equipped and elects to perform the required normalizing or fabricates by hot forming as provided in 2-3-2/5.5.1, the plates are to be accepted on the basis of tests made at the plate manufacturer's plant on specimens heat-treated in accordance with the purchaser's order requirements. If the heat-treatment temperatures are not indicated on the purchase order, the plate manufacturer is to heat-treat the specimens under conditions considered appropriate to meet the test requirements. The plate manufacturer is to inform the fabricator of the procedure followed in treating the specimens at the mill for guidance in treating the plates. When the plates are to be normalized at the plate manufacturer's plant, the mechanical properties are to be determined on specimens simultaneously treated with the plates.

## 5.7 Chemical Composition

The steel is to conform to the requirements of 2-3-2/9 TABLE 1 as to chemical composition.

## 5.9 Test Specimens

### 5.9.1 Plates Not Requiring Heat Treatment

For plates not requiring heat treatment (see 2-3-2/5.5.1), the test specimens are to be prepared for testing from the material in its rolled condition. When Grades H, I and J plates are to be used in a boiler or pressure vessel which is to be stress-relieved, the test specimens for Grades H, I and J are to be stress-relieved. See 2-3-2/1.9.

### 5.9.2 Plates Requiring Heat Treatment

For plates requiring heat treatment (see 2-3-2/5.5.1), the test specimens are to be prepared from the material in its heat-treated condition, or from full-thickness samples similarly and simultaneously treated. When Grades H, I and J plates are to be used in a boiler or pressure vessel which is to be stress-relieved, the test specimens for Grades H, I and J are to be stress-relieved following the heat treatment. See 2-3-2/1.9 and 2-3-2/5.5.

## 5.11 Tensile Properties

The material is to conform to the requirements of 2-3-2/9 TABLE 2 as to tensile properties.

# 7 Steel Plates for Intermediate- and Lower-temperature Service

## 7.1 Scope

Four grades of carbon-manganese-silicon steel plates made to fine-grain practice in four tensile-strength ranges designated K, L, M, N are covered.

## 7.3 General

The various grades are in substantial agreement with ASTM designations as follows.

ASTM - A516 Grades 55, 60, 65, 70

ABS - Grades K, L, M, N

Plates are limited in thickness, as follows: Grade K to 304.8 mm (12.0 in.); Grades L, M and N to 203.2 mm (8.0 in.).

Materials for Liquefied Gas Carriers are to comply with Section 5C-8-6 of the *Marine Vessel Rules*.

## 7.5 Heat Treatment

### 7.5.1 Grain Refinement

Plates over 38.1 mm (1.5 in.) are to be heat-treated to produce grain refinement either by normalizing or heating uniformly for hot forming. If the required treatment is to be obtained in

conjunction with hot forming, the temperature to which the plates are heated for hot forming is to be equivalent to and is not to exceed significantly the normalizing temperature. If this treatment is not done at the rolling mill, the testing is to be carried out in accordance with 2-3-2/7.5.3. When improved notch toughness is required for plates 38 mm (1.5 in.) and under in thickness, heat treatment is to be specified as above.

### 7.5.2 Heat-treatment Instructions on Orders

Orders to the plate manufacturer or the fabricator are to specify when plates are to be heat-treated for grain refinement, and any special requirements that the test specimens be stress-relieved, so that proper provision may be made for the heat treatment of the test specimens. The purchaser is also to indicate in the orders to the mill whether the rolling mill or the fabricator is to perform the required heat treatment of the plates.

### 7.5.3 Responsibility for Heat Treatment

When a fabricator is equipped and elects to perform the required normalizing or fabricates by hot forming as provided in 2-3-2/7.5.1, the plates are to be accepted on the basis of tests made at the plate manufacturer's plant on specimens heat-treated in accordance with the purchaser's order requirements. If the heat-treatment temperatures are not indicated on the purchase order, the plate manufacturer is to heat-treat the specimens under conditions considered appropriate for grain refinement, and to meet the test requirements. The plate manufacturer is to inform the fabricator of the procedure followed in treating the specimens at the mill for guidance in treating the plates. When the plates are to be normalized at the plate manufacturer's plant, the mechanical properties are to be determined on specimens simultaneously treated with the plates.

## 7.7 Chemical Composition

The steel is to conform to the requirements of 2-3-2/9 TABLE 3 as to chemical composition.

## 7.9 Test Specimens

### 7.9.1 Plates 38.1 mm (1.5 in.) and Under in Thickness

For plates 38.1 mm (1.5 in.) and under in thickness, not requiring heat treatment, the test specimens are to be prepared for testing from the material in its rolled condition.

### 7.9.2 Plates Requiring Heat Treatment

For plates 38.1 mm (1.5 in.) and under in thickness, requiring heat treatment (see 2-3-2/7.5.1), or for plates over 38.1 mm (1.5 in.) in thickness, the test specimens are to be prepared from the material in its heat-treated condition, or from full-thickness samples similarly and simultaneously treated.

## 7.11 Tensile Properties

The material is to conform to the requirements of 2-3-2/9 TABLE 4 as to tensile properties.

## 9 Materials for Low Temperature Service [Below - 18°C (0°F)]

Materials intended for service temperatures of below -18°C (0°F) may be provided in accordance with those requirements listed in 2-1-4/9. Other special low temperature materials, when the Charpy V-notch impact tests are conducted at 5°C (10°F) below minimum design temperature in accordance with 2-1-4/5.1 and meet the applicable requirements of 2-1-2/11 and 5C-8-6/4 (ABS) may also be accepted. Such tests are not required for austenitic stainless steels, or aluminum alloys such as type 5083.

**TABLE 1**  
**Chemical Composition for Plate Grades MD, ME, MF, MG, H, I, J**

*Note:* See also 2-3-2/1.7

	<i>MD</i>	<i>ME</i>	<i>MF</i>	<i>MG</i>	<i>H</i>	<i>I</i>	<i>J</i>
Carbon, max., %:							
For plates 25.4 mm (1.0 in.) and under in thickness	0.20	0.24	0.28	0.31	0.18	0.20	0.23
For plates over 25.4 mm (1.0 in.) to 50.8 mm (2.0 in.) incl., in thickness	0.22	0.27	0.31	0.33	0.21	0.23	0.26
For plates over 50.8 mm (2.0 in.) to 101.6 mm (4.0 in.) incl., in thickness	0.24	0.29	0.33	0.35	0.23	0.25	0.28
For plates over 101.6 mm (4.0 in.) to 203.2 mm (8.0 in.) incl., in thickness	0.26	0.31	0.33	0.35	0.25	0.27	
For plates over 203.2 mm (8.0 in.) to 304.8 mm (12.0 in.) incl., in thickness	0.28						
Manganese, max., %	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Phosphorous max., %	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Sulphur, max., %	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Silicon, %:							
Ladle analysis	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30
Check analysis	0.13-0.33	0.13-0.33	0.13-0.33	0.13-0.33	0.13-0.32	0.13-0.32	0.13-0.32
Molybdenum, %:							
Ladle analysis					0.45-0.60	0.45-0.60	0.45-0.60
Check analysis					0.41-0.64	0.41-0.64	0.41-0.64

**TABLE 2**  
**Tensile Properties for Plate Grades MD, ME, MF, MG, H, I, J**

A characteristic of certain types of alloy steels is a local disproportionate increase in the degree of necking down or contraction of the specimens under tension tests, resulting in a decrease in the percentage of elongation as the gauge length is increased. The effect is not so pronounced in the thicker plates.

	<i>MD</i>	<i>ME</i>	<i>MF</i>	<i>MG</i>	<i>H</i>	<i>I</i>	<i>J</i>
Tensile Strength,							
N/mm <sup>2</sup>	380-515	415-550	450-585	485-620	450-585	485-620	515-655
kgf/mm <sup>2</sup>	39-53	42-56	46-60	49-63	46-60	49-63	53-67
psi	55000-75000	60000-80000	65000-85000	70000-90000	65000-85000	70000-90000	75000-95000
	0	0	0	0	0	0	0
Yield Strength, min.,							
N/mm <sup>2</sup>	205	220	240	260	255	275	295
kgf/mm <sup>2</sup>	21	22.5	24.5	27	26	28	30.5
psi	30000	32000	35000	38000	37000	40000	43000

	<i>MD</i>	<i>ME</i>	<i>MF</i>	<i>MG</i>	<i>H</i>	<i>I</i>	<i>J</i>
Elongation in 200 mm, (8 in.), min., %	23 <sup>(a)</sup>	21 <sup>(a)</sup>	19 <sup>(a)</sup>	17 <sup>(a)</sup>	19 <sup>(a,d)</sup>	17 <sup>(a,d)</sup>	16 <sup>(a,d)</sup>
	27 <sup>(b)</sup>	25 <sup>(b)</sup>	23 <sup>(b)</sup>	21 <sup>(b)</sup>	23 <sup>(b)</sup>	21 <sup>(b)</sup>	20 <sup>(b)</sup>
Elongation in 50 mm, (2in.) min., % <sup>(c)</sup>							

**Notes:**

- a** See 2-3-2/1.11.2
- b** See 2-3-2/1.11.3
- c** When specimen shown in 2-3-1/11.13 FIGURE 2 is used.
- d** For plates over 6.4 mm (0.25 in.) to 19.1 mm (0.75 in.) inclusive, in thickness, if the percentage of elongation of a 200 mm (8 in.) gauge-length test specimen falls not more than 3% below the amount specified, the elongation is to be considered satisfactory, provided the percentage of elongation in 50 mm (2 in.) across the break is not less than 25%.

**TABLE 3**  
**Chemical Composition for Plate Grades K, L, M, N**

**Note:** See also 2-3-2/1.7

	<i>K</i>	<i>L</i>	<i>M</i>	<i>N</i>
Carbon, max., %: For plates 12.7 mm (0.50 in.) and under in thickness	0.18	0.21	0.24	0.27
Over 12.7 mm (0.50 in.) to 50.8 mm (2.0 in.) incl.	0.20	0.23	0.26	0.28
Over 50.8 mm (2.0 in.) to 101.6 mm (4.0 in.) incl.	0.22	0.25	0.28	0.30
Over 101.6 mm (4.0 in.) to 203.2 mm (8.0 in.) incl.	0.24	0.27	0.29	0.31
Over 203.2 mm (8.0 in.) to 304.8 mm (12.0 in.) incl.	0.26			
Manganese, %: For plates 12.7 mm (0.50 in.) and under in thickness				
Ladle	0.60/0.90	0.60/0.90	0.85/1.20	0.85/1.20
Check	0.56/0.94	0.56/0.94	0.80/1.25	0.80/1.25
Over 12.7 mm (0.50 in.) to 304.8 mm (12.0 in.) incl				
Ladle	0.60/1.20	0.85/1.20	0.85/1.20	0.85/1.20
Check	0.56/1.25	0.80/1.25	0.80/1.25	0.80/1.25
Phosphorus, max., %	0.035	0.035	0.035	0.035
Sulphur, max., %	0.04	0.04	0.04	0.04
Silicon, %: Ladle	0.15/0.30	0.15/0.30	0.15/0.30	0.15/0.30
Check	0.13/0.33	0.13/0.33	0.13/0.33	0.13/0.33

**TABLE 4**  
**Tensile Properties for Plate Grades K, L, M, N**

	<i>K</i>	<i>L</i>	<i>M</i>	<i>N</i>
Tensile Strength,				
N/mm <sup>2</sup>	380-515	415-550	450-585	485-620
kgf/mm <sup>2</sup>	39 to 53	42 to 56	46 to 60	49 to 63
psi	55000-75000	60000-80000	65000-85000	70000-90000
Yield Strength, min.,				
N/mm <sup>2</sup>	205	220	240	260
kgf/mm <sup>2</sup>	21	22.5	24.5	27
psi	30000	32000	35000	38000
Elongation in 200 mm, (8 in.), min., %	23 <sup>(a)</sup>	21 <sup>(a)</sup>	19 <sup>(a)</sup>	17 <sup>(a)</sup>
Elongation in 50 mm, (2 in.), min., % <sup>(c)</sup>	27 <sup>(b)</sup>	25 <sup>(b)</sup>	23 <sup>(b)</sup>	21 <sup>(b)</sup>

**Notes:**

- a** See 2-3-2/1.11.2
- b** See 2-3-2/1.11.3
- c** When specimen shown in 2-3-1/11.13 FIGURE 2 is used.

*Note:* In substantial agreement with ASTM A266 as to physical properties for Classes 1 and 3.

### **1 Tests and Inspections**

In the event that any seamless forged-steel drums are presented for survey after special approval for each specific application, they are to be tested and surveyed in general accordance with the applicable procedures given for steel forgings. One tension test is to be taken from each end of the forging midway between the inner and outer surfaces of the wall in a tangential direction, the two specimens being taken from opposite sides of the drum. Grade A material is to have the following minimum properties, tensile strength 415 N/mm<sup>2</sup> (42 kgf/mm<sup>2</sup>, 60,000 psi), yield strength 205 N/mm<sup>2</sup> (21 kgf/mm<sup>2</sup>, 30,000 psi), elongation 23% in a 50 mm (2 in.) gauge length; Grade B material is to have the following minimum properties, tensile strength 515 N/mm<sup>2</sup> (53 kgf/mm<sup>2</sup>, 75,000 psi), yield strength 260 N/mm<sup>2</sup> (26.5 kgf/mm<sup>2</sup>, 37,500 psi), elongation 19% in a 50 mm (2 in.) gauge length.

### **3 Heat Treatment**

Except as specified herein, tests for acceptance are to be made after final treatment of the forgings. When the ends of drums are closed in by reforging after machining, the drums may be treated and tested prior to reforging. After reforging, the whole of the forging is to be simultaneously re-treated. If the original treatment was annealing, the re-anneal is to be above the transformation range, but not above the temperature of the first anneal. If the original treatment was normalizing and tempering, the re-treatment is to be identical with the original.

**1 General**

The material for the manufacture of and the finished seamless pressure vessels are to be free from seams, cracks or other defects. Test specimens are to be cut from each cylinder before the necking-down process, stamped with the identification mark of the Surveyor and is to receive all heat treatments simultaneously with the cylinders.

**3 Tension Test**

A standard test specimen cut either longitudinally or circumferentially from each cylinder is to show the material to have a minimum tensile strength of 415 N/mm<sup>2</sup> (42 kgf/mm<sup>2</sup>, 60,000 psi), maximum yield point of 70% of the tensile strength and a minimum elongation of 10% in 200 mm (8 in.).

**5 Flattening Test**

A ring 200 mm (8 in.) long is to be cut from each cylinder and is to stand being flattened without signs of fracture until the outside distance over the parallel sides is not greater than six times the thickness of the material.

**7 Hydrostatic Test**

Each cylinder is to be subjected to a hydrostatic pressure of not less than one and one-half times the working pressure while submerged in a water jacket for a period of at least thirty seconds. The permanent volumetric expansion is not to exceed 5% of the total volumetric expansion at the prescribed test pressure. This test is to be made without previously subjecting the cylinder to any pressure in excess of one-third of the working pressure.

**9 Inspection**

All cylinders are to be properly annealed and be free from dirt and scale. Before necking-down, the Surveyor is to examine the cylinders carefully for defects and gauge the cylinder walls to ascertain that the thickness of the material is in accordance with the approved plan.

**11 Marking**

Upon satisfactory compliance with the above requirements, the cylinders will be stamped **AB** with the identification mark of the Surveyor, the serial number, hydrostatic pressure and the date of acceptance.

**1 Scope (1998)**

The following specifications cover thirteen grades of boiler and superheater tubes designated D, F, G, H, J, K, L, M, N, O, P, R, and S.

**3 General****3.1 Grades D and F**

Grades D and F cover electric-resistance-welded tubes made of carbon steel and intended for boiler tubes, boiler flues, superheater flues and safe ends. Grade F tubes are not suitable for safe-ending by forge-welding.

**3.3 Grade G**

Grade G covers electric-resistance-welded, steel boiler and superheater tubes intended for high-pressure service.

**3.5 Grade H**

Grade H covers seamless carbon-steel boiler tubes and superheater tubes intended for high-pressure service.

**3.7 Grade J**

Grade J covers seamless medium carbon-steel boiler tubes and superheater tubes, boiler flues, including safe ends, arch and stay tubes. Grade J tubes are not suitable for safe-ending by forge-welding.

**3.9 Grades K, L and M**

Grades K, L and M cover seamless carbon-molybdenum alloy-steel boiler and superheater tubes.

**3.11 Grades N, O and P**

Grades N, O and P cover seamless chromium-molybdenum alloy-steel boiler and superheater tubes.

**3.13 Grades R and S (1998)**

Grades R and S cover seamless austenitic stainless steel superheater tubes.



### 3.15 ASTM Designation (1998)

The various Grades are in substantial agreement with ASTM, as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
D	A178, Grade A
F	A178, Grade C
G	A226
H	A192
J	A210, Grade A-1
K	A209, Grade T1
L	A209, Grade T1a
M	A209, Grade T1b
N	A213, Grade T11
O	A213, Grade T12
P	A213, Grade T22
R	A213, Grade TP321
S	A213, Grade TP347

## 5 Process of Manufacture

### 5.1 Grades D, F, and G

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. Special consideration may be given to other processes, subject to such supplementary requirements or limits on application as will be specially determined in each case. Grade G is to be killed steel. All tubes of Grade D, F, and G are to be made by electric-resistance welding and are to be normalized at a temperature above the upper critical temperature.

### 5.3 Grades H, J, K, L, and M (1998)

The steel is to be killed steel made by one or more of the following processes: open hearth, electric furnace, or basic oxygen furnace. Tubes are to be made by the seamless process and are to be either hot-finished or cold-drawn. Cold-drawn tubes are to be heat-treated by isothermal annealing or by full annealing at a temperature of 650°C (1200°F) or higher. Cold-drawn tubes of Grades H, and J may also be heat-treated by normalizing. Cold-drawn tubes of Grades K, L, and M may also be heat-treated by normalizing and tempering at 650°C (1200°F) or higher. Hot-finished Grades H and J tubes need not be heat-treated. Hot-finished Grades K, L, and M tubes are to be heat-treated at a temperature of 650°C (1200°F) or higher.

### 5.5 Grades N, O, and P (1998)

The steel is to be made by the electric-furnace process or other approved process, except that Grade N may be made by the basic oxygen process and Grade O by basic oxygen or open hearth process. Tubes are to be made by the seamless process and are to be either hot-finished or cold-drawn. All material is to be furnished in the heat-treated condition. The heat treatment for Grades N and P is to consist of full annealing, isothermal annealing, or normalizing and tempering, as necessary to meet the requirements. The tempering temperature following normalizing is to be 650°C (1200°F) or higher for Grade N and 680°C (1250°F) or higher for Grade P. The hot-rolled or cold-drawn tubes Grade O, as a final heat treatment, are to be process annealed at 650°C (1200°F) to 730°C (1350°F).

## 5.7 Grades R and S (1998)

The steel is to be made by the electric-furnace or other approved process. Tubes are to be made by the seamless process and are to be either hot-finished or cold-drawn. After the completion of mechanical working, tubes are to be solution annealed at a minimum of 1040°C (1900°F) and then quenched in water or rapidly cooled by other means. Solution annealing above 1065°C (1950°F) may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions. Subsequent to the initial high-temperature solution anneal, a stabilization or resolution anneal at 815°C to 900°C (1500°F to 1650°F) may be used to meet the requirements.

## 7 Marking (1998)

Identification markings are to be legibly stenciled on each tube 31.8 mm (1.25 in.) in outside diameter or over, provided the length is not under 900 mm (3 ft). For Grades R and S tubes, the marking fluid, ID tags and securing wire are not to contain any harmful metal or metal salt such as zinc, lead or copper, which cause corrosive attack upon heating. For tubes less than 31.8 mm (1.25 in.) in outside diameter and all tubes less than 900 mm (3 ft) in length, the required markings are to be marked on a tag securely attached to the bundle or box in which the tubes are shipped. The markings are to include: the name or brand of the manufacturer; either the ABS grade or the ASTM designation and grade for the material from which the tube is made; the hydrostatic test pressure or the letters NDET; whether electric-resistance-welded or seamless, hot-finished or cold-drawn; also the ABS markings as furnished by the Surveyor and indicating satisfactory compliance with the Rule requirements. The markings are to be arranged as follows:

- The name or brand of the manufacturer
- The ABS grade or ASTM designation and type or grade
- The test pressure or the letters NDET
- The method of forming (i.e., seamless hot-finished or cold-drawn or electric-resistance-welded)
- The ABS markings from the Surveyor

## 9 Chemical Composition - Ladle Analysis

An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-5/39.3 TABLE 1.

## 11 Check Analysis

### 11.1 General (1998)

A check analysis is required for Grades K, L, M, N, O, P, R, and S. Check analysis for other grades may also be made where required by the purchaser. The check analysis is to be in accordance with the following requirements and the chemical composition is to conform to the requirements in 2-3-5/39.3 TABLE 1.

### 11.3 Samples

Samples for check analysis are to be taken by drilling several points around each tube selected for analysis or, when taken from the billet, they are to be obtained by drilling parallel to the axis at any point midway between the outside and center of the piece, or the samples may be taken as prescribed in ASTM E59 (Method of Sampling Steel for Determination of Chemical Composition).

### 11.5 Grades D, F, G, and H

For these Grades, the check analysis is to be made by the supplier from one tube per heat or from one tube per lot.

*Note:*

A lot consists of 250 tubes for sizes 76.2 mm (3.0 in.) and under or 100 tubes for sizes over 76.2 mm (3.0 in.) prior to cutting length.

### 11.7 Grades J, K, L, M, N, O, P, R, and S (1998)

For these Grades, check analysis is to be made by the supplier from one tube or billet per heat.

### 11.9 Retests for Seamless Tubes (1998)

If the original test for check analysis for Grades H, J, K, L, M, N, O, P, R, or S tubes fails, retests of two additional billets or tubes are to be made. Both retests for the elements in question are to meet the requirements; otherwise, all remaining material in the heat or lot is to be rejected or, at the option of the supplier, each billet or tube may be individually tested for acceptance.

### 11.11 Retests for Electric-resistance-welded Tubes

If the original test for check analysis for Grades D, F, or G tubes fails, retests of two additional lengths of flat-rolled stock or tubes are to be made. Both retests, for the elements in question, are to meet the requirements; otherwise all remaining material in the heat or lot is to be rejected or, at the option of the supplier, each length of flat-rolled stock or tube may be individually tested for acceptance.

## 13 Mechanical Tests Required

The type and number of mechanical tests are to be in accordance with 2-3-5/39.3 TABLE 2. For a description and requirements of each test see 2-3-5/17 through and including 2-3-5/33. For retests see 2-3-5/35.

## 15 Test Specimens

### 15.1 Selection of Specimens (1998)

Test specimens required for the flattening, flanging, flaring, tension, crushing and reverse flattening tests are to be taken from the ends of drawn tubes after any heat treatment and straightening, but prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They are to be smooth on the ends and free from burrs and defects.

### 15.3 Tension Test Specimens

If desirable and practicable, tension tests may be made on full sections of the tubes up to the capacity of the testing machine. For larger-size tubes, the tension test specimen is to consist of a strip cut longitudinally from the tube not flattened between gauge marks. The sides of this specimen are to be parallel between gauge marks; the width, irrespective of the thickness, is to be 25 mm (1 in.); the gauge length is to be 50 mm (2 in.).

### 15.5 Testing Temperature

All specimens are to be tested at room temperature.

## 17 Tensile Properties

The material is to conform to the requirements as to tensile properties in the grades specified in 2-3-5/39.3 TABLE 3.

## 19 Flattening Test

### 19.1 Seamless and Electric-resistance-welded Tubes (1998)

For all Grades of tubing, a section of tube, not less than 65 mm (2.5 in.) in length for seamless and not less than 100 mm (4 in.) in length for welded, is to be flattened cold between parallel plates in two steps.

During the first step, which is a test for ductility, no cracks or breaks on the inside, outside or end surfaces of seamless tubes, or on the inside or outside surfaces of electric-resistance-welded tubes is to occur until the distance between the plates is less than the value  $H$  obtained from the following equation:

$$H = (1 + e)t / (e + t/D)$$

where

- $H$  = distance between flattening plates, in mm (in.)
- $t$  = specified wall thickness of tube, in mm (in.)
- $D$  = specified outside diameter of tube, in mm (in.)
- $e$  = deformation per unit length, constant for a given grade as follows.
  - = 0.09 for Grades D, G, H, R, and S
  - = 0.08 for Grades K, L, M, N, O, and P
  - = 0.07 for Grades F and J

During the second step, which is a test for soundness, the flattening is to be continued until the specimen breaks or the opposite walls of the tube meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test is to be cause for rejection. Superficial ruptures as a result of surface imperfections are not to be cause for rejection.

### 19.3 Electric-resistance-welded Tubes

In the case of Grades D, F, and G tubes, the weld is to be placed 90 degrees from the line of direction of the applied force.

### 21 Reverse Flattening Test

For Grades D, F, and G tubes, a section 100 mm (4 in.) in length is to be taken from every 460 m (1500 ft) of finished welded tubing and it is to be split longitudinally 90 degrees on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There is to be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

### 23 Flange Test

For Grades D, F, and G tubes, a section of tube is to be capable of having a flange turned over at a right angle to the body of the tube without cracking or developing defects. The width of the flange is not to be less than the following.

Outside Diameter of Tube mm (in.)	Width of Flange	
	D, G	F
Over 19.1 mm (0.75 in.) to 63.5 mm (2.50 in.) incl.	15% of outside diameter	75% of that required for Grades D and G
Over 63.5 mm (2.5 in.) to 95.3 mm (3.75 in.) incl.	12½% of outside diameter	
Over 95.3 mm (3.75 in.)	10% of outside diameter	

## 25 Flaring Test (1998)

For Grades H, J, K, L, M, N, O, P, R, and S tubes, a section of tube approximately 100 mm (4 in.) in length is to stand being flared with a tool having a 60-degree included angle until the tube at the mouth of the flare has been expanded to the following percentages, without cracking or developing defects.

<i>Ratio of Inside Diameter to Outside Diameter *</i>	<i>Minimum Expansion of Inside Diameter, %</i>	
	<i>H, J, K, L, M, R, S</i>	<i>N, O, P</i>
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

\* In determining the ratio of inside diameter to outside diameter, the inside diameter is to be defined as the actual mean inside diameter of the material to be tested.

## 27 Crush Test

For Grade D tubes, when required by the Surveyor, crushing tests are to be made on sections of tube 65 mm (2.5 in.) in length which are to stand crushing longitudinally, without cracking, splitting or opening at the weld, as shown in the following table. For tubing less than 25.4 mm (1.0 in.) in outside diameter, the length of the specimen is to be  $2\frac{1}{2}$  times the outside diameter of the tube. Slight surface checks are not to be cause for rejection.

<i>Wall Thickness</i>	<i>Height of Section After Crushing</i>
3.43 mm (0.135 in.) and under	19.1 mm (0.75 in.) or until outside folds are in contact
Over 3.43 mm (0.135 in.)	31.8 mm (1.25 in.)

## 29 Hardness Tests

### 29.1 Type of Test (1998)

Hardness tests are to be made on Grades G, H, J, K, L, M, N, O, P, R, and S tubes. For tubes 5.1 mm (0.2 in.) and over in wall thickness, the Brinell hardness test is to be used and on tubes having wall thicknesses from 5.1 mm (0.2 in.) to 9.5 mm (0.375 in.) exclusive, a 10 mm ball with a 1,500 kg load, or a 5 mm ball with a 750 kg load may be used, at the option of the manufacturer. For tubes less than 5.1 mm (0.2 in.) in wall thickness, the Rockwell hardness test is to be used, except that for tubes with wall thickness less than 1.65 mm (0.065 in.) no hardness tests are required. In making the Brinell and Rockwell hardness tests, reference should be made to the Standard Methods and Definitions for the Mechanical Testing of Steel Products ASTM 370.

### 29.3 Brinell Hardness Test

The Brinell hardness test may be made on the outside of the tube near the end or on the outside of a specimen cut from the tube, at the option of the manufacturer.

### 29.5 Rockwell Hardness Test

The Rockwell hardness test is to be made on the inside of a specimen cut from the tube.

### 29.7 Tubes with Formed Ends

For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test is to be made as prescribed in 2-3-5/29.1 on the outside of the tube near the end after the forming operation and heat treatment.

### 29.9 Maximum Permissible Hardness (1998)

The tubes are to have hardness-numbers not exceeding the following values.

<i>Tube Grade</i>	<i>Brinell Hardness Number Tubes 5.1 mm (0.2 in.) and over in wall thickness</i>	<i>Rockwell Hardness Number Tubes less than 5.1 mm (0.2 in.) in wall thickness</i>
G	125	B 72
H	137	B 77
J	143	B 79
K	146	B 80
L	153	B 81
M	137	B 77
N, O, and P	163	B 85
R, S	192	B 90

## 31 Hydrostatic Test

### 31.1 General

Each tube is to be hydrostatically tested at the mill or be subjected to a non-destructive electric test in accordance with 2-3-5/33. The test may be performed prior to upsetting, swaging, expanding, bending or other forming operation. The hydrostatic test pressure is to be determined by the equation given in 2-3-5/31.3, but is not to exceed the following values except as provided in 2-3-5/31.7.2.

<i>Outside Diam. of Tubes, mm (in.)</i>	<i>Test Pressure, bar (kgf/cm<sup>2</sup>, psi)</i>
Under 25.4 (1.0 in.)	69 (70.3, 1000)
25.4 (1.0 in.) to 38.1 (1.5 in.), excl.	103 (105, 1500)
38.1 (1.5 in.) to 50.8 (2.0 in.), excl.	140 (140, 2000)
50.8 (2.0 in.) to 76.2 (3.0 in.), excl.	170 (175, 2500)
76.2 (3.0 in.) to 127 (5.0 in.), excl.	240 (245, 3500)
127 (5.0 in.) and over	310 (315, 4500)

### 31.3 Maximum Hydrostatic Test Pressure

<i>SI Units</i>	<i>MKS Units</i>	<i>US Units</i>
$P = 20St/D$ $S = PD/20t$	$P = 200St/D$ $S = PD/200t$	$P = 2St/D$ $S = PD/2t$

where

- $P$  = hydrostatic test pressure, in bar (kgf/cm<sup>2</sup>, psi)  
 $S$  = allowable fiber stress of 110 N/mm<sup>2</sup> (11 kgf/mm<sup>2</sup>, 16,000 psi)  
 $t$  = specified wall thickness, in mm (in.)  
 $D$  = specified outside diameter, in mm (in.)

### 31.5 Duration of Test

The test pressure is to be held for a minimum of 5 seconds.

### 31.7 Alternate Tests

#### 31.7.1

When requested by the purchaser and so stated in the order, tubes are to be tested to one and one-half times the specified working pressure (when one and one-half times the specified working pressure exceeds the test pressure prescribed in 2-3-5/31.1), provided the fiber stress corresponding to those test pressures does not exceed 110 N/mm<sup>2</sup> (11 kgf/mm<sup>2</sup>, 16,000 psi) as calculated in accordance with 2-3-5/31.3.

#### 31.7.2

When requested by the purchaser and so stated in the order, or at the option of the manufacturer, tubes are to be tested at pressures, calculated in accordance with 2-3-5/31.1 corresponding to a fiber stress of more than 110 N/mm<sup>2</sup> (11 kgf/mm<sup>2</sup>, 16,000 psi), but not more than 165 N/mm<sup>2</sup> (17 kgf/mm<sup>2</sup>, 24,000 psi).

### 31.9 Rejection

If any tube shows leaks during the hydrostatic test, it is to be rejected.

## 33 Nondestructive Electric Test (NDET) (1998)

### 33.1 General

When specified by the purchaser, each ferritic steel tube, Grades D, F, G, H, J, K, L, M, N, O, and P, is to be tested in accordance with ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing or ASTM E309, for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation, ASTM E570, for Flux Leakage Examination of Ferromagnetic Steel Tubular Products, or other approved standard. When specified by the purchaser, each austenitic stainless steel tube, Grades R and S, is to be tested in accordance with ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing or ASTM E426, for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys, or other approved standard. It is the intent of this test to reject tubes containing defects and the Surveyor is to be satisfied that the nondestructive testing procedures are used in a satisfactory manner

### 33.3 Ultrasonic Calibration Standards

Notches on the inside or outside surfaces may be used. The depth of the notch is not to exceed 12.5% of the specified wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed two times the depth.

### 33.5 Eddy-current Calibration Standards

In order to accommodate the various types of nondestructive electrical testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used at

the option of the producer to establish a minimum sensitivity level for rejection. For welded tubing, they are to be placed in the weld, if visible.

### 33.5.1 Drilled Hole

Three or more holes not larger than 0.785 mm (0.031 in.) in diameter and equally spaced about the pipe circumference and sufficiently separated longitudinally to ensure a separately distinguishable response are to be drilled radially and completely through tube wall, care being taken to avoid distortion of the tube while drilling. Alternatively, one hole may be used, provided that the calibration tube is scanned at a minimum of three locations each 120 degrees apart, or at more frequent scans with smaller angular increments, provided that the entire 360 degrees of the eddy-current coil is checked.

### 33.5.2 Transverse Tangential Notch

Using a round tool or file with a 6.35 mm (0.25 in.) diameter, a notch is to be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. Said notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater.

### 33.5.3 Longitudinal Notch

A notch 0.785 mm (0.031 in.) or less in width is to be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

## 33.7 Flux Leakage Calibration Standards

The depth of longitudinal notches on the inside and outside surfaces is not to exceed 12.5% of the specified wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed the depth, and the length of the notch is not to exceed 25.4 mm (1.0 in.). Outside and inside surface notches are to be located sufficiently apart to allow distinct identification of the signal from each notch.

## 33.9 Rejection

Tubing producing a signal equal to or greater than the calibration defect is to be subject to rejection.

## 33.11 Affidavits

When each tube is subjected to an approved nondestructive electrical test as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 35 Retests (1998)

For all grades of tubes, if the results of the mechanical tests do not conform to the requirements, retests may be made on additional tubes from the same lot, double the original number specified, each of which is to conform to the requirements. If heat-treated tubes fail to conform to the test requirements, the individual tubes, groups or lots of tubes represented, may be re-heat-treated and resubmitted for retest, as indicated. Only two reheat treatments will be permitted.

## 37 Finish (2008)

Tubes of all grades are to be examined by the Surveyor prior to fabrication or installation, and are to be reasonably straight and have smooth ends free from burrs. At a minimum, the finished tubes are to be visually inspected at the same frequency as that required for the flattening test specified in 2-3-5/39.3 TABLE 2 for the applicable grade. They are to be free from defects and are to have a workmanlike finish. Grade R and S tubes are to be free from scale by pickling or by the use of bright annealing. Minor defects may be removed by grinding provided the wall thicknesses are not decreased beyond the permissible



variations in dimensions. Welding repair to any tube is not to be carried out without the purchaser's approval and is to be to the Surveyor's satisfaction.

### **39 Permissible Variations in Dimensions (1998)**

At a minimum, the finished tubes are to be measured at the same frequency as that required for the flattening test specified in 2-3-5/39.3 TABLE 2 for the applicable grade.

#### **39.1 Wall Thickness**

The permissible variations in wall thickness for all tubes are based on the ordered thickness and should conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all tubes is not to be less than that required by the Rules for a specific application, regardless of such prior acceptance.

#### **39.3 Outside Diameter**

Variations from the ordered outside diameter are not to exceed the amounts prescribed in 2-3-5/39.3 TABLE 4.

**TABLE 1**  
**Chemical Composition for Tubes (1998)**

*Maxima or Permissible Range of Chemical Composition in % ABS Grades*

	D	F	G	H	J	K	L	M	N	O	P	R*	S**
Carbon	0.06 to 0.18	0.35	0.06 to 0.18	0.06 to 0.18	0.27	0.10 to 0.20	0.15 to 0.25	0.14	0.05 to 0.15	0.05 to 0.15	0.05 to 0.15	0.08	0.08
Manganese	0.27 to 0.63	0.80	0.27 to 0.63	0.27 to 0.63	0.93	0.30 to 0.80	0.30 to 0.80	0.30 to 0.80	0.30 to 0.60	0.30 to 0.60	0.30 to 0.60	2.00	2.00
Phosphorus	0.035	0.035	0.05	0.035	0.035	0.025	0.025	0.025	0.025	0.025	0.025	0.040	0.040
Sulfur	0.035	0.035	0.06	0.035	0.035	0.025	0.025	0.025	0.025	0.025	0.025	0.030	0.030
Silicon		0.25	0.25	0.25	0.10 (min.)	0.10 to 0.50	0.10 to 0.50	0.10 to 0.50	0.50 to 1.00	0.50	0.50	0.75	0.75
Chromium									1.00 to 1.50	0.80 to 1.25	1.90 to 2.60	17.0 to 20.0	17.0 to 20.0
Molybdenum						0.44 to 0.65	0.44 to 0.65	0.44 to 0.65	0.44 to 0.65	0.44 to 0.65	0.87 to 1.13		
Nickel												9.00 to 13.00	9.00 to 13.00

**Note:**

\* Grade R is to have a titanium content of not less than five times the carbon content and not more than 0.60%.  
 \*\* Grade S is to have a columbium (niobium) plus tantalum content of not less than ten times the carbon content and not more than 1.00%.

**TABLE 2**  
**Mechanical Tests (1998)**

<i>Grade</i>	<i>Type of Test</i>	<i>Number of Tests</i>
D	Flattening	One test on specimens from each of two tubes from each lot <sup>(1)</sup> or fraction thereof and from each 610 m (2000 ft.) or fraction thereof of safe-end material.
	Flanging	As for flattening test.
	Crushing	As for flattening test when required by the Surveyor.
	Reverse Flattening	One test per 460 m (1500 ft.) of finished welded tubing.
	Hydrostatic or NDET <sup>(3)</sup>	All tubes.
F	Flattening	One test on specimens from each of two tubes from each lot <sup>(1)</sup> or fraction thereof.
	Flanging	As for flattening test.
	Reverse Flattening	One test per each 460 m (1500 ft.) of finished welded tubing.
	Tension	As for flattening test.
	Hydrostatic or NDET <sup>(3)</sup>	All tubes.
G	Flattening	One test on specimens from each of two tubes from each lot <sup>(1)</sup> or fraction thereof.
	Flanging	As for flattening test.
	Reverse Flattening	One test per each 460 m (1500 ft.) of finished welded tubing.
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET <sup>(3)</sup>	All tubes.
H (1998)	Flattening	One test on specimens from each end of two tubes from each lot <sup>(1)</sup> or fraction thereof but not the same tube used for the flaring test.
	Flaring	As for flattening test, but not the same tube used for the flattening test.
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat-treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET <sup>(3)</sup>	All tubes.
J, K, L, M, N, O, P	Flattening	One test on specimens from each end of one finished tube per lot <sup>(2)</sup> , but not the same tube used for the flaring test.
	Flaring	One test on specimens from each end of one finished tube per lot <sup>(2)</sup> , but not the same tube used for the flattening test.
	Tension	One test on one specimen from one tube from each lot <sup>(2)</sup> .
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat-treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET <sup>(3)</sup>	All tubes.

Grade	Type of Test	Number of Tests
R, S (1998)	Flattening	One test on specimens from each end of one finished tube per lot <sup>(2)</sup> , but not the same tube used for the flaring test.
	Flaring	One test on specimens from each end of one finished tube per lot <sup>(2)</sup> , but not the same tube used for flattening test.
	Tension	One test on one specimen for each lot of 50 tubes or less. One test on one specimen from each of two tubes for lots <sup>(4)</sup> of more than 50 tubes.
	Hardness	One Brinell or Rockwell hardness determination on two tubes from each lot <sup>(4)</sup> .
	Hydrostatic or NDET <sup>(3)</sup>	All tubes.

Notes:

- 1 A lot consists of 250 tubes for sizes 76.2 mm (3.0 in.) and under and of 100 tubes for sizes over 76.2 mm (3.0 in.) prior to cutting to length.
- 2 (1998) The term lot, used here, applies to all tubes prior to cutting to length of the same nominal size and wall thickness which are provided from the same heat of steel. When final heat treatment is in a batch-type furnace, a heat-treatment lot is to include only those tubes of the same size and from the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot is to be determined from the size of the tubes as prescribed below.

Size of Tube	Size of Lot
50.8 mm (2.0 in.) and over in outside diameter and 5.1 mm (0.2 in.) and over in wall thickness	Not more than 50 tubes
Less than 50.8 mm (2.0 in.) but over 25.4 mm (1.0 in.) in outside diameter or over 25.4 mm (1.0 in.) in outside diameter and under 5.1 mm (0.2 in.) in wall thickness	Not more than 75 tubes
25.4 mm (1.0 in.) or less in outside diameter	Not more than 125 tubes

- 3 (1998) In lieu of the hydrostatic pressure test, a nondestructive electric test may be used. See 2-3-5/33.
- 4 (1998) The term lot, used here, applies to all tubes prior to cutting to length of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a heat-treatment lot is to include only those tubes of the same size and from the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot is to include all tubes of the same size and heat, heat-treated in the same furnace at the same temperature, time at heat and furnace speed.

**TABLE 3**  
**Tensile Properties of Tubes (1998)**

Tensile Strength, min.	F	G*,H*	J	K	L	M	N,O,P	R,S (1998)
N/mm <sup>2</sup>	415	325	415	380	415	365	415	519
kgf/mm <sup>2</sup>	42	33	42	39	42	37.5	42	53
psi	60000	47000	60000	55000	60000	53000	600	75000
Yield Strength, min.								
N/mm <sup>2</sup>	255	180	255	205	220	195	205	205
Kgf/mm <sup>2</sup>	26	18.5	26	21	22.5	19.5	21	21

<i>Tensile Strength, min.</i>	<i>F</i>	<i>G*,H*</i>	<i>J</i>	<i>K</i>	<i>L</i>	<i>M</i>	<i>N,O,P</i>	<i>R,S (1998)</i>
psi	37000	26000	37000	30000	32000	28000	300	30000
Elongation in 50 mm (2 in.), min. %	30	35	30	30	30	30	30	35
Deduction in elongation for each 0.8 mm (0.031 in.) decrease in wall thickness below 7.9 mm (0.313 in.) on longitudinal strip tests	1.50	—	1.50	1.50	1.50	1.50	1.50	—

\* No tensile tests are required for these grades, the data is given for design purposes only.

**TABLE 4**  
**Permissible Variations in Outside Diameter for Tubes <sup>(1)</sup>**

<i>Millimeters</i>	<i>Outside Diameter Variation Including Out-of-roundness</i>	
	<i>Over</i>	<i>Under</i>
<i>Outside Diameter</i>		
Seamless, Hot-finished Tubes:		
101.6 and under	0.4	0.8
Over 101.6 to 190.5 inclusive	0.4	1.2
Over 190.5 to 228.6 inclusive	0.4	1.6
Seamless, Cold-drawn Tubes <sup>(2)</sup> and Welded Tubes:		
Under 25.4 <sup>(3)</sup>	0.10	0.10
25.4 to 28.1 inclusive <sup>(3)</sup>	0.15	0.15
Over 38.1 to 50.8 exclusive <sup>(3)</sup>	0.20	0.20
50.8 to 63.5 exclusive	0.25	0.25
63.5 to 76.2 exclusive	0.30	0.30
76.2 to 101.6 inclusive	0.38	0.38
Over 101.6 to 190.5 inclusive	0.38	0.63
Over 190.5 to 228.6 inclusive	0.38	1.14

<i>Inches</i>	<i>Outside Diameter Variation Including Out-of-roundness</i>	
	<i>Over</i>	<i>Under</i>
<i>Outside Diameter</i>		
Seamless, Hot-finished Tubes:		
4 and under	$\frac{1}{64}$	$\frac{1}{32}$
Over 4 to 7.5 inclusive	$\frac{1}{64}$	$\frac{3}{64}$
Over 7.5 to 9 inclusive	$\frac{1}{64}$	$\frac{1}{16}$
Seamless, Cold-drawn Tubes <sup>(2)</sup> and Welded Tubes:		
Under 1 <sup>(3)</sup>	0.004	0.004

<i>Inches</i>	<i>Outside Diameter Variation Including Out-of-roundness</i>	
	<i>Over</i>	<i>Under</i>
<i>Outside Diameter</i>		
1 to 1.5 inclusive <sup>(3)</sup>	0.006	0.006
Over 1.5 to 2 exclusive <sup>(3)</sup>	0.008	0.008
2 to 2.5 exclusive	0.010	0.010
2.5 to 3 exclusive	0.012	0.012
3 to 4 inclusive	0.015	0.015
Over 4 to 7.5 inclusive	0.015	0.025
Over 7.5 to 9 inclusive	0.015	0.045

**Notes:**

- 1 The permissible variations in outside diameters apply only to the tubes as rolled or drawn and before swaging, expanding, bending, polishing or other fabricating operations.
- 2 (1998) Thin wall tubes usually develop significant ovality during final annealing or straightening. Thin wall tubes are those with a wall of 0.5mm (0.020 in.) or less, those with a specified outside diameter equal to or less than 50.8mm (2 in.) and with a wall thickness of 2% of the specified outside diameter or less, and those with a specified outside diameter of greater than 50.8mm (2 in.) and with a wall thickness of 3% of the specified outside diameter or less. The ovality allowance is 2% of the specified outside diameter for tubes over 25.4mm (1 in.) and is 0.5mm (0.020 in.) for tubes with the specified outside diameter equal to and less than 25.4mm (1 in.). In all cases, the average outside diameter must comply with the permissible variation allowed by this table.
- 3 (1998) Grade R and S austenitic stainless steel tube has an ovality allowance for all sizes less than 50.8 mm (2 in.) outside diameter. The allowance provides that the maximum and minimum diameter at any cross section is not to deviate from the nominal diameter by more than  $\pm 0.25$  mm ( $\pm 0.010$  in.). In the event of conflict between the permissible variation allowed by this note and note 2, the larger ovality tolerance will apply. In all cases, the average outside diameter must comply with the permissible variation allowed by this table.

*Note:* In substantial agreement with ASTM A31 Boiler Rivet Steel and Rivets.

## **1 Process of Manufacture (2008)**

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. All such bars and rivets will be examined at the mills by the Surveyor when specially requested by the purchaser. They are to be free from defects and have a workmanlike finish.

## **3 Marking and Retests**

### **3.1 Manufacturer's Markings**

The bars and rivets, when loaded for shipment, are to be properly separated in bundles or containers marked with the name or brand of the manufacturer, the letter indicating the grade of steel and the heat number of identification.

### **3.3 ABS Markings**

The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be marked on the material or on each bundle or container near the marking specified in 2-3-6/3.1.

### **3.5 Retests**

When the result of any of the physical tests specified for any of the material does not conform to the requirements, two additional specimens may, at the request of the manufacturer, be taken from the same lot and tested in the manner specified, but in such case, both of the specimens must conform to the requirements. In the case of tension tests, this retest is to be allowed if the percent of elongation obtained is less than required.

## **5 Tensile Properties**

The material is to conform to the following requirements as to tensile properties.

	<i>Grade A</i>	<i>Grade B</i>
Tensile Strength N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , psi)	310-380 (31.5-39, 45000-55000)	400-470 (41-48, 58000-68000)

Yield Point, min., N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , psi)	155 (16, 23000)	195 (20, 29000)
Elongation in 200 mm (8 in.), min., %	27	22

## 7 Bending Properties

The test specimen for Grade A steel is to stand being bent cold through 180 degrees flat on itself without cracking on the outside of the bent portion. The test specimen for Grade B steel is to stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows: for material 19.1 mm (0.75 in.) and under in diameter, around an inside diameter which is equal to one-half the diameter of the specimen; for material over 19.1 mm (0.75 in.) in diameter, around an inside diameter which is equal to the diameter of the specimen.

## 9 Test Specimens

Bend and tension test specimens are to be the full diameter of the bars as rolled and, in the case of rivet bars which have been cold-drawn, the test specimens shall be normalized before testing.

## 11 Number of Tests

Two tension and two cold-bend tests are to be made from each heat.

## 13 Tests of Finished Rivets

### 13.1 Bending Properties

The rivet shank of Grade A steel is to stand being bent cold through 180 degrees flat on itself without cracking on the outside of the bent portion. The rivet shank of Grade B steel is to stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows: for material 19.1 mm (0.75 in.) and under in diameter, around an inside diameter which is equal to the diameter of the shank; for material over 19.1 mm (0.75 in.) in diameter, around an inside diameter which is equal to one and one-half times the diameter of the shank.

### 13.3 Flattening Tests

The rivet head is to stand being flattened, while hot, to a diameter two and one-half times the diameter of the shank without cracking at the edges.

### 13.5 Number of Tests

Three bend and three flattening tests are to be made from each size in each lot of rivets offered for inspection.



**1 Carbon Steel Machinery Forgings (2000)****1.1 Process of Manufacture****1.1.1 General (2017)**

The following requirements cover carbon-steel forgings intended to be used in machinery construction. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by ABS.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

Raw materials for forging such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS. Steel is to be fully killed and is to be manufactured by a process approved by ABS.

For crankshafts, where grain flow is required in the most favorable direction with regard to the mode of stressing in service, the proposed method of manufacture may require special approval. In such cases, tests may be required to demonstrate that satisfactory microstructure and grain flow are obtained.

For components used in the direct load path of a jacking system, refer to Section 6-1-9 of the *MOU Rules* for additional qualification requirements.

The shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all thermal cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where  $L > D$  and 1.5:1 where  $L \leq D$ .
- For forgings made from rolled products, 4:1 where  $L > D$  and 2:1 where  $L \leq D$ .
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.
- For rolled bars used in lieu of forgings, 6:1.

$L$  and  $D$  are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation.

### 1.1.2 Chemical Composition (2008)

All forgings are to be made from killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-7/7.17 TABLE 1. The carbon content of Grades 2, 3 and 4 is not to exceed 0.23% or carbon equivalent (Ceq) of Grades 2, 3 and 4 is not to exceed 0.41%, unless specially approved, see 2-3-7/7.17 TABLE 1. The carbon content of Grade 4C is not to exceed 0.55%. Welding of Grade 4C is not permitted unless specially approved. Specially approved grades having more than the maximum specified carbon are to have **S** marked after the grade designation.

Forgings for rudder stocks and pintles are to be of weldable quality.

The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

### 1.1.3 ASTM Designations

The grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
2	A668, Class B
3	A668, Class D
4	A668, Class E
4C	A668, Class E

## 1.3 Marking, Retests and Rejection

### 1.3.1 Marking (2005)

The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the forgings when required.

In addition to appropriate identification markings of the manufacturer, ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernible after machining and installation. In addition, Grade 2, Grade 3, Grade 4, and Grade 4C forgings are to be stamped **AB/2**, **AB/3**, **AB/4** and **AB/4C**, respectively.

### 1.3.2 Retests (2005)

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with 2-3-1/9. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with 2-3-7/1.5.6. After reheat-treating, the forgings are to be submitted for all mechanical testing.

### 1.3.3 Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

## 1.5 Heat treatment

### 1.5.1 General (2017)

Heat treatment facilities used in producing ABS certified forgings are to be included in the forge approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Heat treatment details are to be included in the approval documentation.

Forge qualification is to include all of the heat treatment facilities that the forge will use.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

Unless a departure for the following procedures is specifically approved, Grade 2 and 3 forgings are to be annealed, normalized or normalized and tempered. Grade 4 and 4C forgings are to be normalized and tempered or double-normalized and tempered. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature.

In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment. The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

#### 1.5.2 Cooling Prior to Heat Treatment (2016)

After forging and before reheating for heat treatment, the forgings are allowed to cool in a manner to prevent injury and to accomplish transformation.

#### 1.5.3 Annealing

The forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

#### 1.5.4 Normalizing

The forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air. Water sprays and air blasts may be specially approved for use to achieve more rapid cooling. The faster cooling rates are to be agreed to by the purchaser.

#### 1.5.5 Tempering (2005)

The forgings are to be reheated to and held at the proper temperature, which will be below the transformation range, and are then to be cooled under suitable conditions to 315°C (600°F) or lower. The tempering temperature is not to be less than 550°C (1022°F).

#### 1.5.6 Retreatment

The manufacturer may re-heat treat the forging, but not more than three additional times.

#### 1.5.7 Surface Hardening (2017)

Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth, and that it does not impair the soundness and properties of the steel.

Where induction hardening or nitriding is to be carried out, forgings are to be heat-treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage to a condition suitable for subsequent machining and carburizing.

### 1.7 Tensile Properties

The forging tensile properties are to conform the requirements of 2-3-7/7.17 TABLE 2.

### 1.9 Test Specimens

#### 1.9.1 Location and Orientation of Specimens

Mechanical properties are to be determined from test specimens taken from prolongations having a sectional area not less than the body of the forging. Specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or may be taken transversely. The axes of longitudinal specimens are to be located at any point midway

between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings. The axes of transverse specimens may be located close to the surface of the forgings. In the cases of reduction gear ring forgings, reduction gear pinions and gear forgings, and reduction gear shaft forgings, the test specimen location and orientation are specified in 2-3-7/1.11.1(d), 2-3-7/1.11.1(e) and 2-3-7/1.11.1(f) respectively. Test results from other locations may be specially approved, provided appropriate supporting information is presented, which indicates that the specified location will be in conformity with the specified tensile properties.

### 1.9.2 Hollow-drilled Specimens

In lieu of prolongations, the test specimens may be taken from forgings submitted for each test lot; or if satisfactory to the Surveyor, test specimens may be taken from forgings with a hollow drill.

### 1.9.3 Very Small Forgings

In the cases of very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for test. In such cases, the special forgings should be subjected to the same amount of working and reduction as the forgings represented and should be heat-treated with those forgings.

### 1.9.4 Identification of Specimens (2015)

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/tank (for Q & T forgings).

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

## 1.11 Number and Location of Tests

### 1.11.1 Tension Test (2017)

#### 1.11.1(a) Large Forgings.

In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test specimen is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the two tensile test specimens may be taken 180 degrees apart from the same end of the forging.

#### 1.11.1(b) Intermediate-Sized Forgings.

In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test specimen is to be taken from each forging.

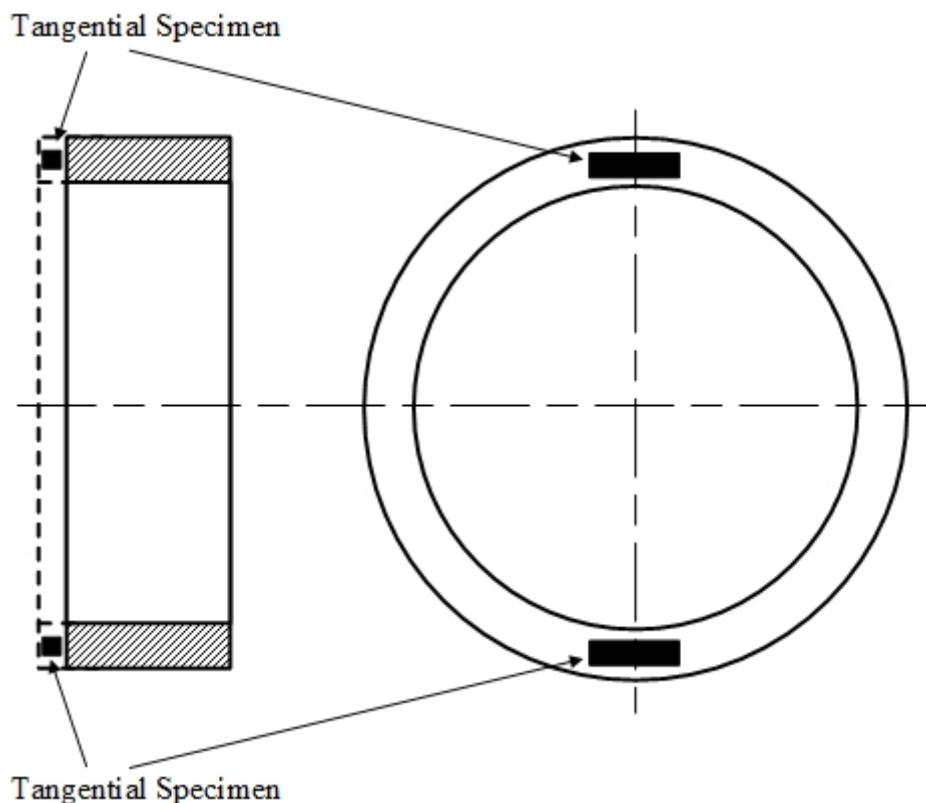
#### 1.11.1(c) Small Forgings (2017).

In the case of small normalized forgings with weight at the time of heat treatment less than 1000 kg (2200 lb), and quenched and tempered forgings with weight at the time of heat treatment less than 500 kg (1100 lb) one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The total mass of the furnace charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

1.11.1(d) Reduction Gear Ring Forgings.

In the case of ring forgings for reduction gears, two tension tests are to be taken 180 degrees apart from a full-size prolongation left on one end of each individual forging or both ends of each multiple forging. Test specimens are to be in a tangential orientation at mid-wall of the ring as close as practical to the end of the rough machined surface of the forging. Refer to 2-3-7/1.11.1(d) FIGURE 1.

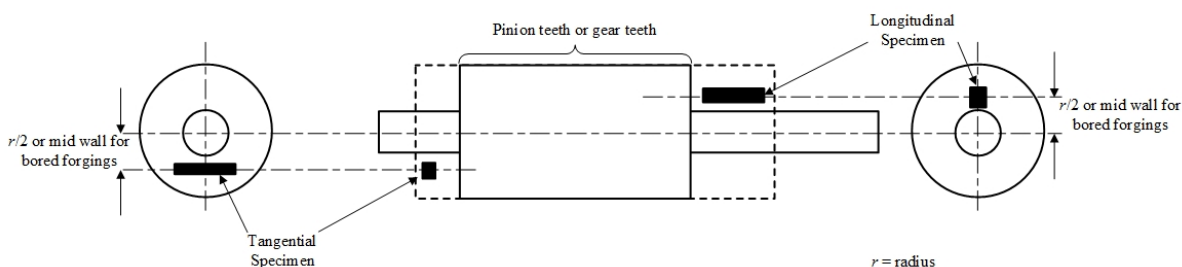
**FIGURE 1**  
**Gear Ring Forgings - Test Speciment Locations and Orientations (2017)**



1.11.1(e) Reduction Gear Pinion and Gear Forgings.

In the case of pinion and gear forgings for reduction gears, the tension test is to be taken in the longitudinal or tangential orientation from a location as close as practical to the mid-radius location of the main body (toothed portion) of solid forgings or the mid-wall of bored forgings. Extending the axial length of the main body (toothed portion) of the forging for a sufficient distance would be an acceptable location for tension specimen removal. Refer to 2-3-7/1.11.1(e) FIGURE 2.

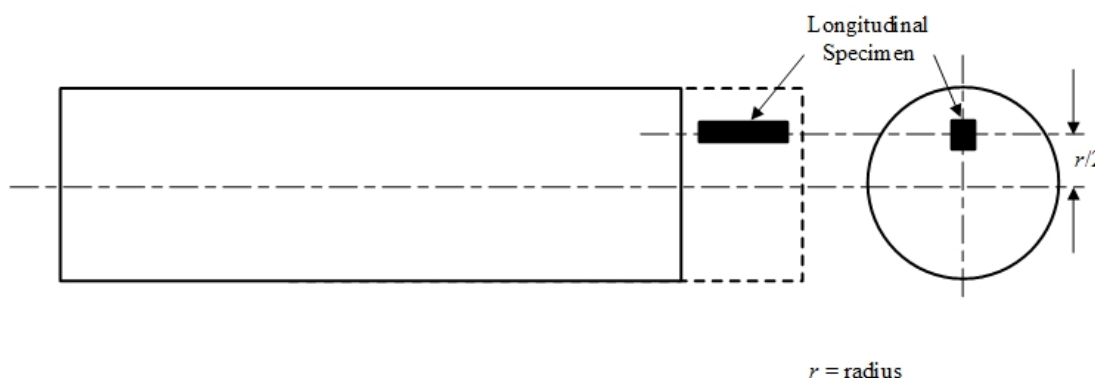
**FIGURE 2**  
**Pinion or Gear Forging - Test Specimen Locations and Orientations**  
**(2017)**



*1.11.1(f) Reduction Gear Shaft Forgings.*

In the case of shaft forgings for reduction gears, the tension test is to be taken in the longitudinal direction at the mid-radius location of a full size prolongation. Refer to 2-3-7/1.11.1(f) FIGURE 3.

**FIGURE 3**  
**Gear Shaft Forging - Test Specimen Locations and Orientations (2017)**



*1.11.1(g) Surface Hardened Forgings (2017).*

When forgings are to be surface hardened, sufficient test material is to be provided for both preliminary tests at the forge and for final tests after completion of surface hardening. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 2-3-7/1.9 except that, irrespective of the dimensions or mass of the forging, the tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction. The test material is to be machined to a diameter of  $D/4$  or 60 mm, whichever is less, where  $D$  is the finished diameter of the toothed portion.

For preliminary tests at the forge, one set of test material is to be given a blank surface hardening and heat treatment cycle simulating that which subsequently will be applied to the forging. For final acceptance tests, the second set of test material is to be blank surface hardening and heat treated along with the forgings which they represent.

At the discretion of the forgemaster or gear manufacturer, test samples of larger cross section may be either surface hardened or blank surface hardened, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing of forgings which are to be surface hardened may be specially agreed with the ABS Materials Department.

*1.11.1(h) Continuous Heat Treatment (2017).*

Whereby a furnace incorporates a method of controlled moving of the component from the charging end, through the furnace at a predetermined temperature and time, to the discharging end. Test coupon sampling procedures are to be specially agreed with the ABS Materials Department.

**1.11.2 Hardness Tests**

*1.11.2(a) Large, Intermediate and Small Sized Forgings.*

Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested to meet the following requirements. The variation in hardness of any forging is not to exceed 30 Brinell Hardness numbers.

<i>ABS Grade</i>	<i>Hardness, BHN, Minimum, (10 mm dia. ball, 3000 kg load)</i>
2	120
3	150
4, 4C	170

*1.11.2(b) Reduction Gear Forgings.*

In the case of ring forgings for reduction gears, Brinell hardness tests are to be taken at approximately  $\frac{1}{4}$  of the radial thickness from the outside diameter and in accordance with the following frequency and locations:

<i>Outside Diameter, cm. (in.)</i>	<i>Number of Hardness Tests</i>
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart
203 to 305 (80 to 120)	3 on each end, 120 degrees apart
Over 305 (120)	4 on each end, 90 degrees apart

*1.11.2(c) Reduction Gear Pinion and Gear Forgings.*

In the case of case of pinion and gear forgings with diameters 203 mm (8 in.) and over, four Brinell hardness tests are to be made on the outside surface of that portion of the forging on which teeth will be cut, two tests being made on each helix 180 degrees apart and the tests on the two Helices are to be 90 degrees apart. On each forging under 203 mm (8 in.) in diameter, two Brinell hardness tests are to be made on each helix 180 degrees apart. Hardness tests are to be taken at the quarter-face width of the toothed portion diameter.

*1.11.2(d) Disc, Ring and Hollow Forgings.*

Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested to meet the requirements of 2-3-7/1.11.2(a). Forgings are to be tested at the approximate mid-radius and 180 degrees apart on each flat surface of the forging; the testing locations on opposite sides are to be offset by 90 degrees.

*1.11.2(e) Very Small Forgings.*



In cases involving very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, the hardness tests may be made from broken tension test specimens, or on a special forging representing the lot; see 2-3-7/1.9.3.

### 1.13 Examination (2008)

All forgings are to be examined by the Surveyor after the final heat treatment and they are to be found free from defects. Where applicable, this is to include the examination of internal surfaces and bores.

The manufacturer is to verify that all dimensions meet the specified requirements.

When required by the relevant construction Rules, or by the approved procedure for welded composite components, appropriate nondestructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria are to be agreed with ABS. Part 2, Appendix 7 is regarded as an example of an acceptable standard.

In the event of any forging proving defective during subsequent machining or testing, it is to be rejected, notwithstanding any previous certification.

#### 1.13.1 Surface Inspection of Tail Shaft Forgings

All tail shaft forgings are to be subjected to a nondestructive examination such as magnetic particle, dye penetrant or other nondestructive method. Discontinuities are to be removed to the satisfaction of the Surveyor. (See 4-3-2/3.7.3 of the *ABS Rules for Building and Classing Marine Vessels*, for surface inspection requirements in finished machined condition.)

#### 1.13.2 Surface Inspection of Jacking Gear Forgings (2020)

Surface inspection such as magnetic particle, dye penetrant or other surface nondestructive method is to be applied on forgings in the final finished condition. Refer to 6-1-9/25.1 of the *MOU Rules* for inspection details/criteria. Any discontinuities are to be removed to the satisfaction of the Surveyor.

#### 1.13.3 Ultrasonic Examination of Tail Shaft Forgings

Forgings for tail shafts 455 mm (18 in.) and over in finished diameter are to be ultrasonically examined to the satisfaction of the attending Surveyor. Conformity with Section 7-A1-12, "Ultrasonic Examination of Carbon Steel Forgings for Tail Shafts" of the *ABS Rules for Survey After Construction (Part 7)*, or equivalent, will be considered to meet this requirement.

#### 1.13.4 Ultrasonic Examination of Jacking Gear Forgings (2020)

For direct load path components (refer to 6-1-9/5 of the *MOU Rules*), UT is to be carried out during the manufacturing of the gear in accordance with the approved design plan. This can be done either on the forged blank and/or at a later manufacturing stage.

**Note:** It may be more effective to UT the forged blanks (without the teeth or splines cut) than to UT a finished gear component containing complex profiles.

### 1.15 Rectification of Defective Forgings (2018)

Defects may be removed by grinding or chipping and grinding, provided that the component dimensions remain acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing.

Repair welding of forgings may be permitted subject to prior approval by ABS. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

Weld procedures for all types of welds are to be appropriately qualified to the satisfaction of the attending Surveyor.

Before undertaking the repair welding of forgings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work intended.

The forging manufacturer is to maintain records of repairs and subsequent inspections that are traceable to each forging repaired. The records are to be presented to the Surveyor on request.

Temporary welds made for operations such as lifting, handling, staging, etc., are to be carried out to qualified welding procedures and qualified welders/operators and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

### 1.17 Certification (2005)

The manufacturer is to provide the required type of inspection certificate giving the following particulars for each forging or batch of forgings which has been accepted:

- i) Purchaser's name and order number
- ii) Description of forgings and steel quality
- iii) Identification number
- iv) Steelmaking process, cast number and chemical analysis of ladle sample
- v) Results of mechanical tests
- vi) Results of nondestructive tests, where applicable
- vii) Details of heat treatment, including temperature and holding times
- viii) Specification

## 3 Alloy Steel Gear Assembly Forgings (2000)

### 3.1 Process of Manufacture

#### 3.1.1 General (2017)

The following requirements cover gear and pinion alloy steel forgings intended to be used principally for propulsion units and auxiliary turbines. Typical components include forging rims and blanks for steel gears and pinions, used in shipboard gear assemblies. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by ABS.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

Raw materials for forging such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS. Steel is to be fully killed and is to be manufactured by a process approved by ABS.

For components used in the direct load path of a jacking system, refer to Section 6-1-9 of the *MOU Rules* for additional qualification requirements.

The shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all thermal cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where  $L > D$  and 1.5:1 where  $L \leq D$ .
- For forgings made from rolled products, 4:1 where  $L > D$  and 2:1 where  $L \leq D$ .
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.
- For rolled bars used in lieu of forgings, 6:1.

$L$  and  $D$  are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation. The forging process is to have ample power to adequately flow the metal within the maximum cross-section of the forging.

### 3.1.2 Chemical Composition (2005)

All forgings are to be made from killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-7/7.17 TABLE 3. The analysis is to be carried out with a coupon cast during the pouring of the heat.

### 3.1.3 ASTM Designations (2009)

The grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
A1	A291 Grade 2
A2	A291 Grade 3
A3	A291 Grade 4
A4	A291 Grade 5
A5	A291 Grade 6
A6	A291 Grade 7

### 3.3 Marking, Retests and Rejection

#### 3.3.1 Marking (2005)

The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the forgings, when required.

In addition to appropriate identification markings of the manufacturer, ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernible after machining and installation. In addition, Grade A1 through Grade A6 forgings are to be stamped **AB/A1**, **AB/A2**, **AB/A3**, **AB/A4**, **AB/A5**, and **AB/A6**, respectively.

#### 3.3.2 Retests (2005)

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with 2-3-1/9 or 2-1-2/11.7. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with 2-3-7/3.5.7. After re-heat treating, the forgings are to be submitted for all mechanical testing.

#### 3.3.3 Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

### 3.5 Heat Treatment

#### 3.5.1 General (2017)

Heat treatment facilities used in producing ABS certified forgings are to be included in the forge approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Heat treatment details are to be included in the approval documentation.

Forge qualification is to include all of the heat treatment facilities that the forge will use.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to

be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment consideration is to be given to a subsequent stress relieving heat treatment.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

The required heat treatment for each forging grade is as follows:

<i>Required Heat Treatment and Minimum Tempering Temperature</i>		
<i>Grade</i>	<i>Heat Treatment</i>	<i>Temperature, in °C (°F)</i>
A1	Quench + Temper	620 (1150)
A2	Quench + Temper	580 (1075)
A3	Quench + Temper	580 (1075)
A4	Quench + Temper	565 (1050)
A5	Quench + Temper	565 (1050)
A6	Quench + Temper	565 (1050)

Alternative heat treatment procedures may be specially approved with due consideration given to the section thickness and the intended function of the forged component. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

### 3.5.2 Cooling Prior to Heat Treatment (2016)

After forging and before reheating for heat treatment, the forgings are allowed to cool in a manner to prevent injury and to accomplish transformation.

### 3.5.3 Annealing

The forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

### 3.5.4 Normalizing

The forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air.

### 3.5.5 Tempering

The forgings are to be reheated to and held at the proper temperature, which is to be below the transformation range but above the minimum temperature in 2-3-7/3.5.1, and are then to be cooled at a rate not exceeding 100°F (55°C) per hour until temperature below 315°C (600°F) is reached.

### 3.5.6 Stress Relieving (2008)

Where heat treatment for mechanical properties is carried out before final machining, the forgings are to be stress relieved after machining at a temperature 28°C (50°F) to 55°C (100°F) below the previous tempering temperature, but in no case less than 540°C (1000°F). The cooling rate is not to exceed 55°C (100°F) per hour until temperature below 315°C (600°F) is reached.

**3.5.7 Retreatment**

The manufacturer may re-heat treat the forging, but not more than three additional times.

**3.5.8 Surface Hardening (2017)**

Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth, and that it does not impair the soundness and properties of the steel.

Where induction hardening or nitriding is to be carried out, forgings are to be heat-treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage to a condition suitable for subsequent machining and carburizing.

**3.7 Mechanical Properties**

**3.7.1 Tensile Properties**

The forging tensile properties are to conform to the requirements of 2-3-7/7.17 TABLE 4.

**3.7.2 Hardness**

Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested to meet the following requirements.

<i>ABS Grade</i>	<i>Hardness, BHN, (10 mm dia. ball, 3000 kg load)</i>
A1	201 to 241
A2	223 to 262
A3	248 to 293
A4	285 to 331
A5	302 to 352
A6	341 to 415

**3.9 Test Specimens**

**3.9.1 Location and Orientation of Specimens**

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or tangential to that direction, as indicated by the ductility requirements in 2-3-7/7.17 TABLE 4. The axes of the longitudinal specimens are to be located at any point 32 mm (1.25 in.) below the surface of the forging. The axes of the tangential specimens are to be located as near to the surface of the forging as practicable. In the cases of reduction gear ring forgings, reduction gear pinions and gear forgings, and reduction gear shaft forgings, the test specimen location and orientation are specified in 2-3-7/3.9.3(d), 2-3-7/3.9.3(e) and 2-3-7/3.9.3(f) respectively.

**3.9.2 Identification of Specimens (2015)**

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/tank (for Q & T forgings).

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to

ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

### 3.9.3 Tension Tests

#### 3.9.3(a) Large Forgings.

In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

#### 3.9.3(b) Intermediate-Sized Forgings.

In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test is to be taken from each forging.

#### 3.9.3(c) Small Forgings (2017).

In the case of small normalized forgings with weight at the time of heat treatment less than 1000 kg (2200 lb) and quenched and tempered forgings with weight at the time of heat treatment less than 500 kg (1100 lb), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The total mass of the furnace charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

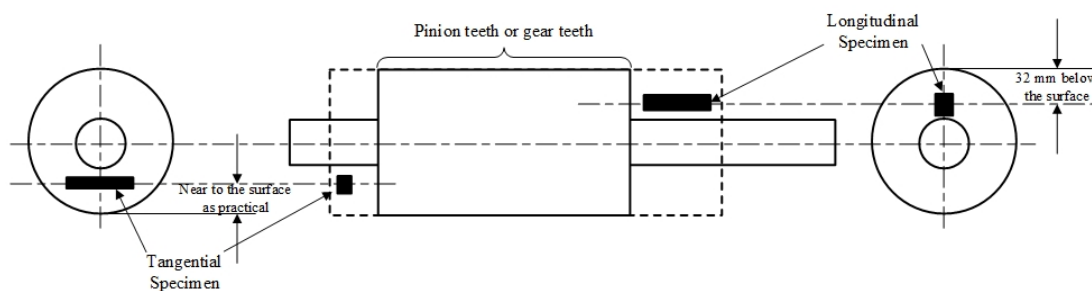
#### 3.9.3(d) Reduction Gear Ring Forgings.

In the case of ring forgings for reduction gears, two tension tests are to be taken 180 degrees apart from a full-size prolongation left on one end of each individual forging or both ends of each multiple forging. Test specimens are to be in a tangential orientation as close as practical to the end of the rough machined surface of the forging. Refer to 2-3-7/1.11.1(d) FIGURE 1.

#### 3.9.3(e) Reduction Gear Pinion and Gear Forgings.

In the case of pinion and gear forgings for reduction gears, the tests are to be taken in the longitudinal or tangential orientation. Extending the axial length of the main body (toothed portion) of the forging for a sufficient distance would be an acceptable location for test specimen removal. Refer to 2-3-7/3.9.3(e) FIGURE 4.

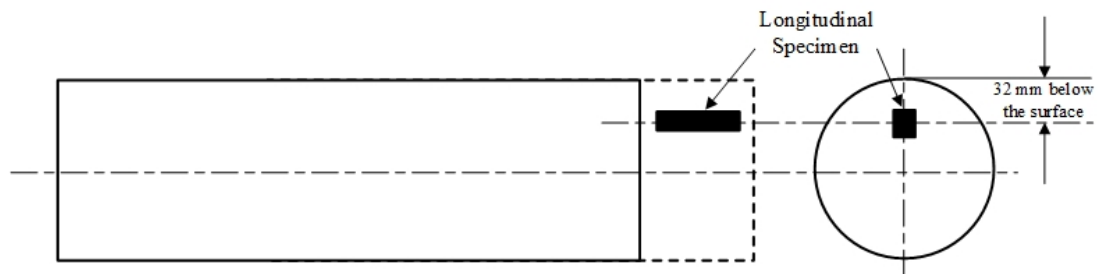
**FIGURE 4**  
**Pinion or Gear Forging - Test Specimen Locations and Orientations**  
**(2017)**



#### 3.9.3(f) Reduction Gear Shaft Forgings.

In the case of shaft forgings for reduction gears, the tests are to be taken in the longitudinal direction from a full size prolongation. Refer to 2-3-7/3.9.3(f) FIGURE 5.

**FIGURE 5**  
**Gear Shaft Forging - Test Speciment Locations and Orientations (2017)**



*3.9.3(g) Surface hardened Forgings (2017).*

When forgings are to be surface hardened, sufficient test material is to be provided for both preliminary tests at the forge and for final tests after completion of surface hardening. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 2-3-7/3.9 except that, irrespective of the dimensions or mass of the forging, the tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction. The test material is to be machined to a diameter of  $D/4$  or 60 mm, whichever is less, where  $D$  is the finished diameter of the toothed portion.

For preliminary tests at the forge, one set of test material is to be given a blank surface hardening and heat treatment cycle simulating that which subsequently will be applied to the forging. For final acceptance tests, the second set of test material is to be blank surface hardened and heat treated along with the forgings which they represent.

At the discretion of the forgemaster or gear manufacturer, test samples of larger cross section may be either surface hardened or blank surface hardened, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing of forgings which are to be carburized may be specially agreed with the Divisional ABS Materials Department.

*3.9.3(h) Continuous Heat Treatment (2017).*

Whereby a furnace incorporates a method of controlled moving of the component from the charging end, through the furnace at a predetermined temperature and time, to the discharging end. Test coupon sampling procedures are to be specially agreed with the ABS Materials Department.

**3.9.4 Hardness**

*3.9.4(a) Large, Intermediate and Small Sized Forgings.*

Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested.

*3.9.4(b) Reduction Gear Forgings.*

In the case of ring forgings for reduction gears, Brinell hardness tests are to be taken at approximately  $1/4$  of the radial thickness from the outside diameter and in accordance with the following frequency and locations:



<i>Outside Diameter, cm. (in.)</i>	<i>Number of Hardness Tests</i>
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart
203 to 305 (80 to 120)	3 on each end, 120 degrees apart
Over 305 (120)	4 on each end, 90 degrees apart

*3.9.4(c) Reduction Gear Pinion and Gear Forgings.*

In the case of case of pinion and gear forgings with diameters 203 mm (8 in.) and over, four Brinell hardness tests are to be made on the outside surface of that portion of the forging on which teeth will be cut, two tests being made on each helix 180 degrees apart and the tests on the two helices are to be 90 degrees apart. On each forging under 203 mm (8 in.) in diameter, two Brinell hardness tests are to be made on each helix 180 degrees apart. Hardness tests are to be taken at the quarter-face width of the toothed portion diameter.

*3.9.4(d) Reduction Gear Shaft Forgings.*

In the case of shaft forgings for reduction gears, two hardness tests at each end, spaced at 180 degrees apart are to be taken.

**3.11 Examination (2008)**

After final heat treatment, all forgings are to be examined in accordance with 2-3-7/1.13 by the Surveyor and found free from defects. The finish is to be free of cracks, seams, laps, cold shuts, laminations, shrinkage and burst indications.

**3.13 Rectification of Defective Forgings (2005)**

Rectification of defects is to be carried out in accordance with 2-3-7/1.15.

**3.15 Certification (2005)**

The manufacturer is to provide the required type of inspection certificate, in accordance with 2-3-7/1.17.

**5 Alloy Steel Shaft and Stock Forgings (2000)**

**5.1 Process of Manufacture**

**5.1.1 General (2017)**

The following requirements cover shaft and stock alloy steel forgings intended to be used principally for propulsion units and stock type applications. Typical components include tail shafts, intermediate shafts, thrust shafts, other torsional shafts, bolts, sleeves, couplings, propeller nuts, rudder stocks and canard stocks, used in shipboard units. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by ABS.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

Raw materials for forging such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS. Steel is to be fully killed and is to be manufactured by a process approved by ABS.

The shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all thermal cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation

Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where  $L > D$  and 1.5:1 where  $L \leq D$ .
- For forgings made from rolled products, 4:1 where  $L > D$  and 2:1 where  $L \leq D$ .
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.
- For rolled bars used in lieu of forgings, 6:1.

$L$  and  $D$  are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation.

### 5.1.2 Chemical Composition (2005)

All forgings are to be made from killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-7/7.17 TABLE 5. The analysis is to be carried out with a coupon cast during the pouring of the heat.

### 5.1.3 Product Analysis

The forgings are to be subjected to a product chemical analysis and meet the requirements of 2-3-7/7.17 TABLE 5, as modified by the product variation requirements specified in A778, General Requirements for Steel Forgings.

### 5.1.4 ASTM Designations

The grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
A7	A470 Class 2
A8	A470 Class 4
A9	A470 Class 6
A10	A470 Class 7

### 5.3 Marking, Retests and Rejection

#### 5.3.1 Marking (2005)

The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the forgings, when required.

In addition to appropriate identification markings of the manufacturer, ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernible after machining and installation. In addition, Grade A7 through Grade A10 forgings are to be stamped **AB/A7**, **AB/A8**, **AB/A9** and **AB/A10** respectively.

#### 5.3.2 Retests (2005)

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with 2-3-1/9 or 2-1-2/11.7. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with 2-3-7/5.5.7. After re-heat treating, the forgings are to be submitted for all mechanical testing.

#### 5.3.3 Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

### 5.5 Heat Treatment

#### 5.5.1 General (2017)

Heat treatment facilities used in producing ABS certified forgings are to be included in the forge approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Heat treatment details are to be included in the approval documentation.

Forge qualification is to include all of the heat treatment facilities that the forge will use.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to

be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

The required heat treatment for each forging grade is as follows:

<i>Required Heat Treatment and Minimum Tempering Temperature</i>		
<i>Grade</i>	<i>Heat Treatment</i>	<i>Temperature, in °C (°F)</i>
A7	Double Normalize + Temper	580 (1075)
A8	Double Normalize + Temper	580 (1075)
A9	Normalize, Quench + Temper	580 (1075)
A10	Normalize, Quench + Temper	580 (1075)

Alternative heat treatment procedures may be specially approved with due consideration given to the section thickness and the intended function of the forged component. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

### 5.5.2 Cooling Prior to Heat Treatment (2016)

After forging and before reheating for heat treatment, forgings are allowed to cool in a manner to prevent injury and to accomplish transformation.

### 5.5.3 Annealing

Forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

### 5.5.4 Normalizing

Forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air. Water sprays and air blasts may be specially approved for use with Grade A7 and A8 forgings to achieve more rapid cooling. The faster cooling rates are to be agreed to by the purchaser.

### 5.5.5 Tempering

Forgings are to be reheated to and held at the proper temperature, which is to be below the transformation range but above the minimum temperature in 2-3-7/5.5.1, and are then to be cooled at a rate not exceeding 100°F (55°C) per hour until temperature below 315°C (600°F) is reached.

### 5.5.6 Stress Relieving

Where heat treatment for mechanical properties is carried out before final machining, the forgings are to be stress relieved at a temperature not more than 55°C (100°F) below the previous tempering temperature, but in no case less than 550°C (1025°F). The cooling rate is not to exceed 55°C (100°F) per hour until a temperature below 315°C (600°F) is reached. Stress relieving may be used to augment tempering, in order to make final adjustments to the mechanical properties. If the stress relief temperature is within 14°C (25°F) of the final tempering temperature or higher for

quenched and tempered steel, mechanical tests are to be made to assure that these temperatures have not adversely affected the mechanical properties of the steel.

**5.5.7 Retreatment**

The manufacturer may re-heat treat the forging, but not more than three additional times.

**5.7 Mechanical Properties**

**5.7.1 Tensile Properties**

The forging tensile properties are to conform to the requirements of 2-3-7/7.17 TABLE 6.

**5.7.2 Hardness**

Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested to meet the following requirements. The variation in hardness of any forging is not to exceed 30 Brinell Hardness numbers.

<i>ABS Grade</i>	<i>Hardness, BHN, (10 mm dia. ball, 3000 kg load)</i>
A7	163 to 207
A8	223 to 262
A9	223 to 262
A10	248 to 293

**5.7.3 Charpy Impact (2005)**

Charpy V-notch impact testing is not required for applications where the service design temperature is 0°C (32°F) and above.

**5.7.4 Thermal Stability Test (2005)**

The thermal stability test is not required for applications where the service design temperature is 0°C (32°F) and above.

**5.9 Test Specimens**

**5.9.1 Location and Orientation of Specimens**

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or may be taken in a radial direction, as indicated by the ductility requirements in 2-3-7/7.17 TABLE 6. The axes of the specimens are to be located at any point midway between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings. In the cases of sleeves, couplings and nut forgings, the test specimen location and orientation are specified in 2-3-7/5.9.3(d).

**5.9.2 Identification of Specimens (2015)**

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/tank (for Q & T forgings).

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

### 5.9.3 Tension Tests

#### 5.9.3(a) Large Forgings.

In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

#### 5.9.3(b) Intermediate-Sized Forgings.

In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test is to be taken from each forging.

#### 5.9.3(c) Small Forgings (2017).

In the case of small normalized forgings with weight at time of heat treatment less than 1000 kg (2200 lb) and quenched and tempered forgings with weight at time of heat treatment less than 500 kg (1100 lb), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The total mass of the furnace charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

#### 5.9.3(d) Sleeves, Couplings and Nut Forgings.

In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the tension test is to be taken from a full-size prolongation left on one end of each individual forging. Test specimens are to be in a longitudinal orientation at mid-wall of the ring or cylinder as close as practical to the end of the rough machined surface of the forging.

#### 5.9.3(e) Continuous Heat treatment (2017).

Whereby a furnace incorporates a method of controlled moving of the component from the charging end, through the furnace at a predetermined temperature and time, to the discharging end. Test coupon sampling procedures are to be specially agreed with the ABS Materials Department.

### 5.9.4 Hardness

#### 5.9.4(a) Large, Intermediate and Small Sized Forgings.

Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested to meet the requirements of 2-3-7/5.7.2. The forging is to be tested at locations 180 degrees apart on each end.

#### 5.9.4(b) Sleeves, Couplings and Nut Forgings.

In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, Brinell hardness tests are to be taken at approximately  $\frac{1}{4}$  of the radial thickness from the outside diameter and in accordance with the following frequency and locations:

<i>Outside Diameter, cm. (in.)</i>	<i>Number of Hardness Tests</i>
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart

## 5.11 Examination (2008)

After final heat treatment, all forgings are to be examined, in accordance with 2-3-7/1.13, by the Surveyor and found free from defects. The finish is to be free of cracks, seams, laps, cold shuts, laminations, shrinkage and burst indications.

### 5.11.1 Surface Inspection of Tail Shaft Forgings

All tail shaft forgings are to be subjected to a nondestructive examination such as magnetic particle, dye penetrant or other nondestructive method. Discontinuities are to be removed to the satisfaction of the Surveyor. (See 4-3-2/3.7.3 of the *ABS Rules for Building and Classing Marine Vessels* for surface inspection requirements in finished machined condition.)

### 5.11.2 Ultrasonic Examination of Tail Shaft Forgings

Forgings for tail shafts 455 mm (18 in) and over in finished diameter are to be ultrasonically examined to the satisfaction of the attending Surveyor. Conformity with Section 7-A1-12, "Ultrasonic Examination of Carbon Steel Forgings of Tail Shafts" of the *ABS Rules for Survey After Construction (Part 7)*, or equivalent, will be considered to meet this requirement.

## 5.13 Rectification of Defective Forgings (2005)

Rectification of defects is to be carried out in accordance with 2-3-7/1.15.

## 5.15 Certification (2005)

The manufacturer is to provide the required type of inspection certificate, in accordance with 2-3-7/1.17.

# 7 General Shipboard Alloy Steel Forgings (2000)

## 7.1 Process of Manufacture

### 7.1.1 General (2017)

The following requirements cover alloy steel forgings intended to be used for general shipboard applications. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by ABS.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

Raw materials for forging such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS. Steel is to be fully killed and is to be manufactured by a process approved by ABS.

The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is

initially upset, this reference area may be taken as the average cross-sectional area after this operation.

Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where  $L > D$  and 1.5:1 where  $L \leq D$ .
- For forgings made from rolled products, 4:1 where  $L > D$  and 2:1 where  $L \leq D$ .
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.
- For rolled bars used in lieu of forgings, 6:1.

$L$  and  $D$  are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation. The forging process is to have ample power to adequately flow the metal within the maximum cross-section of the forging.

### 7.1.2 Chemical Composition (2005)

All forgings are to be made from killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-7/7.17 TABLE 7. The analysis is to be carried out with a coupon cast during the pouring of the heat.

### 7.1.3 ASTM Designations

The grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
A11	A668 Class J
A12	A668 Class K
A13	A668 Class L
A14	A668 Class M
A15	A668 Class N

## 7.3 Marking, Retests and Rejection

### 7.3.1 Marking (2005)

The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the forgings, when required.

In addition to appropriate identification markings of the manufacturer, ABS markings, indicating satisfactory compliance with the Rule requirements and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernible after machining and installation. In addition, Grade A11 through Grade A15 forgings are to be stamped **AB/A11**, **AB/A12**, **AB/A13**, **AB/A14** and **AB/A15**, respectively.

### 7.3.2 Retests (2005)

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with 2-3-1/9 or 2-1-2/11.7. If



satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with 2-3-7/7.5.6. After re-heat treating, the forgings are to be submitted for all mechanical testing.

### 7.3.3 Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

## 7.5 Heat Treatment

### 7.5.1 General (2017)

Heat treatment facilities used in producing ABS certified forgings are to be included in the forge approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Heat treatment details are to be included in the approval documentation.

Forge qualification is to include all of the heat treatment facilities that the forge will use.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

Unless a departure from the following procedures is specifically approved, Grade A11 forgings are to be normalized and tempered, or normalized, quenched and tempered. Grades A12, A13, A14 and A15 forgings are to be normalized, quenched and tempered. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

### 7.5.2 Cooling Prior to Heat Treatment (2016)

After forging and before reheating for heat treatment, forgings are allowed to cool in a manner to prevent injury and to accomplish transformation.

### 7.5.3 Annealing

Forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

### 7.5.4 Normalizing

Forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air. Water sprays and air blasts may be specially approved for use to achieve more rapid cooling. The faster cooling rates are to be agreed by the purchaser.

### 7.5.5 Tempering

Forgings are to be reheated to and held at the proper temperature, which will be below the transformation range, and are then to be cooled under suitable conditions to 315°C (600°F) or lower.

### 7.5.6 Retreatment

The manufacturer may re-heat treat the forging, but not more than three additional times.

## 7.7 Mechanical Properties

### 7.7.1 Tensile Properties

The forging tensile properties are to conform to the requirements of 2-3-7/7.17 TABLE 8.

### 7.7.2 Hardness

Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the following requirements. The variation in hardness of Grade A11 forgings is not to exceed 40 Brinell Hardness numbers. The variation in hardness of Grades A12 forgings through A15 forgings is not to exceed 50 Brinell Hardness numbers.

<i>ABS Grade</i>	<i>Size, in mm. (in.)</i>	<i>Hardness, BHN, (10 mm dia. ball, 3000 kg load)</i>
A11	≤180 (7) > 180 (7), ≤255 (10) > 255 (10), ≤510 (20)	197 to 255 187 to 235 187 to 255
A12	≤180 (7) > 180 (7), ≤510 (20)	212 to 269 207 to 269
A13	≤100 (4) > 100 (4), ≤180 (7) > 180 (7), ≤510 (20)	255 to 321 235 to 302 223 to 293
A14	≤100 (4) > 100 (4), ≤180 (7) > 180 (7), ≤255 (10) > 255 (10), ≤510 (20)	293 to 352 285 to 341 269 to 331 269 to 341
A15	≤180 (7) > 180 (7), ≤255 (10) > 255 (10), ≤510 (20)	331 to 401 321 to 388 321 to 402

## 7.9 Mechanical Testing

### 7.9.1 Location and Orientation of Specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The length of the prolongation is to be such that the distance from the test specimen mid-gauge to the end of the prolongation is to be 89 mm (3.5 in.) or one-half the forging section thickness or diameter, whichever is less. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or tangential to that direction, as indicated by the ductility requirements in 2-3-7/7.17 TABLE 8. The axes of the specimens are to be located at any point midway between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings.

### 7.9.2 Hollow-drilled Specimens

In lieu of prolongations, the test specimens may be taken from forgings submitted for each test lot; or if satisfactory to the Surveyor, test specimens may be taken from forgings with a hollow drill.

### 7.9.3 Very Small Forgings

In the cases of very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for test. In such cases, the special forgings should be subjected to the same amount of working and reduction as the forgings represented and should be heat-treated with those forgings.

### 7.9.4 Identification of Specimens (2015)

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/tank (for Q & T forgings).

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

## 7.11 Number and Location of Tests

### 7.11.1 Tension Tests

#### 7.11.1(a) Large Forgings.

In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

#### 7.11.1(b) Intermediate-Sized Forgings.

In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test is to be taken from each forging.

#### 7.11.1(c) Small Forgings (2017).

In the case of small normalized forgings with weight at time of heat treatment less than 1000 kg (2200 lb) and quenched and tempered forgings with weight at time of heat treatment less than 500 kg (1100 lb), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The total mass of the furnace

charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

*7.11.1(d) Sleeves, Couplings and Nut Forgings.*

In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the tension test is to be taken from a full-size prolongation left on one end of each individual forging. Test specimens are to be in a longitudinal orientation at mid-wall of the ring or cylinder as close as practical to the end of the rough machined surface of the forging.

*7.11.1(e) Continuous Heat Treatment (2017).*

Whereby a furnace incorporates a method of controlled moving of the component from the charging end, through the furnace at a predetermined temperature and time, to the discharging end. Test coupon sampling procedures are to be specially agreed with the ABS Materials Department.

**7.11.2 Hardness Tests**

*7.11.2(a) Large, Intermediate and Small Sized Forgings.*

Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested to meet the requirements of 2-3-7/7.7.2. Forgings are to be tested at locations 180 degrees apart on each end.

*7.11.2(b) Discs, Rings and Hollow Forgings.*

Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested to meet the requirements of 2-3-7/7.7.2. Forgings are to be tested at the approximate mid-radius and 180 degrees apart on each flat surface of the forging; the testing locations on opposite sides are to be offset by 90 degrees.

*7.11.2(c) Very Small Forgings.*

In cases involving very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, the hardness tests may be made from broken tension test specimens, or on a special forging representing the lot; see 2-3-7/7.9.3.

**7.13 Examination (2008)**

After final heat treatment, all forgings are to be examined, in accordance with 2-3-7/1.13, by the Surveyor and found free from defects. The finish is to be free of scale, cracks, seams, laps, fins, cold shuts, laminations, nicks, gouges, pipe, shrinkage, porosity and burst indications.

**7.15 Rectification of Defective Forgings (2005)**

Rectification of defects is to be carried out in accordance with 2-3-7/1.15.

**7.17 Certification (2005)**

The manufacturer is to provide the required type of inspection certificate, in accordance with 2-3-7/1.17.

**TABLE 1**  
**Chemical Composition Requirements for**  
**Carbon Steel Machinery Forgings <sup>(1)</sup>, in percent (2013)**

<i>Element</i>	<i>Grade 2</i>	<i>Grade 3</i>	<i>Grade 4</i>	<i>Grade 4C</i>
Carbon	0.23 <sup>(2)</sup>	0.23 <sup>(2)</sup>	0.23 <sup>(2)</sup>	0.36 to 0.55
Manganese	0.30 - 1.50	0.30 - 1.50	0.30 - 1.50	0.30 - 1.35

Element	Grade 2	Grade 3	Grade 4	Grade 4C
Silicon <sup>(3)</sup>	0.10 - 0.45	0.10 - 0.45	0.10 - 0.45	0.10 - 0.45
Sulfur	0.035	0.035	0.035	0.035
Phosphorus	0.035	0.035	0.035	0.035

Note:

- Single values are maxima, unless noted.
- (2013) The carbon content may be increased above this level, provided that the carbon equivalent (C<sub>eq</sub>) is not more than 0.41 %, as calculated using the following formula:  

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} (\%)$$
- Silicon minimum is applicable if the steel is silicon killed.

**TABLE 2**  
**Tensile Property Requirements<sup>(1)</sup>**  
**for Carbon-steel Machinery Forgings (2013)**

Grade	Size, in mm (in)	Tensile Strength <sup>(2)</sup> in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Yield Strength <sup>(3)</sup> in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Longitudinal <sup>(4)</sup>			Tangential <sup>(4)</sup>		
				Elongation <sup>(5)</sup> , in percent		RA, in percent	Elongation <sup>(5)</sup> , in percent		RA, in percent
				Gauge Length			Gauge Length		
				4d	5d	4d	5d		
2	≤300 (12)	415 (42, 60)	205 (21, 30)	25	23	38	20	18	29
	> 300 (12)	415 (42, 60)	205 (21, 30)	24	22	36			
3	≤200 (8)	515 (53, 75)	260 (26.5, 37.5)	24	22	40	18	16	28
	> 200 (8)	515 (53, 75)	260 (26.5, 37.5)	22	20	35			
	≤300 (12)			20	18	32			
	> 300 (12)	> 500 (20)	515 (53, 75)	260 (26.5, 37.5)	19	17			
4, 4C <sup>(6)</sup>	≤ 500 (20)	570 (58.5, 83)	295 (30.5, 43)	20	18	35	17	16	27

*Notes:*

- 1 All tensile property requirements are minima, unless indicated.
  - 2 In the case of large forgings requiring two tension tests, the range of tensile strength is not to exceed 70 N/mm<sup>2</sup> (7 kgf/mm<sup>2</sup>, 10000 psi).
  - 3 Yield strength is determined by the 0.2% offset method.
  - 4 When tangential specimens are taken from wheels, rings, rims, discs, etc. in which the major final hot working is in the tangential direction, the tension test results are to meet the requirements for longitudinal specimens.
  - 5 Elongation gauge length is 50 mm (2 in); see 2-3-1/11.13 FIGURE 2.
  - 6 (2013) Size over 500 mm (20 in.) will be specially considered.
- RA = Reduction of Area

**TABLE 3**  
**Chemical Composition Requirements for**  
**Alloy Steel Gear Assembly Forgings <sup>(1)</sup>, in percent**

<i>Element</i>	<i>Grade A1</i>	<i>Grade A2</i>	<i>Grades A3, A4, A5 and A6</i>
<i>Carbon</i>	0.50	0.45	0.35 to 0.50
<i>Manganese</i>	0.40 to 0.90	0.40 to 0.90	0.40 to 0.90
<i>Silicon</i> <sup>(2)</sup>	0.35	0.35	0.35
<i>Sulfur</i>	0.040	0.040	0.040
<i>Phosphorus</i>	0.040	0.040	0.040
<i>Nickel</i>	Note 3	0.50	1.65 min.
<i>Chromium</i>	Note 3	1.25	0.60 min.
<i>Molybdenum</i>	Note 3	0.15 min.	0.20 to 0.60
<i>Copper</i>	0.35	0.35	0.35
<i>Vanadium</i>	0.10	0.50	0.10

*Notes:*

- 1 Single values are maxima, unless noted.
- 2 If the steel is vacuum-carbon deoxidized, the silicon content is to be 0.10 maximum.
- 3 The nickel, chromium and molybdenum contents are to be specially approved.

**TABLE 4**  
**Tensile Property Requirements for**  
**Alloy Steel Gear Assembly Forgings <sup>(1)</sup> (2008)**

Grade	Diameter, in mm (in)	Tensile Strength in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Yield Strength <sup>(2)</sup> in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Longitudinal			Tangential		
				Elongation <sup>(3)</sup> , in percent		RA, in percent	Elongation <sup>(3)</sup> , in percent		RA, in percent
				Gauge Length			Gauge Length		
				4d	5d	4d	5d		
A1	≤255 (10)	655 (67, 95)	485 (49, 70)	20	18	45	18	16	35
	> 255 (10) ≤510 (20)	655 (67, 95)	485 (49, 70)	20	18	45	19	16	34
	> 510 (20)	655 (67, 95)	485 (49, 70)	18	16	38	16	15	30
A2	≤255 (10)	725 (74, 105)	550 (56, 80)	19	17	45	17	16	34
	> 255 (10) ≤510 (20)	725 (74, 105)	550 (56, 80)	19	17	45	16	15	32
	> 510 (20)	725 (74, 105)	550 (56, 80)	18	16	38	14	13	30
A3	≤255 (10)	825 (84, 120)	655 (67, 95)	16	15	40	13	12	32
	> 255 (10) ≤510 (20)	825 (84, 120)	655 (67, 95)	14	13	35	12	11	30
	> 510 (20)	795 (81, 115)	620 (63, 90)	13	12	33	10	9	25
A4	≤255 (10)	965 (98, 140)	795 (81, 115)	16	15	40	14	13	35
	> 255 (10) ≤510 (20)	930 (95, 135)	760 (77, 110)	14	13	35	12	11	30
	> 510 (20)	895 (91, 130)	725 (74, 105)	12	11	30	10	9	25
A5	≤255 (10)	1000 (102, 145)	825 (84, 120)	15	14	40	13	12	35
	> 255 (10) ≤510 (20)	965 (98, 140)	795 (81, 115)	14	13	35	12	11	30
	> 510 (20)	930 (95, 135)	760 (77, 110)	12	11	30	10	9	25

Grade	Diameter, in mm (in)	Tensile Strength in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Yield Strength <sup>(2)</sup> in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Longitudinal			Tangential		
				Elongation <sup>(3)</sup> , in percent		RA, in percent	Elongation <sup>(3)</sup> , in percent		RA, in percent
				Gauge Length			Gauge Length		
				4d	5d		4d	5d	
A6	≤255 (10)	1170 (120, 170)	965 (98, 140)	14	13	35	12	11	30
	> 255 (10) ≤510 (20)	1140 (116, 165)	930 (95, 135)	12	11	30	10	9	25
	> 510 (20)	1105 (112, 160)	895 (91, 130)	10	9	25	10	9	25

**Notes:**

- 1 All tensile property requirements are minima, unless indicated.
- 2 Yield strength is determined by the 0.2% offset method.
- 3 Elongation gauge length is 50 mm (2 in); see 2-3-1/11.13 FIGURE 2  
RA = Reduction of Area

**TABLE 5**  
**Chemical Composition Requirements for**  
**Alloy Steel Shaft and Stock Forgings<sup>(1)</sup>, in percent**

Element	Grade A7	Grade A8	Grades A9 and A10
Carbon	0.25	0.28	0.28
Manganese	0.20 to 0.60	0.20 to 0.60	0.20 to 0.60
Silicon	0.15 to 0.30 <sup>(2)</sup>	0.15 to 0.30 <sup>(2)</sup>	0.10 <sup>(3)</sup>
Sulfur	0.015	0.015	0.015
Phosphorus	0.012	0.012	0.012
Nickel	2.50 min.	2.50 min.	3.25 to 4.00
Chromium	0.75	0.75	1.25 to 2.00
Molybdenum	0.25 min.	0.25 min.	0.25 to 0.60
Vanadium	0.03 min.	0.03 min.	0.05 to 0.15
Antimony	Note 4	Note 4	Note 4

**Notes:**

- 1 Single values are maxima, unless noted.
- 2 If the steel is vacuum-carbon deoxidized, the silicon content is to be 0.10 maximum.
- 3 If the steel is vacuum arc remelted, the silicon content range may be 0.15% to 0.30%.
- 4 The antimony content is to be reported for information.



**TABLE 6**  
**Tensile Property Requirements for**  
**Alloy Steel Shaft and Stock Forgings <sup>(1)</sup> (2008)**

Grade	Tensile Strength, in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Yield Strength <sup>(2)</sup> , in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Yield Strength <sup>(3)</sup> , in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Longitudinal		Radial			
				Elongation <sup>(4)</sup> , in percent		RA, in percent	Elongation <sup>(4)</sup> , in percent		RA, in percent
				Gauge Length			Gauge Length		
				4d	5d	4d	5d		
A7	550 (56, 80)	415 (42, 60)	380 (39, 55)	22	20	50	20	18	50
A8	725 (74, 105)	620 (63, 90)	585 (60, 85)	17	16	45	16	15	40
A9	725 (74, 105) to 860 (88, 125)	620 (63, 90)	585 (60, 85)	18	16	52	17	16	50
A10	825 (84, 120) to 930 (95, 135)	690 (70, 100)	655 (67, 95)	18	16	52	17	16	50

**Notes:**

- 1 All tensile property requirements are minima, unless indicated.
  - 2 Yield strength is determined by the 0.2% offset method.
  - 3 Yield strength is determined by the 0.02% offset method.
  - 4 Elongation gauge length is 50 mm (2 in); see 2-3-1/11.13 FIGURE 2.
- RA = Reduction of Area

**TABLE 7**  
**Chemical Composition Requirements for**  
**General Shipboard Alloy Steel Forgings <sup>(1)</sup>, in percent**

Element	Grades A11, A12, A13, A14 and A15
Carbon	Note 2
Manganese	Note 2
Silicon <sup>(3)</sup>	0.10 min.
Sulfur	0.040
Phosphorus	0.040
Nickel	Note 2
Chromium	Note 2
Molybdenum	Note 2

<i>Element</i>	<i>Grades A11, A12, A13, A14 and A15</i>
Copper	Note 2
Vanadium	Note 2

**Notes:**

- 1 Single values are maxima, unless noted.
- 2 The indicate contents are to be reported.
- 3 Silicon minimum is applicable if the steel is silicon killed.

**TABLE 8  
 Tensile Property Requirements for  
 General Shipboard Alloy Steel Forgings <sup>(1)</sup> (2008)**

<i>Grade</i>	<i>Size, in mm (in)</i>	<i>Tensile Strength, in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Yield Strength (<sup>2</sup>), in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Longitudinal</i>			<i>Tangential</i>		
				<i>Elongation <sup>(3)</sup>, in percent</i>		<i>RA, in percent</i>	<i>Elongation <sup>(3)</sup>, in percent</i>		<i>RA, in percent</i>
				<i>Gauge Length</i>			<i>Gauge Length</i>		
				<i>4d</i>	<i>5d</i>	<i>4d</i>	<i>5d</i>		
A11	≤180 (7)	655 (67, 95)	485 (49, 70)	20	18	50	18	16	40
	> 180 (7) ≤255 (10)	620 (63, 90)	450 (46, 65)	20	18	50	18	16	40
	> 255 (10) ≤510 (20)	620 (63, 90)	450 (46, 65)	18	16	48	16	15	40
A12	≤180 (7)	725 (74, 105)	550 (56, 80)	20	18	50	18	16	40
	> 180 (7) ≤255 (10)	690 (70, 100)	515 (53, 75)	19	17	50	17	16	40
	> 255 (10) ≤510 (20)	690 (70, 100)	515 (53, 75)	18	16	48	16	15	40
A13	≤100 (4)	860 (88, 125)	725 (74, 105)	16	15	50	14	13	40
	> 100 (4) ≤180 (7)	795 (81, 115)	655 (67, 95)	16	15	45	14	13	35
	> 180 (7) ≤255 (10)	760 (77, 110)	585 (60, 85)	16	15	45	14	13	35
	> 255 (10) ≤510 (20)	760 (77, 110)	585 (60, 85)	14	13	40	12	11	30

Grade	Size, in mm (in)	Tensile Strength, in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Yield Strength <sup>(2)</sup> , in N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Longitudinal			Tangential		
				Elongation <sup>(3)</sup> , in percent		RA, in percent	Elongation <sup>(3)</sup> , in percent		RA, in percent
				Gauge Length			Gauge Length		
				4d	5d		4d	5d	
A14	≤100 (4)	1000 (102, 145)	825 (84, 120)	15	14	45	13	12	35
	> 100 (4) ≤180 (7)	965 (98, 140)	795 (81, 115)	14	13	40	12	11	30
	> 180 (7) ≤255 (10)	930 (95, 135)	760 (77, 110)	13	12	40	12	11	30
	> 255 (10) ≤510 (20)	930 (95, 135)	760 (77, 110)	12	11	38	11	10	30
A15	≤100 (4)	1170 (120, 170)	965 (98, 140)	13	12	40	11	10	30
	> 100 (4) ≤180 (7)	1140 (116, 165)	930 (95, 135)	12	11	35	11	10	30
	> 180 (7) ≤255 (10)	1105 (112, 160)	895 (91, 130)	11	10	35	10	9	28
	> 255 (10) ≤510 (20)	1105 (112, 160)	895 (91, 130)	11	10	35	10	9	28

**Notes:**

- 1 All tensile property requirements are minima, unless indicated.
- 2 Yield strength is determined by the 0.2% offset method.
- 3 Elongation gauge length is 50 mm (2 in); see 2-3-1/11.13 FIGURE 2  
RA = Reduction of Area

**1 Hot-rolled Steel Bars (2018)**

Hot-rolled steel bars up to and including 305 mm (12 in.) diameter, presented for inspection after special approval for each specific application, are to be made by one or more of the following processes: open hearth, basic-oxygen, electric-furnace or such other process as may be approved. Hot rolled bars are to be made by a manufacturer approved by ABS. ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of bar production. Raw materials for rolled bar manufacturers such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS.

Hot-rolled bars used in lieu of carbon-steel forgings (see Section 2-3-7) are to be fully killed, heat treated in accordance with 2-3-7/1.5, and the cross-sectional area of the unmachined finished bar is not to exceed one-sixth of the cross-sectional area of the ingot. In addition, hot-rolled bars used in lieu of forgings for tail shafts are to meet the nondestructive examination requirements of 2-3-7/1.13.1. The tensile properties are to meet the requirements of 2-3-7/1.7 for the proposed application.

**3 Number of Tests**

Four tension tests are to be taken from each lot of material exceeding 907 kg (2000 lb) in weight. When the weight of a lot is 907 kg (2000 lb) or less, two tension tests may be taken. In any case, only one tension test will be required from any one bar. A lot is to consist of bars from the same heat; if the bars are heat-treated, then a lot is to consist of bars from the same heat which have been heat-treated in the same furnace charge. If the bars in a lot differ 9.5 mm (0.375 in.) or more in diameter, the test specimens taken are to be representative of the greatest and least diameter bar

**1 General****1.1 Process of Manufacture (2012)**

The following requirements cover carbon-steel castings intended to be used in machinery, boiler and pressure-vessel construction, such as crankshafts, turbine casings and bedplates. For other applications, additional requirements may be necessary, especially when the castings are intended for service at low temperatures. Castings which comply with national or proprietary specifications may also be accepted, provided such specifications give reasonable equivalence to these requirements. None of the above preclude the use of alloy steels in accordance with the permissibility expressed in 2-3-1/1. The steel is to be manufactured by a process approved by ABS.

Castings are to be made by a manufacturer approved by ABS. ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection. Thermal cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.

When two or more castings are joined by welding to form a composite component, the proposed welding procedure is to be submitted for approval and welding is to be carried out to the satisfaction of the attending Surveyor.

Sulfur and phosphorous contents are to be less than 0.040% and silicon less than 0.60%.

For welded construction, the maximum carbon content is to be 0.23%.

**1.3 ASTM Designations (2005)**

The various Grades are in substantial agreement with ASTM, as follows and, in addition, the requirements of this Section apply:

<i>ABS Grade</i>	<i>ASTM Designation</i>
1	A27, Grade 60-30
2	A27, Grade 70-36
3	A216, Grade WCA
4	A216, Grade WCB

### 3 Marking and Retests

#### 3.1 Marking (2005)

The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the castings when required.

The manufacturer's name or identification mark and pattern number is to be cast on all castings, except those of such small size as to make this type of marking impracticable. The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor is to be stamped on all castings accepted in such location as to be discernible after machining and installation. Grade 1, 2, 3 and 4 castings are to be stamped **AB/1**, **AB/2**, **AB/3** and **AB/4**, respectively. In addition, identification numbers of the heats used for pouring the castings are to be stamped on all castings individually weighing 227 kg (500 lb) or more.

#### 3.3 Retests (2005)

If the results of the physical tests for any casting or any lot of castings do not conform to the requirements specified, the manufacturer may reheat-treat castings or lots of castings that have failed to meet test requirements. Two additional test samples representative of the casting or casting batch may be taken. If satisfactory results are obtained from both of the additional tests, the casting or batch of castings is acceptable. If one or both retests fail, the casting or batch of castings is to be rejected.

### 5 Heat Treatment (2017)

Heat treatment facilities used in producing ABS certified castings are to be included in the foundry approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of foundry approval.

Heat treatment details are to be included in the approval documentation.

Foundry qualification is to include all of the heat treatment facilities that the foundry will use.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

Except in cases specifically approved otherwise, all castings are to be either fully annealed, normalized or normalized and tempered in a furnace of ample proportions to bring the whole casting to uniform

temperature above the transformation range on the annealing or normalizing cycle. The furnaces are to be maintained and have adequate means for control and recording temperature. Castings are to be held soaking at the proper temperature for at least a length of time equivalent to one hour per 25.5 mm (1 in.) of thickness of the heaviest member. No annealed casting is to be removed from the furnace until the temperature of the entire furnace charge has fallen to or below a temperature of 455°C (850°F). A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals. Tempering is to be carried out at a temperature of not less than 550°C (1022°F).

Local heating or cooling and bending and straightening of annealed castings are not permitted, except with the express sanction of the Surveyor.

The foundry is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

## 7 Tensile Properties (2008)

Steel castings are to conform to the following requirements as to tensile properties.

ABS Grade	Tensile Strength, Min., N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , psi)	Yield Point/ Yield Strength, Min., N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , psi)	Elongation Min., %		Reduction of Area Min%
			Gauge Length		
			4d	5d	
1	415 (42, 60000)	205 (21.0, 30000)	24	22	35
2	485 (49, 70000)	250 (25.5, 36000)	22	20	30
3	415 (42, 60000)	205 (21.0, 30000)	24	22	35
4	485 (49, 70000)	250 (25.5, 36000)	22	20	35

## 9 Application

### 9.1 General and High-temperature Applications

Any of the above grades may be used for miscellaneous applications. Grade 3 or Grade 4 castings are to be used for boiler mountings, valves, fittings and for pressure parts of boilers and other pressure vessels where the temperature does not exceed 427°C (800°F). See 4-6-2/3.1.3 of the ABS *Rules for Building and Classing Marine Vessels*.

### 9.3 Propeller and Forging Applications

Any of the above grades may be used for propellers and for castings which have been approved to take the place of forgings.

### 9.5 Alloy Steels or Special Carbon Steels

When alloy steels or carbon steels differing from the requirements of 2-3-9/7 are proposed for any purpose, the purchaser's specification shall be submitted for approval in connection with the approval of the design for which the material is proposed. Specifications such as ASTM A356 or A217 Grades WC1, WC6, or WC9, or other steels suitable for the intended service will be considered.

## 11 Test Specimens

### 11.1 Material Coupons (2016)

Castings and test material are to be heat treated together in the same furnace, and quenched in the same bath/tank (for Q & T forgings).

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each casting. The physical properties are to be determined from test specimens prepared from coupons which, except as specified in 2-3-9/11.3, are to be cast integral with the casting to be inspected. When this is impracticable, the coupons may be cast with and gated to the casting and are to have a thickness of not less than the critical controlling cross section thickness of the casting or 30 mm (1.2 in.), whichever is greater. In any case, these coupons are not to be detached until the heat treatment of the castings has been completed, nor until the coupons have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

Where the casting finished mass exceeds 10,000 kg (22,000 lb) or is of complex design, two test samples are to be provided. Where large castings are made from two or more casts which are not from the same pour, two or more test samples are to be provided, corresponding to the number of casts involved. The samples are to be integrally cast at locations as widely separated as possible.

*Note:*

Controlling cross section thickness is the diameter of the largest theoretical sphere which can be inscribed within the volume of the casting.

### 11.3 Separately Cast Coupons

In the case of small castings having an estimated weight of less than 907 kg (2000 lb), each of the coupons may be cast separately, provided the Surveyor is furnished an affidavit by the manufacturer stating that the separately cast coupons were cast from the same heat as the castings represented and that they were heat-treated with the castings.

## 13 Number of Tests

### 13.1 Machinery Castings (2005)

At least one tension test is to be made from each heat in each heat-treatment charge except where two or more samples are required as indicated in 2-3-9/11.1. If the manufacturer's quality-control procedure includes satisfactory automatic chart recording of temperature and time, then one tension test from each heat for castings subject to the same heat-treating procedure may be allowed at the discretion of the attending Surveyor.

### 13.3 Steel Propeller Castings

One tension test is to be made from each blade of a built-up propeller, and for solid propellers there is to be one tension test from each of two opposite blades when the propeller is over 2130 mm (7 ft) in diameter and one tension test from one of the blades when the diameter of the propeller is 2130 mm (7 ft) or smaller.

## 15 Inspection and Repair

### 15.1 General (2008)

All castings are to be examined by the Surveyor after final heat treatment and thorough cleaning to ensure that the castings are free from defects. Where applicable internal surfaces are to be inspected, surfaces are not to be hammered or peened or treated in any way which may obscure defects.



In the event of a casting proving to be defective during subsequent machining or testing, it is to be rejected, notwithstanding any previous certification.

The manufacturer is to verify that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer's recorded dimensions.

When required by the relevant construction Rules, castings are to be pressure tested before final acceptance. The tests are to be carried out in the presence and to the satisfaction of the attending Surveyor.

### 15.3 Minor Defects (2006)

Defects are to be considered minor when the cavity prepared for welding has a depth not greater than 20% of the actual wall thickness, but in no case greater than 25 mm (1 in.), and has no lineal dimension greater than four times the wall thickness nor greater than 150 mm (6 in.). Shallow grooves or depressions resulting from the removal of defects may be accepted, provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT. Repairs of minor defects where welding is required are to be treated as weld repairs and repaired in accordance with an approved procedure. Minor defects in critical locations are to be treated as, and repaired in the same manner as, major defects.

### 15.5 Major Defects

Defects other than minor defects with dimensions greater than those given in 2-3-9/15.3 above, may, with the Surveyor's approval, be repaired by welding using an approved procedure.

### 15.7 Welded Repair (2018)

After it has been agreed that a casting can be repaired by welding, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

Weld procedures for all types of welds are to be appropriately qualified to the satisfaction of the attending Surveyor.

Before undertaking the repair welding of castings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work intended.

Removal of defects and weld repair are to be carried out in accordance with a recognized standard. See Part 2, Appendix 6. The defects are to be removed to sound metal, and before welding, the excavation is to be investigated by suitable approved, nondestructive examination methods to ensure that the defect has been removed. In the case of repair of major defects, welding is not permitted on unheat-treated castings. Corrective welding is to be associated with the use of preheat.

Temporary welds made for operations such as lifting, handling, staging, etc., are to be carried out to qualified welding procedures and qualified welders/operators and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

### 15.9 Postweld-repair Heat Treatment (2012)

All welded repairs of defects are to be given a suitable postweld heat treatment, as indicated in 2-3-9/5, or subject to the prior agreement of the ABS materials department consideration may be given to the acceptance of a local stress relieving heat treatment at a temperature of not less than 550°C (1022°F). The heat treatment employed will be dependent on the chemical composition of the casting, the casting and repair weld dimensions, and the position of the repairs. The extent of weld repair is to be in accordance with 2-1-5/13.

On completion of heat treatment, the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography may also be required, depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of nondestructive testing used.

The manufacturer is to maintain full records detailing the extent and location of minor and major repairs made to each casting and details of weld procedures and heat treatments applied. These records are to be available to the Surveyor and copies provided on request.

#### **15.11 Crankshaft Castings (2005)**

The foregoing provisions may not apply in their entirety to the repair of crankshaft castings. In the case of repair of crankshaft castings, the applicable procedures and extent of repairs will be specially considered. All castings for crankshafts are to be suitably preheated prior to welding.

### **17 Nondestructive Testing (2005)**

When required by the relevant construction Rules or by the approved procedure for welded components, appropriate nondestructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria are to be agreed with ABS. Part 2, Appendix 6 is regarded as an example of an acceptable standard. Additional NDE is to be considered at chaplet locations and areas of expected defects.

### **19 Certification (2005)**

The manufacturer is to provide the required type of inspection certificate giving the following particulars for each casting or batch of castings which has been accepted:

- i)* Purchaser's name and order number
- ii)* Description of forgings and steel quality
- iii)* Identification number
- iv)* Steelmaking process, cast number and chemical analysis of ladle sample
- v)* Results of mechanical tests
- vi)* Results of nondestructive tests, where applicable
- vii)* Details of heat treatment, including temperature and holding times.
- viii)* Where applicable, test pressure.
- ix)* Specification

**1 Scope****1.1**

Important spheroidal or nodular graphite iron castings, as defined in the relevant construction Rules, are to be manufactured and tested in accordance with the requirements of this Section.

**1.3**

These requirements are applicable only to castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures.

**1.5**

Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by ABS.

**1.7**

Where small castings are produced in large quantities, the manufacturer may employ alternative procedures for testing and inspection subject to the approval of ABS.

**3 Manufacture****3.1 (2012)**

Ductile iron castings (for example, castings that are required to be certified per 4-2-1/15.11 TABLE 1 of the *Marine Vessel Rules*) are to be made at ABS-approved foundries where the manufacturer has demonstrated to the satisfaction of ABS that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection.

### 3.3

Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

### 3.5

Where castings of the same type are regularly produced in quantity, the manufacturer is to make tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

## 5 Quality of Casting

Castings are to be free from surface or internal defects which would prove detrimental to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved design.

## 7 Chemical Composition

The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings. The chemical composition of the ladle samples is to be reported to ABS.

## 9 Heat Treatment

### 9.1

Except as required by 2-3-10/9.3, castings may be supplied in either the as cast or heat-treated condition.

### 9.3

For applications such as high temperature service or where dimensional stability is important, it may be required that castings be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining. The materials in 2-3-10/13.7 TABLE 2 are to undergo a ferritizing heat treatment.

### 9.5

Where it is proposed to locally harden the surfaces of a casting, full details of the proposed procedure and specification are to be submitted for approval.

### 9.7 (2018)

Heat treatment facilities used in producing ABS certified castings are to be included in the foundry approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of foundry approval.

### 9.9 (2018)

Heat treatment details are to be included in the approval documentation.

### 9.11 (2018)

Foundry qualification is to include all of the heat treatment facilities that the foundry will use.

### 9.13 (2018)

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

**9.15 (2018)**

If additional facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

**9.17 (2018)**

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

**9.19 (2018)**

Temporary attachments for handling are to be cast integrally or threaded. Welding of temporary attachments is to be avoided.

**11 Mechanical Tests**

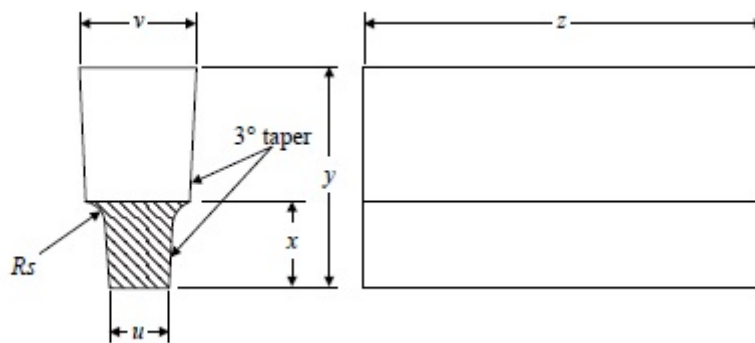
**11.1**

Test material, sufficient for the required tests and for possible re-test purposes, is to be provided for each casting or batch of castings.

**11.3**

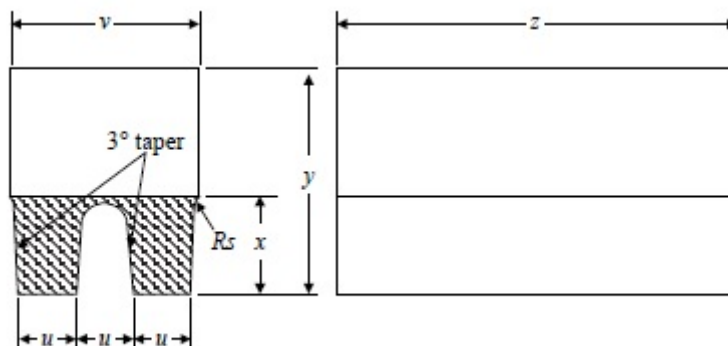
The test samples are generally to be one of the standard types detailed in 2-3-10/Figures.1, 2 and 3 with a thickness of 25 mm (1.0 in.). Test samples of other dimensions to 2-3-10/Figures 1, 2 and 3 may, however, be specially required for some components.

**FIGURE 1  
 Type A Test Samples (U-type)**



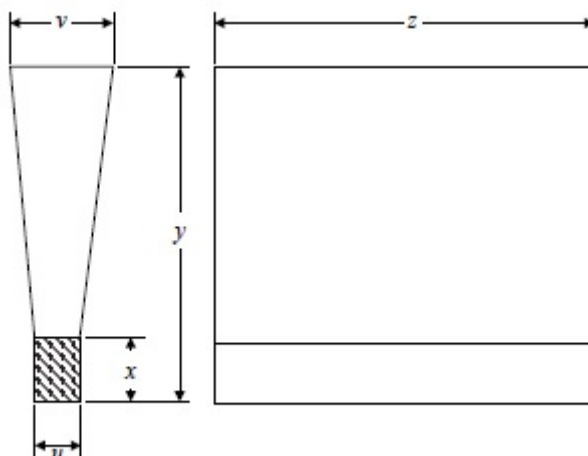
<i>Dimensions – mm (in.)</i>	<i>Standard Sample</i>	<i>Alternative Samples when Specially Required</i>		
<i>u</i>	25 (1.0)	12 (0.5)	50 (2.0)	75 (3.0)
<i>v</i>	55 (2.2)	40 (1.6)	90 (3.5)	125 (5.0)
<i>x</i>	40 (1.6)	30 (1.2)	60 (2.4)	65 (2.6)
<i>y</i>	100 (4.0)	80 (3.2)	150 (6.0)	165 (6.5)
<i>z</i>	To suit testing machine			
<i>Rs</i>	Approximately 5 mm (0.20 in.)			

**FIGURE 2**  
**Type B Test Samples (Double U-type)**



<i>Dimensions – mm (in.)</i>	<i>Standard Sample</i>
<i>u</i>	25 (1.0)
<i>v</i>	90 (3.5)
<i>x</i>	40 (1.6)
<i>y</i>	100 (4.0)
<i>z</i>	To suit testing machine
<i>Rs</i>	Approximately 5 mm (0.20 in.)

**FIGURE 3**  
**Type C Test Samples (Y-type)**



<i>Dimensions – mm (in.)</i>	<i>Standard Sample</i>	<i>Alternative Samples when Specially Required</i>		
<i>u</i>	25 (1.0)	12 (0.5)	50 (2.0)	75 (3.0)
<i>v</i>	55 (2.2)	40 (1.6)	100 (4.0)	125 (5.0)
<i>x</i>	40 (1.6)	25 (1.0)	50 (2.4)	65 (2.6)
<i>y</i>	140 (5.5)	135 (5.5)	150 (6.0)	175 (7.0)
<i>z</i>	To suit testing machine			
Min. thickness of mold surrounding test sample	40 (1.6)	40 (1.6)	80 (3.2)	80 (3.2)

**11.5**

At least one test sample is to be provided for each casting and, unless otherwise required, may be either gated to the casting or separately cast. Alternatively, test material of other suitable dimensions may be provided integral with the casting.

**11.7**

For large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.

**11.9 (2016)**

As an alternative to 2-3-10/11.5, a batch testing procedure may be adopted for castings with a fettled mass of 1,000 kg (2,200 lb) or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2,000 kg (4,400 lb) of fettled castings in the batch.

**11.11**

Where separately cast test samples are used, they are to be cast in molds made from the same type of material as used for the castings and are to be taken towards the end of pouring of the castings. The samples are not to be stripped from the molds until the temperature is below 500°C (930°F).

**11.13**

All test samples are to be suitably marked to identify them with the castings which they represent.

**11.15**

Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

**11.17**

One tensile specimen is to be prepared from each test sample and is to be machined to the dimensions given in 2-3-1/11.13 FIGURE 2. Note that for nodular cast iron with an elongation less than 10%, the radius  $R \geq 20$  mm (0.8 in.).

**11.19**

All tensile tests are to be carried out using test procedures in accordance with Section 2-3-1. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyor.

### 11.21

Impact tests may additionally be required. In such cases a set of three specimens of an agreed type is to be prepared from each sample. Where Charpy V-notch test specimens are used, the dimensions and testing procedures are to be in accordance with 2-1-1/16 FIGURE 4.

## 13 Mechanical Properties

### 13.1

2-3-10/Tables 1 and 2 give the minimum requirement for 0.2% proof stress and elongation corresponding to different strength levels. Typical Brinell hardness values are also given in 2-3-10/13.7 TABLE 1 and are intended for information purposes only.

### 13.3

Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in 2-3-10/13.7 TABLE 1, and any additional requirements of the relevant construction Rules.

### 13.5

Unless otherwise agreed, only the tensile strength and elongation need to be determined. The results of all tensile tests are to comply with the appropriate requirements of 2-3-10/13.7 TABLE 1.

### 13.7

When the tensile test fails to meet the requirements, two further tests may be made from the same piece. If both these additional tests are satisfactory, the item and/or batch (as applicable) is acceptable. If one or both of these tests fail, the item and/or batch is to be rejected.

The additional tests detailed above are to be taken preferably from material taken adjacent to the original tests, but alternatively from another test position or sample representative of the item/batch.

**TABLE 1**  
**Mechanical Properties for Spheroidal or Nodular Cast Iron**

<i>Specified minimum Tensile strength, N/mm<sup>2</sup> (ksi)</i>	<i>0.2% proof stress, N/mm<sup>2</sup> (ksi)</i>	<i>Elongation on <math>5.65\sqrt{S_0}</math> (%) min</i>	<i>Typical hardness (Brinell)</i>	<i>Typical structure of matrix</i>
370 (54)	230 (33)	17	120-180	Ferrite
400 (58)	250 (36)	12	140-200	Ferrite
500 (73)	320 (46)	7	170-240	Ferrite/Pearlite
600 (87)	370 (54)	3	190-270	Ferrite/Pearlite
700 (102)	420 (61)	2	230-300	Pearlite
800 (116)	480 (70)	2	250-350	Pearlite or tempered structure



**TABLE 2**  
**Mechanical Properties for Spheroidal or Nodular Cast Iron with Additional Charpy Requirements**

Specified minimum Tensile strength, N/mm <sup>2</sup> (ksi)	0.2% proof stress, N/mm <sup>2</sup> (ksi)	Elongation on 5.65√S <sub>0</sub> (%) min	Typical hardness (Brinell)	Impact energy test min values <sup>(3)</sup>		Typical structure of matrix
				Test temp.	Ave Joules	
350 (51)	220 (32)	22 <sup>(2)</sup>	110-170	+20	17 (14)	Ferrite
400 (58)	250 (36)	18 <sup>(2)</sup>	140-200	+20	14 (11)	Ferrite

Notes for tables 1 and 2:

- 1 Intermediate values for mechanical properties may be obtained by interpolation
- 2 In the case of integrally cast samples, the elongation may be 2 percentage points less.
- 3 The average value measured on three Charpy V-notch specimens. One result may be below the average value but not less than the minimum shown in parentheses.

## 15 Inspection

### 15.1

All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

### 15.3

All castings are to be visually examined by the Surveyor including, where applicable, the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer

### 15.5

Supplementary examination of castings by suitable nondestructive test procedures is generally not required unless otherwise stated on the approved plan or in circumstances where there is reason to suspect the soundness of the casting.

### 15.7

When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

### 15.9

In the event of any casting proving defective during subsequent machining or testing is to be rejected notwithstanding any previous certification.

### 15.11

Cast crankshafts are to be subjected to a magnetic particle inspection. Crack like indications are not allowed.

## 17 Metallographic Examination

### 17.1

For crankshafts, a metallographic examination is to be carried out.

### 17.3

When required, a representative sample from each ladle of treated metal is to be prepared for metallographic examination. These samples may be taken from the tensile test specimens but alternative arrangements for the provisions of the samples may be adopted provided that they are taken from the ladle towards the end of the casting period.

### 17.5

Examination of the samples is to show that at least 90% of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in 2-3-10/13.7 TABLE 1 and are intended for information purposes only.

## 19 Rectification of Defective Castings

### 19.1

At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

### 19.3

Subject to approval, castings containing local porosity may be rectified by impregnation with suitable plastic filler.

### 19.5

Repairs by welding are generally not permitted.

## 21 Identification of Castings

### 21.1

The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original ladle of treated metal and the Surveyor is to be given full facilities for tracing the castings when required.

### 21.3

Before acceptance, all castings, which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

- i)* Grade of cast iron
- ii)* Identification number or other marking enabling the full history of the casting to be traced.
- iii)* Manufacturer's name or trademark.
- iv)* Date of final inspection.
- v)* ABS office, initials or symbol.
- vi)* Personal stamp of Surveyor responsible for inspection
- vii)* Test pressure, if applicable

## 21.5

Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

## 23 Certification

### 23.1

The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casing or batch of castings which has been accepted:

- i)* Purchaser's name and order number
- ii)* Description of castings and quality of cast iron
- iii)* Identification number
- iv)* Results of mechanical tests
- v)* Where applicable, general details of heat treatment
- vi)* Where specifically required, the chemical analysis of the ladle samples
- vii)* Where applicable, test pressure



## PART 2

### CHAPTER 3

## Materials for Machinery, Boilers, Pressure Vessels, and Piping

### SECTION 11

## Gray-iron Castings (2006)

### 1 Scope

#### 1.1

Gray iron castings, as defined in the relevant construction rules, are to be manufactured and tested in accordance with the requirements of this Section.

#### 1.3

Alternatively, castings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by ABS.

#### 1.5

Where small castings are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of ABS.

### 3 Process of Manufacture

#### 3.1 (2012)

Gray iron castings (for example, castings that are required to be certified per 4-2-1/15.11 TABLE 1 of the *Marine Vessel Rules*) are to be made at ABS-approved foundries where the manufacturer has demonstrated to the satisfaction of ABS that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection.

#### 3.3

Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

### 3.5

Where castings of the same type are regularly produced in quantity, the manufacturer is to carry out tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

## 5 Quality of Castings

Castings are to be free from surface or internal defects, which would prove detrimental to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved design.

## 7 Chemical Composition

The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain mechanical properties specified for the castings. The composition of ladle sample is to be reported to ABS.

## 9 Heat Treatment

### 9.1

Except as required for 2-3-11/9.3, castings may be supplied in either the cast or heat treated condition.

### 9.3

For applications such as high temperature service or when dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment.

### 9.5 (2018)

Heat treatment facilities used in producing ABS certified castings are to be included in the foundry approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of foundry approval.

### 9.7 (2018)

Heat treatment details are to be included in the approval documentation.

### 9.9 (2018)

Foundry qualification is to include all of the heat treatment facilities that the foundry will use.

### 9.11 (2018)

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

### 9.13 (2018)

If additional facilities are selected to carry out heat treatment an ABS approval is to be obtained for the new facility.

### 9.15 (2018)

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

**9.17 (2018)**

Temporary attachments for handling are to be cast integrally or threaded. Welding of temporary attachments is to be avoided.

**11 Mechanical Tests**

**11.1**

Test material sufficient for the required tests and for possible re-tests is to be provided for each casting or batch of castings.

**11.3**

Separately cast test samples are to be used unless otherwise agreed between the manufacturer and purchaser, and are to be in the form of round bars 30 mm (1.2 in.) in diameter and of a suitable length. They are to be of cast iron from the same ladle as the castings in molds of the same type of material as the molds for the castings and are not to be stripped from the molds until the metal temperature is below 500°C (930°F). When two or more test samples are cast simultaneously in a single mold, the bars are to be at least 50 mm (2.0 in.) apart.

**11.5**

Integrally cast samples may be used when a casting is more than 20 mm (0.8 in.) thick and its mass exceeds 200 kg (440 lb), subject to agreement between the manufacturer and the purchaser. The type and location of the sample are to be selected to provide approximately the same cooling conditions as for the casting it represents and also subject to agreement.

**11.7**

With the exception of 2-3-11/11.13, at least one test sample is to be cast with each batch.

**11.9**

With the exception of 2-3-11/11.11, a batch consists of the castings poured from a single ladle of metal, provided that they are all of similar type and dimensions. A batch should not normally exceed 2,000 kg (4,400 lbs) of fettled castings and a single casting will constitute a batch if its mass is 2,000 kg (4,400 lbs) or more.

**11.11**

For large mass casting of the same grade, produced by continuous melting, the batch weight may be taken as the weight of casting produced in two hours of pouring. The pouring rate is not to be accelerated beyond the capacity of the caster.

**11.13**

If one grade of cast iron is melted in large quantities and production is monitored by systematic checking of the melting process, such as a chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals, as agreed by the Surveyor.

**11.15**

All test samples are to be suitably marked to identify them with the castings which they represent.

**11.17**

Where castings are supplied in the heat-treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on-test samples, the sample shall not be removed from the casting until after the heat treatment.

### 11.19

One tensile test specimen is to be prepared from each test sample. 30 mm (1.2 in.) diameter samples are to be machined to the dimensions given in 2-3-1/11.13 FIGURE 3. Where test samples of other dimensions are specially required, the tensile test specimens are to be machined to agreed dimensions.

### 11.21

All tensile tests are to be carried out using test procedures in accordance with Section 2-3-1. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyor.

## 13 Mechanical Properties

### 13.1 Tensile Strength

#### 13.1.1

The tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. The value selected for the specified minimum tensile strength is not to be less than 200 N/mm<sup>2</sup> (29.0 ksi) but subject to any additional requirements of the relevant construction Rules. The fractured surfaces of all tensile test specimens are to be granular and gray in appearance.

#### 13.1.2

When the tensile test fails to meet the requirements, two further tests may be made from the same piece. If both of these additional tests are satisfactory, the item and/or batch (as applicable) is acceptable. If one or both of these tests fail, the item and/or batch is to be rejected.

#### 13.1.3 Higher Strength Castings

When higher-strength cast iron is proposed for any purpose, the purchaser's specifications are to be submitted specially for approval in connection with the approval of the design for which the material is intended.

## 15 Inspection

### 15.1

All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

### 15.3

All castings are to be visually examined by the Surveyor including the examination of internal surfaces where applicable. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

### 15.5

Supplementary examination of castings by suitable nondestructive testing procedures is generally not required unless otherwise stated on the approved plan or in circumstances where there is reason to suspect the soundness of the casting.

### 15.7

When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

## 15.9

In any event of any casting proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

## 17 Rectification of Defective Casting

### 17.1

At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

### 17.3

Subject to approval, castings containing local porosity may be rectified by impregnation with a suitable plastic filler.

### 17.5

Repairs by welding are generally not permitted. In cases where welding is proposed, full details of the proposed repair are to be submitted for review prior to commencing the repair.

## 19 Identification of Castings

### 19.1

The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original ladle of metal. The Surveyor is to be given full facilities for tracing the castings when required.

### 19.3

Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

- Grade of cast iron
- Identification number or other marking enabling the full history of the casting to be traced.
- Manufacturer's name or trademark.
- Date of final inspection
- ABS office, initials or symbol
- Personal stamp of Surveyor responsible for inspection
- Test pressure, if applicable

### 19.5

Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

## 21 Certification

The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:

- Purchaser's name and order number
- Description of castings and quality of cast iron
- Identification number
- Results of mechanical test



- Where applicable, general details of the heat treatment
- Where specifically required, the chemical analysis of ladle samples
- Where applicable, test pressures

**1 Scope (1998)**

The following specifications cover thirteen grades of steel pipe designated 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13 and 14.

**3 General****3.1 Grades 1, 2 and 3**

Grades 1, 2 and 3 cover seamless and welded steel pipe. Pipe ordered under these grades is of a nominal (average) wall thickness suitable for welding and suitable for forming operations involving coiling, bending and flanging, subject to the following limitations: Grade 1 furnace-butt-welded pipe is not intended for flanging; when seamless or electric-resistance-welded pipe is required for close-coiling or cold-bending, Grade 2 should be specified; this provision is not intended to prohibit the cold-bending of Grade 3 pipe. When pipe is required for close-coiling, this is to be specified on the order. Electric-resistance-welded Grades 2 and 3 may be furnished either non-expanded or cold-expanded, at the option of the manufacturer. When pipe is cold expanded, the amount of expansion is not to exceed 1.5% of the outside diameter pipe size.

**3.3 Grades 4 and 5**

Grades 4 and 5 cover seamless carbon-steel pipe for high-temperature service. Pipe ordered to these grades is of a nominal (average) wall thickness and is to be suitable for bending, flanging and similar forming operations. Grade 4 rather than Grade 5 pipe should be used for close-coiling, cold-bending or forge-welding; this provision is not intended to prohibit the cold-bending of Grade 5 pipe.

**3.5 Grade 6**

Grade 6 covers seamless carbon-molybdenum alloy-steel pipe for high-temperature service. Pipe ordered to this grade is of a nominal (average) wall thickness and is to be suitable for bending, flanging (vanstoning) and similar forming operations, and for fusion-welding.

**3.7 Grades 7, 11, 12, 13 and 14 (1998)**

Grades 7, 11, 12, 13 and 14 cover seamless chromium-molybdenum alloy-steel pipe for high-temperature service. Pipe ordered to these grades is of a nominal (average) wall thickness and is to be suitable for bending, flanging (vanstoning) and similar forming operations, and for fusion-welding.

### 3.9 Grades 8 and 9

Grades 8 and 9 cover electric-resistance-welded steel pipe 762 mm (30 in.) and under in diameter. Pipe ordered to these grades is of a nominal (average) wall thickness and is intended for conveying liquid, gas or vapor. Only Grade 8 is adapted for flanging and bending; this provision is not intended to prohibit the cold-bending of Grade 9 pipe. The pipe may be furnished either cold-expanded or non-expanded.

### 3.11 ASTM Designations (2006)

The various grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
1	A53, Grade A, Furnace-welded
2	A53, Grade A Seamless or Electric-resistance-welded
3	A53, Grade B Seamless or Electric-resistance-welded
4	A106, Grade A
5	A106, Grade B
6	A335, Grade P1
7	A335, Grade P2
8	A135, Grade A
9	A135, Grade B
11	A335, Grade P11
12	A335, Grade P12
13	A335, Grade P22
14	A335, Grade P5

## 5 Process of Manufacture

### 5.1 Grades 1, 2 and 3

The steel for welded or seamless steel pipe in these Grades is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. Special consideration may be given to other processes, subject to such supplementary requirements or limits on application as are to be specially determined in each case.

### 5.3 Grades 4 and 5

The steel for seamless steel pipe in these Grades is to be killed steel made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. Pipe that is 60.3 mm in outside diameter (2 in. nominal diameter) and over is to be, unless otherwise specified, furnished hot-finished. Hot-finished pipe need not be annealed. Cold-drawn pipe is to be process-annealed after the final cold-draw pass at a temperature of 650°C (1200°F) or higher.

### 5.5 Grades 6 and 7

The steel for seamless steel pipe in these Grades is to be made by either or both the open-hearth or electric-furnace process or other approved process. A sufficient discard is to be made from each ingot to secure freedom from injurious piping and undue segregation. Pipe that is 60.3 mm in outside diameter (2 in. nominal size) and over is to be, unless otherwise specified, furnished hot-finished, and pipe under 60.3 mm O.D. (2 in. diameter) may be furnished either hot-finished or cold-drawn. The hot-rolled or cold-drawn pipe Grades 6 and 7 as a final heat treatment, are to be stress-relief-annealed at 650°C (1200°F) to 705°C

(1300°F). The steel from which Grade 7 pipe is made is to be a coarse-grained steel having a carburized austenitic grain size of 1 to 5 as determined in accordance with the Methods for Estimating the Average Grain Size of Metals (ASTM E112) and its Plate IV, by carburizing at 925°C (1700°F) for 8 hours. The specimen is to be taken from the bloom or billet.

### 5.7 Grades 8 and 9

The steel for electric-resistance-welded steel pipe in these Grades is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace.

### 5.9 Grades 11, 12, 13 and 14 (1998)

The steel for seamless alloy steel pipe is to be made by the electric-furnace process or other approved process, except that Grade 12 may be made by the open-hearth process. A sufficient discard is to be made from each ingot to secure freedom from injurious piping and undue segregation. Pipe that is 60.3 mm in outside diameter (2 in. nominal diameter) and over is to be, unless otherwise specified, furnished hot-finished, and pipe under 60.3 mm O.D. (2 in. nominal diameter) may be furnished either hot-finished or cold-drawn. The steel for Grade 12 pipe is to be made by coarse-grain melting practice. Grades 11, 13 and 14 pipe are to be reheated and furnished in the full-annealed, isothermal annealed or normalized and tempered condition; if furnished in the normalized and tempered condition, or if cold drawn pipe is furnished, the temperature for tempering following normalizing or cold drawing is to be 677°C (1250°F) or higher for Grades 13 and 14, and 650°C (1200°F) or higher for Grade 11. The hot-rolled or cold-drawn Grade 12 pipe, as a final heat treatment, is to be given a stress-relieving treatment at 650°C (1200°F) to 705°C (1300°F).

## 7 Marking (1998)

Identification markings are to be legibly stenciled, stamped, or rolled on each length of pipe, except that in the case of small-diameter pipe which is bundled, the required markings are to be placed on a tag securely attached to the bundle. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- ABS Grade or ASTM Designation and Type or Grade. Heat number or manufacturer's number by which the heat can be identified (For Grades 6, 7, 11, 12, 13 and 14 pipe only)
- Test pressure or the letters NDE
- Method of forming (i.e. butt-welded, lap-welded, electric-resistance-welded or seamless hot-finished or cold-drawn)
- “XS” for extra strong or “XXS” for double-extra strong (when applicable for Grades 1, 2 and 3 pipe only)
- ABS markings by the Surveyor

## 9 Chemical Composition

The material for pipe is to conform to the applicable requirements as to chemical composition shown in 2-3-12/39.7 TABLE 1.

## 11 Ladle Analysis (1998)

For Grades 4, 5, 6, 7, 8, 9, 11, 12, 13 and 14, the manufacturer is to submit a report showing the ladle analysis of each heat of steel from which the pipe has been made and the chemical composition is to conform to the requirements specified in 2-3-12/9. In lieu of a report of the ladle analysis, a report of check analysis as provided for in 2-3-12/13 will be acceptable.

## 13 Check Analysis

### 13.1 General

A check analysis may be made where so specified by the purchaser. The chemical composition thus determined is to conform to the requirements specified in 2-3-12/9. If check analyses are made, they are to be in accordance with the following requirements.

### 13.3 Samples

Samples for check analysis are to be taken by drilling several points around each pipe selected for analysis or when taken from the billet they are to be obtained by drilling parallel to the billet axis at a point midway between the outside and center or when taken from a broken tension test specimen, they are to be taken so as to represent the entire cross section of the specimen.

### 13.5 Grades 1, 2 and 3

For these grades, analyses of two pipes from each lot of 500 lengths or fraction thereof are to be made.

### 13.7 Grades 4 and 5

For these grades, analyses of two pipes from each lot of 400 lengths or fraction thereof, of each size and heat 60.3 mm O.D. (2 in. nominal diameter) up to, but not including 168.3 mm O.D. (6 in. nominal diameter), and from each lot of 200 lengths or fraction thereof of each size and heat 168.3 mm O.D. (6 in. nominal diameter) and over, are to be made.

### 13.9 Grades 6, 7, 11, 12, 13 and 14 (1998)

For these grades, analyses of two pipes from each lot and heat, as specified in 2-3-12/39.7 TABLE 2, are to be made.

### 13.11 Grades 8 and 9

For these grades, analyses of two pipes from each lot of 400 lengths or fraction thereof of each size under 168.3 mm O.D. (6 in. nominal), from each lot of 200 lengths or fraction thereof of each size 168.3 mm O.D. (6 in. nominal diameter) to 508 mm (20 in.) O.D., and from each lot of 100 lengths or fraction thereof of each size over 508 mm (20 in.) O.D. to 762 mm (30 in.) O.D. are to be made. With the Surveyor's permission, the analysis may be made of the skelp and the number is to be determined in the same manner as when taken from the finished pipe.

### 13.13 Retests for Grades 1, 2, 3, 4 and 5

If an analysis for these grades does not conform to the requirements specified, analyses are to be made on additional pipes of double the original number from the same lot, each of which is to conform to the requirements specified.

### 13.15 Retests for Grades 6, 7, 11, 12, 13 and 14 (1998)

If a check or ladle analysis for these grades does not conform to the requirements specified, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements are to be accepted.

### 13.17 Retests for Grades 8 and 9

For these grades, if the analysis of either length of pipe or length of skelp does not conform to the requirements, analyses of two additional lengths from the same lot are to be made, each of which is to conform to the requirements specified.

## 15 Mechanical Tests Required (1998)

The type and number of mechanical tests are to be in accordance with 2-3-12/39.7 TABLE 3. For a description and the requirements of each test see 2-3-12/17 through and including 2-3-12/29. For retests see 2-3-12/33.

## 17 Tension Test Specimens

### 17.1 Grades 1, 2 and 3

For these grades, tension test specimens are to be cut longitudinally from the end of the pipe and not flattened between gauge marks. The sides of strip specimens are to be parallel between gauge marks; the width is to be 38 mm (1.5 in.) and the gauge length 50 mm (2 in.). If desired, tension test specimens may consist of a full section of pipe. When impracticable to pull a test specimen in full thickness, the tension test specimen shown in 2-3-1/11.13 FIGURE 2 may be used. The transverse-weld tension test specimens from electric-resistance-welded Grade 2 and Grade 3 pipe are to be taken with the weld at the center of the specimen and are to be 38 mm (1.5 in.) wide in the gauge length.

### 17.3 Grades 4, 5, 6, 7, 11, 12, 13 and 14 (1998)

For these grades, the tension test specimens are to be cut longitudinally, but may be cut transversely for pipe 219.1 mm in outside diameter (8 in. nominal diameter) and over.

#### 17.3.1 Longitudinal Tension Test Specimens

The longitudinal tension test may be made in full section of the pipe, up to the capacity of the testing machine. For larger sizes, tension test specimens are to consist of strips cut from the pipe; the width of these specimens is to be 38 mm (1.5 in.) and they are to have a gauge length of 50 mm (2 in.). When the pipe-wall thickness is 19.1 mm (0.75 in.) and over, the tension test specimen shown in 2-3-1/11.13 FIGURE 2 may be used. Longitudinal tension test specimens are not to be flattened between gauge marks. The sides of the specimens are to be parallel between gauge marks.

#### 17.3.2 Transverse Tension Test Specimens

Transverse tension test specimens may be taken from a ring cut from the pipe or from sections resulting from the flattening tests. Test specimens are to consist of strips cut transversely from the pipe; the width of the specimens is to be 38 mm (1.5 in.) and their gauge length 50 mm (2 in.). When the pipe-wall thickness is 19.1 mm (0.75 in.) and over, the tension test specimen shown in 2-3-1/11.13 FIGURE 2 may be used. Specimens cut from the ring section are to be flattened cold and are to be parallel between gauge marks. Specimens from Grades 6, 7, 11, 12, 13 and 14 pipes are to be flattened cold and heat-treated in the same manner as the pipe. Transverse tension test specimens may be machined off on either or both surfaces to secure uniform thickness.

### 17.5 Grades 8 and 9

For these grades, the tension test specimens are to be cut longitudinally from the end of the pipe, or by agreement between the manufacturer and the Surveyor, the specimens may be taken from the skelp, at a point approximately 90 degrees from the weld. The specimens are not to be flattened between the gauge marks. Transverse tension test specimens are to be taken across the weld and from the same end of the pipe as the longitudinal test specimens. The sides of each strip specimen are to be parallel between gauge marks; the width is to be 38 mm (1.5 in.) and the gauge length 50 mm (2 in.). When impracticable to pull a test specimen in full thickness, the tension test specimen shown 2-3-1/11.13 FIGURE 2 may be used.

## 19 Bend and Flattening Test Specimens

Test specimens for the bend and flattening tests are to consist of sections cut from a pipe and the specimens for flattening tests are to be smooth on the ends and free from burrs, except when made on crop ends.

## 21 Testing Temperature

All test specimens are to be tested at room temperature.

## 23 Tensile Properties

The material is to conform to the applicable requirements as to tensile properties shown in 2-3-12/39.7 TABLE 4.

## 25 Bend Test

### 25.1 General

This test is required for Grades 1, 2, 3, 4 and 5 pipe having outside diameters of 60.3 mm (2 in. nominal diameter) and under, except that double-extra-strong pipe over 42.2 mm in outside diameter (1.25 in. nominal diameter) need not be subjected to a bend test.

### 25.3 Details of Test

A sufficient length of pipe is to stand being bent cold around a cylindrical mandrel without developing cracks at any portion or without opening the weld. The requirements for bending angle, mandrel diameter, and pipe diameter are tabulated below.

<i>Pipe Grade</i>	<i>Bending Angle in degrees</i>	<i>Ratio of Mandrel Diameter to Nominal Pipe Diameter</i>
1, 2, 3, 4, 5	90	12
1, 2, 3, 4, 5 for close-coiling	180	8

## 27 Flattening Test

### 27.1 General

Flattening tests are to be made for all Grades of pipe except Grades 1, 2 and 3 double extra strong and Grades 1, 2, 3, 4 and 5 in sizes 60.3 mm in outside diameter (2 in. nominal diameter) and under. The test is to consist of flattening cold a section of pipe between parallel plates.

### 27.3 Furnace-welded Pipe

For Grade 1 furnace-welded pipe, the test section is not to be less than 100 mm (4 in.) in length and the weld is to be located 45 degrees from the line of direction of the applied force. The test is to be made in three steps.

#### 27.3.1 Test Step No. 1

During the first step, which is a test for quality of the weld, no cracks or breaks on the inside, outside or end surfaces are to occur until the distance between the plates is less than three-fourths of the original outside diameter.

#### 27.3.2 Test Step No. 2

During the second step, which is a test for ductility exclusive of the weld, the flattening is to be continued and no cracks or breaks on the inside, outside or end surfaces are to occur until the distance between the plates is less than 60% of the original outside diameter for butt-welded pipe.

#### 27.3.3 Test Step No. 3

During the third step, which is a test for soundness, the flattening is to be continued until the test specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound

material or of incomplete weld that is revealed during the entire flattening test is to be cause for rejection. Superficial ruptures as a result of surface imperfections are not to be cause for rejection.

## 27.5 Electric-resistance-welded Pipe

For electric-resistance-welded pipe of Grades 2, 3, 8 and 9 the crop ends, at least 100 mm (4 in.) in length, cut from each end of each single length of pipe are to be flattened and the tests from each end are to be made alternately with the welds at 0 degrees and 90 degrees from the line of direction of force. When produced in multiple lengths, flattening tests are required from each end of each multiple length or coil with the weld at 90 degrees from the line of direction of force. In addition, tests are to be made on two intermediate rings cut from each multiple length or coil with the weld at 0 degrees from the line of direction of force. The test is to be made in three steps.

### 27.5.1 Test Step No. 1

During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces are to occur until the distance between the plates is less than two-thirds of the original outside diameter of the pipe.

### 27.5.2 Test Step No. 2

During the second step, which is a test for ductility exclusive of the weld, the flattening is to be continued and no cracks or breaks on the inside or outside surfaces, elsewhere than in the weld, are to occur until the distance between the plates is less than one-third of the original outside diameter of the pipe.

### 27.5.3 Test Step No. 3

During the third step, which is a test for soundness, the flattening is to be continued until the test specimen breaks or the opposite walls of the pipe meet. Evidence of laminated, burned or unsound material or of an incomplete weld that is revealed during the entire flattening test is to be cause for rejection. Superficial ruptures as a result of surface imperfections are not to be cause for rejection.

## 27.7 Seamless Pipe (1998)

For seamless pipe of Grades 2, 3, 4, 5, 6, 7, 11, 12, 13 and 14, the test section is not to be less than 63.5 mm (2.5 in.) in length. The test is to be made in two steps.

### 27.7.1 Test Step No. 1

During the first step, which is a test for ductility, no cracks or breaks on the inside or outside or end surfaces are to occur until the distance between the plates is less than the value of  $H$  obtained from the following equation:

$$H = (1 + e)t / (e + t/D)$$

where

$H$  = distance between flattening plates, in mm (in.)

$t$  = specified wall thickness of pipe, in mm (in.)

$D$  = specified outside diameter of pipe, in mm (in.)

$e$  = deformation per unit length, constant for a given Grade as follows.

= 0.09 for Grade 2

= 0.08 for Grades 4, 6, 7, 11, 12, 13 and 14

= 0.07 for Grades 3 and 5



### 27.7.2 Test Step No. 2

During the second step, which is a test for soundness, the flattening is to be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated, burned or unsound material that is revealed during the entire flattening test is to be cause for rejection.

## 29 Hydrostatic Test

### 29.1 General (1998)

Except when intended for structural use, such as stanchions, each length of pipe of all grades is to be hydrostatically tested at the mill in accordance with the following requirements, or when specified by the purchaser, seamless pipe is to be subjected to a nondestructive electrical test in accordance with 2-3-12/31. When each pipe is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

### 29.3 Grades 1, 2 and 3 (1999)

For these grades, each pipe is to withstand an internal hydrostatic pressure as shown in 2-3-12/39.7 TABLE 5. This does not prohibit testing at a higher pressure, but the maximum fiber stress produced by the test is not to exceed 90% of the minimum specified yield strength of the material. Welded pipe that is 60.3 mm O.D. (2 in. nominal diameter) and larger is to be jarred near one end while under test pressure. The hydrostatic pressure is to be maintained for not less than 5 seconds for all sizes of seamless and electric-welded pipe.

### 29.5 Grades 4, 5, 6, 7, 11, 12, 13 and 14 (1999)

For these grades, each pipe is to withstand an internal hydrostatic test pressure which will produce in the pipe wall a stress of not less than 60% of the minimum specified yield point at room temperature. This pressure is to be determined by the equation given in 2-3-12/29.9. The hydrostatic test pressure determined by the equation is to be rounded to the nearest 5 bar (5 kgf/cm<sup>2</sup>, 50 psi) for pressures below 70 bar (70 kgf/cm<sup>2</sup>, 1000 psi) and to the nearest 10 bar (10 kgf/cm<sup>2</sup>, 100 psi) for pressures 70 bar (70 kgf/cm<sup>2</sup>, 1000 psi) and above. Regardless of the pipe wall stress determined by the equation in 2-3-12/29.9, the minimum hydrostatic test pressure required to satisfy this requirement need not exceed 170 bar (170 kgf/cm<sup>2</sup>, 2500 psi) for sizes 88.9 mm O.D. (3 in. nominal diameter) and under, or 190 bar (190 kgf/cm<sup>2</sup>, 2800 psi) for all sizes over 88.9 mm O.D. (3 in. nominal diameter). This does not prohibit testing at a higher pressure, but the maximum fiber stress produced by the test is not to exceed 90% of the minimum specified yield strength of the material. The hydrostatic pressure is to be maintained for not less than 5 seconds.

### 29.7 Grades 8 and 9

For these grades, each pipe is to withstand an internal hydrostatic test pressure calculated from the equation given in 2-3-12/29.9. The maximum test pressure is not to exceed 172 bar (176 kgf/cm<sup>2</sup>, 2500 psi). For pipe with a wall thickness greater than 3.9 mm (0.154 in.) the pipe is to be jarred near both ends with a 1 kg (2 lb.) hammer or its equivalent while under the test pressure. The hydrostatic pressure is to be maintained for not less than 5 seconds.

### 29.9 Test Pressures (1999)

The test pressures for applicable grades are to be determined by the following equation.

$$P = KSt/D$$

where

$$K = 20 \text{ (200, 2)}$$

$$P = \text{maximum hydrostatic-test pressure, in bar (kgf/cm}^2\text{, psi)}$$

$$t = \text{specified thickness of pipe wall, in mm (in.)}$$

- $D$  = specified outside diameter of pipe, in mm (in.)
- $S$  = permissible fiber stress
  - = 0.60 times the specified yield point, in N/mm<sup>2</sup> (kgf/mm<sup>2</sup> or psi), for ABS Grades 4, 5, 6, 7, 11, 12, 13 and 14
  - = 110 N/mm<sup>2</sup> (11 kgf/mm<sup>2</sup>, 16000 psi) to 125 N/mm<sup>2</sup> (12.5 kgf/mm<sup>2</sup>, 18000 psi), but in no case is the stress produced to exceed 80% of the specified yield point for ABS Grade 8
  - = 140 N/mm<sup>2</sup> (14 kgf/mm<sup>2</sup>, 20000 psi) to 150 N/mm<sup>2</sup> (15.5 kgf/mm<sup>2</sup>, 22000 psi), but in no case is the stress produced to exceed 80% of the specified yield point for ABS Grade 9

### 29.11 Exceptions (1999)

The maximum test pressure for special service pipes, such as diesel engine high pressure fuel injection piping, will be specially considered. The manufacturer is to submit the proposed maximum test pressure along with technical justification and manufacturing control process for the piping. The justification is to include pipe fiber stress analysis and substantiating prototype test results.

## 31 Nondestructive Electric Test (NDET) for Seamless Pipe (1998)

### 31.1 General

When specified by the purchaser, seamless pipe is to be tested in accordance with ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing, or ASTM E309, for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation, or ASTM E570, for Flux Leakage Examination of Ferromagnetic Steel Tubular Products, or other approved standard. It is the intent of this test to reject tubes containing defects and the Surveyor is to be satisfied that the nondestructive testing procedures are used in a satisfactory manner

### 31.3 Ultrasonic Calibration Standards

Notches on the inside or outside surfaces may be used. The depth of the notch is not to exceed 12.5% of the specified wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed two times the depth.

### 31.5 Eddy-Current Calibration Standards

In order to accommodate the various types of nondestructive electrical testing equipment and techniques in use and manufacturing practices employed, any one of the following calibration standards may be used at the option of the producer to establish a minimum sensitivity level for rejection.

#### 31.5.1 Drilled Hole

Three or four holes equally spaced about the pipe circumference and sufficiently separated longitudinally to ensure a separately distinguishable response are to be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe wall while drilling. The diameter of the holes is to be as follows:

<i>Calibration Pipe Diameter in mm (inch)</i>	<i>Hole Diameter in mm (inch)</i>
under 12.5 (0.5)	1 (0.039)
12.5 (0.5) to 31.8 (1.25), excl.	1.4 (0.055)
31.8 (1.25) to 50 (2.0), excl.	1.8 (0.071)
50 (2.0) to 125 (5.0), excl.	2.2 (0.087)
125 (5.0) and over	2.7 (0.106)

### 31.5.2 Transverse Tangential Notch

Using a round file or tool with a 6.35 mm (0.25 in.) diameter, a notch is to be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater.

### 31.5.3 Longitudinal Notch

A notch 0.785 mm. (0.031 in.) or less in width is to be machined in a radial plane parallel to the pipe axis on the outside surface of the tube to a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

## 31.7 Flux Leakage Calibration Standards

The depth of longitudinal notches on the inside and outside surfaces is not to exceed 12.5% of the specified wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed the depth, and the length of the notch is not to exceed 25.4 mm (1.0 in.). Outside and inside surface notches are to be located sufficiently apart to allow distinct identification of the signal from each notch.

## 31.9 Rejection

Tubing producing a signal equal to or greater than the calibration defect is to be subject to rejection.

## 31.11 Affidavits

When each tube is subjected to an approved nondestructive electric test as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 33 Retests

### 33.1 General (1998)

For all grades of pipe, if the results of the mechanical tests of any lot do not conform to the requirements, retests may be made on additional pipe of double the original number from the same lot, each of which is to conform to the requirements specified.

### 33.3 Grades 1, 2, 3, 8 and 9

For these grades, should any section fail when flattening tests are made on the crop ends of each length of welded pipe, other pieces from the length may be cut until satisfactory tests are obtained, otherwise, the length is to be rejected.

### 33.5 Grades 4 and 5

For these grades, should a crop end of a finished pipe fail in the flattening test, one retest may be made from the failed end. The pipe may be normalized either before or after the first test, but the pipe is to be subjected to only two normalizing treatments.

### 33.7 Grades 6, 7, 11, 12, 13 and 14 (1998)

For these grades, should individual lengths of pipe selected to represent any lot fail to conform to the mechanical requirements, the lot may be reheat-treated and resubmitted for test, except that any individual lengths which meet the test requirements before re-treating will be accepted.

## **35 Pipe Testing and Inspection**

### **35.1 Group I Piping (2008)**

Pipes intended for use in Group I piping systems (Class I and Class II, see 4-6-1/5, *Rules for Building and Classing Marine Vessels*) are to be tested, preferably at the mill, to the satisfaction of the Surveyor. The material surfaces will be examined by the Surveyor when specially requested by the purchaser. See also 4-6-7/3.5.1 of the *Rules for Building and Classing Marine Vessels*.

### **35.3 Group I and II Piping (1998)**

The pipes are to be reasonably straight, free from defects, and have a workmanlike finish. At a minimum, the finished pipe is to be visually inspected at the same frequency as that required for the tension test specified in 2-3-12/39.7 TABLE 3 for the applicable grade. Welding repair to the pipe is not to be carried out without the purchasers approval and is to be the Surveyors satisfaction.

## **37 Permissible Variation in Wall Thickness (1998)**

The permissible variations in wall thickness for all pipe are based on the ordered thickness and are to conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application regardless of such prior acceptance. At a minimum, the finished pipe is to be measured at the same frequency as that required for the tension test specified in 2-3-12/39.7 TABLE 3 for the applicable grade.

## **39 Permissible Variations in Outside Diameter**

### **39.1 Grades 1, 2, 3**

For pipe of these grades 48.3 mm O.D. (1.5 in. nominal diameter) and under, the outside diameter at any point is not to vary more than 0.4 mm (0.016 in.) over nor more than 0.8 mm (0.131 in.) under the specified diameter. For pipe 60.3 mm O.D. (2 in. nominal diameter) and over, the outside diameter is not to vary more than plus or minus 1% from the specified diameter.

### **39.3 Grades 4, 5, 6, 7, 11, 12, 13 and 14 (1998)**

For these grades, variation in outside diameter from that specified is not to exceed the amount prescribed in 2-3-12/39.7 TABLE 6.

### **39.5 Grades 8 and 9**

For these grades, the outside diameter is not to vary more than plus or minus 1% from the nominal diameter specified.

### **39.7 Inspection (1998)**

At a minimum, the finished pipe is to be measured at the same frequency as that required for the tension test specified in 2-3-12/39.7 TABLE 3 for the applicable grade.

**TABLE 1**  
**Maxima or Permissible Range of Chemical Composition**  
**in Percent for Pipe (1998)**

	<i>ABS Grades</i>												
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>
Carbon	0.30	0.25	0.30	0.25	0.30	0.10 to 0.20	0.10 to 0.20	0.25	0.30	0.05 to 0.15	0.05 to 0.15	0.05 to 0.15	0.15
Manganese	1.20	0.95	1.20	0.27 to 0.93	0.29 to 1.06	0.30 to 0.80	0.30 to 0.61	0.95	1.20	0.30 to 0.60	0.30 to 0.61	0.30 to 0.60	0.30 to 0.60
Phosphorus	0.05	0.05	0.05	0.035	0.035	0.025	0.025	0.035	0.035	0.025	0.025	0.025	0.025
Sulfur	0.045	0.045	0.045	0.035	0.035	0.025	0.025	0.035	0.035	0.025	0.025	0.025	0.025
Silicon				0.10 (min)	0.10 (min)	0.10 to 0.50	0.10 to 0.30			0.50 to 1.00	0.50	0.50	0.50
Chromium	0.40	0.40	0.40	0.40	0.40		0.50 to 0.81			1.00 to 1.50	0.80 to 1.25	1.90 to 2.60	4.00 to 6.00
Molybdenum	0.15	0.15	0.15	0.15	0.15	0.44 to 0.65	0.44 to 0.65			0.44 to 0.65	0.44 to 0.65	0.87 to 1.13	0.45 to 0.65
Nickel	0.40	0.40	0.40	0.40	0.40								
Copper	0.40	0.40	0.40	0.40	0.40								
Vanadium	0.08	0.08	0.08	0.08	0.08								

**TABLE 2**  
**Lot Sizes for Pipe Grades 6, 7, 11, 12, 13 and 14 (1998)**

<i>Outside Diameter</i>	<i>Lengths of Pipe in Lot</i>
Under 60.3 mm (2 in.)*	400 or fraction thereof
60.3 mm to 141.3 mm incl. (2 in. to 5 in. incl.)*	200 or fraction thereof
168.3 mm and over (6 in. and over)*	100 or fraction thereof

\* Dimensions refer to nominal pipe diameter.

**TABLE 3**  
**Mechanical Tests for Pipe (1998)**

<i>Grade</i>	<i>Type of Test</i>	<i>Number of Tests</i>
1,2,3	Tension (Longitudinal)	One test on one length of pipe from each lot of 500 lengths or fraction there of each size.
	Transverse Weld Tension <sup>(1)</sup>	As for tension test only for electric-resistance-welded pipe 219.1 mm in outside diameter (8 in. nominal diameter) and over.
	Bend <sup>(1)</sup>	As for tension test only for pipe 60.3 mm in outside diameter (2 in. nominal diameter) and under except not required for double-extra- strong-pipe over 42.2 mm in outside diameter (1- <sup>1</sup> / <sub>4</sub> in. nominal diameter).
	Flattening	As for tension test except: 1 Not required for pipe 60.3 mm in outside diameter (2 in. nominal diameter) and under. 2 Not required for double-extra strong pipe. 3 In the case of welded pipe ordered for flanging and electric-resistance-welded pipe, the crop ends cut from each length are to be subjected to this test. 4 (1998) When pipe is produced in multiple lengths, tests are required on the crop ends from the front and back ends of each coil and on two tests are required on the crop ends from the intermediate rings representing each coil.
	Hydrostatic <sup>(1)</sup>	All pipes.
4,5	Tension (Longitudinal or Transverse <sup>(5)</sup> )	One test on one length of pipe from each lot <sup>(2)</sup> of 400 lengths or fraction thereof of each size under 168.3 mm in outside diameter (6 in. Nominal diameter) and one test on one length of pipe from each lot of 200 lengths or fraction thereof of each size 168.3 mm in outside diameter (6 in. nominal diameter) and over.
	Bend <sup>(1)</sup>	One test on one length of pipe from each lot <sup>(2)</sup> of 400 lengths or fraction thereof of each size 60.3 mm in outside diameter (2 in. nominal diameter) and under except not required for double-extra-strong pipe over 42.2 mm in outside diameter (1- <sup>1</sup> / <sub>4</sub> in. nominal diameter).
	Flattening	As for tension test only for pipe over 60.3 mm in outside diameter (2 in. diameter).
		Hydrostatic <sup>(1)</sup>
6,7,11, 12,13,14 (1998)	Tension (Longitudinal or Transverse <sup>(5)</sup> )	One test on 5% of the pipe in a lot <sup>(3)</sup> . For the pipe heat-treated in a batch-type furnace, at least one pipe from each heat-treated lot <sup>(3)</sup> . For pipe heat-treated by continuous process, at least two pipes from each heat-treated lot <sup>(3)</sup> are to be tested.
	Flattening	As for tension test.
		Hydrostatic <sup>(1)</sup>

Grade	Type of Test	Number of Tests
8,9	Tension (Longitudinal)	One test on one length of pipe from each of 400 lengths or fraction thereof of each size 168.3 mm in outside diameter (6 in. nominal diameter) and one test on one length of pipe from each lot of 200 lengths or fraction thereof of each size from 168.3 mm in outside diameter (6 in. nominal diameter) to and including 508 mm (20 in.) in outside diameter and one test on one length of pipe from each lot of 100 length or fraction thereof of each size over 508 mm (20 in.) in outside diameters. <sup>(4)</sup>
	Transverse <sup>(1)</sup> Weld Tension	As for tension test only for pipe 168.3 mm in outside diameter (6 in. nominal diameter) and over. <sup>(4)</sup>
	Flattening	One test on each of both crop ends cut from each length of pipe. When pipe is produced in multiple lengths, tests are required on the crop ends from the front and back ends of each coil and on two intermediate rings representing each coil.
	Hydrostatic <sup>(1)</sup>	All pipes.

**Notes:**

- 1 Pipes intended for structural use, such as stanchions, need *not* be subjected to this test.
- 2 A lot, in this case, consists of all pipe of the same size and wall thickness from any one heat.
- 3 The term “lot” used here applies to all pipe of the same nominal size and wall thickness which is produced from the same heat of steel and subjected to the same finishing heat treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot is to include only that pipe which is heat-treated in the same furnace charge. When no heat treatment is performed following the forming operations, the lot is to include hot-rolled material only or cold-drawn material only.
- 4 When taken from the skelp, the number of tests is to be determined in the same manner as when taken from finished pipe.
- 5 The transverse tension test may*not* be made on pipe under 219.1 mm in outside diameter (8 inch nominal diameter).

**TABLE 4  
 Tensile Requirements for Pipe (1998)**

**SI Units & MKS Units**

	ABS Grades								
	1	2 <sup>(c)</sup>	3 <sup>(c)</sup>	4	5	6 and 7	8 <sup>(b)</sup>	9 <sup>(b)</sup>	11, 12, 13, 14 (1998)
Tensile Strength, min. N/mm <sup>2</sup> (kgf/mm <sup>2</sup> )	310 (31.5)	330 (33.7)	415 (42)	330 (33.7)	415 (42)	380 (39)	330 (33.7)	415 (42)	415 (42)
Yield Strength, min. N/mm <sup>2</sup> (kgf/mm <sup>2</sup> )	170 (17.5)	205 (21)	240 (24.5)	205 (21)	240 (24.5)	205 (21)	205 (21)	240 (24.5)	205 (21)
Elongation in 200 mm, min., %	20 <sup>(a)</sup>								

	<i>ABS Grades</i>								
	<i>1</i>	<i>2<sup>(c)</sup></i>	<i>3<sup>(c)</sup></i>	<i>4</i>	<i>5</i>	<i>6 and 7</i>	<i>8<sup>(b)</sup></i>	<i>9<sup>(b)</sup></i>	<i>11, 12, 13, 14 (1998)</i>
Elongation in 50 mm. min., percent. Basic minimum elongation for walls 7.9 mm and over, strip tests, and for all small sizes tested in full section. Transverse Longitudinal		35	30	25 35	16.5 30	20 30	35	30	20 30
When standard round 50 mm gauge length test specimen is used. Transverse Longitudinal	30	28	22	20 28	12 22	14 22			14 22
Deduction in elongation or each 0.8 mm decrease in wall thickness below 7.9 mm for strip test. Transverse Longitudinal		1.75	1.50	1.25 1.75	1.00 1.50	1.00 1.50	1.75	1.50	1.00 1.50

**Note:**

a Gauge distances for measuring elongation on pipe of 26.7 mm O.D. and smaller are to be as follows:

<i>O.D.</i>	<i>Gauge Length</i>
26.7 mm and 21.3 mm	150 mm
17.1 mm and 13.7 mm	100 mm
103 mm	50 mm

- b. The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade pipe ordered. This test will not be required for pipe under 168.3 mm in outside diameter.
- c. The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade of pipe ordered. This test will not be required for pipe under 219.1 mm in outside diameter.

**US Units**

	<i>ABS Grades</i>								
	<i>1</i>	<i>2<sup>(c)</sup></i>	<i>3<sup>(c)</sup></i>	<i>4</i>	<i>5</i>	<i>6 and 7</i>	<i>8<sup>(b)</sup></i>	<i>9<sup>(b)</sup></i>	<i>11, 12, 13, 14 (1998)</i>
Tensile Strength, min., psi	45000	48000	60000	48000	60000	55000	48000	60000	60000
Yield Strength, min. psi	25000	30000	35000	30000	35000	30000	30000	35000	30000
Elongation in 8 in., min., %	20 <sup>(a)</sup>								



	<i>ABS Grades</i>								
	<i>1</i>	<i>2<sup>(c)</sup></i>	<i>3<sup>(c)</sup></i>	<i>4</i>	<i>5</i>	<i>6 and 7</i>	<i>8<sup>(b)</sup></i>	<i>9<sup>(b)</sup></i>	<i>11, 12, 13, 14 (1998)</i>
Elongation in 2 in. min., percent. Basic minimum elongation for walls $\frac{5}{16}$ in. and over, strip tests, and for all small sizes tested in full section. Transverse Longitudinal		35	30	25 35	16.5 30	20 30	35	30	20 30
When standard round 2in. gauge length test specimen is used. Transverse Longitudinal	30	28	22	20 28	12 22	14 22			14 22
Deduction in elongation for each $\frac{1}{32}$ in. decrease in wall thickness below $\frac{5}{16}$ in. for strip test. Transverse Longitudinal		1.75	1.50	1.25 1.75	1.00 1.50	1.00 1.50	1.75	1.50	1.00 1.50

*Notes:*

- a Gauge distances for measuring elongation on pipe of nominal sizes  $\frac{3}{4}$  in. and smaller are to be as follows:

<i>Nominal Size</i>	<i>Gauge Length</i>
$\frac{3}{4}$ in. and $\frac{1}{2}$ in.	6 in.
$\frac{3}{8}$ in. and $\frac{1}{4}$ in.	4 in.
$\frac{1}{8}$ in.	2 in.

- b The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade pipe ordered. This test will not be required for pipe under 6 in. in nominal diameter.
- c The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade of pipe ordered. This test will not be required for pipe under 8 in. in nominal diameter.

**TABLE 5**  
**Hydrostatic-test Pressure for Welded and Seamless Plain-end Steel Pipe**

**SI Units**

*Pressure in bars*

Outside Diameter, mm	Standard Weight			Extra-strong			Double Extra-strong		
	Grade	Grade	Grade	Grade	Grade	Grade	Grade	Grade	Grade
	1	2	3	1	2	3	1	2	3
10.3 to 33.4	48	48	48	59	59	59	69	69	69
42.2 and 48.3	69	69	76	90	103	110	97	124	131
60.3	69	159	172	90	172	172	97	172	172
73.0	69	172	172	90	172	172	97	172	172
88.9	69	152	172	90	172	172		172	172
101.6	83	138	165	117	193	193			
114.3	83	131	152	117	186	193		193	193
141.3		117	131		165	193		193	193
168.3		103	124		159	186		193	193
219.1		90	110		145	165		193	193
273.1		83	97		117	138		193	193
323.9		76	83		97	110		193	193
355.6		66	76		90	103			
406.4		59	69		76	90			
457.2		52	62		69	83			
508.0		48	55		62	69			
609.6		38	45		52	62			

**MKS Units**

Pressure in kgf/cm<sup>2</sup>

Outside Diameter, mm	Standard Weight			Extra-strong			Double Extra-strong		
	Grade	Grade	Grade	Grade	Grade	Grade	Grade	Grade	Grade
	1	2	3	1	2	3	1	2	3
10.3 to 33.4	49.2	49.2	49.2	59.8	59.8	59.8	70.3	70.3	70.3
42.2 and 48.3	70.3	70.3	77.3	91.3	103	112	98.4	124	134
60.3	70.3	162	176	91.4	176	176	98.4	176	176
73.0	70.3	176	176	91.4	176	176	98.4	176	176
88.9	70.3	155	176	91.4	176	176		176	176
101.6	84.4	141	169	120	197	197			
114.3	84.4	136	155	120	190	190		197	197

Outside Diameter, mm	Standard Weight			Extra-strong			Double Extra-strong		
	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3
141.3		120	136		169	197		197	197
168.3		105	127		162	190		197	197
219.1		91.4	112		148	169		197	197
273.1		84.4	98.4		120	141		197	197
323.9		77.3	84.4		98.4	112		197	197
355.6		66.8	77.3		91.4	105			
406.4		59.8	70.3		77.3	91.4			
457.2		52.7	63.3		70.3	84.4			
508.0		49.2	56.2		63.3	70.3			
609.6		38.7	45.7		52.7	63.3			

US Units

Pressure in psi

IPS Size, in.	Standard Weight			Extra-strong			Double Extra-strong		
	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3
1/8 to 1	700	700	700	850	850	850	1000	1000	1000
1 1/4 and 1 1/2	1000	1000	1100	1300	1500	1600	1400	1800	1900
2	1000	2300	2500	1300	2500	2500	1400	2500	2500
2 1/2	1000	2500	2500	1300	2500	2500	1400	2500	2500
3	1000	2200	2500	1300	2500	2500		2500	2500
3 1/2	1200	2000	2400	1700	2800	2800			
4	1200	1900	2200	1700	2700	2800		2800	2800
5		1700	1900		2400	2800		2800	2800
6		1500	1800		2300	2700		2800	2800
8		1300	1600		2100	2400		2800	2800
10		1200	1400		1700	2000		2800	2800
12		1100	1200		1400	1600		2800	2800
14		950	1100		1300	1500			
16		850	1000		1100	1300			
18		750	900		1000	1200			

IPS Size, in.	Standard Weight			Extra-strong			Double Extra-strong		
	Grade	Grade	Grade	Grade	Grade	Grade	Grade	Grade	Grade
	1	2	3	1	2	3	1	2	3
20		700	800		900	1000			
24		550	650		750	900			

**TABLE 6**  
**Out-of-roundness Variation (1998)**

**Millimeters**

Pipe Outside Diameter	Out-of-roundness Variation	
	Over	Under
10.3 to 48.3 incl.	0.38	0.79
Over 48.3 to 114.3 incl.	0.79	0.79
Over 114.3 to 219.1 incl.	1.57	0.79
Over 219.1 to 457.2 incl.	2.36	0.79
Over 457.2 to 660.4 incl.	3.17	0.79
Over 660.4 to 863.6 incl. (1998)	4.0	0.8
Over 863.6 to 1219.2 incl. (1998)	4.8	0.8

**Inches**

Nominal Pipe Size	Out-of-roundness Variation	
	Over	Under
1/8 to 1 1/2 incl.	1/64 (0.015)	1/32 (0.031)
Over 1 1/2 to 4 incl.	1/32 (0.031)	1/32 (0.031)
Over 4 to 8 incl.	1/16 (0.062)	1/32 (0.031)
Over 8 to 18 incl.	3/32 (0.093)	1/32 (0.031)
Over 18 to 26 incl.	1/8 (0.125)	1/32 (0.031)
Over 26 to 34 incl. (1998)	5/32 (0.156)	1/32 (0.031)
Over 34 to 48 incl. (1998)	3/16 (0.187)	1/32 (0.031)

# PART 2

## CHAPTER 3

### Materials for Machinery, Boilers, Pressure Vessels, and Piping

#### SECTION 13

### Piping, Valves and Fittings for Low-temperature Service [ Below -18°C (0°F) ]

#### 1 Scope

The following specifications cover six representative grades of steel for pipes, valves and fittings for use in piping systems designed for temperatures lower than -18°C (0°F). Steels differing in chemical composition, mechanical properties or heat treatment will be specially considered. The requirements for aluminum alloys or other non-ferrous materials will be specially considered.

Materials for Liquefied Gas Carrier are to comply with 5C-8-6 of the *Marine Vessel Rules*

#### 3 Designation (2013)

The various grades are to be in substantial agreement with ASTM as follows.

ABS Grade	Nominal Composition	ASTM
1L	Carbon Steels	A333 Grades 1 and 6; A334 Grades 1 and 6; A350 Grades LF1 and LF2; A352 Grade LCB; A420 Grade WPL6
2L	$\frac{1}{2}$ Mo	A352 Grade LC1
3L	$2\frac{1}{2}$ Ni	A333 Grade 7; A334 Grade 7; A352 Grade LC2
4L	$3\frac{1}{2}$ Ni	A333 Grade 3; A334 Grade 3; A350 Grade LF3; A352 Grade LC3; A420 Grade WPL3
5L	9 Ni	A333 Grade 8; A334 Grade 8; A522; A420 Grade WPL8
6L	10 Ni 20 Cr or 20 Ni 25 Cr	A351 Grades CF8C and CK20

#### 5 Manufacture

The steel is to be made by the basic oxygen, open hearth or electric furnace process. The steel is to be killed and made with a fine-grain deoxidation practice.

#### 7 Heat Treatment

The steel is to be furnished in the normalized condition or as required by the applicable specification.

## 9 Marking

The name or brand of the manufacturer is to be legibly marked on each pipe, flange and fitting. The ABS grade and initials **AB** are to be placed on the material near the marking of the manufacturer.

## 11 Chemical Composition

The materials selected from 2-3-13/3 are to conform to the chemical requirements given in the ASTM designation indicated except as modified by 2-3-13/5 or otherwise specially approved.

## 13 Mechanical Tests

The materials selected from 2-3-13/3 are to be tested in accordance with the requirements of the applicable ASTM designation as to tension test, hydrostatic test, flattening test, etc., unless otherwise specially approved.

## 15 Impact Properties

The materials selected from 2-3-13/3 are to conform to the toughness requirements of 2-3-13/23.

## 17 Steels for Service Temperatures Between -18°C (0°F) and -196°C (-320°F)

The following grades may be used for the minimum design service temperature indicated.

Grade	Minimum Design Service Temperature °C (°F)
1L	-34 (-30)
2L	-46 (-50)
3L	-73 (-100)
4L	-101 (-150)
5L & 6L	-196 (-320)

## 19 Steels for Service Temperatures Below -196°C (-320°F)

Steels intended for service temperatures below -196°C (-320°F) are to be austenitic stainless steels. The chemical composition, heat treatment and tensile properties of these materials are to be submitted for each application.

## 21 Materials for Nuts and Bolts

Ferritic-alloy nuts and bolts conforming to ASTM A194 Grade 4 and A320 L43 may be used where system service temperatures are not below -101°C (-150°F). Austenitic-alloy nuts and bolts conforming to ASTM A194 Grades 8T and 8F and A320 Grades B8T, B8F and B8M may be used where the design service temperature is not below -196°C (-320°F).

## 23 Toughness

Low temperature notch toughness is to be determined by impact testing using Charpy V-notch specimens. Testing is to consist of at least three longitudinally oriented specimens from each lot. Lot size is as defined in the applicable ASTM designation except that at least one set of impact tests is to be made from each heat in each heat treatment charge. The energies absorbed by each set of impact specimens for Grades 1L and 2L is to conform to the requirements specified below.

Specimen Size	Minimum Average		Minimum-One Specimen	
	J	(kgf-m, ft-lbf)	J	(kgf-m, ft-lbf)
mm				

10×10	27.0	(2.8, 20)	18.5	(1.9, 13.5)
10×7.5	22.5	(2.3, 16.5)	15.0	(1.5, 11)
10×5.0	18.5	(1.9, 13.5)	12.0	(1.2, 9)
10×2.5	13.5	(1.4, 10)	9.0	(0.9, 6.5)

The Charpy impact requirements for Grades 3L, 4L and 5L are 125% of the values shown above. Charpy impact tests are not required for Grade 6L. Where material thicknesses are such that the quarter size impact specimen cannot be obtained, the requirements for toughness testing will be specially considered.

## 25 Impact Test Temperature

Materials selected from 2-3-13/3 are not to be used at temperatures lower than those indicated in 2-3-13/17 and are to be tested at temperatures at least 5.5°C (10°F) below the minimum design service temperature. Where the test temperature is determined to be below -196°C (-320°F), testing may be conducted at -196°C (-320°F).

## 27 Witnessed Tests (2006)

Piping intended for temperature below -18°C (0°F) is to be tested in the presence of the Surveyor. Materials intended for fabrication of valves fittings and piping are to be tested by the manufacturers and, upon request, the test results are to be submitted to ABS.

For vessels intended to carry Liquefied Gases in Bulk, see 5C-8-6/2.2 of the *Marine Vessel Rules*.

## 29 Retests

When the material fails to meet the minimum impact requirements of 2-3-13/23 by an amount not exceeding 15%, retests are permitted in accordance with 2-1-2/11.7.

## 31 Welding

Weld procedure is to be approved in accordance with the requirements of 2-4-3/5.3. See also 2-4-2/9.9.

## 1 For General Purposes

### 1.1 Tensile Properties

The castings are to be free from injurious defects. The material is to have the following tensile properties.

<i>Type</i>	<i>Tensile Strength Minimum, N/ mm<sup>2</sup> (kgf/mm<sup>2</sup>, psi)</i>	<i>Elongation in 50 mm (2 in.) Minimum percent</i>	<i>Stamping</i>
1	205 (21, 30000)	15	AB/1

### 1.3 Number of Tests (2012)

At least one tension test is to be made from each melt and the tension test specimen is to be machined to the dimensions shown in 2-3-1/11.13 FIGURE 1 (Round Specimen Alternative C).

## 3 Propellers and Propeller Blades

### 3.1 Foundry Approval (2006)

#### 3.1.1 Approval (2012)

All propellers and propeller components are to be cast by ABS-approved foundries. For this purpose, the foundries are to demonstrate that they have available the necessary facilities and skilled personnel to enable proper manufacture of propellers which will satisfy these Rules.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection. Refer to 7-A1-10/1 of the *ABS Rules for Survey After Construction (Part 7)*.

#### 3.1.2 Scope of the Approval Test (1 July 2021)

The following aspects of manufacture are to be taken into account:

- Casting types and sizes
- Material specifications



- Repair procedures
- Ladle capacities
- Manufacturing practices and procedures for melting and pouring, molding, heat treatment, welding repairs, hot and cold straightening, test sampling, destructive and nondestructive testing methods and equipment, and chemical and metallographic capabilities.

Cast coupons of the propeller materials involved are to be tested in order to verify that composition and mechanical properties comply with these Rules.

### 3.1.3 Quality Control

In addition, information as to the company’s facilities and organization, especially as they relate to quality control, is also required to be presented, including certification in accordance with national or international standards, such as ISO standards.

## 3.2 Castings

The castings are to be free from defects.

## 3.3 Chemical Composition (1 July 2013)

The chemical composition in % is to conform to an approved specification, four of which are listed in the table below as representative of bronze alloys currently used for propellers and propeller blades. See also 2-3-14/3.19. The samples for chemical analysis may be taken from test coupons or representative castings.

	<i>Type 2 Mn Bronze</i>	<i>Type 3 Ni-Mn Bronze</i>	<i>Type 4 Ni-Al Bronze</i>	<i>Type 5 Mn-Ni-Al Bronze</i>
Copper	55-60	53.5-57	78 min	71 min
Tin	1.50 max	1.50 max	—	—
Lead	0.40 max	0.20 max	0.03 max	0.03 max
Iron	0.4-2.0	1.0-2.5	3.0-5.0	2.0-4.0
Manganese	1.5 max	2.5-4.0	3.5 max	11.0-14.0
Aluminum	0.5-1.5	2.0 max	8.5-11.0	7.0-8.5
Nickel	0.5 max	2.5-4.0	3.0-5.5	1.5-3.0
Silicon	—	—	—	0.10 max
Zinc	Remainder	Remainder	—	—
Total Others	—	—	0.50 max	0.50 max

## 3.5 Zinc Equivalent (1 July 2021)

The chemical composition of Type 2 and Type 3 alloys are to be so controlled that the zinc equivalent, based on the following equation, does not exceed 45.0%.

$$\% \text{ zinc equivalent} = 100 - \left( \frac{100 \times \% \text{ copper}}{100 + A} \right)$$

$$\text{where } A = (\% \text{ Tin}) + (0.5 \times \% \text{ Aluminum}) - (0.5 \times \% \text{ Manganese}) - (0.1 \times \% \text{ Iron}) - (2.3 \times \% \text{ Nickel})$$

## 3.7 Alternative Zinc Equivalent

When the alpha content of a specimen taken from the end of the acceptance test bar is determined by microscopic measurement to be 20% or more, the foregoing “zinc equivalent” requirement will be waived.

### 3.9 Tensile Properties (2012)

The material represented by the test specimens machined from separately cast test coupons is to conform to the following minimum tensile properties.

#### Tensile Properties of Separately Cast Test Coupons <sup>(1,2)</sup>

Type	Tensile Strength		Yield Strength <sup>(3)</sup>		Elongation Min. percent (5d Gauge Length)
	N/mm <sup>2</sup>	(kgf/mm <sup>2</sup> , psi)	N/mm <sup>2</sup>	(kgf/mm <sup>2</sup> , psi)	
2	450	(46, 65,000)	175	(18, 25,000)	18
3	515	(53, 75,000)	220	(22.5, 32,000)	16
4	590	(60, 86,000)	245	(25, 36,000)	15
5	630	(64, 91,000)	275	(28, 40,000)	18

**Notes:**

- 1 These properties are generally not representative of the tensile properties of the propeller casting itself, which could be substantially lower than that of a separately cast test coupon.
- 2 The tensile requirements of integral-cast test coupons are to be specially approved.
- 3 Yield strength is to be determined in accordance with 2-3-1/13.3.

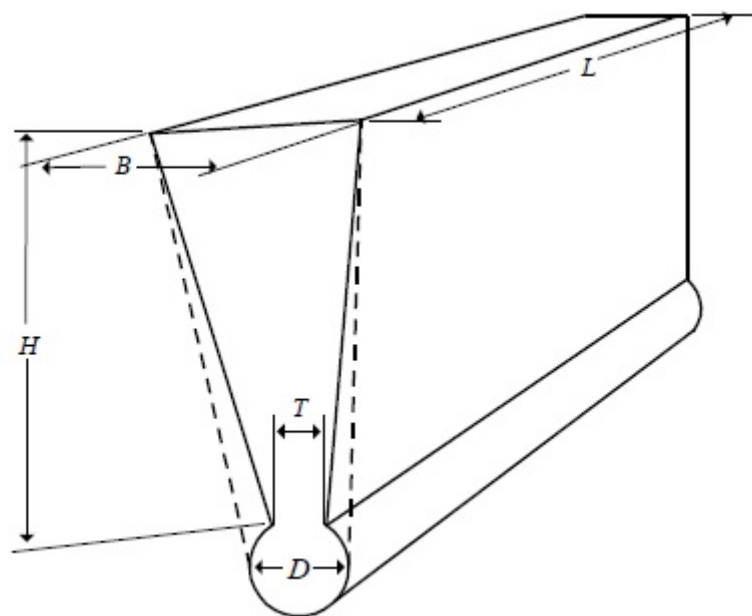
### 3.11 Test Specimens (2008)

The test-coupon casting from which the tensile test specimen is machined is to be of an approved form. The tensile test specimen is to be machined to the dimensions shown in 2-3-1/11.13 FIGURE 1 (Round Specimen Alternative C). The test coupons may be separately cast or integral with the casting.

### 3.13 Separately Cast Coupons (1996)

Separately cast test coupons as shown in 2-3-14/3.13 FIGURE 1 (test coupon according to the broken line may also be accepted) or in accordance with a recognized national standard, are to be poured from the same ladles of metal used to pour the castings, and into molds of the same material as used for the casting. In cases where more than one ladle of metal is required for a casting, a test coupon is to be provided for each ladle. Satisfactory evidence is to be furnished the Surveyor to identify the test coupons as representing the material to be tested.

**FIGURE 1**  
**Test Coupons (1996)**



$H = 100 \text{ mm (4 in.)}$   
 $B = 50 \text{ mm (2 in.)}$   
 $L > 150 \text{ mm (6 in.)}$   
 $T = 15 \text{ mm (0.59 in.)}$   
 $D = 25 \text{ mm (1 in.)}$

### 3.15 Integrally Cast Coupons

Integrally cast coupons are to be furnished as coupons cast on the surfaces of the castings.

### 3.17 Number of Tests (1 July 2021)

One tension test is to be made for each casting when integrally cast test coupons are provided and one tension test is to be made from each ladle when separately cast test coupons are provided. The test results are to comply with the requirements prescribed in 2-3-14/3.9.

If propellers are subjected to a heat treatment, the test samples are to be heat treated together with the propeller.

### 3.19 Special Compositions

It is recognized that other bronze alloys have been developed and proven by tests and service experience to be satisfactory. When propeller materials not meeting the chemical compositions in 2-3-14/3.3 are proposed, specifications are to be submitted for approval in connection with the approval of the design for which the material is intended.

### 3.21 Inspection and Repair (2014)

The entire surface of the finished propeller is to be visually examined. A liquid penetrant examination of critical areas is to be made on all propellers over 2 m (78 in.) in diameter. In addition, liquid penetrant examination is to be conducted on all suspect areas. All inspections and repairs are to be to the satisfaction of the Surveyor. Conformity with the 7-A1-10, "Bronze and Stainless Steel Propeller Castings" of the ABS

*Rules for Survey After Construction (Part 7)*, will be considered to meet requirements for the inspection and repair of propeller castings.

In addition to the above requirements, Controllable Pitch Propeller (CPP) blades are to undergo the following:

- Each blade is to be weighed and recorded for all accuracy classes, CPP blades (ISO 484 /1 & 2). The deviation of each blade should be less than the maximum permissible balancing mass as defined by ISO 484 / 1 & 2 or as specified on the approved drawing.
- Each bolt hole area of a CPP blade is to be air tested in the final delivery condition. The air tightness test is to be conducted with a 5 bar pressure held for 15 minutes, followed by a soap and water check around the bolt hole areas. Or alternatively a 1.5 times hydrostatic working pressure test for 30 minutes minimum as specified in the assembly drawing may be carried out.
- A liquid penetrant examination of the flange and bolt hole area of the CPP blade is to be made regardless of blade size. The PT is to be witnessed by attending Surveyor(s) and should be free from any significant surface defects. Acceptance Criteria is shown in 7-A1-10 of the *ABS Rules for Survey After Construction (Part 7)*.

### 3.23 Marking

The manufacturer's name and other appropriate identification markings are to be stamped on each propeller or propeller blade in such location as to be discernible after finishing and assembly. In addition, Type 2, 3, 4 and 5 castings are to be stamped **AB/2**, **AB/3**, **AB/4** or **AB/5**, respectively, to indicate satisfactory compliance with Rule requirements. Bronze alloys produced to specifications other than those covered herein in accordance with the permissibility expressed in 2-3-14/3.19 are to be stamped **AB/S** and with the applicable specification number.

*Note:*

In substantial agreement with ASTM A-743, Grade CF-3

**1 Process of Manufacture and Foundry Approval (2006)****1.1 Process of Manufacture**

The following requirements cover austenitic stainless steel castings intended to be used for propellers and propeller blades. The stainless steel is to be melted by the electric arc or electric induction process, or other process as may be approved.

**1.3 Foundry Approval (2012)**

Stainless steel propellers and propeller components, including grade CF-3 and other grades, as indicated in 7-A1-10 of the *ABS Rules for Survey After Construction (Part 7)*, are to be cast by ABS-approved foundries. For this purpose, foundries are to demonstrate that they have available the necessary facilities and skilled personnel to enable proper manufacture of propellers which will satisfy these Rules.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection. Refer to 7-A1-10/1.3.1 of the *ABS Rules for Survey After Construction (Part 7)*.

**1.5 Scope of the Approval Test**

The following aspects of manufacture are to be taken into account:

- Casting types and sizes
- Material specifications
- Repair procedures
- Ladle capacities
- Manufacturing practices and procedures for: Melting and pouring, molding, heat treatment, welding repairs, hot and cold straightening, destructive and nondestructive testing methods and equipment, and chemical and metallographic capabilities.

Cast coupons of the propeller materials involved are to be tested in order to verify that composition and mechanical properties comply with these Rules.

### 1.7 Quality Control

In addition, information as to the company's facilities and organization, especially as they relate to quality control, is required to be presented, including certification in accordance with national or international organizations standards, such as ISO standards.

## 3 Inspection and Repair

The entire surface of the finished propeller is to be visually examined. A liquid penetrant examination of critical areas is to be made. In addition, all suspect areas should be examined by the liquid penetrant method. The surfaces of all propellers are to be suitably protected from the corrosive effects of industrial environments until fitted on the vessel. All inspections and repairs are to be to the satisfaction of the Surveyor. Conformity with 7-A1-10, "Bronze and Stainless Steel Propeller Castings" of the *ABS Rules for Survey After Construction (Part 7)*, will be considered to meet requirements for the inspection and repair of propeller castings.

## 5 Chemical Composition

An analysis of each heat is to be made by the manufacturer from a test sample that is representative of the heat and that is taken during the pouring of the heat. The chemical composition in % thus determined is to conform to the requirements specified below.

Carbon max. *	0.03
Manganese max.	1.50
Silicon max.	2.00
Phosphorus max.	0.04
Sulfur max.	0.04
Chromium	17.0-21.0
Nickel	8.0-12.0

\* A carbon content up to and including 0.0345% is considered to meet the 0.03 maximum requirement.

## 7 Tensile Properties

The metal represented by the test specimens is to conform to the following minimum tensile properties.

Grade	Tensile Strength $N/mm^2$ ( $kgf/mm^2$ , psi)	Yield Strength $N/mm^2$ ( $kgf/mm^2$ , psi)	Elongation in 50 mm (2 in.) %
CF-3	485 (49, 70,000)	205 (21, 30,000)	35

## 9 Tests and Marking

### 9.1 Test Specimens

The test-coupon casting from which the tension test specimen is machined is to be of an approved form. The tension test specimen is to be machined to the dimensions shown in 2-3-1/11.13 FIGURE 2. The test coupons may be separately or integrally cast.

### 9.3 Separately Cast Coupons (2006)

Separately cast test coupons are to be poured from the same ladles of metal used to pour the castings, and into molds of the same material as used for the casting. Test coupons are to be heat treated with the castings represented. In cases where more than one ladle of metal is required for a casting, a test coupon is to be provided for each ladle. Satisfactory evidence is to be furnished the Surveyor to identify the test coupons as representing the material to be tested.

### 9.5 Integral Coupons (2006)

Integral test coupons are to be furnished as coupons attached to the hub or on the blade. Where possible, test bars attached on blades are to be located in an area between  $0.5$  to  $0.6R$ , where  $R$  is the radius of the propeller. Test bars are not to be detached from the casting until final heat treatment has been carried out. Removal is to be by non-thermal means.

### 9.7 Number of Tests

One tension test is to be made for each casting when integrally cast test coupons are provided and one tension test is to be made from each ladle when separately cast test coupons are provided. The test results are to comply with the requirements prescribed in 2-3-15/7.

### 9.9 Special Compositions

It is recognized that other alloys have been developed and proven by tests and service experience to be satisfactory. When propeller materials not meeting the chemical compositions in 2-3-15/5 are proposed, specifications are to be submitted for approval in connection with the approval of the design for which the material is intended.

### 9.11 Marking

The manufacturer's name and other appropriate identification markings are to be stamped on each propeller or propeller blade in such location as to be discernible after finishing and assembly. In addition, Grade CF-3 castings are to be stamped **AB/CF-3** to indicate satisfactory compliance with Rule requirements. Alloys produced to specifications other than those covered herein in accordance with the permissibility expressed in 2-3-15/9.9 are to be stamped **AB/S**, and with the applicable specification number.

# PART 2

## CHAPTER 3

### Materials for Machinery, Boilers, Pressure Vessels, and Piping

#### SECTION 16

#### Seamless Copper Piping (1998)

*Note:*

In substantial agreement with ASTM B42.

### 1 Scope

The following specifications cover seven grades of seamless copper pipe designated C1, C2, C3, C4, C5, C6 and C7.

### 3 General

#### 3.1 Grades C1, C2, C3, C4, C5, C6 and C7

These grades cover seamless copper pipe intended for boiler feed-water lines, plumbing, and other similar service. Pipe ordered in all standard pipe sizes, both regular and extra strong, under these grades is considered suitable for welding and brazing.

#### 3.3 ASTM Designation

These grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
C1	UNS C10100
C2	B42, UNS C10200
C3	B42, UNS C10300
C4	B42, UNS C10800
C5	B42, UNS C12000
C6	B42, UNS C12200
C7	UNS C14200



## 5 Process of Manufacture (2009)

The material is to be produced by either hot or cold working operations, or both. It is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified. All pipe is to be normally furnished in the drawn-temper condition, (H55). Hard-drawn temper (H80) may be furnished also. When pipe is required for bending, the pipe is to be furnished with a proper bending temper, or annealed temper (061). All pipes for working pressures over 10 bar (10.5 kgf/cm<sup>2</sup>, 150 psi) are to be tested and inspected at the mills to the satisfaction of the Surveyor. The pipes are examined by the Surveyor when requested by the purchaser. The pipe is to be commercially round and is to be free from defects that interfere with normal applications.

## 7 Marking

### 7.1 Manufacturer's Marking

The name or brand of the manufacturer, the designation B42, and the test pressure are to be legibly marked by stamping or stenciling on each length of pipe. On small-diameter pipe, which is bundled, this information may be marked on a tag securely attached to each bundle.

### 7.3 ABS Markings

The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be placed on the material near the markings specified in 2-3-16/7.1.

## 9 Chemical Composition

The material is to conform to the applicable requirements as to chemical composition as shown in 2-3-16/23 TABLE 1.

## 11 Tension Test

### 11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the pipe. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the pipe in accordance with ASTM E8.

### 11.3 Tensile Properties

The material is to conform to the applicable requirements as to tensile properties shown in 2-3-16/23 TABLE 2.

## 13 Expansion Test

Specimens selected for test, after annealing, are to withstand an expansion of 25% of the outside diameter when expanded by a tapered pin having a 60-degree included angle. The expanded tube is to show no cracking or rupture visible to the unaided eye.

## 15 Flattening Test

As an alternate to the expansion test for pipe over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, a section 100 mm (4 in.) in length is to be cut from the end of one of the lengths for a flattening test. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at three times the wall thickness will pass over the pipe freely throughout the flattened part. The pipe so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the specimens are to be slowly flattened by one stroke of the press.

## 17 Hydrostatic Test

### 17.1 Limiting Test Pressures

Each length of the pipe is to stand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 41 N/mm<sup>2</sup> (4.22 kgf/mm<sup>2</sup>, 6000 psi), determined by the following equation. No pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm<sup>2</sup>, 1000 psi) unless so specified. At the option of the manufacturer, annealed pipe with wall thickness up to 2.11 mm (0.083 in.) inclusive may be tested in the hard-drawn condition prior to annealing.

$$P = KSt / (D - 0.8t)$$

where

- $P$  = pressure in bar (kgf/cm<sup>2</sup>, psi)
- $S$  = allowable unit stress of the material, 41 N/mm<sup>2</sup> (4.22 kgf/mm<sup>2</sup>, 6000 psi)
- $t$  = thickness of pipe wall, in mm (in.)
- $D$  = outside diameter of the pipe, in mm (in.)
- $K$  = 20 (200, 2)

### 17.3 Affidavits of Tests

Where each pipe is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 19 Number of Tests

The lot is to consist of pipe of the same size and temper. The lot size is to be 2270 kg (5000 lb) or a fraction thereof for pipe up to 48.3 mm O.D. (1.5 in. nominal size) incl.; 4550 kg (10,000 lb) or a fraction thereof for pipe over 48.3 mm O.D. (1.5 in. nominal size) to 114.3 mm O.D. (4 in. nominal size) incl., 18,150 kg (40,000 lb) or a fraction thereof for pipe over 114.3 mm O.D. (4 in. nominal size). Sample pieces are to be taken for test purposes from each lot as follows:

<i>Number of Pieces in Lot</i>	<i>Number of Sample Pieces to Be Taken</i>
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, bend tests, where required, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the hydrostatic test specified in 2-3-16/17.

## 21 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

## 23 Permissible Variations in Dimensions

The permissible variations in wall thickness and diameter are based on the ordered thickness and are to conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of such prior acceptance.

**TABLE 1**  
**Chemical Composition for Copper Pipe and Tube (1998)**

<i>Pipe Grade</i>	<i>Tube Grade</i>	<i>Minimum Copper*, %</i>	<i>Phosphorus, %</i>	<i>Arsenic, %</i>	<i>Maximum Oxygen, ppm</i>
C1	CA	99.99	—	—	—
C2	CB	99.5	—	—	10
C3	CC	99.95**	0.001 to 0.005	—	—
C4	CD	99.95**	0.005 to 0.012	—	—
C5	CE	99.90	0.004 to 0.012	—	—
C6	CF	99.9	0.015 to 0.040	—	—
C7	CG	99.40	0.015 to 0.040	0.15-0.50	—

*Note:*

\* Including silver.

\*\* Total of copper, silver and phosphorus.

**TABLE 2**  
**Tensile Properties for Copper Pipe and Tube (1998)**

<i>Temper Designation</i>		<i>Tensile Strength, min N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Yield Strength*, min. N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>
<i>Standard</i>	<i>Former</i>		
061/060	annealed	205 (21, 30)	62 (6, 9)**
H55	light drawn	250 (25, 36)	205 (21, 30)
H80	hard drawn	310 (32, 45)	275 (28, 40)

*Note:*

\* At 0.5% extension under load.

\*\* Light straightening operation is permitted.

*Note:*

In substantial agreement with ASTM B43.

**1 Process of Manufacture (2009)**

The material is to be produced by either hot or cold working operations, or both. It is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified. All pipe is normally to be furnished in the annealed condition. The degree of anneal is to be sufficient to show complete recrystallization and to enable the pipe to meet the test requirements prescribed in these specifications. The pipe may be furnished in the drawn-temper condition instead of the annealed condition if so specified by the purchaser. All pipes for working pressures over 10 bar (10.5 kgf/cm<sup>2</sup>, 150 psi) are to be tested and inspected at the mills to the satisfaction of the Surveyor. The pipes are examined by the Surveyor when requested by the purchaser. The pipe is to be commercially round and is to be free from defects that interfere with normal applications.

**3 Marking****3.1 Manufacturer's Marking**

The name or brand of the manufacturer, the designation B43, and the test pressure is to be legibly marked by stamping or stenciling on each length of pipe. On small-diameter pipe, which is bundled, this information may be marked on a tag securely attached to each bundle.

**3.3 ABS Marking**

The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be marked on the material near the markings specified in 2-3-17/3.1.

**5 Scope**

These specifications cover seamless red-brass pipe in all standard sizes, both regular and extra strong.

**7 Chemical Composition**

The material is to conform to the following requirements as to chemical composition.

Copper	84.00% to 86.00%
Lead	0.06% max.
Iron	0.05% max.
Zinc	remainder
Total other elements	0.15%

Analysis is regularly to be made only for the elements specifically mentioned in this table. If, however, the presence of other elements is suspected or indicated in the course of routine analysis, further analysis is to be made to determine that the total of these other elements is not in excess of the limit specified.

## 9 Expansion Test

Specimens selected for test, after annealing, are to withstand an expansion of 25% of the inside diameter, without cracking, when expanded by a tapered pin having a 60-degree included angle. The expanded tube is to show no cracking or rupture visible to the unaided eye.

## 11 Flattening Test

As an alternate to the expansion test for pipe over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, a section 100 mm (4 in.) in length is to be cut from the end of one of the lengths for a flattening test. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at three times the wall thickness will pass over the pipe freely through the flattened part. The pipe so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the elements are to be slowly flattened by one stroke of the press.

## 13 Mercurous Nitrate Test

A test specimen 150 mm (6 in.) in length is to be taken from each pipe selected for test and, after proper cleaning, is to withstand, without cracking, an immersion of 30 minutes in an aqueous mercurous nitrate solution containing 10 grams of mercurous nitrate and 10 milliliters of nitric acid (specific gravity 1.42) per liter of solution. Immediately after removal from the solution, the specimen is to be wiped free of excess mercury and examined for cracks.

## 15 Bend Test

In the case of pipe required for bending, annealed full sections of the pipe are to stand being bent cold through an angle of 180 degrees around a pin, the diameter of which is one and one-half times the inside diameter of the pipe, without cracking on the outside of the bent portion. This test is to apply only to sizes 50.8 mm (2 in.) and under in outside diameter.

## 17 Hydrostatic Test

### 17.1 Limiting Test Pressures

Each length of the pipe is to stand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm<sup>2</sup> (4.92 kgf/mm<sup>2</sup>, 7000 psi), determined by the following equation. No pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm<sup>2</sup>, 1000 psi) unless so specified.

$$P = KSt / (D - 0.8t)$$

where

- $P$  = pressure, in bar (kgf/cm<sup>2</sup>, psi)  
 $S$  = allowable unit stress of the material, 48 N/mm<sup>2</sup> (4.92 kgf/mm<sup>2</sup>, 7000 psi)  
 $t$  = thickness of pipe wall, in mm (in.)  
 $D$  = outside diameter of the pipe, in mm (in.)  
 $K$  = 20 (200, 2)

### 17.3 Affidavits of Tests

Where each pipe is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 19 Number of Tests

The lot is to consist of pipe of the same size and temper. The lot size is to be 2270 kg (5000 lb) or a fraction thereof for pipe up to 48.3 mm O.D. (1.5 in. nominal size) incl., 4540 kg (10,000 lb) or a fraction thereof for pipe over 48.3 mm O.D. (1.5 in. nominal size) to 114.3 mm O.D. incl. (4 in. nominal size), 18,150 kg (40,000 lb) or a fraction thereof for pipe over 114.3 mm O.D. (4 in. nominal size). Sample pieces are to be taken for test purposes from each lot as follows.

<i>Number of Pieces in Lot</i>	<i>Number of Sample Pieces to Be Taken</i>
1 to 50	1
51 to 200	2
701 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Expansion, flattening and bend tests, where required, are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the hydrostatic test specified in 2-3-17/17.1.

## 21 Retests

If the results of the test on one of the specimens, made to determine the physical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests are to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

## 23 Permissible Variations in Dimensions

The permissible variations in wall thicknesses are based on the ordered thicknesses and is to conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of such prior acceptance.



# PART 2

## CHAPTER 3

### Materials for Machinery, Boilers, Pressure Vessels, and Piping

#### SECTION 18

#### Seamless Copper Tube (1998)

*Note:*

In substantial agreement with ASTM B75.

### 1 Scope

The following specifications cover seven grades of seamless copper tube designated CA, CB, CC, CD, CE, CF and CG.

### 3 General

#### 3.1 Grades CA, CB, CC, CD, CE, CF and CG

These grades cover seamless copper tube intended for boiler feedwater lines, plumbing, and general engineering applications. Tube is to be ordered to outer diameter and wall thickness specified by the purchaser and approved for the application. Tube ordered under these grades are considered suitable for welding and brazing. Seamless round copper tube in standard pipe sizes and schedules is considered to be pipe and is covered by Section 2-3-16.

#### 3.3 ASTM Designation

The grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
CA	B75, UNS C10100
CB	B75, UNS C10200
CC	B75, UNS C10300
CD	B75, UNS C10800
CE	B75, UNS C12000
CF	B75, UNS C12200
CG	B75, UNS C14200

## 5 Process of Manufacture (2009)

The material is to be produced by either hot or cold working operations, or both. It is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified. All tube is to be normally furnished in the drawn-temper condition, (H55). Hard-drawn temper (H80) may be furnished also. When tube is required for bending, the tube is to be furnished with a proper bending temper, or annealed temper (O60). All tubes for working pressures over 10 bar (10.5 kgf/cm<sup>2</sup>, 150 psi) are to be tested and inspected at the mills to the satisfaction of the Surveyor. The pipes are examined by the Surveyor when requested by the purchaser. The tube is to be commercially round and is to be free from defects that interfere with normal applications.

## 7 Marking

### 7.1 Manufacturer's Marking

The name or brand of the manufacturer, the designation B75, and the test pressure are to be legibly marked by stamping or stenciled on each length of tube. On small-diameter tube, which is bundled, this information may be marked on a tag securely attached to each bundle.

### 7.3 ABS Markings

The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be placed on the material near the markings specified in 2-3-18/7.1.

## 9 Chemical Composition

The material is to conform to the applicable requirements as to chemical composition as shown in 2-3-16/23 TABLE 1.

## 11 Tension Test

### 11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8.

### 11.3 Tensile Properties

The material is to conform to the applicable requirements as to tensile properties shown in 2-3-16/23 TABLE 2.

## 13 Expansion Test

*Note:*

This test is required for tubes manufactured in the annealed temper.

Specimens selected for test, after annealing, are to withstand an expansion of the outside diameter when expanded by a tapered pin having a 60-degree included angle to 30 percent for tube over 19.0 mm (<sup>3</sup>/<sub>4</sub> in.) in outside diameter and to 40 percent for smaller sized tube. The expanded tube is to show no cracking or rupture visible to the unaided eye.

## 15 Flattening Test

As an alternate to the expansion test for tube over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, a section 100 mm (4 in.) in length is to be cut from the end of one of the lengths for a flattening test. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at three times the wall thickness will pass over the pipe freely throughout the flattened part. The tube so tested is to develop no



cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the specimens are to be slowly flattened by one stroke of the press.

## 17 Hydrostatic Test

### 17.1 Limiting Test Pressures

Each length of the tube is to stand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 41 N/mm<sup>2</sup> (4.22 kgf/mm<sup>2</sup>, 6000 psi), determined by the following equation. No pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm<sup>2</sup>, 1000 psi) unless so specified. At the option of the manufacturer, annealed tube with wall thickness up to 2.11 mm (0.083 in.) inclusive may be tested in the hard-drawn condition prior to annealing.

$$P = KSt / (D - 0.8t)$$

where

- $P$  = pressure, in bar (kgf/cm<sup>2</sup>, psi)
- $S$  = allowable unit stress of the material, 41 N/mm<sup>2</sup> (4.22 kgf/mm<sup>2</sup>, 6000 psi)
- $t$  = thickness of pipe wall, in mm (in.)
- $D$  = outside diameter of the pipe, in mm (in.)
- $K$  = 20 (200, 2)

### 17.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 19 Number of Tests

The lot is to consist of tubes of the same size and temper. The lot size is to be 4540 kg (10,000 lb) or a fraction thereof. Sample pieces are to be taken for test purposes at random from each lot, as follows:

<i>Number of Pieces in Lot</i>	<i>Number of Sample Pieces to be Taken</i>
1 to 50	1
51 to 200	2
201 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, bend tests, where required, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the hydrostatic test specified in 2-3-18/19.

## 21 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

## 23 Permissible Variations in Dimensions

The permissible variations in wall thickness and diameter are based on the ordered thickness and are to conform to that given in the applicable ASTM for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of any prior acceptance.

*Note:*

In substantial agreement with ASTM B111.

**1 Scope**

The following specifications covers two grades of seamless copper-nickel tube designated CNA and CNB.

**3 General****3.1 Grades CNA and CNB**

Grades CNA, and CNB cover seamless copper-nickel tube intended for use in condensers, evaporators and heat exchanger which may use sea water as the cooling medium. Tube ordered under these grades is considered suitable for welding, and suitable for forming operations involving coiling, bending, flaring and tube rolling. Tube is to be ordered to outer diameter and wall thickness specified by the purchaser and approved for the application.

**3.3 ASTM Designation**

The grades are in substantial agreement with ASTM, as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
CNA	B111, UNS C70600
CNB	B111, UNS C71500

**5 Process of Manufacture****5.1 Grade CNA**

Grade CNA tube is to be cold worked to the specified size. The tube may be supplied either in the annealed temper (O61) or in the light drawn temper (H55).

**5.3 Grade CNB**

Grade CNB tube is to be cold worked to the specified size. The tube may be supplied either in the annealed temper (O61) or in the drawn and stress relieved temper (HR50).

All grades of tube shall be round, straight, clean, smooth and free from harmful defects and deleterious films in the bore.

## 7 Marking

Identification markings are to be legibly stenciled, or suitably marked on each length of tube, except that in the case of smaller-diameter tube which is bundled, the required markings are to be placed on a tag securely attached to the bundle. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- ABS Grade or ASTM Designation and Grade
- Temper number
- Tube diameter
- Wall thickness
- Test Pressure, or the letters NDET
- ABS markings by the Surveyor

## 9 Chemical Composition

### 9.1 Chemical Requirements

The material is to conform to the applicable requirements as to chemical composition as shown in 2-3-19/27.7 TABLE 1.

### 9.3 Chemical Analysis Sampling

Samples may be taken at the time the metal is cast or may be taken from semi-finished product, or from finished product in accordance with sampling in 2-3-19/21.

## 11 Tension Test

### 11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8, for Tension Testing of Metallic Materials.

### 11.3 Tensile Properties

The material is to conform to the applicable requirements as to tensile properties shown in 2-3-19/27.7 TABLE 2.

## 13 Expansion Test

Specimens selected for testing in accordance with ASTM B153, for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30 percent for annealed temper (O61) tube and to 20 percent for drawn temper (H55 or HR50) tube. The expanded tube is to show no cracking or rupture visible to the unaided eye.

## 15 Flattening Test

The specimen selected for testing is to be at least 450 mm (18 in.) in length, and is to be flattened so that a gauge set at three times the wall thickness will pass over the tube freely throughout the flattened part. The

tube so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the specimens are to be slowly flattened by one stroke of the press. Specimens not initially in the annealed temper (O61) are to be annealed prior to flattening.

## 17 Nondestructive Electric Test (NDET)

All tubes are to be eddy-current tested in accordance with ASTM E243, for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes or, alternatively, when specified, may be hydrostatically tested in accordance with 2-3-19/19. A calibration reference standard is to be made from a length of tube of the same type, wall thickness, and outside diameter as that to be tested. The standard is to have transverse notches or drilled holes in accordance with the dimensions shown. Tubing producing a signal equal to or greater than the calibration defect is to be rejected.

### Diameter of Drilled Hole

Tube OD, in mm (inch)	Diameter, in mm (inch)
6.0 (0.25) ≤ OD ≤ 19.0 (0.75)	0.635 (0.025)
19.0 (0.75) < OD ≤ 25.4 (1.0)	0.785 (0.031)
25.4 (1.0) < OD ≤ 31.8 (1.25)	0.915 (0.036)
31.8 (1.25) < OD ≤ 38.1 (1.5)	1.07 (0.042)
38.1 (1.5) < OD ≤ 44.4 (1.75)	1.17 (0.046)
44.4 (1.75) < OD ≤ 50.8 (2.0)	1.32 (0.052)

### Notch Depth

Tube Wall Thickness, in mm (inch)	Tube OD, in mm (inch)		
	6.4 (0.25) ≤ ≤ 19.1 (0.75)	19.1 (0.75) < ≤ 31.8 (1.25)	31.8 (1.25) < ≤ 80 (3.125)
0.43 (0.17) < T < 0.8 (0.032)	0.127 (0.005)	0.152 (0.006)	0.179 (0.007)
0.80 (0.032) < T < 1.24 (0.049)	0.152 (0.006)	0.152 (0.006)	0.191 (0.0075)
1.24 (0.049) < T < 2.10 (0.083)	0.179 (0.007)	0.191 (0.0075)	0.216 (0.008)
2.10 (0.083) < T < 2.77 (0.109)	0.191 (0.0075)	0.216 (0.0085)	0.241 (0.0095)
2.77 (0.109) < T < 3.05 (0.120)	0.229 (0.009)	0.229 (0.009)	0.279 (0.011)

## 19 Hydrostatic Test

### 19.1 Limiting Test Pressures

As an alternate to the eddy-current test, hydrostatic testing may be performed. Each tube that is tested is to stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm<sup>2</sup> (4.92 kgf/mm<sup>2</sup>, 7000 psi), determined by the following equation for thin hollow cylinders under tension. The tube is not to be tested at a hydrostatic pressure of over 69 bar (70.3 kgf/cm<sup>2</sup>, 1000 psi) unless so specified.

$$P = KSt / (D - 0.8t)$$

where

- $P$  = pressure in bar (kgf/cm<sup>2</sup>, psi)
- $S$  = allowable unit stress of the material, 48 N/mm<sup>2</sup> (4.92 kgf/mm<sup>2</sup>, 7000 psi)
- $t$  = thickness of pipe wall, in mm (in.)
- $D$  = outside diameter of the pipe, in mm (in.)
- $K$  = 20 (200, 2)

### 19.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 21 Number of Tests

The lot is to consist of tubes of the same size and temper. The lot size is to be 4540 kg (10,000 lb) or a fraction thereof. Sample pieces are to be taken for test purposes at random from each lot, as follows:

<i>Number of Pieces in Lot</i>	<i>Number of Sample Pieces to be Taken</i>
1 to 50	1
51 to 200	2
201 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the eddy-current test or the hydrostatic test.

## 23 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

## 25 Finish

Tubes selected for testing are to be examined for finish and workmanship. Tubes are to be free from cracks, injurious surface flaws, and similar defects to the extent determinable by visual or NDET examination. Tubes are to be clean and free of any foreign material that would render the tubes unfit for the intended use. Cut ends of tubes are to be deburred.

## 27 Dimensions and Tolerances

Tubes selected for testing are to be measured and examined for dimensions and tolerances.

### 27.1 Diameter

The tube outside diameter is to not vary from the specified values by more than the amounts shown.

**Diameter Tolerances, mm (inches)**

Outside Diameter, mm (inch)	Wall Thickness, mm (inch)				
	0.51 (0.020) to 0.71 (0.028*)	0.81 (0.032)	0.89 (0.035)	1.07 (0.042)	1.24 and over (0.049) and over
Up to 12.5, incl. Up to (0.500), incl.	0.076 (0.003)	0.064 (0.0025)	0.064 (0.0025)	0.064 (0.0025)	0.064 (0.0025)
Over 12.5-19.0, incl. Over (0.500-0.740), incl.	0.102 (0.0040)	0.102 (0.004)	0.102 (0.004)	0.089 (0.0035)	0.076 (0.003)
Over 19.0-25.4, incl. Over (0.740-1,000), incl.	0.152 (0.0060)	0.152 (0.006)	0.127 (0.005)	0.114 (0.0045)	0.102 (0.004)
Over 25.4-31.8, incl. Over (1,000-1,250), incl.	... ...	0.229 (0.009)	0.203 (0.008)	0.152 (0.006)	0.114 (0.0045)
Over 31.8-35.0, incl. Over (1,250-1,375), incl.	... ...	... ...	... ...	0.203 (0.008)	0.127 (0.005)
Over 35.0-50.8, incl. Over (1,375-2,000), incl.	... ...	... ...	... ...	... ...	0.152 (0.006)

\* Tolerances in this column are applicable to light and drawn tempers only. Tolerances for annealed tempers are to be as agreed upon between the manufacturer and the purchaser.

**27.3 Wall Thickness Tolerances**

For tubes ordered to minimum wall, no tube wall at its thinnest point is to be less than the specified wall thickness and no tube at its thickest point is to have a plus deviation greater than twice the value shown. For tubes ordered to nominal wall thickness, the maximum plus and minus deviation in inches from the nominal wall at any point is to not exceed the values shown.

### Wall Thickness Tolerances, mm (inches)

Wall Thickness, mm (inch)	Outside Diameter, mm (inch)		
	Over 3.2 (0.125) to Over 15.9 (0.625), incl.	Over 15.9 (0.625) to 25.4 (1.0), incl.	Over 25.4 (1.0) to 50 (2.0), incl.
0.51, incl. to 0.81 (0.020), incl. to (0.032)	0.076 (0.003)	0.076 (0.003)	
0.81, incl. to 0.89 (0.032), incl. to (0.035)	0.076 (0.003)	0.076 (0.003)	0.102 (0.004)
0.89, incl. to 1.47 0.035, incl. to 0.058	0.102 (0.004)	0.114 (0.0045)	0.114 (0.0045)
1.47, incl. to 2.11 (0.058), incl. to (0.083)	0.114 (0.0045)	0.127 (0.005)	0.127 (0.005)
2.11, incl. to 3.05 (0.083), incl. to (0.120)	0.127 (0.005)	0.165 (0.0065)	0.165 (0.0065)
3.05, incl. to 3.40 (0.120), incl. to (0.134)	0.179 (0.007)	0.179 (0.007)	0.191 (0.0075)

### 27.5 Length

The length of tubes is to not be less than that specified when measured at a temperature of 20°C (68°F) and may exceed the specified values by the amounts shown.

Specified Length, m (feet)	Tolerance, All Plus, mm (inch)
Up to 4.5 (15)	2.4 ( <sup>3</sup> / <sub>32</sub> )
Over 4.5 (15) to 6.0 (20), incl.	3.2 ( <sup>1</sup> / <sub>8</sub> )
Over 6.0 (20) to 10 (30), incl.	4.0 ( <sup>5</sup> / <sub>32</sub> )
Over 10 (30) to 18 (60), incl.	9.5 ( <sup>3</sup> / <sub>8</sub> )
Over 18 (60) to 30 (100), incl.*	13.0 ( <sup>1</sup> / <sub>2</sub> )

\* Length tolerances for wall thickness 0.51 mm (0.020 in.) to 0.81 mm (0.032 in.) are to be as agreed upon between the manufacturer or supplier and the purchaser.

### 27.7 Squareness of Cut

The departure from squareness of the end of the tube is to not exceed the following.

Specified Outside Diameter	Tolerance
Up to 15.9 mm ( <sup>5</sup> / <sub>8</sub> in.) incl.	0.25 mm (0.010 in.)
Over 15.9 mm ( <sup>5</sup> / <sub>8</sub> in.)	0.016 mm/mm (0.016 in./in.) of diameter



**TABLE 1**  
**Chemical Composition for Copper Nickel Pipe and Tube (1998)**

<i>Element</i>	<i>Grade CNA Grade CNI Grade CN3</i>	<i>Grade CNB Grade CN2 Grade CN4</i>
Copper	Remainder	Remainder
Nickel + Cobalt	9.0 to 11.0	29.0 to 33.0
Iron	1.0 to 1.8	0.40 to 1.0
Manganese	1.0	1.0
Zinc	0.50	0.50
Lead	0.02	0.02
Carbon	0.05	0.05
Sulfur	0.02	0.02
Phosphorus	0.02	0.02

Single values are maximum

**TABLE 2**  
**Tensile Properties for Seamless Copper Nickel Pipe and Tube (1998)**

<i>Grade</i>	<i>Temper Designation</i>	<i>Tensile Strength, min. N/mm<sup>2</sup>(kgf/mm<sup>2</sup>, ksi)</i>	<i>Yield Strength, min. N/mm<sup>2</sup>(kgf/mm<sup>2</sup>, ksi)</i>	<i>Elongation, min. percent</i>
CNA	061	275 (28,40)	105 (11,15)	—
CNA	H55	310 (32,45)	240 (25,35)	—
CNB	061	360 (36,52)	125 (13,18)	—
CNB	HR50	495 (51,72)	345 (35,50)	12*,15**

\* For wall thickness 1.21 mm (0.048 in.) and less

\*\* For wall thickness over 1.21 mm (0.048 in.).

# PART 2

## CHAPTER 3

### Materials for Machinery, Boilers, Pressure Vessels, and Piping

#### SECTION 20

#### Copper-Nickel Tube and Pipe (1998)

*Note:*

In substantial agreement with ASTM B466 and B467.

### 1 Scope

This specification covers four grades of seamless and welded copper-nickel tube and pipe designated CN1, CN2, CN3 and CN4.

### 3 General

#### 3.1 Grades CN1 and CN2

Grades CN1 and CN2 cover seamless copper-nickel tube and pipe intended for use in general engineering applications requiring seawater corrosion resistance. Tube and pipe ordered under these grades are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging. Tube is to be ordered to outer diameter and wall thickness specified by the purchaser and approved for the application.

#### 3.3 Grades CN3 and CN4

Grades CN3 and CN4 cover welded copper-nickel pipe intended for use in general engineering applications requiring seawater corrosion resistance. Pipe ordered under these grades are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging.

#### 3.5 ASTM Designation

These grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>ASTM Designation</i>
CN1	B466, UNS C70600
CN2	B466, UNS C71500
CN3	B467, UNS C70600
CN4	B467, UNS C71500

## 5 Process of Manufacture

The material is to be produced by either hot or cold working operations, or both. The tubing is to be finished, unless otherwise specified, by such cold working or annealing or heat treatment as may be necessary to meet the properties for either annealed or light drawn material. The light drawn properties apply only to grades CN1 and CN3.

### 5.1 Grades CN1 and CN2

Grade CN1 may be supplied in either annealed (O60) or light drawn (H55) tempers. Grade CN2 may be supplied in only annealed (O60) temper.

### 5.3 Grades CN3 and CN4

Grade CN3 may be supplied in either the welded from annealed skelp temper (WM50), or the welded and fully finished as annealed temper (WO61). Grade CN4 may be supplied in the welded and fully finished as annealed temper (WO61). The internal and external flash is to be removed by scarfing and there is to be no crevice in the weld seam visible to the unaided eye.

## 7 Marking

Identification markings are to be legibly stenciled, or suitably marked on each length of tubular, except that in the case of small-diameter tubular which is bundled, the required markings are to be placed on a tag securely attached to the bundle. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- ABS Grade or ASTM Designation and Grade
- Temper number
- Diameter
- Wall thickness or Pipe Schedule
- Test Pressure, or the letters NDET
- ABS markings by the Surveyor

## 9 Chemical Composition

### 9.1 Chemical Requirements

The material is to conform to the chemical requirements specified in 2-3-19/27.7 TABLE 1.

### 9.3 Chemical Analysis Sampling

Samples may be taken at the time the metal is cast or may be taken from semi-furnished product, or from finished product in accordance with sampling in 2-3-20/21.

## 11 Tension Test

### 11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8, for Tension Testing of Metallic Materials.

### 11.3 Seamless Tensile Properties

Seamless material is to conform to the applicable requirements as to tensile properties shown.

<i>Temper Number</i>	<i>Temper</i>	<i>Grade</i>	<i>Tensile Strength, min. N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Yield Strength, min. N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>
060	Soft anneal	CN1	260 (27, 38)	90 (9, 13)
		CN2	360 (37, 52)	125 (13, 18)
H55	Light Drawn	CN1	310 (32, 45)	240 (25, 35)

### 11.5 Welded (WO61) Tensile Properties

Welded and fully finished pipe furnished in the annealed temper (WO61) is to conform to the applicable requirements as to the tensile properties shown.

<i>Grade</i>	<i>Outside Diameter, mm (inch)</i>	<i>Tensile Strength, min. N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Yield Strength, min. N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Elongation percent</i>
CN3	Up to 114 (4.5), incl.	275 (28, 40)	105 (11, 15)	25.0
	over 114 (4.5)	260 (27, 38)	90 (9, 13)	25.0
CN4	Up to 114 (4.5), incl.	345 (35, 50)	140 (14, 20)	30.0
	over 114 (4.5)	310 (32, 45)	105 (11, 15)	30.0

### 11.7 Welded (WO50) Tensile Properties

As-welded pipe fabricated from annealed strip (WO50) is to conform to the applicable requirements as to the tensile properties shown.

<i>Grade</i>	<i>Outside Diameter, mm (inch)</i>	<i>Tensile Strength, min. N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>	<i>Yield Strength, min. N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, ksi)</i>
CN3	up to 114 (4.5), incl.	310 (32, 45)	205 (21, 30)

## 13 Expansion Test

*Note:*

This test is required for tubes manufactured in the annealed temper.

### 13.1 Grades CN1 and CN2

Annealed specimens selected for testing in accordance with ASTM B153, for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30 percent. The expanded specimen is to show no cracking or rupture visible to the unaided eye.

### 13.3 Grades CN3 and CN4

Annealed specimens selected for testing in accordance with ASTM B153, for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30 percent. As welded specimens are to withstand an expansion of the outside diameter to 20 percent when similarly tested. The expanded specimen is to show no cracking or rupture visible to the unaided eye.

## 15 Flattening Test

As an alternate to the expansion test for seamless material over 100 mm (4 in.) in diameter and in the annealed condition, a flattening test may be carried out. This specimen selected for testing is to be at least 450 mm (18 in.) in length, and is to be flattened so that a gauge set at three times the wall thickness will pass over the tube freely throughout the flattened part. The tube so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the specimens are to be

slowly flattened by one stroke of the press. Specimens not initially in the annealed temper (O60) are to be annealed prior to flattening.

## 17 Nondestructive Examination

### 17.1 Nondestructive Electric Test (NDET)

All tubes are to be eddy-current tested in accordance with ASTM E243, for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes or, alternatively, when specified, may be hydrostatically tested in accordance with . A calibration reference standard is to be made from a length tube of the same type, wall thickness and outside diameter as that to be tested. The standard is to have transverse notches of depth that when rounded to 0.25 mm (0.001 in.) represents 22 percent of the wall thickness. The notch depth tolerance is to be 0.013 mm (0.0005 in.). Tubulars producing a signal equal to or greater than the calibration defect are to be rejected.

### 17.3 Radiographic Examination

When specified, the welds of Grades CN3 and CN4 are to be examined by radiography.

## 19 Hydrostatic Test

### 19.1 Limiting Test Pressures

As an alternate to the eddy-current test, hydrostatic testing may be performed. Each tube that is tested to stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm<sup>2</sup> (4.92 kgf/mm<sup>2</sup>, 7000 psi), determined by the following equation for thin hollow cylinders under tension. The tube is not to be tested at a hydrostatic pressure of 69 bar (70.3 kgf/cm<sup>2</sup>, 1000 psi) unless so specified.

$$P = KSt / (D - 0.8t)$$

where

- $P$  = pressure in bar (kgf/cm<sup>2</sup>, psi)
- $S$  = allowable unit stress of the material, 48 N/mm<sup>2</sup> (4.92 kgf/mm<sup>2</sup>, 7000 psi)
- $t$  = thickness of tube wall, in mm (in.)
- $D$  = outside diameter of the tube, in mm (in.)
- $K$  = 20 (200, 2)

### 19.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 21 Number of Tests

The lot is to consist of tubulars of the same size and temper. The lot size is to be 5000 kg (10000 lb) or a fraction thereof. For Grades CN3 and CN4 over 100 mm (4 in.) in diameter, the lot size is to be 9100 kg (20000 lb) or a fraction thereof. Sample pieces are to be taken for test purposes from each lot as follows:

<i>Number of Pieces in Lot</i>	<i>Number of Sample Pieces to Be Taken</i>
1 to 50	1
51 to 200	2

<i>Number of Pieces in Lot</i>	<i>Number of Sample Pieces to Be Taken</i>
201 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the hydrostatic test or, when specified, a radiographic examination.

## 23 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

## 25 Finish

Tubes selected for testing are to be examined for finish and workmanship. Tubes are to be free from cracks, injurious surface flaws and similar defects to the extent determinable by visual or NDET examination. Tubes are to be clean and free of any foreign material that would render the tubes unfit for the intended use.

## 27 Dimensions and Tolerances

Each sample selected for testing is to be examined for dimensions and tolerances.

### 27.1 Diameter

The tubular outside diameter is to not vary from the specified values by more than the amounts shown. When all minus diameter tolerances or all plus diameter tolerances are specified, the tolerances shown may be doubled.

<i>Average Diameter</i>	
<i>Specified Diameter mm (inch)</i>	<i>Tolerance, Plus and Minus, mm (inch)</i>
Up to 15.9 ( $\frac{5}{8}$ ), incl.	0.064 (0.0025)
Over 15.9 ( $\frac{5}{8}$ ) to 25.4 (1.0), incl.	0.076 (0.003)
Over 25.4 (1.0) to 50 (2.0), incl.	0.102 (0.004)
Over 50 (2.0) to 76 (3.0), incl.	0.127 (0.005)
Over 76 (3.0) to 100 (4.0), incl.	0.152 (0.006)
Over 100 (4.0) to 125 (5.0), incl.	0.203 (0.008)
Over 125 (5.0) to 150 (6.0), incl.	0.229 (0.009)
Over 150 (6.0) to 200 (8.0), incl.	0.254 (0.010)
Over 200 (8.0) to 255 (10.0), incl.	0.330 (0.013)
Over 255 (10.0) to 305 (12.0), incl.	0.381 (0.015)
Over 305 (12.0)	0.5%

### 27.3 Roundness

The difference between the major diameter and the minor diameter as determined at any one cross section is not the following.

<i>Roundness</i>		
<i>Grade</i>	<i>t/D</i> <sup>(2)</sup>	<i>Tolerance Percent</i> <sup>(3)</sup>
CN1 <sup>(1)</sup> and CN2 <sup>(1)</sup>	0.01 to 0.03, incl.	1.5
	Over 0.03 to 0.05, incl.	1.0
	Over 0.05 to 0.10, incl.	0.8*
	Over 0.10	0.7*
CN3 and CN4	All ratios	3.0

1 Drawn, unannealed straight lengths, wall thickness not less than 0.41 mm (0.016 in.)

2 Ratio of wall thickness to outside diameter

3 Percent of outside diameter, to nearest 0.025mm (0.001 in.)

\* Or 0.051 mm (0.002 in.) whichever is greater

### 27.5 Wall Thickness Tolerances

The permissible variations in wall thickness for all tubulars are based upon the ordered thickness and are to conform to that given in the applicable ASTM designation for acceptance.

### 27.7 Length

The length of tubulars is to not be less than that specified when measured at a temperature of 20°C (68°F) and may exceed specified values by the amounts shown. The tolerance for stock lengths and for specific lengths with ends is 25.4 mm (1.0 in.).

#### **Length Tolerance, mm (inch) Applicable Only to Full-Length Pieces**

<i>Specified Lengths</i>	<i>Grades CN1 and CN2</i>			<i>Grades CN3 CN4</i>
	<i>≤25 mm (1 in.)</i>	<i>&gt; 25.4 mm (1 in.) &lt; 100 mm (4 in.)</i>	<i>&gt; 100 mm (4 in.)</i>	
Up to 150 mm (6 in.), incl.	0.8 ( <sup>1</sup> / <sub>32</sub> )	1.5 ( <sup>1</sup> / <sub>16</sub> )	—	1.5 ( <sup>1</sup> / <sub>16</sub> )
Over 150 to 600 mm (6 in. to 2 ft), incl.	1.5 ( <sup>1</sup> / <sub>16</sub> )	2.5 ( <sup>3</sup> / <sub>32</sub> )	3.0 ( <sup>1</sup> / <sub>8</sub> )	2.5 ( <sup>3</sup> / <sub>32</sub> )
Over 600 to 2000 mm (2 to 6 ft), incl.	2.5 ( <sup>3</sup> / <sub>32</sub> )	3.0 ( <sup>1</sup> / <sub>8</sub> )	6.0 ( <sup>1</sup> / <sub>4</sub> )	3.0 ( <sup>1</sup> / <sub>8</sub> )
Over 2000 to 4000 mm (6 to 14 ft), incl.	6.0 ( <sup>1</sup> / <sub>4</sub> )	6.0 ( <sup>1</sup> / <sub>4</sub> )	6.0 ( <sup>1</sup> / <sub>4</sub> )	6.0 ( <sup>1</sup> / <sub>4</sub> )
Over 4000 mm (14 ft)	12.0 ( <sup>1</sup> / <sub>2</sub> )	12.0 ( <sup>1</sup> / <sub>2</sub> )	12.0 ( <sup>1</sup> / <sub>2</sub> )	12.0 ( <sup>1</sup> / <sub>2</sub> )

### 27.9 Squareness of Cut

The departure from squareness of the end of the tube is to not exceed the following:

<i>Specified Outside Diameter</i>	<i>Tolerance</i>
Up to 15.9 mm ( $\frac{5}{8}$ in.) incl. of CN1 and CN2	0.25 mm (0.010 in.)
All diameters of CN3 and CN4.	0.016 mm/mm (0.016 in./in.) of diameter

### 27.11 Straightness Tolerances

For seamless tubulars of any drawn temper, 6.0 mm (0.25 in.) to 100 mm (3.5 in.) in outside diameter, inclusive, but not for redrawn, extruded or annealed tubulars, the straightness tolerances are as shown.

#### **Maximum Curvature**

<i>Length, mm (feet)</i>	<i>(Depth of Arc), mm (inch)</i>
Over 1000 to 2000 (3 to 6), incl.	5.0 ( $\frac{3}{16}$ )
Over 2000 to 2500 (6 to 8), incl.	8.0 ( $\frac{5}{16}$ )
Over 2500 to 3000 (8 to 10), incl.	12.0 ( $\frac{1}{2}$ )

For lengths greater than 3000 mm (10 ft), the maximum curvature is to not exceed 12.5 mm ( $\frac{1}{2}$  in.) in any 3000 mm (10 ft) portion of the total length.



# PART 2

## CHAPTER 3

### Materials for Machinery, Boilers, Pressure Vessels, and Piping

#### SECTION 21

#### Monel Pipe and Tube (1999)

### 1 Scope

This specification covers four grades of seamless and welded nickel-copper (Monel) pipe and tube, designated M1, M2, M3, and M4.

### 3 General

#### 3.1 Grades M1 and M2

Grades M1 and M2 cover cold-worked, seamless nickel-copper pipe and pipe intended for use in general engineering applications requiring superior seawater corrosion resistance. Pipe and tube ordered under these grades are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging. Pipe is to be ordered to ANSI B36.19. Tube is to be ordered to an outer diameter and a nominal or minimum wall thickness specified by the purchaser and approved for the application.

#### 3.3 Grades M3 and M4

Grades M3 and M4 cover welded, cold-worked nickel-copper pipe and pipe intended for use in general engineering applications requiring superior seawater corrosion resistance. Pipe and tube ordered under these grades are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging. Pipe is to be ordered to ANSI B36.19. Tube is to be ordered to an outer diameter and a nominal or minimum wall thickness specified by the purchaser and approved for the application.

#### 3.5 ASTM Designation

The grades are in substantial agreement with ASTM as follows:

<i>ABS Grade</i>	<i>Heat Treatment</i>	<i>ASTM Designation</i>	<i>Product Form</i>
M1	Annealed	B165, UNS N04400	Seamless Pipe and Tube
M2	Stress Relieved	B165, UNS N04400	Seamless Pipe and Tube
M3	Annealed	B730, UNS N04400	Welded Pipe and Tube
M4	Stress Relieved	B730, UNS N04400	Welded Pipe and Tube

## 5 Process of Manufacture

### 5.1 Grades M1 and M2

These grades are to be finished by cold-working in order to assure that acceptable corrosion resistance in the weld area and base metal will be developed during heat treatment. These grades of pipe and tube are to be supplied in the annealed, Grade M1 or stress-relieved, Grade M2 condition.

### 5.3 Grades M3 and M4

These grades are to be made from flat-rolled material by an automatic welding process with no addition of filler metal. After welding but before heat treatment, the pipe and tube are to be cold worked in order to assure that acceptable corrosion resistance in the weld area and base metal will be developed during heat treatment. Heat treatment is to consist of annealing, as Grade M3, or stress-relieving, as Grade M4. Welded pipe and tube are to be furnished with a scale-free finish. When bright annealing is used, descaling is not necessary.

## 7 Marking

Identification markings are to be legibly stenciled, or marked on each length of pipe and tube. The marking fluid is not to be harmful to the pipe and tube and is not to rub off or smear in normal handling. The fluid is not to be affected by solvents used in subsequent cleaning and preservation operations, but is to be readily removed by hot alkaline solution. In the case of small-diameter tube or pipe with an outside diameter less than 19.0 mm ( $\frac{3}{4}$  in.) which is bundled or boxed, the required markings are to be placed on a tag securely attached to the bundle or box, or on the box. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- ABS Grade or ASTM Specification and Grade
- UNS Alloy Number
- Heat number or manufacturer's number by which the heat can be identified
- Temper designation
- Tube diameter/NPS Designation
- Wall thickness (specify minimum or nominal)/NPS schedule
- Test pressure
- NDET if so tested
- ABS markings by Surveyor

## 9 Chemical Composition

### 9.1 Ladle Analysis

The material is to conform to the chemical requirements specified below.

<i>Element</i>	<i>Content* , in percent</i>
Nickel	63.0 min.
Copper	28.0 to 34.0
Iron	2.5
Manganese	2.0
Carbon	0.3

<i>Element</i>	<i>Content* , in percent</i>
Silicon	0.5
Sulfur	0.024

\* Single values are maxima, unless noted.

### 9.3 Chemical Composition -Check Analysis

A check analysis may be made where so specified by the purchaser. The chemical composition thus determined is to conform to the requirements specified in 2-3-21/9.1, as modified by the product analysis tolerances of the relevant ASTM specification.

## 11 Tension Test

### 11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the pipe or tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the pipe or tube in accordance with ASTM E8, for Tension Testing of Metallic Materials.

### 11.3 Annealed Tensile Properties

Annealed pipe and tube, Grades M1 and M3, is to conform to the applicable requirements as to the tensile properties shown.

<i>Outside Diameter in mm (in.)</i>	<i>Tensile Strength, min in N/mm<sup>2</sup> (ksi)</i>	<i>0.2% Offset Yield Strength, min in N/mm<sup>2</sup> (ksi)</i>	<i>Percent Elongation, min, in 50mm (2in.), or 4 D</i>
127 mm (5 in.) and less	480 (70)	195 (28)	35
Over 127 mm (5 in.)	480 (70)	170 (25)	35

### 11.5 Stress Relieved Tensile Properties

Stress relieved pipe and tube, Grades M2 and M4, is to conform to the applicable requirements as to the tensile properties shown.

<i>Tensile Strength, min in N/mm<sup>2</sup> (ksi)</i>	<i>0.2% Offset Yield Strength, min in N/mm<sup>2</sup> (ksi)</i>	<i>Percent Elongation, min, in 50mm (2in.), or 4 D</i>
585 (85)	380 (55)	15

## 13 Flattening Test

Test specimens taken from samples of welded pipe and tube, Grades M3 or M4, having lengths not less than three times the specified outside diameter or 102 mm (4 in.), whichever is longer, are to be flattened under a load applied gradually at room temperature until the distance between the platens is not greater than five times the wall thickness. The weld is to be positioned 90 degrees from the direction of the applied flattening force. The flattened specimen is to show no cracking, breaks or ruptures on any surface when viewed with the unaided eye.

## 15 Flare Test

Grades M1 and M3 pipe and tube 76 mm (3 in.) or less in specified outside diameter are to be subjected to a flare test. The flare test specimen is to be expanded by means of an expanding tool having an included

angle of 60 degrees until the specified outside diameter has been increased by 30 percent. The expanded specimen is to show no cracking or rupture visible to the unaided eye.

## 17 Flange Test

Test specimens taken from samples of welded pipe and tube, Grade M4, having lengths not less than three times the specified outside diameter or 102 mm (4 in.), whichever is longer, are to be flanged at a right angle to the tube until the width of the flange is not less than 15 percent the diameter of the tube. The flanged specimen is to show no cracking, breaks or ruptures on any surface when viewed with the unaided eye.

## 19 Number of Tests

### 19.1 Chemical Analysis

A chemical analysis (ladle) is to be carried out for each heat of material. Certificates issued by the material producer may be used to satisfy this requirement.

### 19.3 Other Tests

The lot is to consist of tubulars of the same heat, same size (diameter and wall), same condition, and heat treated together in the same batch or in a continuous furnace under the same conditions of temperature, time at temperature, furnace speed, and furnace atmosphere. The lot size for continuously heat treated tubulars is to be 9100 kg (20,000 lb) or a fraction thereof. Where the material cannot be identified by heat, the lot weight is not to exceed 277 kg (500 lb). For test purposes, sample pieces are to be taken at random from each lot at the following frequency for each of the following tests, as specified.

<i>Test or Examination</i>	<i>Frequency</i>
Tension	One
Flattening	One
Flare	One
Flange	One
Hydrostatic	Every Piece
Nondestructive	Every Piece
Finish	1%, minimum of 1, maximum of 10
Dimensions	1%, minimum of 1, maximum of 10

## 21 Hydrostatic Test

### 21.1 Limiting Test Pressures

Each pipe or tube is to stand, without showing evidence of leakage, an internal hydrostatic pressure of 69 bar (70.3 kgf/cm<sup>2</sup>, 1000 psi), provided the fiber stress as calculated from the following equation does not exceed the allowable fiber stress for the material under test.

$$P = KSt/D$$

where

$$K = 20 \text{ (200, 2)}$$

$$P = \text{pressure, in bar (kgf/cm}^2\text{, psi)}$$

- $t$  = thickness of tubular wall, in mm (in.)  
 $D$  = outside diameter of the tubular, in mm (in.)  
 $S$  = allowable fiber stress of the material, in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>, psi)

<i>Condition</i>	<i>Grade</i>	<i>Outside Diameter</i>	<i>Allowable Fiber Stress, S</i>
Annealed	M1, M3	127 mm (5 in.) and less	120 N/mm <sup>2</sup> , (12 kgf/mm <sup>2</sup> , 17,500 psi)
	M1	Over 127 mm (5 in.)	115 N/mm <sup>2</sup> , (11.5 kgf/mm <sup>2</sup> , 16,700 psi)
	M3	Over 127 mm (5 in.)	120 N/mm <sup>2</sup> , (12 kgf/mm <sup>2</sup> , 17,500 psi)
Stress Relieved	All	All diameters	145 N/mm <sup>2</sup> , (14.5 kgf/mm <sup>2</sup> , 21,200 psi)

### 21.3 Exceeding Limiting Test Pressures

When so agreed, the hydrostatic test pressure may exceed the limits stated in Section 2-3-3 to a maximum of 1.5 times the allowable fiber stress values shown above.

### 21.5 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 23 Nondestructive Electric Test (NDET)

### 23.1 General

When specified by the purchaser, welded pipe or tube is to be tested in accordance with ASTM E213, for Ultrasonic Inspection of Metal Pipe and Tubing, ASTM E571, for Electromagnetic (Eddy-current) Examination of Nickel and Nickel Alloy Tubular Products, or other approved standard. It is the intent of these tests to reject tubes containing defects, and the Surveyor is to be satisfied that the nondestructive testing procedures are used in a satisfactory manner.

### 23.3 Ultrasonic Calibration Standards

Longitudinal notches machined on the outside surface and on the inside surface are to be used. The notch depth is to not exceed 12.5% of the specified wall thickness or 0.004 inch (0.10 mm), whichever is greater. The notch is to be placed in the weld if visible.

### 23.5 Eddy-Current Calibration Standards

In order to accommodate the various types of nondestructive electrical testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used at the option of the producer to establish a minimum sensitivity level for rejection. The holes and notches are to be placed in the weld, if visible.

#### 23.5.1 Drilled Hole

A hole not larger than 0.79 mm (0.031 in.) in diameter is to be drilled radially and completely through tube wall, care being taken to avoid distortion of the tube while drilling.

### 23.5.2 Transverse Tangential Notch

Using a round file or tool with a 6.4 mm (0.25 in.) diameter, a notch is to be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. Said notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.10 mm (0.004 in.), whichever is greater.

### 23.5.3 Longitudinal Notch

A notch 0.79 mm. (0.031 in.) or less in width is to be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.10 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

## 23.7 Rejection

Tubulars producing a signal equal to or greater than the calibration defect are to be subject to rejection.

## 23.9 Affidavits

When each tubular is subjected to an approved nondestructive electrical test as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

## 25 Retests

If the results of the test on one of the specimens made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces from same group or lot, and the results of both of these tests are to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

## 27 Finish

Pipe or tube selected for testing is to be examined for finish and workmanship. The samples examined are to be free from cracks, injurious surface flaws and similar defects to the extent determinable by visual or NDET examination. All pipe or tube is to be clean and free of any foreign material that would render the tubulars unfit for the intended use.

## 29 Dimensions and Tolerances

Pipe or tube selected for testing is to be examined and measured for dimensions and tolerances.

### 29.1 Diameter

The outside diameter of pipe and tube, including ovality, is not to exceed the following permissible variations.

<i>Nominal Outside Diameter in mm (in.)</i>	<i>Over and Under Tolerances in mm (in.)</i>
Over 3.2 (0.125) to 16 ( <sup>5</sup> / <sub>8</sub> ), excl.	0.13 (0.005)
16 ( <sup>5</sup> / <sub>8</sub> ) to 38 (1 <sup>1</sup> / <sub>2</sub> ), incl.	0.19 (0.0075)
Over 38 (1 <sup>1</sup> / <sub>2</sub> ) to 76 (3), incl.	0.25 (0.010)
Over 76 (3) to 114 (4 <sup>1</sup> / <sub>2</sub> ), incl.	0.38 (0.015)
Over 114 (4 <sup>1</sup> / <sub>2</sub> ) to 152 (6), incl.	0.51(0.020)
Over 152 (6) to 168 (6 <sup>5</sup> / <sub>8</sub> ), incl.	0.64 (0.025)
Over 168 (6 <sup>5</sup> / <sub>8</sub> ) to 219 (8 <sup>5</sup> / <sub>8</sub> ), incl.	0.79 (0.031)

For pipe and tube having a nominal wall thickness of 3% or less of the nominal outside diameter, the mean outside diameter is to conform to the above permissible variations and individual measurements (including ovality) are to conform to the over and under values, with the values increased by 0.5% of the nominal outside diameter. For pipe and tube over 114 mm (4½ in.) in outside diameter with a nominal wall thickness greater than 3% of the nominal outside diameter, the mean outside diameter is to conform to the above permissible variations, and individual measurements are not to exceed twice the above permissible variations.

### 29.3 Wall Thickness -Seamless

The wall thickness of seamless pipe and tube is not to exceed the permissible variations shown below for the type (nominal or minimum) of specified wall thickness ordered.

<i>Nominal Outside Diameter in mm (in.)</i>	<i>Variation in Thickness of Specified Nominal Wall</i>		<i>Variation in Thickness of Specified Minimum Wall</i>	
	<i>Over in percent</i>	<i>Under in percent</i>	<i>Over in percent</i>	<i>Under in percent</i>
Over 10 (0.400) to 16 (5/8), excl.	15.0	15.0	30	0
16 (5/8) to 38 (1½), incl.	10.0	10.0	22	0
Over 38 (1½) to 76 (3), incl.	10.0	10.0	22	0
Over 76 (3) to 114 (4½), incl.	10.0	10.0	22	0
Over 114 (4½) to 152 (6), incl.	12.5	12.5	28	0
Over 152 (6) to 168 (65/8), incl.	12.5	12.5	28	0
Over 168 (65/8) to 219 (85/8), incl.	12.5	12.5	28	0

### 29.5 Wall Thickness -Welded

The wall thickness of welded pipe and tube is not to exceed the permissible variations shown below for the type (nominal or minimum) of specified wall thickness ordered.

<i>Nominal Outside Diameter in mm (in.)</i>	<i>Variation in Thickness of Specified Nominal Wall</i>		<i>Variation in Thickness of Specified Minimum Wall</i>	
	<i>Over in percent</i>	<i>Under in percent</i>	<i>Over in percent</i>	<i>Under in percent</i>
Over 3.2 (0.125) to 16 (5/8), excl.	15.0	15.0	30	0
16 (5/8) to 38 (1½), incl.	12.5	12.5	28	0
Over 38 (1½) to 76 (3), incl.	12.5	12.5	28	0
Over 76 (3) to 114 (4½), incl.	12.5	12.5	28	0
Over 114 (4½) to 152 (6), incl.	12.5	12.5	28	0
Over 152 (6) to 168 (65/8), incl.	12.5	12.5	28	0
Over 168 (65/8) to 219 (85/8), incl.	12.5	12.5	28	0

### 29.7 Cut Ends

Ends are to be plain or cut and deburred unless otherwise specified.

## 29.9 Straightness

Pipe and tube are to be reasonably straight and free of bends and kinks.



# PART 2

## CHAPTER 4 Welding and Fabrication

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Hull Construction.....</b>	<b>306</b>
	1	General.....	306
	1.1	Hull Welding.....	306
	1.3	Plans and Specifications (2013).....	306
	1.5	Workmanship and Supervision.....	306
	1.7	Welding Procedures.....	306
	1.9	TMCP Plates -Note to Users (1996).....	307
	3	Preparation for Welding.....	307
	3.1	Edge Preparation and Fitting.....	307
	3.3	Alignment.....	307
	3.5	Cleanliness.....	307
	3.7	Tack Welds.....	308
	3.9	Run-on and Run-off Tabs.....	308
	3.11	Stud Welding.....	308
	3.13	Forming (1 July 2013).....	308
	5	Production Welding.....	308
	5.1	Environment.....	308
	5.3	Sequence.....	308
	5.5	Preheat and Interpass Temperature Control.....	309
	5.7	Low-hydrogen Electrodes or Welding Processes.....	310
	5.9	Back Gouging.....	310
	5.11	Peening (2010).....	311
	5.12	Weld Profiling (2010).....	311
	5.13	Fairing and Flame Shrinking.....	311
	5.15	Surface Appearance and Weld Soundness.....	311
	5.17	Inspection of Welds.....	311
	5.19	Repair Welding (2006).....	312
	5.21	Fillet Weld Ends (2018).....	312
	5.23	Post Weld Heat Treatment of Welds in Dissimilar Materials (2011).....	312
	7	Butt Welds.....	312
	7.1	Manual Welding Using Covered Electrodes.....	312

7.3	Submerged-arc Welding.....	313
7.5	Gas Metal-arc and Flux Cored-arc Welding (2005).....	313
7.7	Electroslag and Electrogas Welding.....	313
7.9	Special Welding Processes and Techniques (2008).....	313

FIGURE 1	Illustration of Setup to Qualify Weld Procedures with Water Backing.....	316
----------	--	-----

FIGURE 2	Fillet Weld Test Specimen.....	317
----------	--------------------------------	-----

**SECTION 1 Appendix 1 - Welding In Way of Water Backing..... 314**

1	General.....	314
1.1	Weld Procedure Qualification Requirements.....	314
1.3	Alternative Requirements.....	315
3	Welding Procedure Qualification Tests.....	315
3.1	General.....	315
3.3	Butt Weld Testing.....	315
3.5	Fillet Weld Testing.....	316
3.7	Acceptance Criteria.....	317
3.9	Approval Range.....	317

FIGURE 1	Illustration of Setup to Qualify Weld Procedures with Water Backing.....	316
----------	--	-----

FIGURE 2	Fillet Weld Test Specimen.....	317
----------	--------------------------------	-----

**SECTION 2 Boilers, Unfired Pressure Vessels, Piping and Engineering Structures\*..... 319**

1	General Considerations .....	319
1.1	Fabrication.....	319
1.3	Welding Approval (2010).....	319
1.5	Grouping of Welded Structures.....	319
1.7	Weld Repairs to Ductile (Nodular) Iron.....	321
3	Plans and Specifications.....	321
3.1	Details.....	321
3.3	Base Materials.....	321
5	Workmanship and Supervision.....	321
5.1	Construction.....	321
5.3	Joint Tolerance.....	321
5.5	Surfaces of Parts.....	322
5.7	Out of Roundness.....	322
7	Details of Joints.....	322
7.1	Dimensions and Shape.....	322
7.3	Double-welded Butt Joints.....	322
7.5	Single-welded Butt Joints.....	322
7.7	Joint Finish.....	323

	7.9	Lap Joints.....	323
	7.11	Head to Shell Attachments.....	323
	7.13	Bending Stresses in Welds.....	323
	7.15	Connections.....	323
	7.17	Nozzles.....	323
	7.19	Limitations.....	324
9		Forms of Welded Joints Required.....	324
	9.1	Boilers and Group I Pressure Vessels.....	324
	9.3	Group II Pressure Vessels.....	324
	9.5	Group I Pipe Welded Joints.....	325
	9.7	Group II Pipe Welded Joints.....	325
	9.9	Low-temperature Piping Systems [Below -18°C (0°F)]..	326
	9.11	Engineering Structures.....	326
11		Preheat.....	326
	11.1	Boilers, Pressure Vessels, and Group I Piping.....	326
	11.3	Group I Pipe Connections.....	327
13		General Requirements for Postweld Heat Treatment.....	327
	13.1	General.....	327
	13.3	Heat-treatment Determination.....	327
15		Fusion-welded Boilers.....	327
	15.1	Postweld Heat Treatment.....	327
	15.3	Lower Temperatures - Carbon and Carbon Molybdenum Steels.....	328
	15.5	Heat-treatment Exceptions for Fusion-welded Boilers - ABS Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N, Tube Grades D, F, G, H, J and Group I Piping Grades 1, 2, 3, 4, 5, 8, and 9.....	328
	15.7	Heat-treatment Exceptions for Fusion-welded Boilers - ABS Plate Grades H, I, J, Tube Grades K, L, M, and Group I Piping Grades 6 and 7.....	329
	15.9	Heat Treatment Exceptions for Fusion-welded Boilers - ABS Tube Grades N, O and Group I Pipe Grades 11 and 12.....	329
	15.11	Heat Treatment Exceptions for Fusion Welded Boilers - ABS Tube Grade P and Group I Pipe Grade 13.....	330
	15.13	Other Materials.....	330
	15.15	Other Welded Connections.....	330
	15.17	Welded Joints.....	331
17		Fusion-welded Pressure Vessels.....	331
	17.1	Postweld Heat Treatment.....	331
	17.3	Heat-treatment Exceptions - ABS Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N and Tube Grades D, F, G, H, J.....	331
	17.5	Heat-treatment Exceptions - ABS Plate Grades, H, I, J and Tube Grades K, L, M.....	332

	17.7	Heat-treatment Exceptions - Attachments.....	332
	17.9	Other Materials.....	332
	17.11	Welded Connections.....	332
19		Pipe Welded Joints and Engineering Structures.....	332
	19.1	Group I Pipe Welded Joints.....	332
	19.3	Group II Pipe Welded Joints.....	333
	19.5	Group I Engineering Structures.....	333
	19.7	Group II Engineering Structures.....	333
	19.9	Low-temperatures Piping Systems [Below -18°C (0°F)]	333
21		Postweld Heat-treatment Details.....	333
	21.1	Boilers and Pressure Vessels.....	333
	21.3	Pipe Connections.....	333
	21.5	Other Steels.....	333
	21.7	Clad Pressure Vessels.....	333
	21.9	Opening Connections.....	333
	21.11	Seal Welding.....	334
23		Radiography.....	334
	23.1	General.....	334
	23.3	Boilers.....	334
	23.5	Other Pressure Vessels.....	334
	23.7	Group I Pipe Connections (1999).....	335
	23.9	Group II Pipe Connections(1999).....	335
	23.11	Low Temperature Piping Connections [Below -18°C (0°F)].....	335
	23.13	Group I Engineering Structures.....	335
	23.15	Group II Engineering Structures.....	335
	23.17	Engine Bedplates.....	336
	23.19	Miscellaneous.....	336
25		Hydrostatic Test.....	336
	25.1	Boilers and Pressure Vessels.....	336
	25.3	Piping.....	336
	25.5	Defects.....	336
	25.7	Retest.....	337

	TABLE 1	Hydrostatic Testing of Piping.....	336
--	---------	------------------------------------	-----

	FIGURE 1	Head to Shell Attachments.....	338
--	----------	--------------------------------	-----

	FIGURE 2	Types of Fusion-welded Construction Details.....	341
--	----------	--	-----

**SECTION 3 Weld Tests..... 344**

	1	General (2018).....	344
	1.1	Weld Groups.....	344
	1.3	Tests (2018).....	344

3	Filler Metals.....	344
3.1	General (2018).....	344
3.3	Approval Basis (2005).....	345
5	Approval of Welding Procedures.....	345
5.1	Approved Filler Metals.....	345
5.3	Surveyor's Acceptance.....	345
5.5	New Procedures and Methods.....	345
5.7	Tests (2006).....	345
5.9	Special Tests.....	346
5.11	Repair and Cladding of Stern Tube and Tail Shafts.....	346
7	Workmanship Tests.....	346
7.1	Hull Construction.....	346
7.3	Boilers and Group I Pressure Vessels.....	346
7.5	Other Pressure Vessels.....	347
7.7	Group I Pipe Connections.....	347
7.9	Group II Pipe Connections.....	347
7.11	Group I Engineering Structures.....	347
7.13	Group II Engineering Structures.....	347
9	Radiographic or Ultrasonic Inspection.....	347
9.1	Hull Construction.....	347
9.3	Boilers, Pressure Vessels, Machinery and Piping (2014).....	347
11	Welders.....	348
11.1	General Requirements.....	348
11.3	Qualification Tests.....	348
11.5	Tests Nos. Q1, Q2, and Q3 (2016).....	349
TABLE 1	Welder Qualification Tests (2010).....	349
TABLE 2	Minimum Average Weld Metal and HAZ CVN Impact Values for ABS Grade Steels .....	367
FIGURE 1	Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2.....	351
FIGURE 2	Typical Arrangement of Test Plates for Workmanship Tests in Group B1.....	353
FIGURE 3	Test No. 1 -Reduced-section Tension Test for Plate (2016).....	354
FIGURE 4	Test No. 1 -Reduced-section Tension Test for Pipe (2016)	355
FIGURE 5	Test No. 2 - Guided Bend Test for Root Bend and Face Bend(Plate or Pipe) (2007).....	356
FIGURE 6	Test No. 2 - Guided Bend Test for Side Bend (Plate or Pipe)(1996).....	356
FIGURE 7	Guided Bend Test Jig (2016).....	357
FIGURE 8	Test No. 3 -Fillet-weld Test.....	358
FIGURE 9	Welder Qualification Test No. Q1.....	359

FIGURE 10	Welder Qualification Test No. Q2.....	360
FIGURE 11A	Welder Qualification Test No. Q3 (2005).....	361
FIGURE 11B	Welder Qualification Test No. Q3 - 6GR.....	362
FIGURE 11C	Welder Qualification Test No. Q3R (2014).....	363
FIGURE 12	Welder Qualification Test No. Q4.....	365
FIGURE 13	Orientation and Location of Charpy V-notch Specimens for Weld and Heat Affected Zone Properties (2013).....	366

<b>SECTION</b>	<b>4 Piping.....</b>	<b>369</b>
1	General.....	369
1.1	Application.....	369
1.3	Pipe Classes.....	369
1.5	Materials.....	369
1.7	Welding Filler Metals.....	370
3	Welding Procedures and Welders.....	370
3.1	Welding Procedures.....	370
3.3	Welders and Welding Operators.....	370
5	Types of Welded Joints.....	371
5.1	Full Penetration Butt Joints.....	371
5.3	Square-groove Butt Joint.....	371
5.5	Fillet-welded Joints.....	371
5.7	Flange Attachment Welds.....	372
5.9	Branch Connections.....	372
5.11	Tack Welding.....	372
5.13	Brazing (2005).....	372
7	Preheat.....	372
9	Post-weld Heat Treatment.....	373
9.1	Procedure.....	373
9.3	Requirement.....	373
11	Nondestructive Examination.....	374
11.1	Visual Examination.....	374
11.3	Butt Weld Joints.....	374
11.5	Fillet Weld Joints.....	375
13	Weld Repair.....	375
15	Pipe Forming and Bending.....	375
15.1	Cold Forming.....	375
15.3	Hot Forming (2013).....	375
17	Additional Requirements for Low Temperature Piping [below -10°C (14°F)].....	376
17.1	Application.....	376
17.3	Welding Procedure.....	376
17.5	Pipe Joints.....	376
17.7	Post-weld Heat Treatment.....	376
17.9	Nondestructive Examination.....	376

<b>SECTION</b>	<b>5</b>	<b>Aluminum Welding in Hull Construction (2018)</b> .....	<b>377</b>
	1	General.....	377
	1.1	Hull Welding.....	377
	1.3	Plans and Specifications.....	377
	1.5	Workmanship and Supervision.....	377
	1.7	Welding Procedures.....	377
	3	Preparation for Welding.....	378
	3.1	Edge Preparation and Fitting.....	378
	3.3	Alignment.....	378
	3.5	Cleanliness (2012).....	380
	3.7	Tack Welds.....	380
	3.9	Stud Welding.....	380
	3.11	Temporary Back-up Plates and Tapes.....	381
	3.13	Run-on and Run-off Tabs.....	381
	3.15	Forming.....	381
	5	Production Welding.....	382
	5.1	Environment.....	382
	5.3	Preheat.....	382
	5.5	Postheating.....	382
	5.7	Accessibility.....	382
	5.8	Avoiding Joint Corrosion.....	382
	5.9	Sequence.....	383
	5.11	Back Gouging.....	383
	5.13	Fairing and Flame Shrinking.....	383
	5.15	Inspection of Welds.....	383
	5.17	Workmanship Requirements.....	386
	5.19	Quality Control.....	387
	5.21	Repair Welding.....	387
	7	Butt Welds.....	387
	7.1	Joint Design.....	387
	9	Fillet Welds.....	387
	11	Filler Metals.....	388
	11.1	General.....	388
	11.3	Approval Basis.....	388
	13	Approval of Welding Procedures.....	388
	13.1	Approved Filler Metals.....	388
	13.3	Surveyor's Acceptance.....	388
	13.5	New Procedures and Methods.....	388
	13.7	Tests.....	388
	13.9	Special Tests.....	389
	15	Welder Qualifications.....	389
	15.1	General.....	389
	15.3	Qualification Tests.....	389
	17	Alternatives.....	389

TABLE 1	Minimum Cold-forming Radii for Aluminum Alloys <sup>(1, 2, 3)</sup> ....	381
TABLE 2	Minimum Mechanical Properties for Butt-Welded Aluminum Alloys.....	389
TABLE 3	Aluminum Alloy Filler Metal Composition (2016).....	390
TABLE 4	Filler Metals for Welding Aluminum Alloy – Sheet, Plate and Extrusions (2016).....	391
TABLE 5	Filler Metals for Welding Aluminum Alloy Castings to Castings and Plate.....	391
TABLE 6	Welder Qualification Tests.....	392
FIGURE 1A	Inserts and Patches in Plating.....	379
FIGURE 1B	Inserts and Patches in Plating.....	380
FIGURE 2	Repairs of Misalignments.....	384
FIGURE 3	Permissible Unfairness in Aluminum Welded Structure.....	393
FIGURE 4	Permissible Unfairness in Other Aluminum Welded Structure.....	394
FIGURE 5	Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2.....	395
FIGURE 6	Typical Arrangement of Test Plates for Workmanship Tests in Group B1.....	397
FIGURE 7	Test No. 1 – Reduced-section Tension Test for Plate.....	398
FIGURE 8	Test No. 1 – Reduced-section Tension Test for Pipe.....	399
FIGURE 9	Test No. 2 – Guided Bend Test for Root Bend and Face Bend (Plate or Pipe) (2007).....	400
FIGURE 10	Test No. 2 – Guided Bend Test for Side Bend (Plate or Pipe).....	400
FIGURE 11	Guided Bend Test Jig.....	400
FIGURE 12	Alternative Guided Bend Test Jig.....	402
FIGURE 13	Test No. 3 – Fillet Weld Test (2013).....	402
FIGURE 14	Welder Qualification Test No. Q1.....	403
FIGURE 15	Welder Qualification Test No. Q2.....	404
FIGURE 16	Welder Qualification Test No. Q4.....	406
FIGURE 17	Welder Qualification Test No. Q5.....	408



# PART 2

## CHAPTER 4 Welding and Fabrication

### SECTION 1 Hull Construction (1 July 2021)

#### 1 General

##### 1.1 Hull Welding (1 July 2021)

Welding in hull construction is to comply with the requirements of this section, unless specially approved otherwise. It is recommended that appropriate permanent markings be applied to the side shell of welded vessels to indicate the location of bulkheads for reference. In all instances welding procedures and filler metals are to produce sound welds having strength and toughness comparable to the base material. For weld design, see Section 3-2-19 of the *Marine Vessel Rules*.

In cases where welding is proposed with water backing, refer to Appendix 2-4-1-A1, which includes requirements for qualification of weld procedures with water backing.

##### 1.3 Plans and Specifications (2013)

The plans submitted are to clearly indicate the proposed extent of welding to be used in the principal parts of the structure. The welding process, filler metal and joint design indicating full/partial penetration weld are to be shown on the detail drawings or in separate specifications submitted for approval which should distinguish between manual and automatic welding. The shipbuilders are to prepare and file with the Surveyor a planned procedure to be followed in the erection and welding of the important structural members.

##### 1.5 Workmanship and Supervision

The Surveyor is to satisfy himself that all welders and welding operators to be employed in the construction of vessels to be classed are properly qualified and are experienced in the work proposed. The Surveyor is also to be satisfied as to the employment of a sufficient number of skilled supervisors to ensure a thorough supervision and control of all welding operations. Inspection of welds employing methods outlined in 2-4-1/5.17 is to be carried out to the satisfaction of the Surveyor.

##### 1.7 Welding Procedures

###### 1.7.1 General (2021)

Welding procedures are to be qualified to Part 2, Appendix 9 or to equivalent recognized standards such as AWS, EN, ISO, ASME, MIL and JIS. Also refer to Section 2-4-3. which may be applied as an alternative to Part 2, Appendix 9.

Procedures for the welding of all joints are to be established before construction for the welding processes, types of electrodes, edge preparations, welding techniques, and positions proposed. See 2-4-3/5. Details of proposed welding procedures and sequences may be required to be submitted for review depending on the intended application.

#### 1.7.2 Weld Metal Toughness -Criteria for ABS Grades of Steel (2009)

For steels shown in 2-1-2/15.9 TABLE 4 and 2-1-3/7.3 TABLE 4 of these Rules, and 2-1-8/5.11 TABLE 5A of the *ABS Rules for Materials and Welding (Part 2)*, Approved filler metals appropriate to the grades shown in Part 2, Appendix 3 may be used.

#### 1.7.3 Weld Metal Toughness -Criteria for Other Steels

Weld metal is to exhibit Charpy V-notch toughness values at least equivalent to transverse base metal requirements ( $2/3$  of the longitudinal base metal requirements).

### 1.9 TMCP Plates -Note to Users (1996)

When considering thermo-mechanically controlled steels for further heating for forming or stress relieving, or for high heat input welding, the attention of the fabricator is drawn to the possible reduction in the mechanical properties. A procedure test using representative material is to be considered.

## 3 Preparation for Welding

### 3.1 Edge Preparation and Fitting (1 July 2020)

The edge preparation is to be accurate and uniform and the parts to be welded are to be fitted in accordance with the approved joint detail. All means adopted for correcting improper fitting are to be to the satisfaction of the Surveyor. The Surveyor may accept a welding procedure for build up of each edge that does not exceed one half the thickness of the member or 12.5 mm (0.5 in.), whichever is the lesser. The Surveyor may accept edge build up in excess of the above, up to the full thickness of the member on a case-by-case basis, provided the Surveyor is notified of such cases before the members are welded together. Where plates to be joined differ in thickness and have an offset on either side of more than 4 mm (0.16 in.), a suitable transition taper is to be provided. For the transverse butts in bottom shell, sheer strake, and strength deck plating within the midship portion of the hull, and other joints which may be subject to comparatively high stresses, the transition taper length is to be not less than three times the offset. The transition may be formed by tapering the thicker member or by specifying a weld joint design which will provide the required transition.

### 3.3 Alignment

Means are to be provided for maintaining the parts to be welded in correct position and alignment during the welding operation. In general, strong backs, or other appliances used for this purpose are to be so arranged as to allow for expansion and contraction during production welding. The removal of such items is to be carried out to the satisfaction of the Surveyor.

### 3.5 Cleanliness (2019)

All surfaces to be welded are to be free from moisture, grease, loose mill scale, paint, and excessive rust. Primer coatings of ordinary thickness, thin coatings of linseed oil, or equivalent coatings may be used, provided it is demonstrated that their use has no adverse effect in the production of satisfactory welds. Slag and scale are to be removed not only from the edges to be welded but also from each pass or layer before the deposition of subsequent passes or layers. Weld joints prepared by arc-air gouging may require additional preparation by grinding or chipping and wire brushing prior to welding to minimize the possibility of excessive carbon on the scarfed surfaces. Compliance with these cleanliness requirements is of prime importance in the welding of higher-strength steels, especially those which are quenched and tempered.

### 3.7 Tack Welds

Tack welds of consistently good quality, made with the same grade of filler metal as intended for production welding and deposited in such a manner as not to interfere with the completion of the final weld, need not be removed, provided they are found upon examination to be thoroughly clean and free from cracks or other defects. Preheat may be necessary prior to tack welding when the materials to be joined are highly restrained. Special consideration is to be given to use the same preheat as specified in the welding procedure when tack welding higher-strength steels, particularly those materials which are quenched and tempered. These same precautions are to be followed when making any permanent welded markings.

### 3.9 Run-on and Run-off Tabs

When used, run-on and run-off tabs are to be designed to minimize the possibility of high-stress concentrations and base-metal and weld-metal cracking.

### 3.11 Stud Welding

The attachment of pins, hangers, studs, and other related items to ordinary and higher-strength hull structural steels or equivalent by stud welding may be approved at the discretion of the Surveyor. Stud welded attachment to quenched and tempered steel is to be specially approved. At the Surveyor's discretion, trial stud welds may be tested to demonstrate that the base material in way of the stud welds is free from cracking and excessively high hardness. The use of stud welding for structural attachments is subject to special approval and may require special procedure tests appropriate to each application.

### 3.13 Forming (1 July 2013)

Steel is not to be formed between the upper and lower critical temperatures; forming of ordinary-strength and higher-strength steel in the range between 205°C (400°F) and 425°C (800°F) should be avoided. Forming of high-strength quenched and tempered steel in the range between 260°C (500°F) and 595°C (1100°F) should be avoided. If it is intended to form within these ranges for either of the above steels, the manufacturer should be consulted prior to forming. If the forming temperature exceeds 650°C (1200°F) for as-rolled, controlled rolled, thermo-mechanical controlled rolled or normalized steels, or is not at least 28°C (50°F) lower than the tempering temperature for quenched and tempered steels, mechanical tests are to be made to assure that these temperatures have not adversely affected the mechanical properties of the steel. See 2-4-1/1.9.

For applications where toughness is of particular concern (such as Class III in 3-1-2/3.3 TABLE 2A of the *Marine Vessel Rules*), when steel is formed below 650°C (1200°F) beyond 3% strain\* on the outer fiber, supporting data is to be provided to the satisfaction of the Surveyor indicating that the impact properties meet minimum requirements after forming. After straining, specimens used in Charpy impact tests are to be subjected to an artificial aging treatment of 250°C (480°F) for one (1) hour before testing. Rule steels of 2-1-2/15.9 TABLE 5 and 2-1-3/7.3 TABLE 5 or equivalent steels used for radius gunwales (in accordance with 3-1-2/3.3 TABLE 1 of the *Marine Vessel Rules*) may be cold formed to a minimum radius of 15*t* without requiring stress relieving or other supporting data.

\* Calculated on the basis of % strain =  $\frac{65 \times \text{plate thickness}}{\text{outer radius}}$

## 5 Production Welding

### 5.1 Environment

Proper precautions are to be taken to insure that all welding is done under conditions where the welding site is protected against the deleterious effects of moisture, wind and severe cold.

### 5.3 Sequence

Welding is to be planned to progress symmetrically so that shrinkage on both sides of the structure will be equalized. The ends of frames and stiffeners should be left unattached to the plating at the subassembly

stage until connecting welds are made in the intersecting systems of plating, framing and stiffeners at the erection stage. Welds are not to be carried across an unwelded joint or beyond an unwelded joint which terminates at the joint being welded unless specially approved.

### 5.5 Preheat and Interpass Temperature Control (1 July 2018)

Preheat and interpass temperatures are to be in accordance with the approved welding procedure specification; that is appropriate to the alloy chemistry and thickness.

An increase in specified preheat is to be considered during the weld procedure qualification for steels with specific property requirements, such as, high toughness, extra high strength, crack arrest and enhanced corrosion resistance.

The minimum preheat temperature is to be maintained throughout all welding operations, including tack welds and temporary attachment welds.

The minimum and maximum interpass temperatures are to be maintained within the qualified WPS ranges throughout all welding operations, including tack welds and temporary attachment welds.

In all cases, preheat and interpass temperature control are to be sufficient to maintain dry surfaces and minimize the possibility of the formation of fractures.

When welding is performed under high humidity conditions or when the temperature of steel is below 0°C (32°F), the base metal is to be preheated to at least 20°C (70°F) or as specified in the WPS, whichever is the higher.

Particular close attention to control, with verification by the ABS Surveyor, of preheat and interpass temperature (using calibrated equipment) is to be applied when welding extra-high-strength steels, forgings and castings, and materials of thick cross-section or materials subject to high restraint, for example, cruciform T butt welds.

If any of the following apply, an increase in preheat temperature is to be considered:

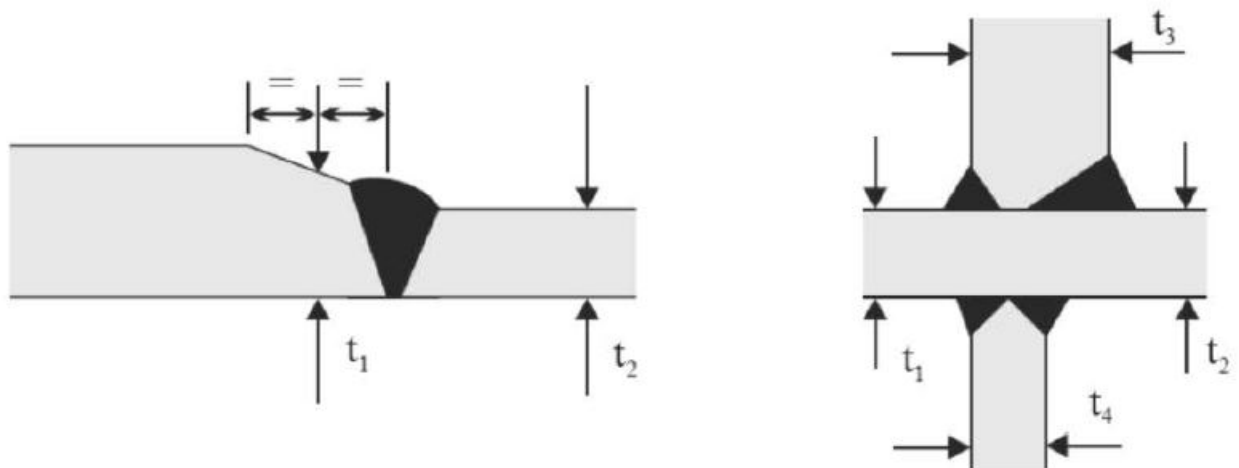
- i) Structural members in critical areas
- ii) Members such as cruciform joints which have high restraint
- iii) Increased material thickness as combined thickness; over 25 mm (1 in.), over 50 mm (2 in.), over 70 mm (2.8 in.), over 100 mm (4.0 in.)
- iv) Welding connections of castings to thick rolled plates or large structures, which could act as heat sinks
- v) Any weld repairs
- vi) Higher Carbon content or high Carbon equivalent

**Note:**

Depending upon the welding code applied (e.g., AWS D1.1, ASME IX), a requalification of a WPS with a higher preheat might be required.

Calculation of Combined Thickness below:

Combined thickness  $t_{comb} = t_1 + t_2 + t_3 + t_4$ , see figure



Preheating may be performed by gas burners, oxy-gas torch, electric blankets, induction heating, or by heating in a furnace.

All specified preheat and interpass temperatures are to be measured or verified by appropriate temperature measuring devices in close proximity to weld. (Typically 75 mm (3 inches) from the weld).

Preheat is to be applied in such a manner as to allow for the complete material thickness to reach the required temperature.

If a torch is used to preheat welds, including tack or short welds, it is to be manipulated around the surrounding joint area to produce uniform heating. Intense, non-uniform heating is to be avoided and may be detrimental, leading to distortion, high residual stress, undesirable metallurgical phases and do little to retard weld cooling.

Preheating may also be necessary before thermal cutting operations.

## 5.7 Low-hydrogen Electrodes or Welding Processes

### 5.7.1 Welding of Ordinary and Higher Strength Steel

The use of low-hydrogen electrodes or welding processes is recommended for welding all higher-strength steel and may also be considered for ordinary-strength steel weldments subject to high restraint. When using low-hydrogen electrodes or processes, proper precautions are to be taken to ensure that the electrodes, fluxes and gases used for welding are clean and dry.

### 5.7.2 Welding of Quenched and Tempered Steels

Unless approved otherwise, matching strength, low-hydrogen electrodes or welding processes are to be used for welding quenched and tempered steels and overmatching should be generally avoided. When welding quenched and tempered steels to other steels, the weld filler metal selection is to be based on the lower strength base material being joined and low hydrogen practice being comparable to that for the higher strength material. In all cases, filler metal strength is to be no less than that of the lowest strength member of the joint unless approved otherwise. The Surveyor is to be satisfied that the procedures for handling and baking filler metals and fluxes are commensurate with the low-hydrogen practices appropriate to the highest strength steel.

## 5.9 Back Gouging

Except as permitted in 2-4-1/7.3, chipping, grinding, arc-air gouging or other suitable methods are to be employed at the root or underside of the weld to obtain sound metal before applying subsequent beads for all full-penetration welds. When arc-air gouging is employed, a selected technique is to be used so that

carbon buildup and burning of the weld or base metal is minimized. Quenched and tempered steels are not to be flame gouged.

### 5.11 Peening (2010)

Peening, when used to correct distortion, is to be effected immediately after depositing and cleaning each weld pass. The use of peening is not recommended for single-pass welds, the root or cover passes on multipass welds, or on the base metal at the edges of the weld except as provided in 2-4-1/5.12 to enhance fatigue life.

### 5.12 Weld Profiling (2010)

For fatigue life enhancement, weld profiling may be carried out (e.g., in critical areas). Welds may be profiled using grinding, TIG dressing, or peening, at weld toes to the satisfaction of the attending Surveyor.

### 5.13 Fairing and Flame Shrinking

Fairing by heating or flame shrinking and other methods of correcting distortion or defective workmanship in fabrication of main strength members within the midship portion of the vessel and other plating which may be subject to high stresses is to be carried out only with the express approval of the Surveyor. These corrective measures are to be kept to an absolute minimum when the higher-strength steels are involved, due to high local stresses and the possible degradation of the mechanical properties of the base material. See 2-4-1/1.9.

## 5.15 Surface Appearance and Weld Soundness

### 5.15.1 Surface Appearance (2011)

The surfaces of welds are to be visually inspected and are to be regular and uniform with a minimum amount of reinforcement and reasonably free from undercut and overlap. Welds and adjacent base metal are to be free from injurious arc strikes. In seawater ballast tanks as required by IMO Resolution MSC.215(82) and ISO 8501-3 Grade P2, welds and surrounding areas are to conform as follows:

- Surfaces are to be free of all loose and lightly adhering weld spatter.
- Surfaces are to be dressed (e.g., by grinding) to remove irregular and sharp-edged profiles.
- Surfaces are to be free from slag.
- Surfaces are to be free from sharp or deep undercut.
- Surface pores are to be sufficiently open to allow penetration of paint or are to be dressed out.
- End craters are to be free from sharp edges.

### 5.15.2 Weld Soundness

Welds are to be sound, crack free throughout the weld cross section, and fused to the base material to the satisfaction of the attending Surveyor and should generally be considered on the basis of 2-4-1/1.5 "Workmanship and Supervision", 2-4-1/1.7 "Welding Procedure Qualification", and 2-4-1/5.17 "Nondestructive Inspection of Welds".

### 5.17 Inspection of Welds (2020)

Inspection of welded joints in important locations is to be carried out by an approved nondestructive test method such as radiographic, ultrasonic, magnetic-particle or dye-penetrant inspection. ABS's separately issued *Guide for Nondestructive Inspection* or an approved equivalent standard is to be used in evaluating radiographs and ultrasonic indications. Evaluation of radiographs and ultrasonic indications is one of the factors in assessing shipyard weld quality control. Radiographic or ultrasonic inspection, or both, is to be used when the overall soundness of the weld cross section is to be evaluated. Magnetic-particle or dye-penetrant inspection or other approved methods are to be used when investigating the outer surface of welds or may be used as a check of intermediate weld passes such as root passes and also to check back-

gouged joints prior to depositing subsequent passes. Surface inspection of important tee or corner joints in critical locations, using an approved magnetic particle or dye penetrant method, is to be conducted to the satisfaction of the Surveyor. Extra high-strength steels, [415-960 N/mm<sup>2</sup> (42-98 kgf/mm<sup>2</sup>, 60,000-139,000 psi) minimum yield strength] may be susceptible to delayed cracking. When welding these materials, the final nondestructive testing is to be delayed sufficiently to permit detection of such defects in accordance with 1/2.5 of the *ABS Guide for Nondestructive Inspection*. Weld run-on or run-off tabs may be used where practical and be sectioned for examination. Where a method (such as radiographic or ultrasonic) is selected as the primary nondestructive method of inspection, the acceptance standards of such a method governs. However, if additional inspection by any method should indicate the presence of defects that could jeopardize the integrity of structure, removal and repair of such defects are to be to the satisfaction of the attending Surveyor.

## 5.19 Repair Welding (2006)

Defective welds and other injurious defects, including base metal defects, as determined by visual inspection, nondestructive test methods, or leakage are to be excavated in way of the defects to sound metal and corrected by rewelding, using a suitable repair welding procedure to be consistent with the material being welded. Removal by grinding of minor surface imperfections such as scars, tack welds and arc strikes may be permitted at the discretion of the attending Surveyor. Special precautions, such as the use of preheat, interpass temperature control, and low-hydrogen electrodes, are to be considered when repairing welds in all higher strength steel, ordinary strength steel of thick cross section, or steel subject to high restraint. Materials thicker than approximately 19 mm (<sup>3</sup>/<sub>4</sub> in.) are considered to be of thick cross-section. In all cases, preheat and interpass temperature control are to be sufficient to maintain dry surfaces and minimize the possibility of the formation of fractures.

### 5.19.1 Repair to Casting Defect Identified after Machining or During Assembly (2017)

After it has been agreed, by the attending Surveyor, that a casting can be repaired by welding, full details of the extent and location of the repair are to be submitted for approval together with the qualified welding procedures, welders' qualifications, heat treatment (if applicable) and subsequent inspection procedures.

Defects are to be removed to sound metal, and the excavation is to be investigated by suitable approved nondestructive examination methods to confirm that the defect has been removed. Corrective welding is to be associated with the use of preheat.

Temporary welds made to castings (for operations such as lifting, handling, staging etc) are to be carried out to qualified welding procedures and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

## 5.21 Fillet Weld Ends (2018)

The ends of continuous fillet welds should be seal welded (wrapped) at terminations of structural members and in way of cut-outs or holes and along all edges of any provided brackets.

## 5.23 Post Weld Heat Treatment of Welds in Dissimilar Materials (2011)

Post weld heat treatment of welds between dissimilar materials, carbon steel to stainless steels or high alloy steels, including weld metal overlay clad base material or parts, requires the prior approval of ABS Materials.

# 7 Butt Welds

## 7.1 Manual Welding Using Covered Electrodes

Manual welding using covered electrodes may be ordinarily employed for butt welds in members not exceeding 6.5 mm (<sup>1</sup>/<sub>4</sub> in.) in thickness without beveling the abutting edges. Members exceeding 6.5 mm (<sup>1</sup>/<sub>4</sub> in.) are to be prepared for welding in a manner acceptable to the Surveyor by using an appropriate edge

preparation, root opening and root face (land) to provide for welding from one or both sides. For welds made from both sides, the root of the first side welded is to be removed to sound metal by an approved method before applying subsequent weld passes on the reverse side. Where welding is to be deposited from one side only, using ordinary welding techniques, appropriate backing (either permanent or temporary) is to be provided. The backing is to be fitted so that spacing between the backing and the members to be joined is in accordance with established procedures. Unless specially approved otherwise, splices in permanent backing strips are to be welded with full penetration welds prior to making the primary weld.

### 7.3 Submerged-arc Welding

Submerged-arc welding, using wire-flux combinations for butt welds in members not exceeding 16 mm ( $\frac{5}{8}$  in.) in thickness, may be ordinarily employed without beveling the abutting edges. Members exceeding 16 mm ( $\frac{5}{8}$  in.) are normally to be prepared for welding in a manner acceptable to the Surveyor by using an appropriate edge preparation, root opening and root face (land) to provide for welding from one or both sides. When it is determined that sound welds can be made without back gouging, the provisions 2-4-1/5.9 are not applicable. Where the metal is to be deposited from one side only, using ordinary welding techniques, backing (either permanent or temporary) is to be provided and the members are to be beveled and fitted in accordance with established procedures.

### 7.5 Gas Metal-arc and Flux Cored-arc Welding (2005)

Semiautomatic or mechanized gas metal-arc welding and flux cored-arc welding using wire-gas combinations and associated processes may be ordinarily employed utilizing the conditions as specified in 2-4-1/7.1, except that specific joint designs may differ between processes.

Short circuit gas metal arc welding (GMAW-S) is to be restricted to welding thickness up to 6.5 mm ( $\frac{1}{4}$  in.) unless specially approved otherwise (see 2-4-3/11.3 for special requirement for welder qualification)

### 7.7 Electroslag and Electrogas Welding

The use of electroslag and electrogas welding processes will be subject to special consideration, depending upon the specific application and the mechanical properties of the resulting welds and heat-affected zones. See 2-4-1/1.9.

### 7.9 Special Welding Processes and Techniques (2008)

Special welding techniques employing any of the basic welding processes mentioned in 2-4-1/7.1 through 2-4-1/7.7 will also be specially considered, depending upon the extent of the variation from the generally accepted technique. Such special techniques include narrow-gap welding, tandem-arc welding and consumable guide electroslag welding. In addition, the use of gas tungsten arc welding will be subject to special consideration, depending upon the application and whether welding is manual or mechanized. Welding processes such as friction stir welding and hybrid laser welding will be specially considered.



**Appendix 1 - Welding In Way of Water Backing (1 July 2021)****1 General**

This section is intended to provide requirements for qualification of weld procedures with water as backing. Some examples include,

- i)* Where the vessel or offshore structure is in water, fillet welds on shell plating below the waterline are considered welding with water backing.
- ii)* Where the vessel or offshore structure is in water, weld build-up on shell plating below the waterline are considered welding with water backing.
- iii)* Where the vessel or offshore structure is in water, full penetration welds with a backing plate on shell plating below waterline is considered welding with water backing (backing plate arrangement prevents water seepage to the root of the weld).

The primary problem encountered in welding steels against water backing is the tendency towards reduced elongation and toughness in the weld metal resulting from the relatively rapid cooling. Special measures are required during production welding, so weld procedures are to be specifically qualified.

Prior to beginning welding a preliminary welding procedure specification (pWPS) is to be submitted to ABS Materials Department for review. After satisfactory testing, the weld procedure (weld procedure specification (WPS) and supporting procedure qualification record (PQR)) are also to be submitted to ABS Materials Department for review.

*Note:* This Appendix is not required to be applied for cases where a cofferdam is installed on the shell plating to remove water as backing.

**1.1 Weld Procedure Qualification Requirements**

Procedure qualification testing is to be carried out to qualify for welding against water backing. Butt welds with backing plate, fillet welds or weld build-up (in corroded/pitted areas) - qualification testing is to be carried out, with welding and testing as indicated below to the satisfaction of the attending Surveyor.

- i)* Base material used in the qualification testing is to be representative of the plate(s) in production welding. Factors that need to be considered during selection of base material are chemical analysis, Carbon content, Carbon equivalent (refer to 2-1-3/7.1), cold cracking susceptibility (refer to 2-1-3/7.3), tensile and impact properties and delivery condition.
- ii)* Weld procedure qualification test assembly and set-up is to simulate the actual welding environment. The qualification should include setting the plate to be welded against a water

backing, Water should be flowing during welding and the water temperature is to be cooled and circulated to maintain a temperature lower than the actual production weld water temperature.

- iii) All moisture is to be removed from the weld prep before welding. Preheat is to be appropriate for the steel grade to be welded. If preheat is required, the minimum preheat temperature it is to be maintained during qualification and production welding. Preheat is to extend to at least 100 mm (4 in.) beyond the weld area or four times the base metal thickness, whichever is greater. If the water temperature is less than 5°C, preheat is to be applied during qualification and production welding.
- iv) Low Hydrogen welding consumables are to be used.
- v) Qualification test assembly is to be carried out in each position intended for production.
- vi) Welding heat input is to be at least 1600 J/mm (40 kJ/in). Welding heat input is determined as follow;

$$\text{Heat Input (J/in)} = \frac{60 \times \text{Volts} \times \text{Amps}}{\text{Travel Speed (in/min)}}$$

Note that in the case of fillet weld qualification testing, only the water backed member need to comply with this section.

### 1.3 Alternative Requirements

Alternative weld procedures qualified to other recognized standards such as MIL-STD-1689A, which specifically includes requirements for water back welding, may be applied provided full compliance with the standard is maintained. The weld procedure is to be submitted for review and acceptance by ABS Materials Department.

Upon review, established weld procedures qualified with water backing, previously reviewed by ABS Materials Department, may be accepted by ABS provided they are suitable and the procedure is supported by proven results.

## 3 Welding Procedure Qualification Tests

### 3.1 General

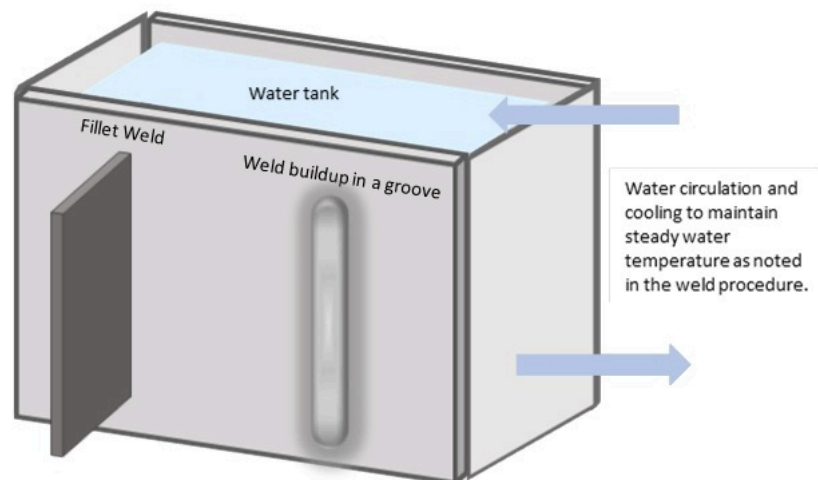
Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor. Figure 1 below provides an illustration of setup to qualify weld procedures with water backing.

### 3.3 Butt Weld Testing

- i) Base metal thickness is to be similar to the full thickness of that being repaired in production.
- ii) The test assembly is to be a butt weld with backing plate. The backing plate should be the same grade as the base metal. Alternatively, the test assembly can represent the production repair joint configuration, such as a weld buildup of a corroded/pitted plate where a depression or groove can be ground out in the test plate to a specified depth representing the actual repair.
- iii) The thickness of the backing plate or the remaining plate thickness is to be the minimum remaining thickness of production plate after removal of corrosion pitting or imperfection. It is to be noted that water backed repair on plate thickness or remaining plate thickness of less than 6 mm (0.24 in.) is not recommended, as there are risks of burn through, of plate cracking, and of embrittlement. In such cases, the use of an external cofferdam with the water evacuated is a safer solution.
- iv) Qualification testing is to include the following (Refer to 2-A9-1/Figure 2 for test sampling);
  - One all-weld metal tensile test
  - Two transverse weld tensile test
  - Four bend test

- Hardness traverse (included the hardness at the backing plate or the remaining plate). Refer to 2-A9/Annex 2.
  - Charpy V-notch tests are to be carried in accordance with 2-A9/Annex 1. Test temperature is to be in accordance with 2-A9-1/Table 1.
- v) Qualification test welds are to be examined by visual, surface and volumetric inspection in accordance with *ABS Guide for Nondestructive Inspection*. Inspection of the welds is to be delayed by at least 24 hours, for steels with minimum yield strength less than 415 MPa (60 ksi). For all other steels, inspection is to be in accordance with guidance in *ABS Guide for Nondestructive Inspection*.

**FIGURE 1**  
**Illustration of Setup to Qualify Weld Procedures with Water Backing**



**Notes:**

- 1 For qualification of butt weld procedures with water backing, thickness of the plate for the water tank is to be the thickness of the backing plate used during production
- 2 The above illustration can be used for qualification of weld procedure for weld build-up, where the thickness of the plate for the water tank is to represent the minimum thickness of the corroded or pitted plate.
- 3 In case of qualification for fillet weld, the fillet is to be welded on the plate forming the water tank. The thickness of the water tank plate is to be the thickness of the shell plating on the vessel or offshore structure.

### 3.5 Fillet Weld Testing

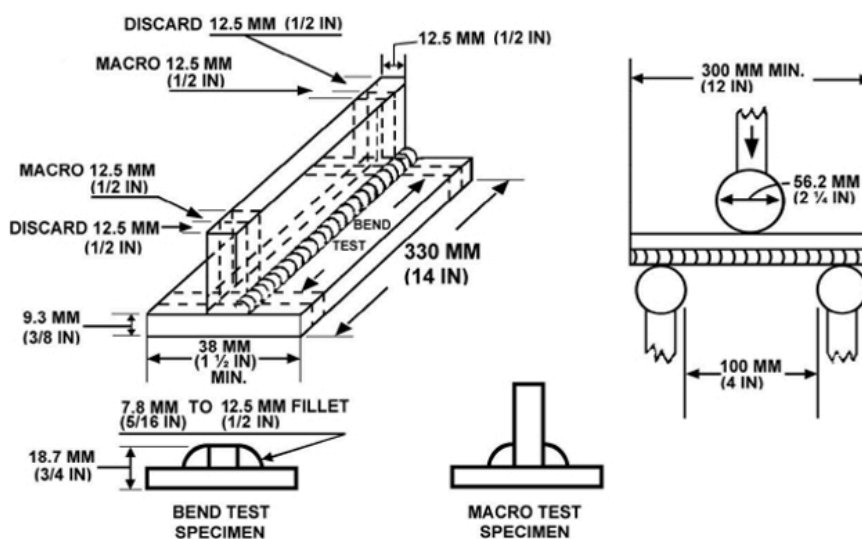
The requirements of fillet weld testing is intended to demonstrate that adequate penetration and elongation properties are achieved.

- i) Test assemblies, one for each filler metal size to be used in production welding.
- ii) The thickness of the the water backed member is to be same as the thinnest shell plate in way of proposed repairs. The same applies as for butt welds in that it is not recommended to attempt to perform a fillet weld where the water backed plate is less than 6 mm (0.24 in.) thick.
- iii) Qualification testing is to include the following;
  - Macro Examination - 2 macros are required. Macro examination is to include approximately 10 mm unaffected base metal.
  - One longitudinal fillet weld guided bend test.
  - Hardness Traverse, refer to 2-9/Annex 2.

- iv) Qualification test welds are to be examined by visual and surface inspection in accordance with *ABS Guide for Nondestructive Inspection*. Inspection of the welds is to be delayed by at least 24 hours, for steels with minimum yield strength less than 415 MPa (60 ksi). For all other steels, inspection is to be in accordance with guidance in *ABS Guide for Nondestructive Inspection*.

For sample preparation and evaluation of the macro examination and longitudinal guided bend test specimens, refer to 2-4-1-A1/Figure 2. Alternative arrangements that meet the technical intent for testing a completed fillet weld can be specifically agreed with ABS.

**FIGURE 2**  
**Fillet Weld Test Specimen**



### 3.7 Acceptance Criteria

#### 3.7.1 Butt Weld

- i) All-weld metal and transverse weld tensile test value is to at least meet the base metal minimum tensile strength.
- ii) After the 180 degree bend test, the weld is to be free of cracks.
- iii) Hardness value are to be in accordance with 2-A9-1/7.3.2(g).
- iv) Charpy V-notch test results are to be in accordance with 2-A9-1/Table 1.

#### 3.7.2 Fillet Weld

- i) Macro examination is to reveal fusion at the root of the weld. The weld metal and heat affected zone (HAZ) are to be free of cracks.
- ii) After the 180 degree bend test, the fillet weld is to be free of cracks.
- iii) Hardness values are to be in accordance with 2-A9-1/7.5.3(c).

### 3.9 Approval Range

- i) The minimum qualified base metal thickness of a water backed weld is limited to the thickness of the water backed test plate or remaining plate thickness (if a grooved out plate). Water backed plate higher than the thickness of the water backed test plate can be welded provided the applied welding code maximum thickness ranges are not exceeded.
- ii) The qualified base metal grade is limited to the grade and delivery condition used in the qualification test.

- iii)* Minimum preheating temperature is not to be less than that used in the qualification test.
- iv)* Maximum interpass temperature is not to be higher than that used in the qualification test.
- v)* Separate weld procedure qualification tests are required for each position. Ideally the production position qualified should be the position of welding during qualification. If a range of qualification is required, procedures are to be qualified in the highest and lowest heat input welding positions.
- vi)* A change in the welding process would require a new weld procedure qualification test.
- vii)* A change in welding consumable would require ABS approval.
- viii)* The upper and lower limit of heat input approved is plus/minus 25% used in the qualification test.
- ix)* Other variables may also be considered in determining the range of approval, on a case-by-case basis.



# PART 2

## CHAPTER 4 Welding and Fabrication

### SECTION 2

## Boilers, Unfired Pressure Vessels, Piping and Engineering Structures\* (1 July 2021)

#### Note:

\* (2016) The piping requirements in this Section are applicable to piping for applications other than for installation on vessels to be built in accordance with the *ABS Rules for Building and Classing Marine Vessels (MVR)*, the *ABS Rules for Building and Classing Mobile Offshore Units (MOU)*, and the *ABS Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels (LHSNV)*. For piping for installation on vessels to be built in accordance with the *ABS Rules for Building and Classing Marine Vessels (MVR)* or the *ABS Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels (LHSNV)*, see Section 2-4-4.

## 1 General Considerations

### 1.1 Fabrication

Drums or shells, other pressure parts of boilers, unfired pressure vessels, pipes and pipe connections, and other engineering structures may be fabricated by means of an approved process of fusion welding in accordance with the following requirements, provided they comply in all other respects with the applicable requirements of Part 4, Chapter 4 and Part 4, Chapter 6 respectively.

### 1.3 Welding Approval (2010)

Before undertaking the welding of any structure subject to the requirements of these Rules, a manufacturer is to prove to the satisfaction of the Surveyor that the welding consumables and the process the manufacturer proposes to use have been approved and that welders and welding operators are duly qualified for the work intended. See 2-4-3/3 and 2-4-3/5.

### 1.5 Grouping of Welded Structures

While, in general, all welding and tests are to be executed in accordance with the requirements of this section, the Rules necessarily vary according to the application in each case and the work is therefore divided into the following groups for the purpose of these Rules.

Category	Service	Limitations		
		Pressure	Temperature	Max. Metal Thickness (See Note 1)
Boilers and Group I Pressure Vessels	Boilers: All pressure parts.	Over 3.4 bar (3.5 kgf/cm <sup>2</sup> , 50 psi)	All	None
	Unfired Pressure Vessels for:			
	a Vapors or Gases b Liquids	Over 41.4 bar (42.2 kgf/cm <sup>2</sup> , 600 psi) Over 41.4 bar (42.2 kgf/cm <sup>2</sup> , 600 psi)	Over 371°C (700°F) Over 204°C (400°F)	None None
Group II Pressure Vessels	Unfired Pressure Vessels for:			
	a Vapors or Gases b Liquids	41.4 bar (42.2 kgf/cm <sup>2</sup> , 600 psi) and under 41.4 bar (42.2 kgf/cm <sup>2</sup> , 600 psi) and under (See Note 2)	371°C (700°F) and under 204°C (400°F) and under	38.1 mm(1.5 in.) 38.1 mm(1.5 in.)

**Notes:**

- 1 The maximum metal thickness does not apply to heads made from a single plate.
- 2 Pressure limit does not apply to hydraulic pressure at atmospheric temperature.

**1.5.1 Boilers and Pressure Vessels**

The group designation of a pressure vessel is determined by the design pressure or temperature or material thickness in accordance with the table above.

**1.5.2 Pipe Connections**

*1.5.2(a) Application - General.*

Group I in general includes all piping intended for working pressures or temperatures in various services as follows:

Service	Pressure bar (kgf/cm <sup>2</sup> , psi)	Temperature °C (°F)
Vapor and gas	Over 10.3 (10.5, 150)	over 343 (650)
Water	Over 15.5 (15.8, 225)	over 177 (350)
Lubricating oil	Over 15.5 (15.8, 225)	over 204 (400)
Fuel oil	Over 10.3 (10.5, 150)	over 66 (150)
Hydraulic fluid	Over 15.5 (15.8, 225)	over 204 (400)

Group II includes all piping intended for working pressures and temperatures at or below those stipulated under Group I, cargo-oil and tank-cleaning piping, and, in addition, such open-ended lines as drains, overflows, vents and boiler escape pipes.

*1.5.2(b) Application - Rules for Building and Classing Marine Vessels (MVR), Rules for Building and Classing Mobile Offshore Units (MOU) and Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels (LHSNV)*

For piping intended for vessels and structures to be built in accordance with *MVR*, *MOU*, and *LHSNV*, the pipe classes are as defined in 4-6-1/5 TABLE 1 of the *Rules for Building and Classing Marine Vessels*, and the welding and fabrication requirements are to be in accordance with Section 2-4-4 of this Chapter.

### 1.5.3 Engineering Structures

Group I includes turbine casings, valve bodies, manifolds and similar constructions which normally would come under Group I Pressure Vessels with the same requirements for workmanship tests, except that where there is no longitudinal seam, no test plates will be required. See also 4-6-2/5.5 of the *Marine Vessel Rules*. Group I also includes gear elements, gear casings and diesel engine entablatures, frames, bedplates and other load support structures.

Group II includes turbine casings, valve bodies, manifolds and similar constructions which normally would come under Group II Pressure Vessels and are to meet the same requirements, except that where there is no longitudinal seam, no workmanship tests are required; Group II includes also engine frames, base plates and other machinery parts not exposed to internal pressures or direct load support. See also 4-6-2/5.15 of the *Marine Vessel Rules*.

## 1.7 Weld Repairs to Ductile (Nodular) Iron

Weld repairs to ductile (nodular) iron castings are subject to special approval. For applications where reduced strength and ductility are permitted, welds which demonstrate satisfactory tensile strength and soundness in procedure tests may be approved.

## 3 Plans and Specifications

### 3.1 Details

All details regarding the process and extent of welding proposed for use in the fabrication of the pressure parts of boilers, unfired pressure vessels, piping and engineering structures, together with the types of joints and welds and the proposed method of procedure are to be clearly shown on the plans and specifications submitted for approval.

### 3.3 Base Materials

All base materials used in fusion-welding construction are to conform to the specifications approved for the design in each case and in ordinary carbon steels, the carbon content is not to exceed 0.35% unless specially approved otherwise.

## 5 Workmanship and Supervision

### 5.1 Construction

Construction is to be carried out in accordance with approved plans and in compliance with Rule requirements. Manufacturers, in all cases, are to be responsible for the quality of the work, and where special supervision is required as stipulated in the applicable section of the Rules, the Surveyor is to satisfy himself that procedure and workmanship, as well as the material used, are in accordance with the Rule requirements and approved plans. Inspection of welds is to be carried out to the satisfaction of the Surveyor in accordance with the acceptance criteria of 2-4-3/9.3.

### 5.3 Joint Tolerance

Plates, shapes or pipes which are to be joined by fusion welding are to be accurately cut to size, and where forming is necessary, this should be done by pressure and not by blows. A tapered transition having a length not less than three times the offset between the adjacent surfaces of abutting sections is to be provided at joints between sections that differ in thickness by more than one-fourth the thickness of the thinner section or by 3 mm ( $\frac{1}{8}$  in.), whichever is less. The transition may be formed by any process that



will provide a uniform taper. The weld may be partly or entirely in the tapered section or adjacent to it. Alignment of sections at edges to be butt welded are to be such that the maximum offset is not greater than the applicable amount as listed in the following table, where  $t$  is the nominal thickness of the thinner section at the joint.

Section Thickness in mm(in.)	Offset in mm (in.) Direction of Joints in Cylindrical Shells	
	Longitudinal	Circumferential
Up to 12.5 (0.5), incl.	$\frac{1}{4}t$	$\frac{1}{4}t$
Over 12.5 (0.5) to 19 (0.75), incl.	3.2 ( $\frac{1}{8}$ in.)	$\frac{1}{4}t$
Over 19 (0.75) to 38 (1.5), incl.	3.2 ( $\frac{1}{8}$ in.)	4.8 ( $\frac{3}{16}$ in.)
Over 38 (1.5) to 51 (2.0), incl.	3.2 ( $\frac{1}{8}$ in.)	$\frac{1}{8}t$
Over 51 (2.0)	$\frac{1}{16}t$ (9.5 ( $\frac{3}{8}$ in.) max.)	$\frac{1}{8}t$ (19 ( $\frac{3}{4}$ in.) max.)

**Note:**

Any offset within the allowable tolerance above should 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.

## 5.5 Surfaces of Parts

The surfaces of parts to be welded are to be cleaned of scale, rust and grease for at least 12.5 mm (0.50 in.) from the welding edge. When it is necessary to deposit metal over a previously welded surface, any scale or slag is to be removed to prevent the inclusion of impurities; if for any reason the welding is stopped, special care is to be taken in restarting to secure thorough fusion.

## 5.7 Out of Roundness

The cylinder or barrel or drum or shell is to 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, and if necessary to meet this requirement, is to be reheated, rerolled or reformed. In fabrications of plates of unequal thickness, the measurements are to be corrected for the plate thickness as they may apply, to determine the diameters at the middle line of the plate thickness.

# 7 Details of Joints

## 7.1 Dimensions and Shape

The dimensions and shape of the edges to be joined are to be such as to insure thorough fusion and complete penetration at the root of the joint.

## 7.3 Double-welded Butt Joints

In this type of joint, the filler metal is deposited from both sides, whether the joint is of the single- or double-grooved type. In manual welding, the reverse side is to be prepared by chipping, grinding or otherwise cleaning out, so as to secure sound metal at the base of the weld metal first deposited, before applying weld metal from the reverse side, unless approved otherwise. The weld reinforcement on each side of the plate is not to exceed the thickness specified in 2-4-2/23.1.1.

## 7.5 Single-welded Butt Joints

This type of joint is a butt joint with the filler metal applied from one side only. A single-welded butt joint may be made the equivalent of a double-welded butt joint by providing means for accomplishing complete penetration and meeting the requirements for weld reinforcement as indicated in 2-4-2/7.3. In the case of boilers, backing strips used at longitudinal welded joints are to be removed.

## 7.7 Joint Finish

Butt joints are to have complete joint penetration and are to be free from overlaps or abrupt ridges or grooves and reasonably free from undercuts. The reinforcements permitted for both double- and single-welded butt joints may be removed upon completion to provide a smooth finish.

## 7.9 Lap Joints

Where lapped joints are permitted, they are to be made with an overlap of the edges not less than four times the thickness of the thinner plate, except as noted in 2-4-2/25.7 FIGURE 1.

## 7.11 Head to Shell Attachments

### 7.11.1 Length of Flange

Dished heads other than concaved hemispherical to the pressure which are to be attached by butt-welding, and flanged heads or flanged furnace connections which are to be fillet-welded are to have a length of flange not less than 25 mm (1 in.) for heads or furnace openings not over 610 mm (24 in.) in external diameter and not less than 38 mm (1.5 in.) for heads or furnace openings over 610 mm (24 in.) in diameter. For unfired pressure vessels, see 2-4-2/25.7 FIGURE 1 for details.

### 7.11.2 Inserted Heads

When dished heads are fitted inside or over a shell, they are to have a driving fit before welding.

### 7.11.3 Connections

Acceptable types of fusion-welded connections of heads to shells are illustrated in 2-4-2/25.7 FIGURE 1, subject to the tabulated limitations in 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*.

## 7.13 Bending Stresses in Welds

The design of a Group I or II welded container is to be such that the weld will not be subjected to direct bending stresses [see 2-4-2/25.7 FIGURE 1]. Corner welds are not to be used unless the plates forming the corner are supported independently of the welds.

## 7.15 Connections

All welding for fusion-welded connections is to be equivalent to that required for the joints of the vessel to which they are attached.

## 7.17 Nozzles

Acceptable types of fusion-welded nozzle connections are illustrated in 2-4-2/25.7 FIGURE 2 and are to comply with the following.

### 7.17.1 2-4-2/Figure 2(a) and (b)

Necks abutting the vessel wall are to be attached by a full penetration groove weld.

### 7.17.2 2-4-2/Figure 2(c) through (h)

Necks inserted into or through a hole cut in the vessel wall and without additional reinforcing elements are to be attached by a full penetration groove weld or by two partial penetration welds, one on each face of the vessel wall. These may be any desired combination of fillet, single-bevel and single-J welds.

### 7.17.3 2-4-2/Figure 2(l), (m), (n), (o) and (p)

Inserted type necks having added reinforcement in the form of one or more separate reinforcing plates are to be attached by welds at the outer edge of the reinforcing plate and at the nozzle-neck periphery. The welds attaching the neck to the vessel wall and to the reinforcement plate are to consist of one of the following combinations.

7.17.3(a) Single-bevel or single-J weld in the shell plate, and full penetration groove weld or a single-bevel or single-J weld in each reinforcement plate. See 2-4-2/25.7 FIGURE 2(n) and (p).

7.17.3(b) A full penetration groove weld in the shell plate, and a fillet, single-bevel, or single-J weld or a full penetration groove weld in each reinforcement plate. See 2-4-2/25.7 FIGURE 2(m) and (o).

7.17.3(c) A full penetration groove weld in each reinforcement plate, and a fillet, single-bevel, or single-J weld in the shell plate. See 2-4-2/25.7 FIGURE 2(l).

#### 7.17.4 2-4-2/Figure 2(k), (q), (r), (s) and (t)

Nozzles with integral reinforcement in the form of extended necks or saddle type pads are to be attached by a full penetration weld or by means of a fillet weld along the outer edge and a fillet, single-bevel, or single-J weld along the inner edge.

#### 7.17.5 2-4-2/Figure 2(u), (v), (w) and (x)

Fittings with internal threads are to be attached by a full penetration groove weld or by two fillet or partial penetration welds, one on each face of the vessel wall. See 2-4-2/25.7 FIGURE 2(u), (v), (w) and (x). Internally threaded fittings not exceeding 89 mm OD (3 in. NPS) may be attached by a fillet groove weld from the outside only. See 2-4-2/25.7 FIGURE 2(w-3).

For all cases, the strength of the welded connection is to be in accordance with the requirements of 4-4-1-A1/7.9.3.ii of the *Marine Vessel Rules*.

### 7.19 Limitations

The use of various types of welded construction is subject to the limitations of the group for which it is intended as well as the limitations tabulated in 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*.

## 9 Forms of Welded Joints Required

### 9.1 Boilers and Group I Pressure Vessels

Joints are to be in accordance with the following details.

#### 9.1.1 Double-welded

All joints are to be of the double-welded butt type, single-or double-grooved, except where a single-welded butt joint is made the equivalent of a double-welded butt joint. See 2-4-2/7.5.

#### 9.1.2 Nozzles and Other Connections

Some acceptable types of welded nozzles and other connections to shells, drums and headers are shown in 2-4-2/25.7 FIGURE 2.

#### 9.1.3 Closing Plates

Closing plates of headers for boilers and superheaters as well as flat heads of other pressure vessels may be attached by welding as indicated in 2-4-2/25.7 FIGURE 1(g) or (h) and 4-4-1-A1/5.7.2 FIGURE 7 of the *Marine Vessel Rules*.

### 9.3 Group II Pressure Vessels

Joints are to be the same as Group I, except as noted below.

#### 9.3.1 Single-welded

Butt joints welded from one side, with or without backing strips, are subject to the tabulated limitations in 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*. When backing strips are used, they may be left in place or removed.

### 9.3.2 Full-fillet Lap

Double full-fillet lap joints or single full-fillet lap joints, with or without plug welds, when used, are subject to the tabulated limitations in 4-4-1-A1/21 TABLE 1. See also 2-4-2/25.7 FIGURE 1.

## 9.5 Group I Pipe Welded Joints

Welded joints are to be in accordance with the following.

### 9.5.1 Pipes Over 89 mm OD (3 in. NPS)

Joints for connecting two lengths of pipe or a pipe to a welding fitting, valve or flange are to be of the grooved type. In welding single-welded butt joints, complete penetration at the root is required and is to be demonstrated by the qualification of the procedure used. If complete penetration cannot otherwise be secured, the procedure is to include backing. The depth of weld is to be not less than the minimum thickness permitted by the applicable material specifications for the particular size and thickness of the pipe used.

### 9.5.2 Pipes 89 mm OD (3 in. NPS) and Below

Joints for connecting two lengths of pipe may be made by sleeves fitted over the joint and attached by fillet welds or by using socket-type joints with a fillet weld. For sleeve joints, the inside diameter of the sleeve is not to exceed the outside diameter of the pipe by more than 2.0 mm (0.080 in.). The fit and fillet weld sizes are to be in accordance with an applicable recognized standard (e.g., ANSI B16.11 for socket-type joints, ASTM F682 for sleeve-type joints and ANSI B31.1 for fillet weld sizes). The depth of insertion of the pipe into the sleeve or socket fitting is to be at least 9.5 mm (0.375 in.). A minimum gap of approximately 2.0 mm (0.080 in.) is to be provided between the ends of the pipe for a sleeve joint or between the pipe and socket shoulder for socket-type joints prior to welding. The fittings are to be reasonably centered around the pipe.

### 9.5.3 Flanges

ANSI slip-on flanges may be attached to piping by double-fillet welds for applications with a service rating no higher than ANSI 300 Class, provided the throats of the fillet welds are not less than 0.7 times the thickness of the part to which the flange is attached. For boiler external piping, the use of slip-on flanges is additionally limited to sizes not exceeding 114 mm OD (4 in. NPS) and the throats of fillet welds may be not less than 0.7 times the thickness of the part to which the flange is attached. Slip-on flanges for higher ratings which comply with ASME or other recognized standards will be subject to special consideration.

Socket-type flanges up to and including ANSI 600 Class may be used in piping 89 mm OD (3 in. NPS) or less and up to and including the ANSI 1500 Class in piping 73 mm OD (2.5 in. NPS) pipe size or less.

### 9.5.4 Backing

Backing for grooved joints may be omitted in pipes under 33 mm OD (1 in. NPS). Backing is recommended for welding pipes on shipboard for all sizes 33 mm OD (1 in. NPS) and above when welded with single butt joints.

### 9.5.5 Welding

Welding in pipe lines is to be done in the shop, as far as practicable, and joints made in the installation onboard ship are to be in positions accessible for proper welding.

## 9.7 Group II Pipe Welded Joints

The type of welded joints in the construction of piping under this Group is to be similar to those in Group I except for the following modifications. For 2-4-2/9.7.1, 2-4-2/9.7.2 and 2-4-2/9.7.3 below, full penetration welds are required.

### 9.7.1 Single-groove

Single-groove welded-butt joints may be without backing in all sizes if the weld is chipped or ground off flush on the root side.

### 9.7.2 Backing

Backing may also be dispensed with, without grinding the root of the weld, in such services as tank-vent and overflow pipes.

### 9.7.3 Square-groove Welds

Square-groove welds may be used in lieu of the single-V groove weld for tank vent and overflow pipes where the thickness of the pipe does not exceed 4.8 mm ( $\frac{3}{16}$  in.).

### 9.7.4 Sleeves

Sleeves fitted over the joint and attached by fillet welds or socket-type joints with a fillet weld will be acceptable in all sizes. The fit and fillet weld sizes are to be in accordance with an applicable recognized standard (e.g., ANSI B16.11 for socket joints, ASTM F682 for sleeve type joints and ANSI B31.1 for fillet weld sizes.) The depth of insertion and gap are to be as per 2-4-2/9.5.2. The fittings are to be reasonably centered around the pipe.

## 9.9 Low-temperature Piping Systems [Below -18°C (0°F)]

For service temperatures lower than -18°C (0°F), each welding procedure is to be approved in accordance with the requirements of 2-4-3/5 and Part 5C, Chapter 8 of the *Marine Vessel Rules*. All piping systems over 10.3 bar (10.5 kgf/cm<sup>2</sup>, 150 psi) are to be considered Group I piping systems, except that socket-weld joints, slip-on flanges, single-welded butt joints with backing strips left in place, pipe-joining sleeves and threaded joints are not to be used, except where permitted by Part 5C, Chapter 8 of the *Marine Vessel Rules*.

## 9.11 Engineering Structures

The type of welded joints used in either Group I or II in this class of construction is subject to special consideration in connection with the design in each case

# 11 Preheat

## 11.1 Boilers, Pressure Vessels, and Group I Piping

When ambient temperatures are below 10°C (50°F), the welded parts of boilers, pressure vessels, and Group I piping are to be preheated prior to welding, so that the parts to be joined by welding will be at a temperature not less than 10°C (50°F). Higher preheat is required for material composition, thicknesses, and carbon content in accordance with the following paragraphs.

### 11.1.1 General

The thicknesses referred to are nominal at the weld for the parts to be joined. Where the qualification procedure specifies a higher preheat, this higher preheat is to be used. Where different materials having different preheat requirements are joined by welding, the higher preheat is to be used. For materials, refer to 2-3-2/1, 2-3-2/3, 2-3-2/5, 2-3-2/7, Section 2-3-5 and Section 2-3-12.

### 11.1.2 Preheat Temperatures

Welds joining pressure parts or attachments to pressure parts are to be preheated to not less than the following temperatures.

*11.1.2(a) ABS Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N, Tube Grades D, F, H, J, and Pipe Grades 1, 2, 3, 4, 5, 8, and 9. to 79°C (175°F) for material which has both specified*

maximum carbon content in excess of 0.30% and a thickness at the joint in excess of 25.4 mm (1.0 in.).

*11.1.2(b) ABS Plate Grades H, I, J, Tube Grades K, L, M and Pipe Grades 6 and 7.* to 79°C (175°F) for material which has either a specified minimum tensile strength in excess of 485 N/mm<sup>2</sup> (49 kgf/mm<sup>2</sup>, 70,000 psi) or a thickness at the joint in excess of 16.0 mm (0.625 in.).

*11.1.2(c) ABS Tube Grades N and O and Piping Grades 11 and 12.* to 121°C (250°F) for material which has a thickness at the joint in excess of 12.5 mm (0.5 in.).

*11.1.2(d) ABS Tube Grade P and Piping Grade 13.* to 149°C (300°F) regardless of thickness.

*11.1.2(e) Other Materials.* The preheating of other materials will be subject to special consideration.

### 11.3 Group I Pipe Connections

All Group I pipe connections defined in 2-4-2/1.5.2 are to be preheated in accordance with 2-4-2/11.

## 13 General Requirements for Postweld Heat Treatment

### 13.1 General

Prior to the application of the following requirements, satisfactory weld-procedure qualifications of the procedures to be used are to be performed in accordance with all the essential variables of Section 2-4-3, including conditions of postweld heat treatment or lack of postweld heat treatment and other restrictions as listed in the following paragraphs.

### 13.3 Heat-treatment Determination

Except as otherwise specifically provided for, all welded pressure parts of boilers and all welded pressure vessels or pressure parts are to be given a postweld heat treatment at a temperature not less than that specified in the following paragraphs. Where pressure parts of two different materials are joined by welding, the postweld heat treatment is to be that specified for the material requiring the higher postweld temperature. When nonpressure parts are welded to pressure parts, the postweld-heat-treatment temperature of the pressure part is to control.

## 15 Fusion-welded Boilers

### 15.1 Postweld Heat Treatment

All boilers of plate, pipe and tube materials listed in 2-3-2/3, 2-3-2/5, 2-3-2/7, Section 2-3-5 and Section 2-3-12 are to be given a post-weld heat treatment after all pads, flanges or nozzles have been welded in place. Postweld heat treatment is to be as follows:

Grades	Minimum * Holding Temperature	Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)	
		Up to 51 mm (2 in.)	Over 51 mm (2 in.)
All Plates, Tubes and Pipes except Grade N, O and P Tubes and Grade 11, 12 and 13 Pipes	593°C (1100°F)	1 hr/25 mm (1 in.) 15 min. minimum	2 hr plus 15 min. for each additional 25 mm (1 in.)
Tube Grades N and O and Pipe Grades 11 and 12	593°C (1100°F)	1 hr/25 mm (1 in.) 15 min. minimum	1 hr/25 mm (1 in.) to 127 mm (5 in.) plus 15 min. for each additional 25 mm (1 in.)
Tube Grade P and Pipe Grade 13	677°C (1250°F)	1 hr/25 mm (1 in.) 15 min. minimum	1 hr/25 mm (1 in.) to 127 mm (5 in.) plus 15 min. for each additional 25 mm (1 in.)

\* Maximum temperature is to be at least 28°C (50°F) below base material tempering temperature.

### 15.3 Lower Temperatures - Carbon and Carbon Molybdenum Steels

When it is impractical to postweld heat-treat materials listed in 2-4-2/15.5 and 2-4-2/15.7 at the temperature specified in 2-4-2/15.1, it is permissible to heat-treat at lower temperatures for longer periods, as follows.

Lower Min. Temp. degrees °C (°F)	Min. Holding Time at Decreased Temp. in hr/25 mm (hr/in.)
566 (1050)	2
538 (1000)	3
510 (950)	5
482 (900)	10

### 15.5 Heat-treatment Exceptions for Fusion-welded Boilers - ABS Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N, Tube Grades D, F, G, H, J and Group I Piping Grades 1, 2, 3, 4, 5, 8, and 9

Postweld heat treatment of these materials and other equivalent pipe, plate and tube material is not required under the following conditions:

#### 15.5.1 Circumferential Welds

For circumferential welds in pipes, tubes or headers where the pipe, tube or header complies with a nominal wall thickness of 19.1 mm (0.75 in.) or less at the joint.

#### 15.5.2 Fillet Welds

For fillet welds, attaching nonpressure parts to pressure parts that have a throat thickness of 12.7 mm (0.50 in.) or less, provided preheat to a minimum temperature of 93°C (200°F) is applied when the thickness of the pressure part exceeds 19.1 mm (0.75 in.).

#### 15.5.3 Heat-absorbing Surfaces

For welds used to attach extended heat-absorbing surfaces to tubes and insulation attachment pins to pressure parts.

#### 15.5.4 Tubes

For tubes or pressure retaining hand hole 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 9.5 mm (0.375 in.) or less.

#### 15.5.5 Studs

For studs welded to pressure parts for purposes not included in 2-4-2/15.5.3, provided preheat to a minimum temperature of 93°C (200°F) is applied when the thickness of the pressure part exceeds 19.1 mm (0.75 in.).

### 15.7 Heat-treatment Exceptions for Fusion-welded Boilers - ABS Plate Grades H, I, J, Tube Grades K, L, M, and Group I Piping Grades 6 and 7

Postweld heat treatment of these materials and other equivalent pipe, plate and tube material is not required under the following conditions.

#### 15.7.1 Circumferential Welds

For circumferential welds in pipes, tubes or headers where the pipes, tubes or headers comply with both a nominal wall thickness of 16 mm (0.625 in.) or less, and a specified maximum carbon content of not more than 0.25%.

#### 15.7.2 Fillet Welds

For fillet welds attaching nonpressure parts having a specified maximum carbon content not more than 0.25% that have a throat thickness of 12.7 mm (0.5 in.) or less, provided preheat to a minimum temperature of 93°C (200°F) is applied when the pressure part exceeds 15.9 mm (0.625 in.).

#### 15.7.3 Heat-absorbing Surfaces

For welds used to attach extended heat-absorbing surfaces to tubes and insulation attachment pins to pressure parts.

#### 15.7.4 Tubes

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 not more than 9.5 mm (0.375 in.).

#### 15.7.5 Studs

Postweld heat treatment is not mandatory for studs welded to pressure parts for purposes not included in 2-4-2/15.7.3 and which have a specified maximum carbon content of not more than 0.25%, provided a preheat to a minimum temperature of 93°C (200°F) is applied when the thickness of the pressure part exceeds 16 mm (0.625 in.).

### 15.9 Heat Treatment Exceptions for Fusion-welded Boilers - ABS Tube Grades N, O and Group I Pipe Grades 11 and 12

Postweld heat treatment of these materials and other equivalent pipe and tube material with 0.15% carbon maximum is not required under the following conditions.

#### 15.9.1 Circumferential Welds

For circumferential welds where the pipe or tubes comply with all of the following.

15.9.1(a) a maximum outside diameter of 101.6 mm (4 in.)

15.9.1(b) a maximum thickness of 16 mm (0.625 in.)

15.9.1(c) a minimum preheat of 121°C (250°F)



### 15.9.2 Fillet Welds

For fillet welds attaching nonpressure parts to pressure parts, provided the fillet weld has a specified throat thickness of 12.5 mm (0.5 in.) or less and the pressure part meets the requirements of 2-4-2/15.9.1(a) and 2-4-2/15.9.1(b).

### 15.9.3 Heat-absorbing Surfaces and Studs

For heat-absorbing surfaces and non-load-carrying studs, provided the material is preheated to 121°C (250°F) minimum and the pressure part meets the requirements of 2-4-2/15.9.1(a) and 2-4-2/15.9.1(b).

### 15.9.4 Tubes

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 9.5 mm (0.375 in.) or less.

## 15.11 Heat Treatment Exceptions for Fusion Welded Boilers - ABS Tube Grade P and Group I Pipe Grade 13

Postweld heat treatment of this material and other equivalent pipe and tube material with 0.15% carbon maximum is not required under the following conditions.

### 15.11.1 Circumferential Welds

For circumferential welds where the pipe or tube complies with all of the following.

*15.11.1(a)* a maximum outside diameter of 101.6 mm (4 in.)

*15.11.1(b)* a maximum thickness of 16 mm (0.625 in.)

*15.11.1(c)* a minimum preheat of 149°C (300°F)

### 15.11.2 Fillet Welds

For fillet welds attaching nonpressure parts that have a specified throat thickness of 12.5 mm (0.5 in.) or less, provided the pressure part meets the requirements of 2-4-2/15.11.1(a) and 2-4-2/15.11.1(b).

### 15.11.3 Heat-absorbing Surfaces and Studs

Heat-absorbing surfaces and non-load-carrying studs, provided the material is preheated to 149°C (300°F) and the pressure part meets the requirements of 2-4-2/15.11.1(a) and 2-4-2/15.11.1(b).

### 15.11.4 Tubes

For tubes or pressure retaining handhole and inspection plugs or fittings with a specified maximum chrome 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 9.5 mm (0.375 in.) or less.

## 15.13 Other Materials

Postweld heat treatment of other materials for boilerplate and tubes will be subject to special consideration.

## 15.15 Other Welded Connections

Nozzles or other welded attachments for which postweld heat treatment is required may be locally postweld heat-treated by heating a circumferential band around the entire vessel with the welded connection located at the middle of the band. The width of the band is to be at least three times the wall thickness of the vessel wider than the nozzle or other attachment weld, and is to be located in such a manner that the entire band will be heated to the temperature and held for the time specified in 2-4-2/15.1 for post-weld heat treatment.

## 15.17 Welded Joints

In the case of welded joints in pipes, tubes and headers, the width of the heated circumferential band is to be at least three times the width of the widest part of the welding groove, but in no case less than twice the width of the weld reinforcement.

# 17 Fusion-welded Pressure Vessels

## 17.1 Postweld Heat Treatment

### 17.1.1 General

All pressure vessels and pressure-vessel parts are to be given a postweld heat treatment at a temperature not less than that specified in 2-4-2/15.1 and 2-4-2/15.3 when the nominal thickness, including corrosion allowance of any welded joint in the vessel or vessel part exceeds the limits as noted in 2-4-2/17.3 and 2-4-2/17.5. In addition, postweld heat treatment is required for the following.

*17.1.1(a)* For all independent cargo tanks where required by Part 5C, Chapter 8 of the *Marine Vessel Rules*.

*17.1.1(b)* For all carbon or carbon manganese steel pressure vessels and independent cargo pressure vessels not covered by 2-4-2/17.1.1(a), when the metal temperature is below -29°C (-20°F).

*17.1.1(c)* For all pressure vessels and independent cargo pressure vessels, which are fabricated of carbon or carbon manganese steel and intended to carry anhydrous ammonia.

### 17.1.2 Welded Joints

When the welded joint connects parts that are of different thickness, the thickness to be used in applying these requirements is to be the thinner of two adjacent butt-welded plates, including head to shell connections, the thickness of the head or shell plate in nozzle attachment welds, and the thickness of the nozzle neck at the joint in nozzle neck to flange connections, the thickness of the shell in connections to tube sheets, flat heads, covers or similar connections, and the thicker of plate in connections of the type shown in 2-4-2/25.7 FIGURE 1.

## 17.3 Heat-treatment Exceptions - ABS Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N and Tube Grades D, F, G, H, J

Postweld heat treatment of these materials is not required under the following conditions.

### 17.3.1 38.1 mm (1.5 in.) and Under

For material up to and including 38.1 mm (1.5 in.) thickness, provided that material over 31.8 mm (1.25 in.) thickness is preheated to a minimum temperature of 93°C (200°F) during welding.

### 17.3.2 Over 38.1 mm (1.5 in.)

For material over 38.1 mm (1.5 in.) thickness, all welded connections and attachments are to be postweld heat-treated except that postweld heat treatment is not required for:

*17.3.2(a) Nozzle Connections.*

Fillet welds with a throat not over 12.7 mm (0.50 in.) and groove welds not over 12.7 mm (0.50 in.) in size that attach nozzle connections having a finished inside diameter not greater than 50.8 mm (2 in.), provided the connections do not form ligaments that require an increase in shell or head thickness, and preheat to a minimum temperature of 93°C (200°F) is applied.

*17.3.2(b) Nonpressure Attachments.*

Fillet welds having a throat not over 12.7 mm (0.5 in.), or groove welds not over 12.7 mm (0.50 in.) in size, used for attaching nonpressure parts to pressure parts, and preheat to a minimum temperature of 93°C (200°F) is applied when the thickness of the pressure part exceeds 19 mm (0.75 in.).

## 17.5 Heat-treatment Exceptions - ABS Plate Grades, H, I, J and Tube Grades K, L, M

Postweld heat treatment of these materials is not required under the following conditions.

### 17.5.1 15.9 mm (0.625 in.) and Under

For material up to and including 15.9 mm (0.625 in.) in thickness having a specified maximum carbon content of not more than 0.25%, provided a welding procedure qualification has been made in equal or greater thickness than the production weld.

### 17.5.2 Over 15.9 mm (0.625 in.)

For material over 15.9 mm (0.625 in.) thicknesses, all welded connections and attachments are to be postweld heat-treated, except that postweld treatment is not required for:

#### 17.5.2(a) Nonpressure Attachments.

Attaching to pressure parts which have a specified maximum carbon content of not more than 0.25% and nonpressure parts with fillet welds that have a throat thickness of 12.7 mm (0.50 in.) or less, provided preheat to a minimum temperature of 80°C (175°F) is applied.

#### 17.5.2(b) Tube or Pipe Attachments.

Circumferential welds in pipes or tubes where the pipes or tubes have both a nominal wall thickness of 12.7 mm (0.50 in.) or less, and a specified maximum carbon content of not more than 0.25%.

## 17.7 Heat-treatment Exceptions - Attachments

On pressure vessels which do not require postweld heat treatment as a whole, connections and other attachments after being attached by fusion welding need not be post-weld heat-treated. See also 2-4-2/21.11 for nozzles or other welded attachments for which postweld heat treatment is not required.

## 17.9 Other Materials

Postweld heat treatment of other materials for boiler plate and tubes will be subject to special consideration.

## 17.11 Welded Connections

Nozzles or other welded attachments for which postweld heat treatment is required may be heat-treated by heating a circumferential band around the entire vessel in such a manner that the entire band is to be brought up uniformly to the required temperature and held for the specified time. The circumferential band is to extend around the entire vessel and include the nozzle or welded attachment, and is to extend at least six times the plate thickness beyond the welding which connects the nozzle or other attachment to the vessel. The portion of the vessel outside of the circumferential band is to be protected so that the temperature gradient is not harmful.

# 19 Pipe Welded Joints and Engineering Structures

## 19.1 Group I Pipe Welded Joints

All Group I Pipe welded joints, defined in 2-4-2/1.5 are to be postweld heat-treated in accordance with 2-4-2/15 or the American National Standard ANSI B31.1.

### 19.3 Group II Pipe Welded Joints

Unless specially required, welded joints in Group II piping need not be postweld heat-treated.

### 19.5 Group I Engineering Structures

All welded structures under this group are to be postweld heat-treated in accordance with the applicable requirements of 2-4-2/17.

### 19.7 Group II Engineering Structures

Postweld heat treatment of structures under this group depends on the type and purpose of the construction, and the matter will be subject to special consideration in connection with the approval of the design.

### 19.9 Low-temperatures Piping Systems [Below -18°C (0°F)]

In general, all piping weldments except socket-weld joints and slip-on flanges, where permitted, are to be postweld heat-treated. Exceptions will be considered for specific materials where it can be shown that postweld heat treatment is unnecessary.

## 21 Postweld Heat-treatment Details

### 21.1 Boilers and Pressure Vessels

The weldment is to be heated uniformly and slowly to the temperature and time specified in 2-4-2/15.1, and is to be allowed to cool slowly in a still atmosphere to a temperature not exceeding 427°C (800°F). The postweld heat treatment may be done either by heating the complete welded structure as a whole or by heating a complete section containing the parts to be postweld heat-treated. The postweld-heat-treatment temperature is to be controlled by at least two pyrometric instruments to avoid the possibility of error.

### 21.3 Pipe Connections

In the case of welded pipe connections requiring postweld heat treatment, the adjacent pipes or fittings are to be heated in a circumferential band at least three (3) times the width of the widest part of the welding groove but not less than twice the width of the weld reinforcement.

### 21.5 Other Steels

The postweld heat treatment of other steels not specifically covered in Part 2, Chapter 3 will be subject to special consideration.

### 21.7 Clad Pressure Vessels

Postweld heat treatment of vessels or parts of vessels constructed of integrally clad or applied corrosion-resistant lining material will be subject to special consideration.

### 21.9 Opening Connections

Welded connections may be added to a vessel after post-weld heat treatment without requiring repostweld heat treatment, provided the following conditions are met.

#### 21.9.1 Size of Weld

The inside and outside attachment welds do not exceed 9.5 mm (0.375 in.) throat dimension.

#### 21.9.2 Opening Diameter

The diameter of the attachment opening in the vessel shell does not exceed that allowed for an unreinforced opening, or does not exceed 50.8 mm (2 in.), whichever is smaller.

### 21.9.3 Exception

This provision does not apply to those connections so placed as to form ligaments in the shell, the efficiency of which will affect the shell thickness. Such added connections are to be postweld heat-treated.

### 21.11 Seal Welding

Seal welding consisting of a fillet weld under 9.5 mm (0.375 in.) without subsequent stress relieving may be applied to secure tightness of connections where the construction is such that no design stress is placed upon the weld even though the structure itself has to be stress-relieved in accordance with these Rules.

## 23 Radiography

### 23.1 General

#### 23.1.1 Welded-joint Preparation

All welded joints to be radiographed are to be prepared as follows: The weld ripples or weld surface irregularities, on both the inside and outside, are to be removed by any suitable mechanical process to such a degree that the resulting radiographic contrast due to any irregularities cannot mask or be confused with the image of any objectionable defect. Also, the weld surface is to merge smoothly into the plate surface. The finished surface of the reinforcement of all butt-welded joints may be flush with the plate or may have a reasonably uniform crown not to exceed the following thickness.

<i>Plate Thickness, in mm (in.)</i>	<i>Thickness of Reinforcement, in mm (in.)</i>
Up to 12.7 (0.5) incl.	1.6 ( <sup>1</sup> / <sub>16</sub> )
Over 12.7 (0.5) to 25.4 (1.0)	2.4 ( <sup>3</sup> / <sub>32</sub> )
Over 25.4 (1.0) to 50.8 (2.0)	3.2 ( <sup>1</sup> / <sub>8</sub> )
Over 50.8 (2.0)	4.0 ( <sup>5</sup> / <sub>32</sub> )

#### 23.1.2 Radiographic Examination with Backing Strip

A single-welded circumferential butt joint with backing strip may be radiographed without removing the backing strip, provided it is not to be removed subsequently and provided the image of the backing strip does not interfere with the interpretation of the resultant radiographs.

#### 23.1.3 Details of Radiographic Search

See 2-4-3/9 for further details of radiographic search of finished joints.

### 23.3 Boilers

All circumferential, longitudinal, and head joints are to be examined for their full length by radiography except that parts of boilers fabricated of pipe material, such as drums, shells, downcomers, risers, cross-pipes, headers, and tubes are to be nondestructively examined as required by 2-4-2/23.7.

### 23.5 Other Pressure Vessels

#### 23.5.1 Full Radiography

Double-welded butt joints or their equivalent are to be examined radiographically for their full length under any of the following conditions.

##### 23.5.1(a) Joint Efficiency.

Where the design of the vessel or vessel section is based on the use of the joint efficiency tabulated in column (a) of 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*.

23.5.1(b) *Material Used.*

Complete radiographic examination is required for each butt-welded joint in vessels built of Steel Plate for Boilers and Pressure Vessels ABS Grades, MA, MB, MC, MD, ME, MF, MG, K, L, M and N having a thickness in excess of 31.8 mm (1.25 in.) as well as for ABS Grades H, I and J having a thickness in excess of 19 mm (0.75 in.). Other steels not specifically covered in Part 2, Chapter 3 will be subject to special consideration.

**23.5.2 Spot (Random) Radiography**

All longitudinal and circumferential double-welded butt joints or their equivalent which are not required to be fully radiographed in 2-4-2/23.5.1 are to be examined by spot (random) radiography where the pressure vessel or pressure vessel section is based on the use of the joint efficiency tabulated in column (b) of 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*. The extent of spot radiography is to compare favorably with accepted practice such as that specified in the ASME Boiler and Pressure Vessel Code and is to be the satisfaction of the Surveyor.

**23.7 Group I Pipe Connections (1999)**

Group I pipe connections are to be radiographically examined according to either of the conditions indicated below, as applicable.

<i>Pipe Size</i>	<i>Extent of Radiography<sup>(1, 2)</sup></i>
Wall Thickness > 9.5 mm ( <sup>3</sup> / <sub>8</sub> in.)	100%
Diameter > 76.1 mm (3.0 in) O.D.	100%

*Notes:*

- 1 Where radiographic testing is not practicable, such as for fillet welds, another effective method of nondestructive testing is to be carried out.
- 2 Where radiographic testing is not required in the above table, alternative nondestructive testing, magnetic particle or penetration methods, may be required by the attending Surveyor when further inspection deems it necessary.

**23.9 Group II Pipe Connections(1999)**

Spot (random) radiographic or ultrasonic examination of welded joints with an outer diameter greater than 101.6 mm (4.0 in) may be required by the Surveyor when further inspection deems it necessary.

**23.11 Low Temperature Piping Connections [Below -18°C (0°F)]**

In all carbon and alloy steel piping with a service temperature below -18°C (0°F) and an inside diameter of more than 75 mm (3 in.) or where the wall thickness exceeds 10 mm or 0.375 in., welds made in accordance with this group are to be subjected to 100% radiographic search or to other approved method of test if the former is not practicable. For pipe of smaller diameter or thickness, welds are to be subjected to spot (random) radiographic examination or to other approved methods of test of at least 10% of the welds, to the satisfaction of the Surveyor.

**23.13 Group I Engineering Structures**

Group I Engineering Structures are to meet the same radiographic requirements as Group I Pressure Vessels.

**23.15 Group II Engineering Structures**

Group II Engineering Structures which correspond in service requirements to Group II Pressure Vessels are not required to be subjected to a full or spot (random) radiographic examination of welded joints.

### 23.17 Engine Bedplates

Bedplates for main propulsion internal-combustion engines with cylinders 458 mm (18 in.) in diameter and over are to be examined radiographically or ultrasonically in way of principal welds.

### 23.19 Miscellaneous

#### 23.19.1 Alloy and Clad Pressure Vessels

The radiographic examination of vessels or parts of vessels constructed of alloy, integrally clad or applied corrosion-resistant lining materials, will be subject to special consideration.

#### 23.19.2 Nozzles, Sumps, etc.

Butt welds of inserted-type nozzles are to be radiographed when used for attachment to a vessel or vessel section that is required to be radiographed or the joint efficiency tabulated in column (a) of 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules* is used. Nozzles and manhole attachment welds which are not of the double-welded butt-type need not be radiographed. Joints used in the fabrication of nozzles, sumps, etc. are to be radiographed when intended for installation in a vessel or vessel section that is required to be radiographed or when the joint efficiency tabulated in column (a) of 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules* is used, except that circumferential-welded butt joints of nozzles and sumps not exceeding 254 mm (10 in.) nominal pipe size or 28.6 mm (1.125 in.) wall thickness need not be radiographed.

## 25 Hydrostatic Test

### 25.1 Boilers and Pressure Vessels

Hydrostatic tests are to be conducted in accordance with 4-4-1/7.11 and 4-4-1-A1/21 of the *Marine Vessel Rules*.

### 25.3 Piping

Hydrostatic tests are to be conducted in accordance with 2-4-2/25.3 TABLE 1 below:

**TABLE 1**  
**Hydrostatic Testing of Piping**

<i>MVR*</i>			<i>MOU*</i>	
<i>Class I</i>	<i>Class II</i>	<i>Class III</i>	<i>Group I</i>	<i>Group II</i>
4-6-2/7.3	4-6-2/7.3	4-6-2/7.3.1	7-1-4/41	7-1-4/41
4-6-7/7.7				

**Note:**

\*

MVR – Rules for Building and Classing Marine Vessels

MOU – Rules for Building and Classing Mobile Offshore Units

For conditions of hydrostatic testing in other Rules and Guides, see the requirements within the relevant Rules or Guides.

### 25.5 Defects

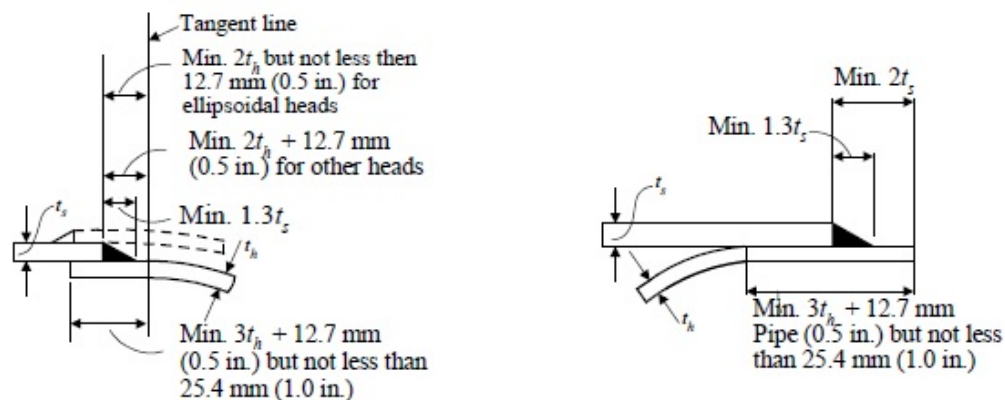
Pinholes, cracks or other defects are to be repaired only by chipping, machining or burning out the defects and rewelding. Boiler drums and vessels requiring stress relieving are to be stress-relieved after any welding repairs have been made.

## **25.7 Retest**

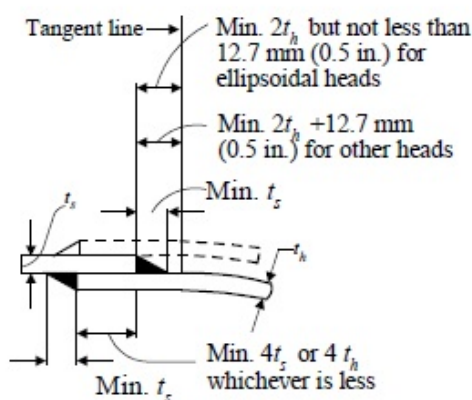
After repairs have been made, the drum, vessel or piping is to be again subjected to the hydrostatic test required in 2-4-2/25.1 through 2-4-2/25.3, inclusive.



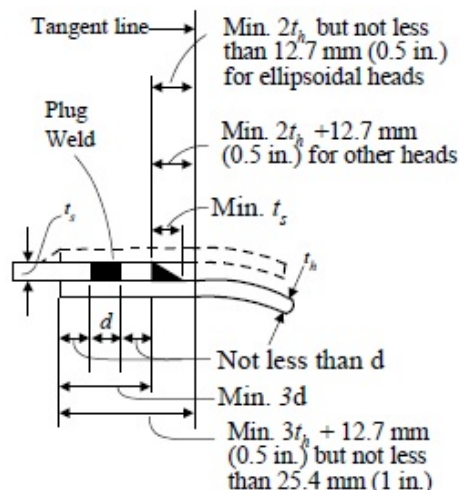
**FIGURE 1**  
**Head to Shell Attachments**



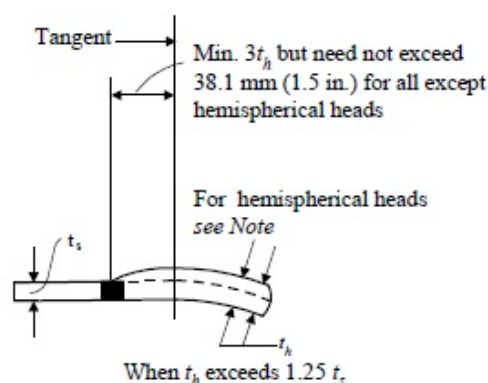
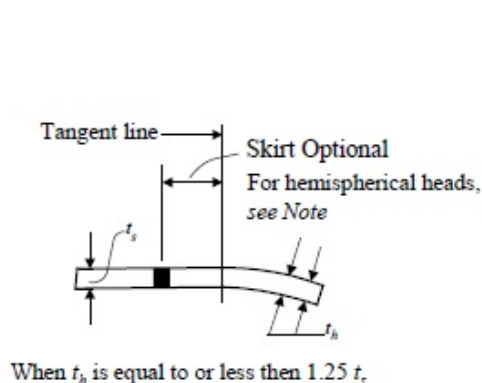
a. Single fillet lap weld



b. Double fillet lap weld

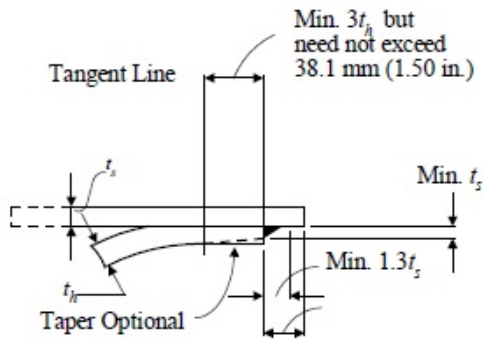


c. Single fillet lap weld with plug welds

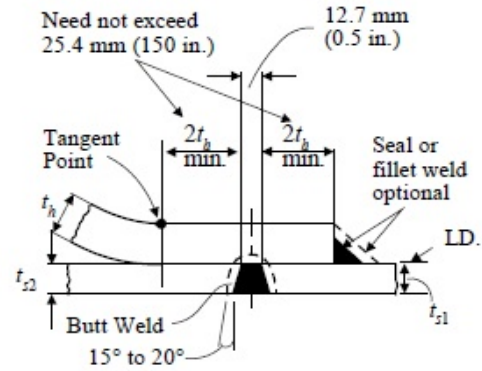


d. Butt weld

Butt weld and fillet weld if used, are to be designed to take shear at 1.5 times the differential pressure that can exist

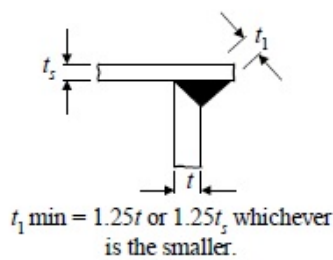


e. Single fillet lap weld

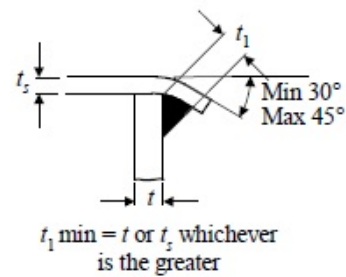


$t_{s1}$  and  $t_{s2}$  may be different

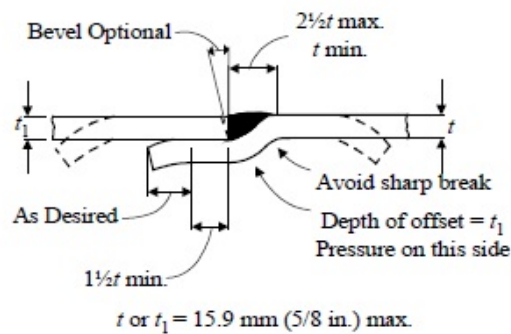
f. Intermediate head



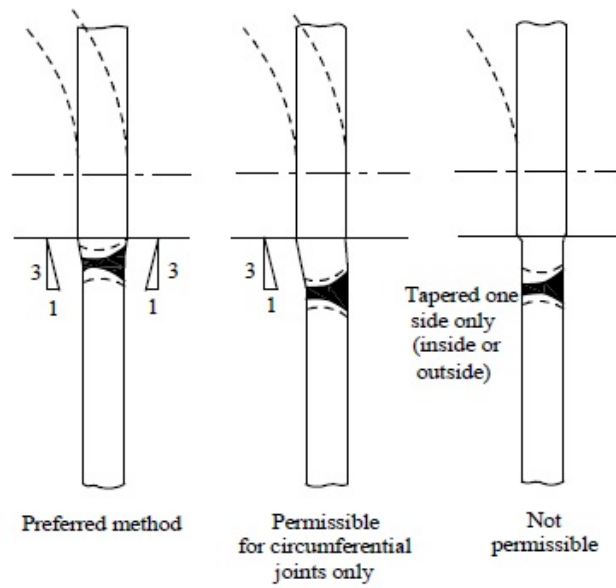
g.



h.



j. Butt weld with one plate edge offset



k. Butt welding of plates of unequal thickness

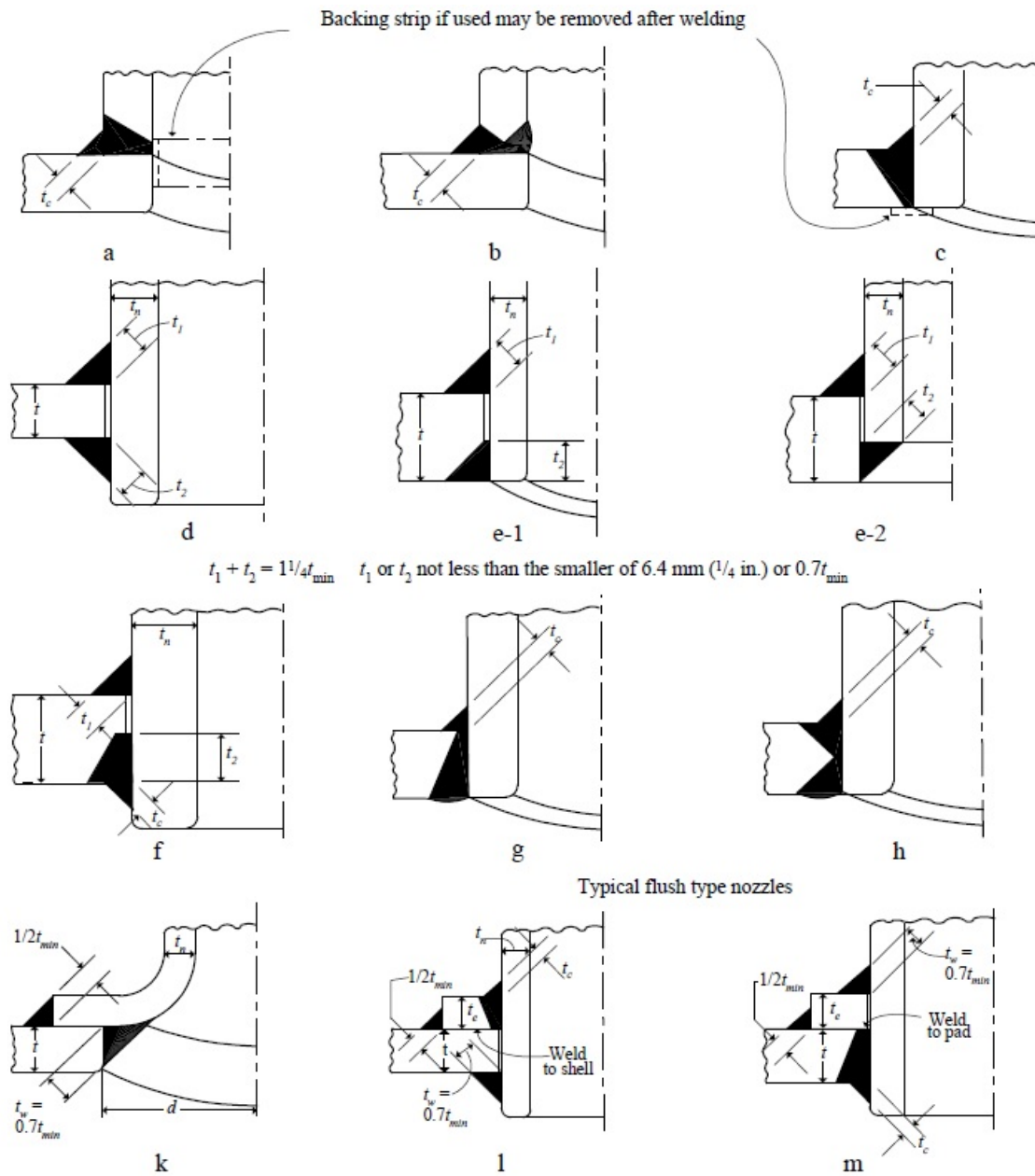


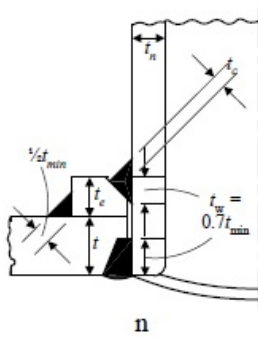
m. Example of corner weld subject to bending stress (not permissible)

**Note:**

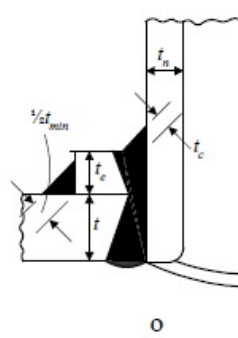
Dished heads of full hemispherical shape, concave to pressure, intended for butt-welded attachment, need not have an integral skirt, but where one is provided, the thickness of the skirt is to be at least that required for a seamless shell of the same diameter.

**FIGURE 2**  
**Types of Fusion-welded Construction Details**

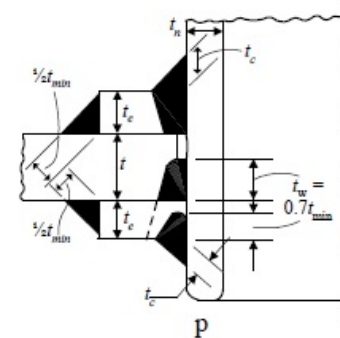




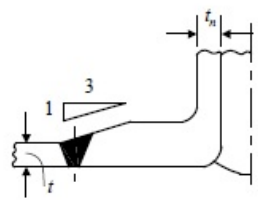
n



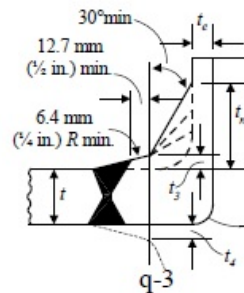
o



p

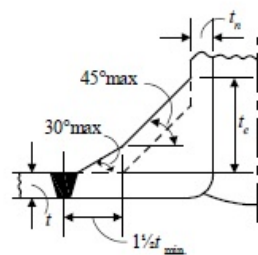


q-1

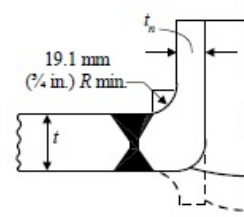


q-3

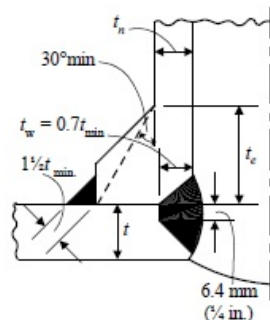
$t_3 + t_4 \leq 0.2t$  but not greater than 6.4 mm (1/4 in.)



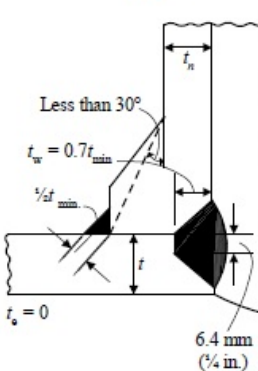
q-2



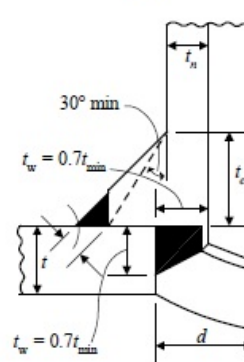
q-4



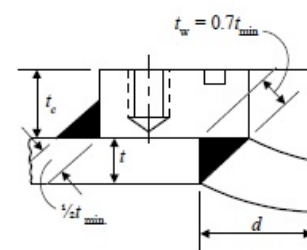
r-1



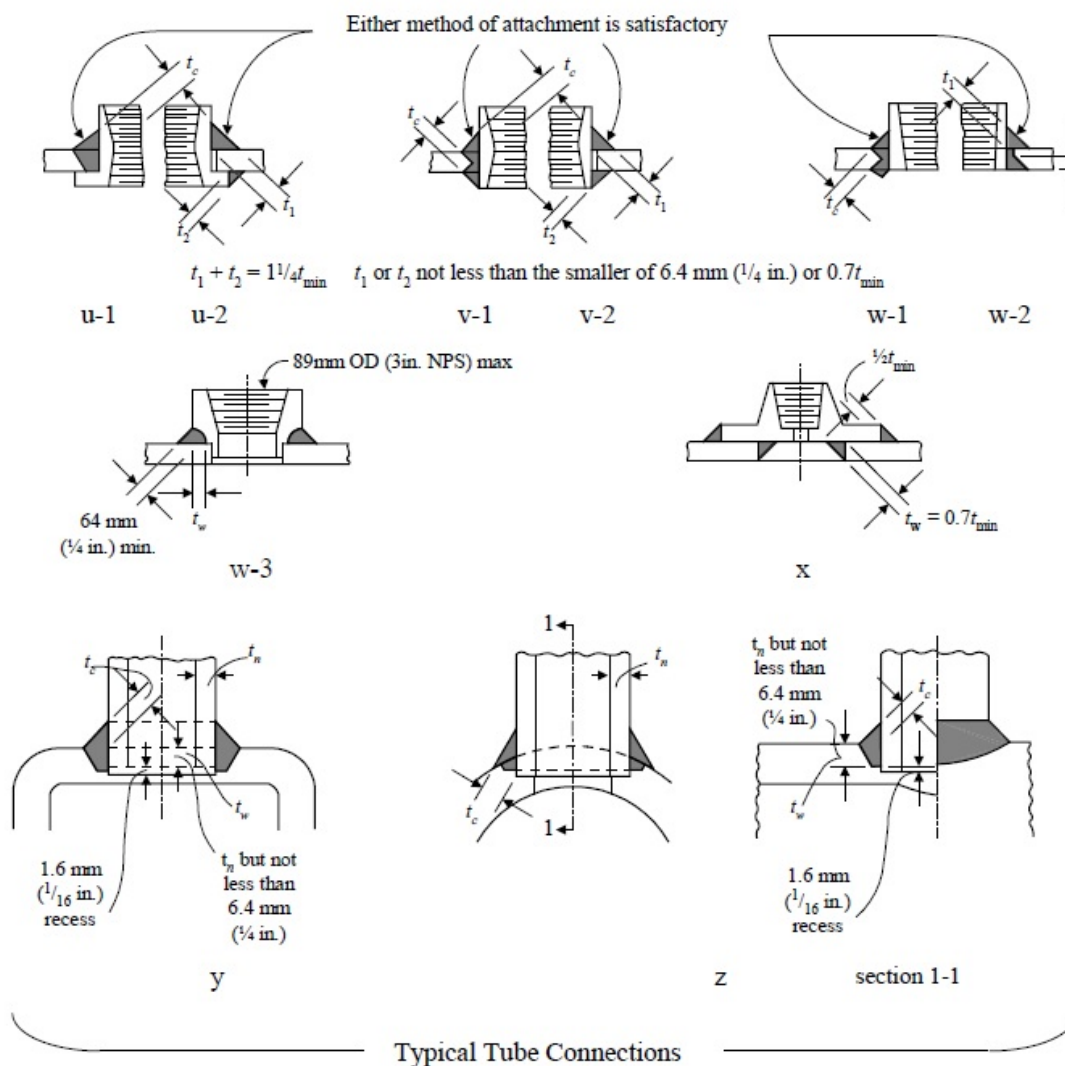
r-2



s



t



(When used for other than square, round, or oval headers, round off corners)

$t$  = thickness of vessel shell or head, less corrosion allowance, in mm (in.)

$t_n$  = thickness of nozzle wall, less corrosion allowance, in mm (in.)

$t_e$  = thickness of reinforcing element, mm (in.)

$t_w$  = dimension of partial-penetration attachment welds (fillet, single-bevel, or single-J), measured as shown, mm (in.)

$t_c$  = the smaller of 6.4 mm ( $1/4$  in.) or  $0.7 t_{\min}$ . (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.)

$t_{\min}$  = the smaller of 19.1 mm ( $3/4$  in.) or the thickness of either of the parts joined by a fillet, single-bevel, or single-J weld, mm (in.)

**1 General (2018)**

The steps to be taken in obtaining approval by ABS of electrodes, filler metals, and welding procedures for qualifying welders and for demonstrating satisfactory workmanship are given below.

**1.1 Weld Groups**

The various groups of welds are designated by index letters and numbers, by which they are referred to in subsequent paragraphs, as follows.

Hull Construction	H	All hull structures
Boilers, etc. Group I	B1	
Unfired Pressure Vessels Group II	B2	
Piping Group I	P1	As defined in 2-4-2/1.5
Piping Group II	P2	
Engineering Structures Group I	E1	
Engineering Structures Group II	E2	

**1.3 Tests (2018)**

Details of tests, preparation of specimens and test results required for approval in each application are given in 2-4-3/3 to 2-4-3/9, and 2-4-3/Figure 1 to 2-4-3/Figure 13. Where position of welding is referred to, the same is to be defined in the American Welding Society D1.1 or 2-A9-A3..

**3 Filler Metals****3.1 General (2018)**

Filler metals are to be a type suitable to produce sound welds that have strength and toughness comparable to the materials being welded. ABS maintains a separately issued list of approved filler metals entitled, “Approved Welding Consumables” in the ABS web site, [www.eagle.org](http://www.eagle.org). This list, together with Part 2, Appendix 3, indicates the grade, and general application for which such filler metals may be employed. It is intended that these lists will serve as useful guides in the selection of suitable filler metals for various welding applications.

### 3.3 Approval Basis (2005)

Filler metals will be approved and listed, subject to tests conducted at a manufacturer's plant or alternatively, at a location outside of the manufacturer's plant under the supervision of the manufacturer. Upon satisfactory completion of tests, a certificate will be issued for general approval, indicating, where applicable, the ABS Grade, operating characteristics and limits of application. Test assemblies are to be prepared in the presence of the Surveyor and all tests are to be carried out in the Surveyor's presence and to the Surveyor's satisfaction. Procedure and testing are to comply with either of the following standards.

#### 3.3.1 ABS Standards

Approval of filler metals for welding vessels and other engineering structures will be granted upon compliance with the Requirements for the Approval of Filler Metals contained in Part 2, Appendix 2.

#### 3.3.2 Standards of Other Agencies

Filler metals will be considered for approval based upon tests conducted to standards established by The American Welding Society or other recognized agencies.

#### 3.3.3 Special Approval

Under circumstances where exact specifications have not been established, ABS will consider approval on the basis of a filler metal manufacturer's guaranteed requirements. Qualified approvals will also be considered, with and without classifying as to grade, for special applications with reliance upon procedure tests at a user's plant.

## 5 Approval of Welding Procedures

### 5.1 Approved Filler Metals

The type of approved filler metals used on ABS-classed weldments will depend upon the specific application for which the filler metal is intended. Procedure tests may be required at the discretion of the attending Surveyor to determine the shipyard or fabricator's capability in the application of the proposed filler metal to the base material. The extent of such tests may vary depending upon the intended application, but generally are to follow those tests outlined in 2-4-3/5.7.

### 5.3 Surveyor's Acceptance

The Surveyor may, at his discretion, accept a filler metal, welding procedure, or both, in a shipyard or fabricator's plant where it is established to the Surveyor's satisfaction that they have been effectively used for similar work under similar conditions.

### 5.5 New Procedures and Methods

Weld tests using procedures and materials similar to those intended for production welding may be required to be prepared by each shipyard or fabricator when new or unusual methods, base metals or filler metals are proposed. All tests are to be made in the presence of the Surveyor and carried out to the Surveyor's satisfaction.

### 5.7 Tests (2006)

See 2-4-3/11.5 FIGURE 1. Unless otherwise approved, the number of specimens is to be as indicated. The minimum test results required are stated with the following figures.

- **Test No. 1** (For butt welds) Reduced-section Tension Test (2-4-3/11.5 FIGURE 3 or 2-4-3/11.5 FIGURE 4). One test assembly for each position involved; two reduced-section tension test specimens taken from each test assembly as shown in 2-4-3/11.5 FIGURE 1.
- **Test No. 2** (For butt welds) Guided Bend Test (2-4-3/11.5 FIGURE 5 and 2-4-3/11.5 FIGURE 6). One test assembly for each position involved. For material 19 mm (0.75 in.) thick and under, two face-bend and two root-bend specimens taken from each test assembly as shown in 2-4-3/11.5 FIGURE 1, except



that at the option of the fabricator, four side bends may be substituted for material thickness over 9.5 mm ( $\frac{3}{8}$  in.). For material over 19 mm (0.75 in.) thick, four side-bend specimens taken from each test assembly as shown in 2-4-3/11.5 FIGURE 1. The bending jig and test requirements are indicated in 2-4-3/11.5 FIGURE 7.

- **Test No. 3** Fillet-weld Test (2-4-3/11.5 FIGURE 8). One specimen made in each position involved.

## 5.9 Special Tests

All weld-metal tension, Charpy V-notch impact, macro-etch or other relevant tests may be required for certain applications, such as higher-strength steels, electroslag welding, one-side welding, etc., and the results submitted for consideration. 2-4-3/11.5 FIGURE 13 defines the location of Charpy V-notch impact tests when heat affected zone tests are required. A Charpy V-notch test is to consist of three specimens per location.

## 5.11 Repair and Cladding of Stern Tube and Tail Shafts

Weld repairs and cladding on stern tube shafts and tail shafts are to be performed in an approved facility.

Approval of welding procedures for the repair or cladding of stern tube shafts and tail shafts is to be in accordance with 7-A1-11 "Repair and Cladding of Shafts" of the *ABS Rules for Survey After Construction (Part 7)*.

# 7 Workmanship Tests

## 7.1 Hull Construction

The Surveyor may, when it is considered desirable, require welders to prepare specimens for Fillet-weld Tests (Test No. 3) for the positions involved. Details of the specimen are shown in 2-4-3/11.5 FIGURE 8.

## 7.3 Boilers and Group I Pressure Vessels

### 7.3.1 Required Tests

The following tests are to be conducted/performed using equivalent material of the same thickness as the boiler or pressure vessel. The results required are stated with the applicable figures and in 2-4-3/9.3.

- **Test No. 1** Reduced-section Tension Test (2-4-3/11.5 FIGURE 3)
- **Test No. 2** Guided Bend Test, (2-4-3/11.5 FIGURE 5 or 2-4-3/11.5 FIGURE 6)
- **Test No. 3** Radiographic Search of Welds on Finished Joint

### 7.3.2 Test Exceptions

Test Nos. 1 and 2 are not required for cylindrical pressure parts of Boilers and Group I Pressure Vessels constructed of ABS Steel Plate for Boilers and Pressure Vessels Grades A through G inclusive and Grades K through N inclusive whose welded joints are fully examined by radiography.

### 7.3.3 Attached Test Plates

Structures made in accordance with the requirements of Group B1 of materials other than those given in 2-4-3/7.3.2 are to have test plates attached as shown in 2-4-3/11.5 FIGURE 2 to permit the longitudinal joint of the shell and test plates to be welded continuously. The test plate is to be of sufficient length to provide two specimens for each of Tests Nos. 1 and 2 detailed above. One specimen is to be tested; the other specimen is for use in retesting, if necessary.

#### 7.3.4 Separate Test Plates

Circumferential joints of a boiler or pressure vessel need not be provided with test plates unless there be no longitudinal welded joint, in which case, test plates are required to be welded separately.

#### 7.3.5 Number of Test Plates

Where several drums or vessels of the same design and grade of material are welded in succession, a set of test plates for each linear 61 m (200 ft) of longitudinal joints, or 61 m (200 ft) of circumferential joints where there are no longitudinal joints, will be acceptable, provided the joints are welded by the same operators and the same welding method. Shells having no longitudinal joints may be considered as being of the same design if the plate thicknesses fall within a range of 6.4 mm (0.25 in.) and the shell diameters do not vary by more than 150 mm (6 in.).

#### 7.3.6 Test-plate Heat Treatment and Retests

In all cases, the welded test plates are to be treated as to stress relieving, etc., in the same manner as the work which they represent. Should any of the tests fail, one retest is to be made for each failure; and should the retest also fail, the welding represented is to be chipped or gouged out and rewelded and new test plates provided.

### 7.5 Other Pressure Vessels

Workmanship test plates are not required for structures in this Group. Test No. 3 is to be carried out when required in 2-4-2/23.3.

### 7.7 Group I Pipe Connections

In carbon and carbon-molybdenum steel piping for all diameters where the thickness exceeds 9.5 mm (0.375 in.) and other alloy-steel piping 76 mm (3 in.) in diameter and over regardless of thickness, welds made in accordance with the requirements of this group are to be subjected to 100% Radiographic Search - Test No. 3, or to other approved method of test, where the former is not applicable.

### 7.9 Group II Pipe Connections

No workmanship tests are required.

### 7.11 Group I Engineering Structures

Group I Engineering Structures are to meet the same requirements as 2-4-3/7.3, except that where there is no longitudinal joint, no test plates will be required.

### 7.13 Group II Engineering Structures

Welds in structures in this group which correspond in service requirements to Group B2 are to be tested in the same manner as Group B2, except that where there is no longitudinal joint, no tests will be required.

## 9 Radiographic or Ultrasonic Inspection

### 9.1 Hull Construction

Where radiographic or ultrasonic inspection is required, such testing should be carried out in accordance with ABS's separately issued *Guide for Nondestructive Inspection*.

### 9.3 Boilers, Pressure Vessels, Machinery and Piping (2014)

#### 9.3.1 General

When radiographic examination of the finished joint is required, as indicated in 2-4-3/7.3, 2-4-3/7.5, 2-4-3/7.7 and 2-4-3/7.11, the radiographs are to be obtained by means of an approved technique and are to compare favorably with accepted standards.

### 9.3.2 Acceptability of Welds-Full Radiography

In general, sections of weld that are shown by full radiography to have any of the following types of imperfections are to be considered unacceptable and are to be repaired.

#### 9.3.2(a) Incomplete Fusion or Penetration.

Any type of crack or zone of incomplete fusion or penetration

#### 9.3.2(b) Elongated Slag Inclusions or Cavities.

Any elongated slag inclusion or cavity which has a length greater than the following, where  $t$  is the thickness of the thinner plate being welded.

6.4 mm (0.25 in.) for  $t$  up to 19.1 mm (0.75 in.)

$\frac{1}{3}t$  for  $t$  from 19.1 mm (0.75 in.) to 57.2 mm (2.25 in.)

19.1 mm (0.75 in.) for  $t$  over 57.2 mm (2.25 in.)

#### 9.3.2(c) Slag Inclusion in Line.

Any group of slag inclusions in line 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

#### 9.3.2(d) Porosity Standards.

Porosity in excess of that permitted by accepted porosity standards such as given in the American Society of Mechanical Engineers' (ASME) Boiler and Pressure Vessel Code.

### 9.3.3 Acceptability of Welds-Spot (Random) Radiography

The inspection of the production welds by spot radiography is to compare favorably with accepted standards and methods, such as given in the ASME Boiler and Pressure Vessel Code.

### 9.3.4 Survey Report Data

In each case, a statement on the extent and the results of the radiographic examination is to accompany the Surveyor's report. The inspection procedure and technique is to be maintained on file by the manufacturer and is to compare favorably with accepted practice such as that specified in the ASME Boiler and Pressure Vessel Code.

### 9.3.5 Pipe-joint Exception

An approved method of test may be used in lieu of the radiographic inspection of pipe joints, where the latter cannot be applied.

## 11 Welders

### 11.1 General Requirements

The Surveyor is to be satisfied that the welders are proficient in the type of work which they are called upon to perform, either through requiring any or all of the tests outlined in the following paragraphs or through due consideration of the system of employment, training, apprenticeship, plant testing, inspection, etc., employed.

### 11.3 Qualification Tests (1 July 2018)

The tests, if required for qualification in the various positions for different materials and thicknesses, are given in 2-4-3/11.5 TABLE 1. The tests are referred to by Nos. Q1 to Q4 inclusive for which specimens are to be prepared in accordance with 2-4-3/Figure 9 to 2-4-3/Figure 12 respectively, and physically tested

if the welder is qualified by this method. Alternatively, upon the request of the employer, the welder may be qualified by use of radiography, except for gas metal arc welding with the short circuit transfer technique for which bend tests are required. Test assemblies for either physical testing or radiographic examination are to be prepared according to material thickness and welding position, as indicated in 2-4-3/11.5 TABLE 1.

As an alternative, welders may be qualified in accordance with 2-A11-A1 or a recognized standard. The application of such recognized standard is to be submitted for agreement by the Surveyor.

### 11.5 Tests Nos. Q1, Q2, and Q3 (2016)

Specimens for qualification Tests Nos. Q1, Q2 and Q3 are to be bent in a bending jig having the profile shown in 2-4-3/11.5 FIGURE 7.

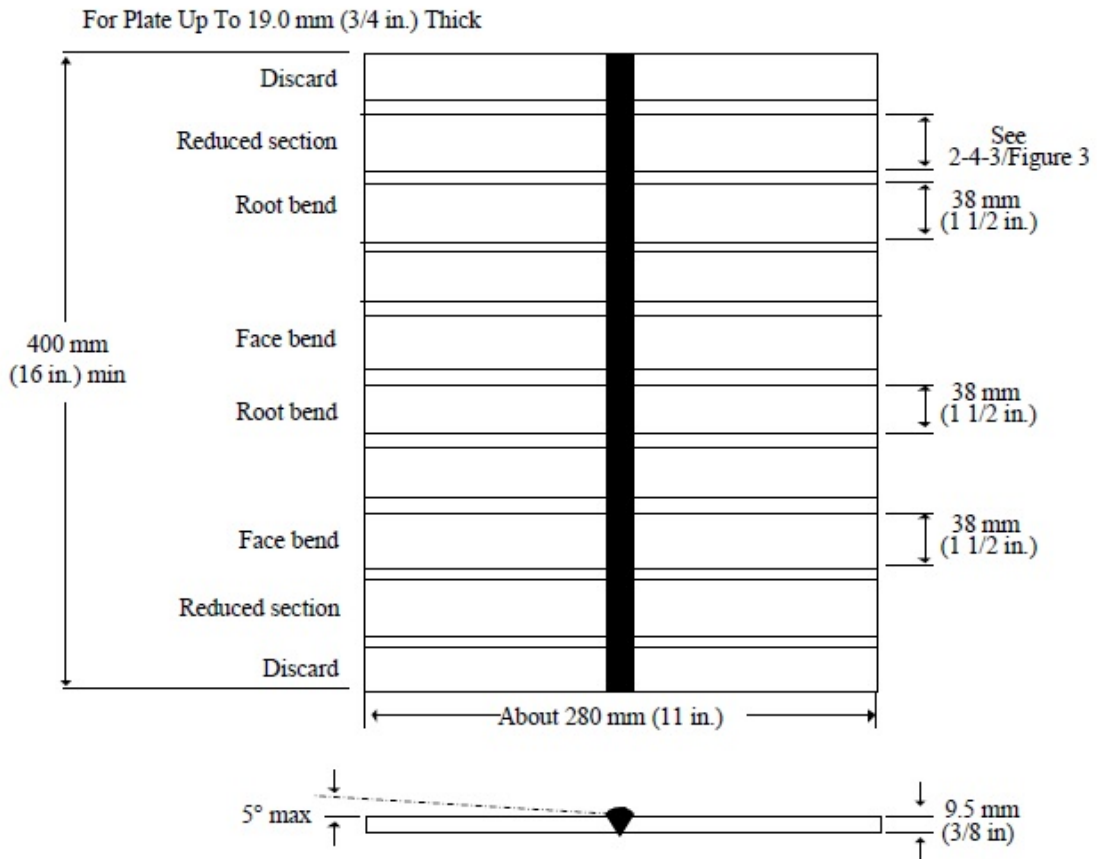
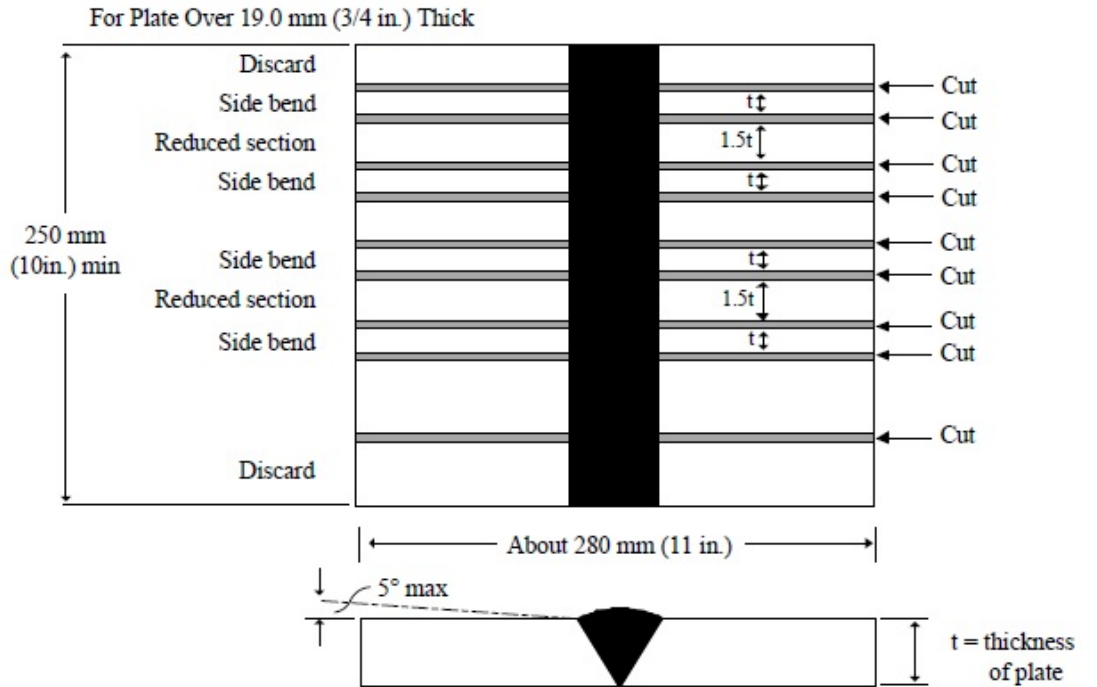
**TABLE 1**  
**Welder Qualification Tests (2010)**

<i>Construction Material</i>	<i>Position in Which Welding Is To Be Done on Job</i>		
	<i>Flat, Horizontal, Vertical and Overhead</i>	<i>Flat and Vertical</i>	<i>Flat Position Only</i>
Plate Material of 19.1 mm ( <sup>3</sup> / <sub>4</sub> in.) or less in thickness (Note 1)	Test No. Q1 in vertical (3G) and overhead (4G) positions	Test No. Q1 in vertical (3G) position	Test No. Q1 in flat (1G) position
Plate material of any thickness	Test No. Q2 in vertical (3G) and horizontal (2G) positions	Test No. Q2 in vertical (3G) position (Note 2)	Test No. Q2 in flat (1G) position
Piping or tubing of any thickness (Note 2)	Test No. Q3 in inclined fixed (6G) position	Test No. Q3 in horizontal fixed (5G) position (Note 4)	Test No. Q3 in horizontal rolled (1G) position (Note 4)
Piping or tubing of any thickness (Note 5)	Test No. Q3R in horizontal and vertical positions		
T, K and Y joints (Note 3)	Test Q3 in inclined fixed position with restriction ring (6GR)		
Tack welders for hull construction (Note 6)	Test No. Q4 in vertical and overhead positions	Test No. Q4 in vertical position	

*Notes:*

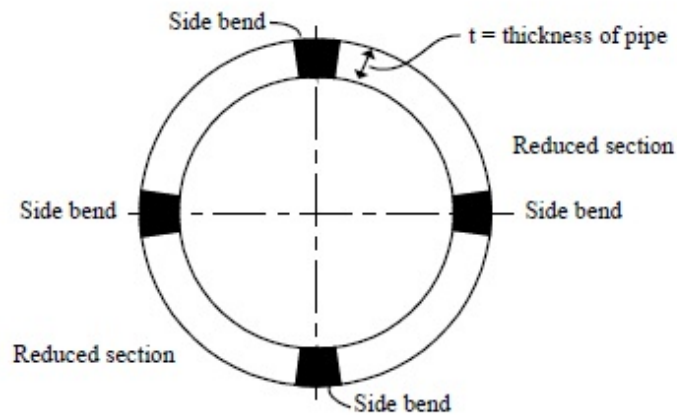
- 1 Where the maximum plate thickness to be welded is less than 9.5 mm ( $\frac{3}{8}$  in.), the test plate thickness is to be 5.0 mm ( $\frac{3}{16}$  in.).
- 2 Welders qualified under the requirements of Test No. Q3 will be considered as qualified to make welds governed by Test Nos. Q1 and Q2, in accordance with test thickness; test thickness over 5.0 mm ( $\frac{3}{16}$  in.) but less than 19.0 mm ( $\frac{3}{4}$  in.) qualifies for range of 1.5 mm ( $\frac{1}{16}$  in.) to  $2t$ ; test thickness 19.0 mm ( $\frac{3}{4}$  in.) and greater qualifies for range of 5.0 mm ( $\frac{3}{16}$  in.) to unlimited thickness. Welders qualified to weld on plate in the vertical position may be permitted to weld on pipe in the horizontal rolled position.
- 3 For qualification of T, K and Y joints, Test No. Q3 in the inclined fixed position with restriction ring (6GR) is required.
- 4 Test No. Q3 in the horizontal fixed (5G) position also qualifies for overhead (4G) welding. Test No. Q3 in the 2G position qualifies for welding in the 1G, 1F, 2G and 2F positions.
- 5 Test No. Q3R may be used when special qualification for welding in areas of restricted access is required.
- 6 See 2-4-4/5.11 applicable for pipe welding.

**FIGURE 1**  
**Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2**

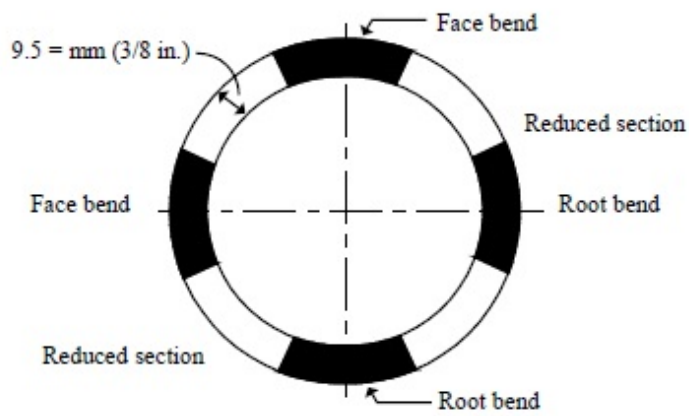


Note: Edge preparation, welding procedure and postweld heat treatment, if any, are to be the same as those for the work represented.

For Pipe Over 19.0 mm (3/4 in.) Thick

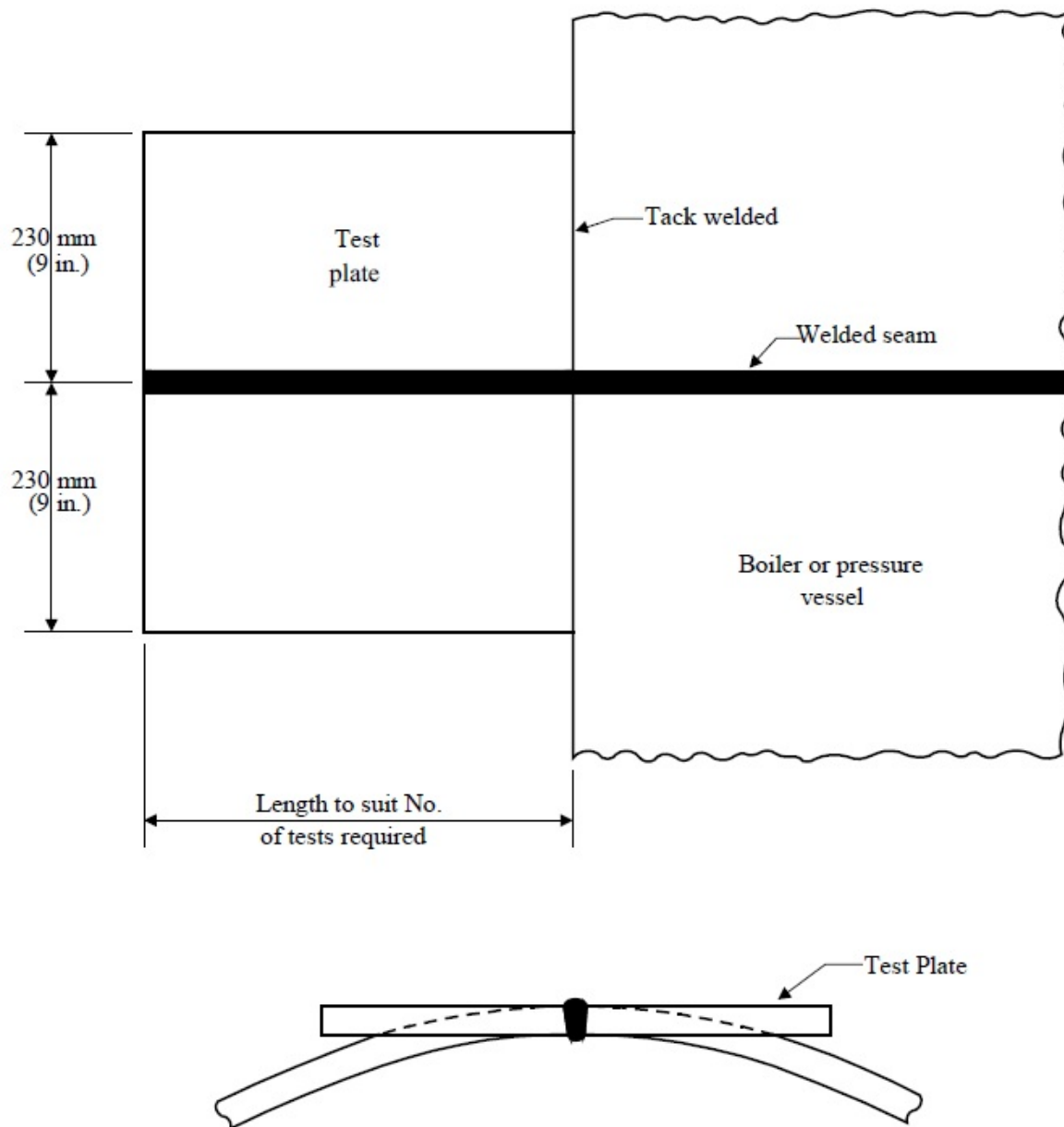


For Pipe Up To 19.0 mm (3/4 in.) Thick



Note: Edge preparation, welding procedure and postweld heat treatment, if any, are to be the same as those for the work represented.

**FIGURE 2**  
**Typical Arrangement of Test Plates for Workmanship Tests in Group B1**

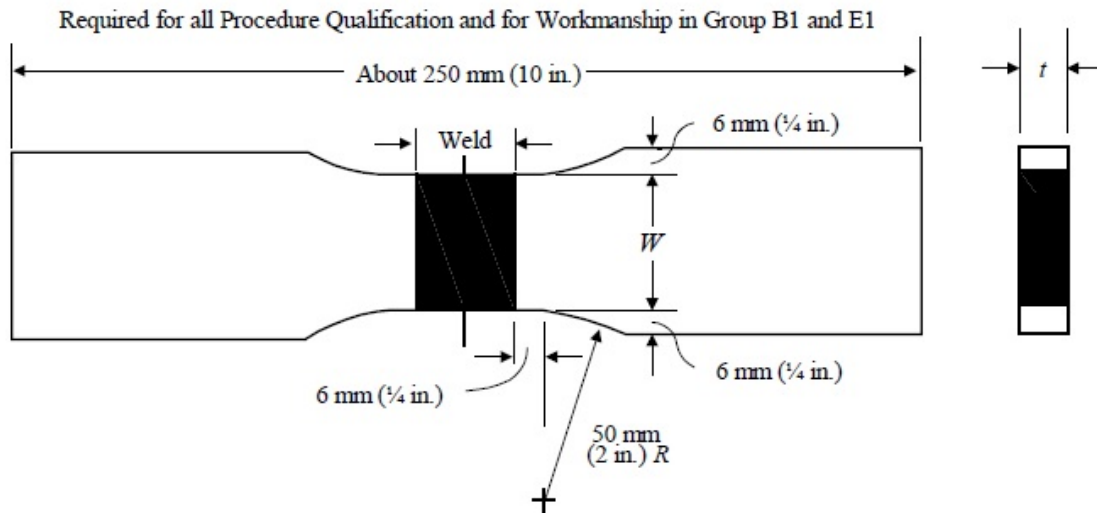


**Note:**

Tack weld test plates together and support test assembly so that warping due to welding does not cause deflection of more than 5 degrees. Should straightening of any test assembly within this limit be necessary to facilitate making test specimens, the test assembly is to be straight-ended after cooling and before any postweld heat treatment.



**FIGURE 3**  
**Test No. 1 -Reduced-section Tension Test for Plate (2016)**



*Notes:*

- 1 Both faces of weld are to be machined flush with base metal.
- 2 For procedure qualification  $t = 9.5 \text{ mm } (\frac{3}{8} \text{ in.})$  for construction materials up to  $19.0 \text{ mm } (\frac{3}{4} \text{ in.})$ . For construction material over  $19.0 \text{ mm } (\frac{3}{4} \text{ in.})$   $t =$  thickness of material.
- 3 For workmanship tests  $t =$  thickness of construction material.
- 4  $W =$  approximately  $38 \text{ mm } (1.5 \text{ in.})$  where  $t$  is  $25.4 \text{ mm } (1 \text{ in.})$  or less.  $W = 25.4 \text{ mm } (1 \text{ in.})$  where  $t$  is more than  $25.4 \text{ mm } (1 \text{ in.})$ .
- 5 When the capacity of the available testing machine does not permit testing of the full thickness specimen, two or more thinner than full thickness specimens may be prepared by cutting the full thickness specimen into sections, each of which is to meet the requirements.

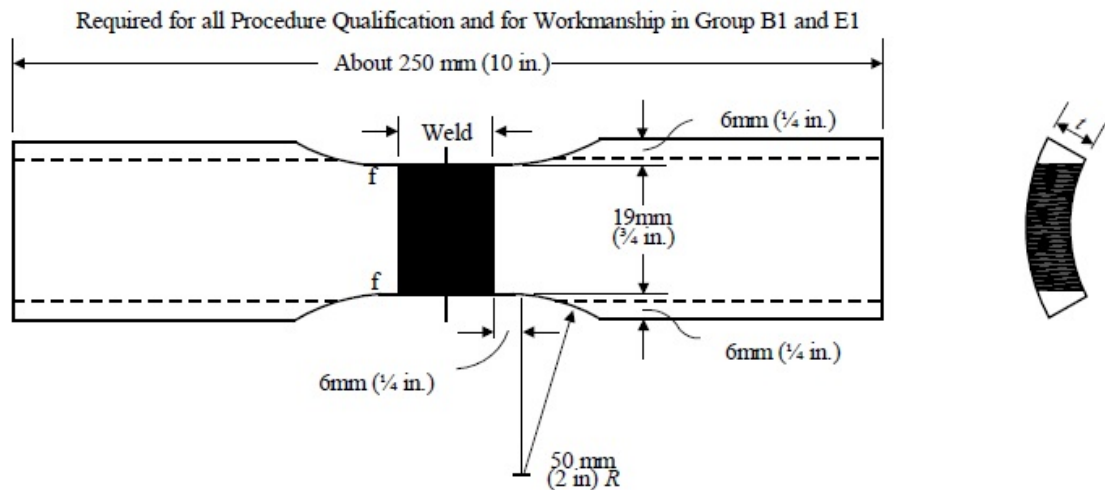
*Requirements:*

- 1 The tensile strength of each specimen, when it breaks in the weld, is not to be less than the minimum specified tensile strength of the base material.
- 2 The tensile strength of each specimen, when it breaks in the base metal and the weld shows no signs of failure, is not to be less than 95% of the minimum specified tensile strength of the base material.

*Retest Procedure (2016):*

- 1 When the tensile test fails to meet the requirements, two retests may be performed with specimens cut from the same tested piece. The results of both test specimens shall meet the test requirements.
- 2 If one or both of these fail, the weld test is to be rejected.

**FIGURE 4**  
**Test No. 1 -Reduced-section Tension Test for Pipe (2016)**



*Notes:*

- 1 Both faces of weld are to be machined flush with base metal. The minimum amount needed to obtain plane parallel faces over 19 mm (3/4 in.) wide reduced section may be machined at the option of the testing facility.
- 2 For procedure qualification  $t = 9.5 \text{ mm}$  (3/8 in.) for construction materials up to 19.0 mm (3/4 in.). For construction material over 19.0 mm (3/4 in.)  $t =$  thickness of material.
- 3 For workmanship tests  $t =$  thickness in material.
- 4 When the capacity of the available testing machine does not permit testing of the full thickness specimen, two or more thinner than full thickness specimens may be prepared by cutting the full thickness specimen into sections, each of which is to meet the requirements.

*Requirements:*

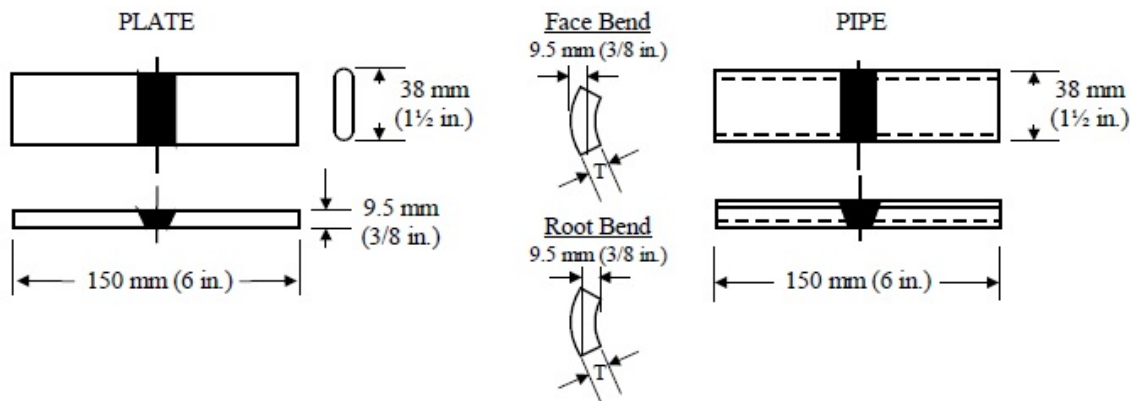
- 1 The tensile strength of each specimen, when it breaks in the weld, is not to be less than the minimum specified tensile strength of the base material.
- 2 The tensile strength of each specimen, when it breaks in the base metal and the weld shows no signs of failure, is not to be less than 95% of the minimum specified tensile strength of the base material.

*Retest Procedure (2016):*

- 1 When the tensile test fails to meet the requirements, two retests may be performed with specimens cut from the same tested piece. The results of both test specimens shall meet the test requirements.
- 2 If one or both of these fail, the weld test is to be rejected.

**FIGURE 5**  
**Test No. 2 - Guided Bend Test for Root Bend and Face Bend**  
**(Plate or Pipe) (2007)**

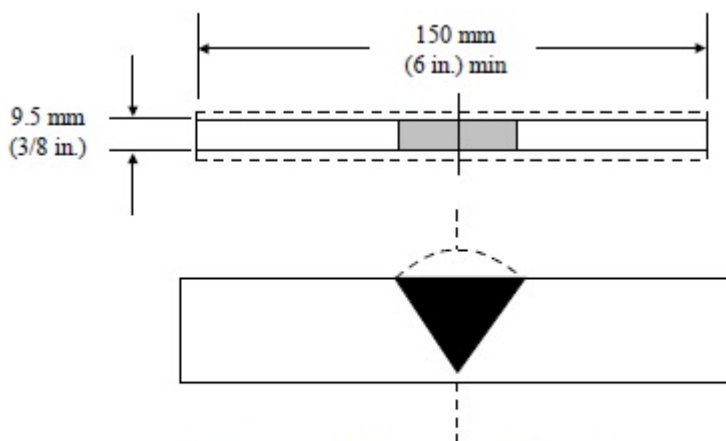
Required for Procedure Qualification, Workmanship Tests in Groups B1, B2, and E1



**Note:**

Both faces of weld to be machined flush with base metal.  
 On test assemblies greater than 9.5 mm (3/8 in.) the opposite side of specimen may be machined as shown.

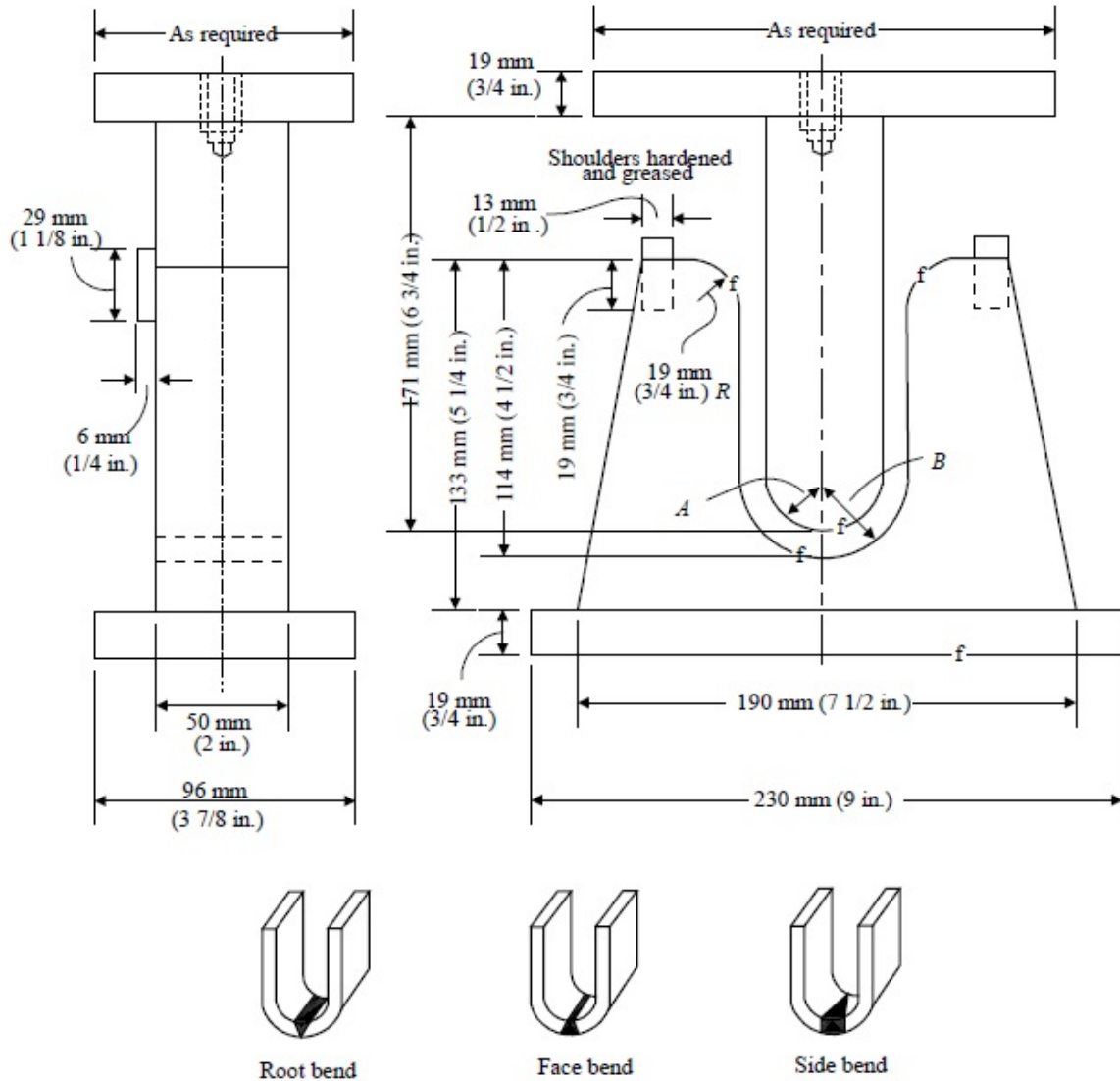
**FIGURE 6**  
**Test No. 2 - Guided Bend Test for Side Bend (Plate or Pipe)(1996)**



Full material thickness is to be tested. Where the thickness is over 38 mm (1 1/2 in.) cut the specimen into multiple strips of approximately equal width between 19 mm (3/4 in.) and 38 mm (1 1/2 in.) and test each strip.

Note Faces of weld to be machined flush with base metal

**FIGURE 7**  
**Guided Bend Test Jig (2016)**



Note:

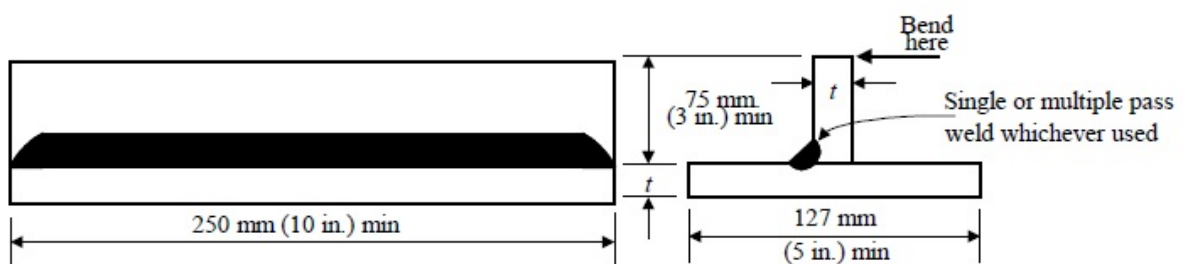
The specimen is to be bent in this jig or in an equivalent guided bend roller jig around a mandrel with the following maximum dimensions proportional to the specimen thickness ( $t$ ).

	A	B
Ordinary strength steel	$2t$	$3t + 1.6 \text{ mm } (\frac{1}{16} \text{ in.})$
Higher strength steel	$2.5t$	$3.5t + 1.6 \text{ mm } (\frac{1}{16} \text{ in.})$
High strength quenched and tempered steel $> 620 \text{ N/mm}^2$ (90 ksi) YS	$3.3t$	$4.3t + 1.6 \text{ mm } (\frac{1}{16} \text{ in.})$

*Requirements (2016):*

- 1 After bending, the specimen is not to show any cracking or other open defect exceeding 3.2 mm ( $1/8$  in.) on the convex side in any direction except at the corners.
- 2 After bending, the sum of the greatest dimensions of all discontinuities exceeding 0.8 mm ( $1/32$  in.) on the convex side is not to exceed 9.5 mm ( $3/8$  in.).
- 3 After bending, the maximum corner crack is not to exceed 6.4 mm ( $1/4$  in.), except when that corner crack results from visible slag inclusion or other fusion type discontinuity, then 3.2 mm ( $1/8$  in.) maximum shall apply.

**FIGURE 8**  
**Test No. 3 -Fillet-weld Test**



*Notes:*

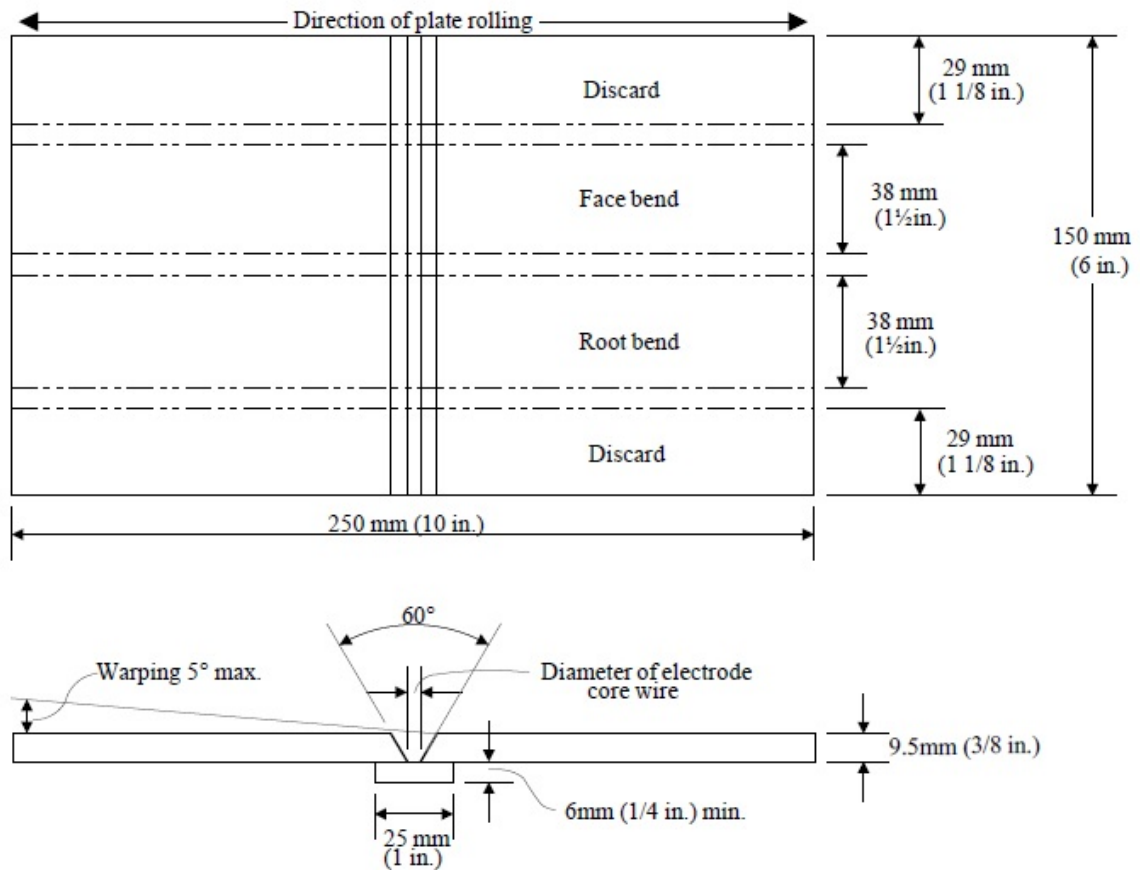
- 1 For procedure qualification  $t = 9.5$  mm ( $3/8$  in.) for construction materials up to 19.0 mm ( $3/4$  in.). For construction material over 19.0 mm ( $3/4$  in.)  $t =$  thickness of material.
- 2 Base and standing web is to be straight and in intimate contact and securely tacked at ends before fillet-weld is made, to insure maximum restraint.
- 3 The test plate may be flame cut into short sections to facilitate breaking open.

*Requirements:*

The fillet is to be of the required contour and size, free from undercutting and overlapping. When broken, as indicated, the fractured surface is to be free from cracks. Visible porosity, incomplete fusion at the root corners and inclusions may be acceptable, provided the total length of these discontinuities is not more than 10% of the total length of the weld.

**FIGURE 9**  
**Welder Qualification Test No. Q1**

For Plate Material 19.0 mm (3/4 in.) or less

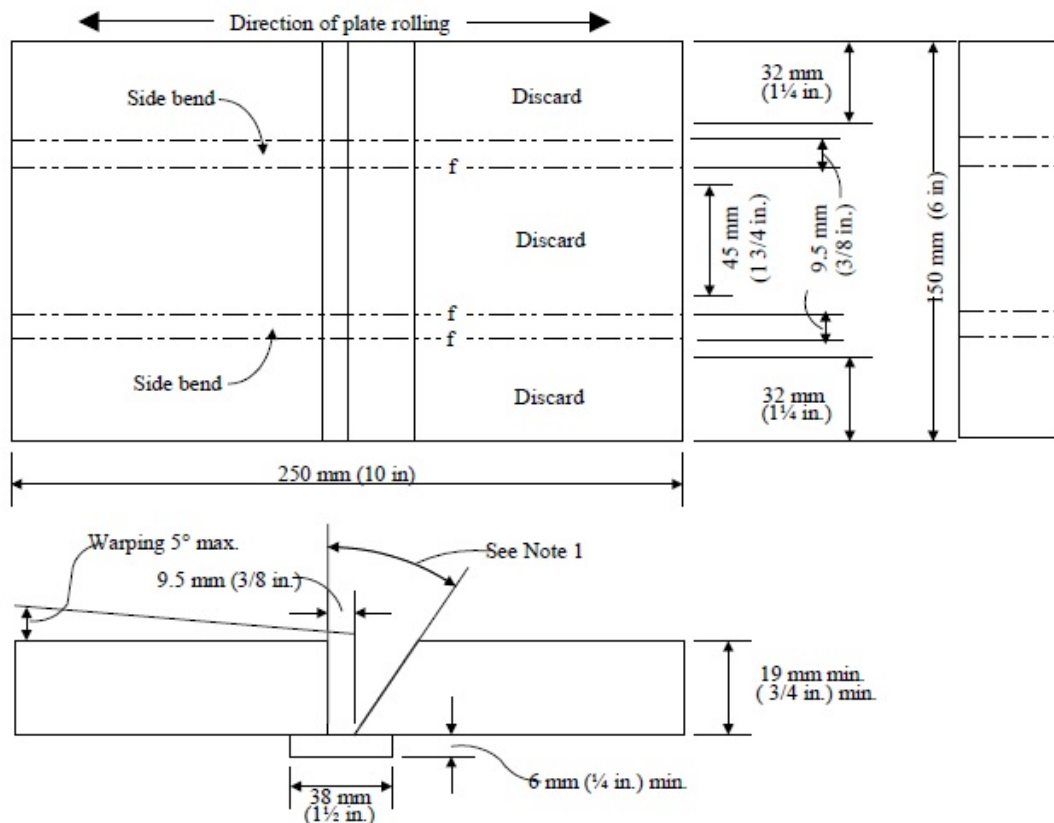


**Notes:**

- 1 Weld is to be made with the maximum size of electrodes that will be used in production.
- 2 Thickness of test assembly is to be reduced to 5 mm (<sup>3</sup>/<sub>16</sub> in.) for qualifying construction material less than 9.5 mm (<sup>3</sup>/<sub>8</sub> in.) per Note 1 of 2-4-3/11.5 TABLE 1.
- 3 Machine reinforcement and backing strap flush. Do not remove any undercutting.
- 4 Machining is to be done transverse to weld.
- 5 All specimens are to be machined or sawed from plate.
- 6 Backing strap is to be contiguous with plates.
- 7 Joints welded in the vertical position are to be welded upwards.
- 8 Welding is to be done from one side only.
- 9 Break edges of specimens to a radius of  $t/6$  maximum.
- 10 Bend specimens in Guided Bend Test Jig (2-4-3/11.5 FIGURE 7)
- 11 1 Face Bend and 1 Root Bend required.

**FIGURE 10**  
**Welder Qualification Test No. Q2**

For Materials Of Any Thickness.



**Notes:**

- 1 When welding in the flat and vertical positions of welding, the groove angle is to be 25 degrees; when welding in the horizontal position, the groove angle is to be 35 degrees and the unbeveled plate is to be located on the top side of the joint.
- 2 Backing strap is to be contiguous with plates.
- 3 Each pass of the weld is to be made with the same size of electrodes that will be used in production.
- 4 Joints welded in the vertical position are to be welded upwards.
- 5 Welding is to be done from one side only.
- 6 Machine reinforcement and backing strap flush. Do not remove any undercutting.
- 7 All specimens are to be machined or sawed from plate.
- 8 Machining is to be done transverse to weld.
- 9 Break edges of specimens to a radius of  $t/6$  maximum.
- 10 Bend Specimen in Guided Bend Test Jig (2-4-3/11.5 FIGURE 7).
- 11 2 Side Bends required for plate. 4 Side Bends required for pipe.

**FIGURE 11A**  
**Welder Qualification Test No. Q3 (2005)**

See also 2-4-3/Table 1  
Positions of test pipe or tubing



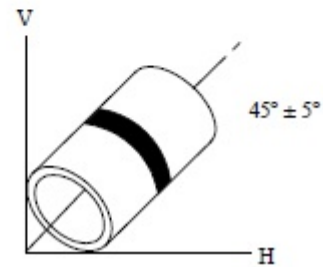
a Horizontal rolled (1G)<sup>9</sup>



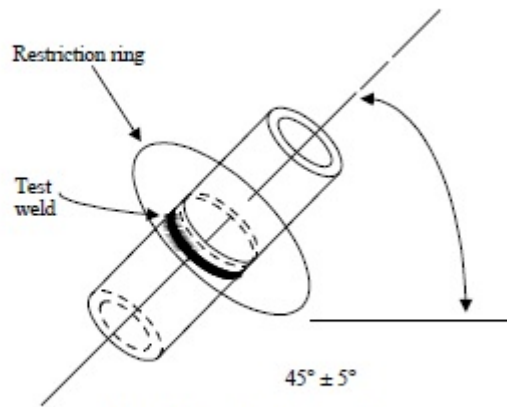
b Vertical fixed (2G)<sup>9</sup>



c Horizontal fixed multiple welding test position (5G)<sup>9</sup>



d Inclined fixed multiple welding test position (6G)<sup>9</sup>



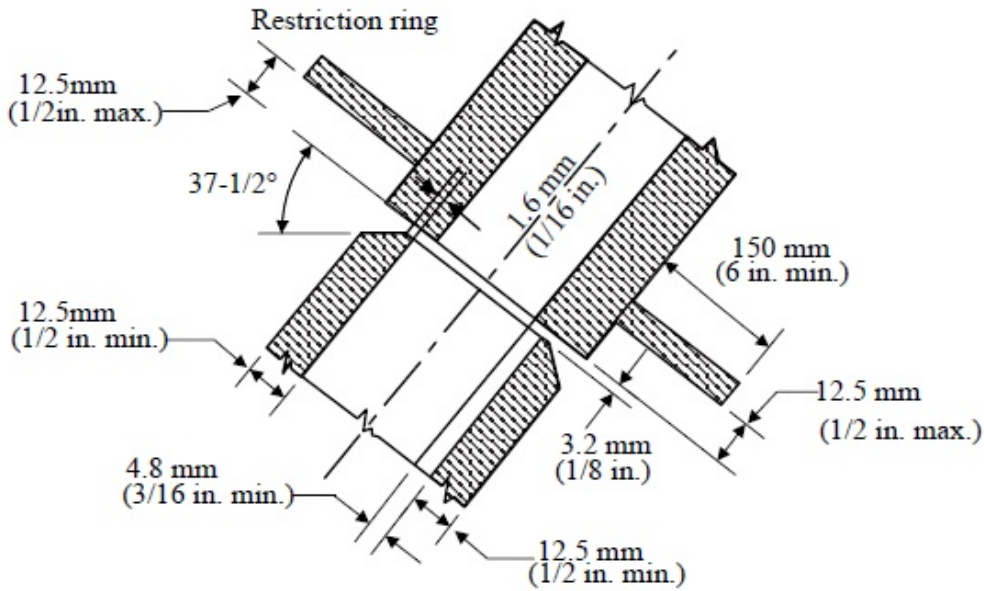
e Inclined fixed multiple welding test position with restriction ring (6GR)<sup>9</sup>

See 2-4-3/Figure 11B for joint details



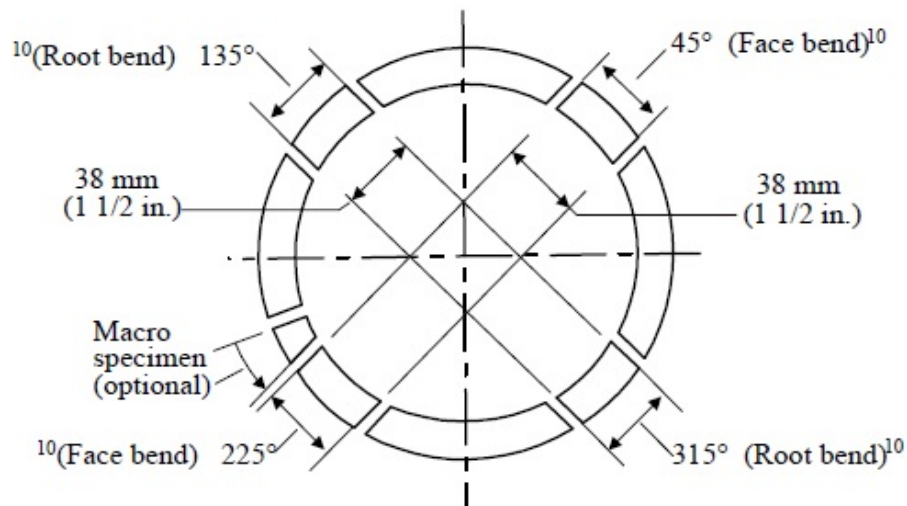
**FIGURE 11B**  
**Welder Qualification Test No. Q3 - 6GR**

Positions of test pipe or tubing

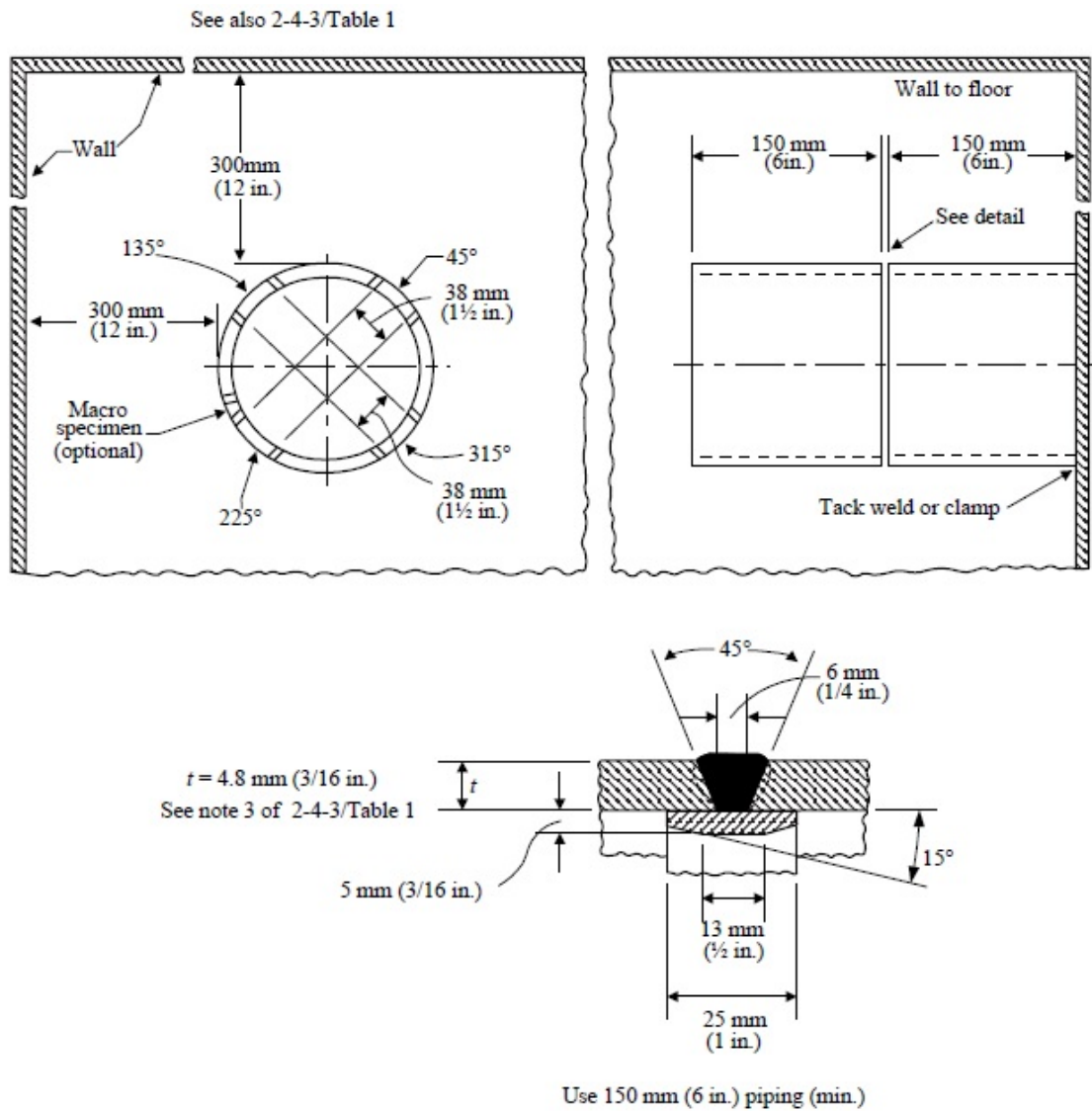


f Joint detail-restriction ring assembly

location of test specimens



**FIGURE 11C**  
**Welder Qualification Test No. Q3R (2014)**

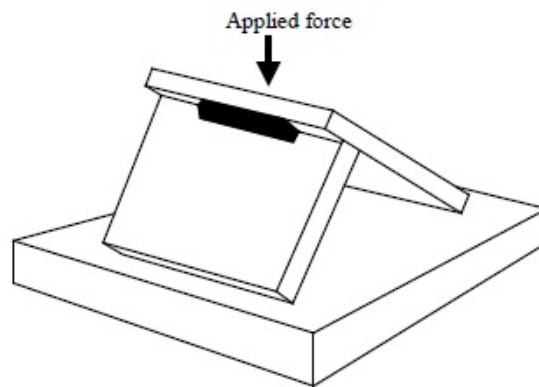
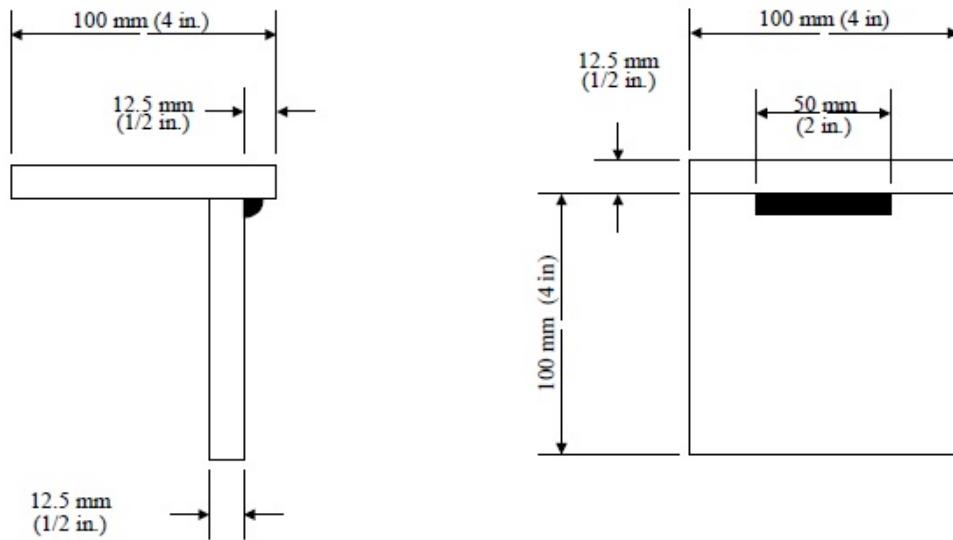


*Notes:*

- 1 Welds are to be made with electrode sizes representative of production.
- 2 Machine reinforcement and backing strap flush. Do not remove any undercutting.
- 3 All specimens are to be machined or sawed from piping.
- 4 break edges of bend specimens to a radius of  $t/6$  maximum.
- 5 Mark top and front of piping to insure proper location of specimens.
- 6 Remove face-bend specimens from 45 and 225 degree points, and root-bend specimens from 135 and 315 degree points as indicated. If piping of greater wall thickness than 9.5 mm ( $3/8$  in.) is used in this test four (4) side bend tests are to be conducted in lieu of root and face bends.
- 7 Welding is to be done from one side only.
- 8 Bend specimens in Guided Bend Test Jig (2-4-3/11.5 FIGURE 7).
- 9 Position designations.

**FIGURE 12**  
**Welder Qualification Test No. Q4**

Tack Welders for Hull Construction (See 2-4-4/5.11 - applicable for pipe welding.)

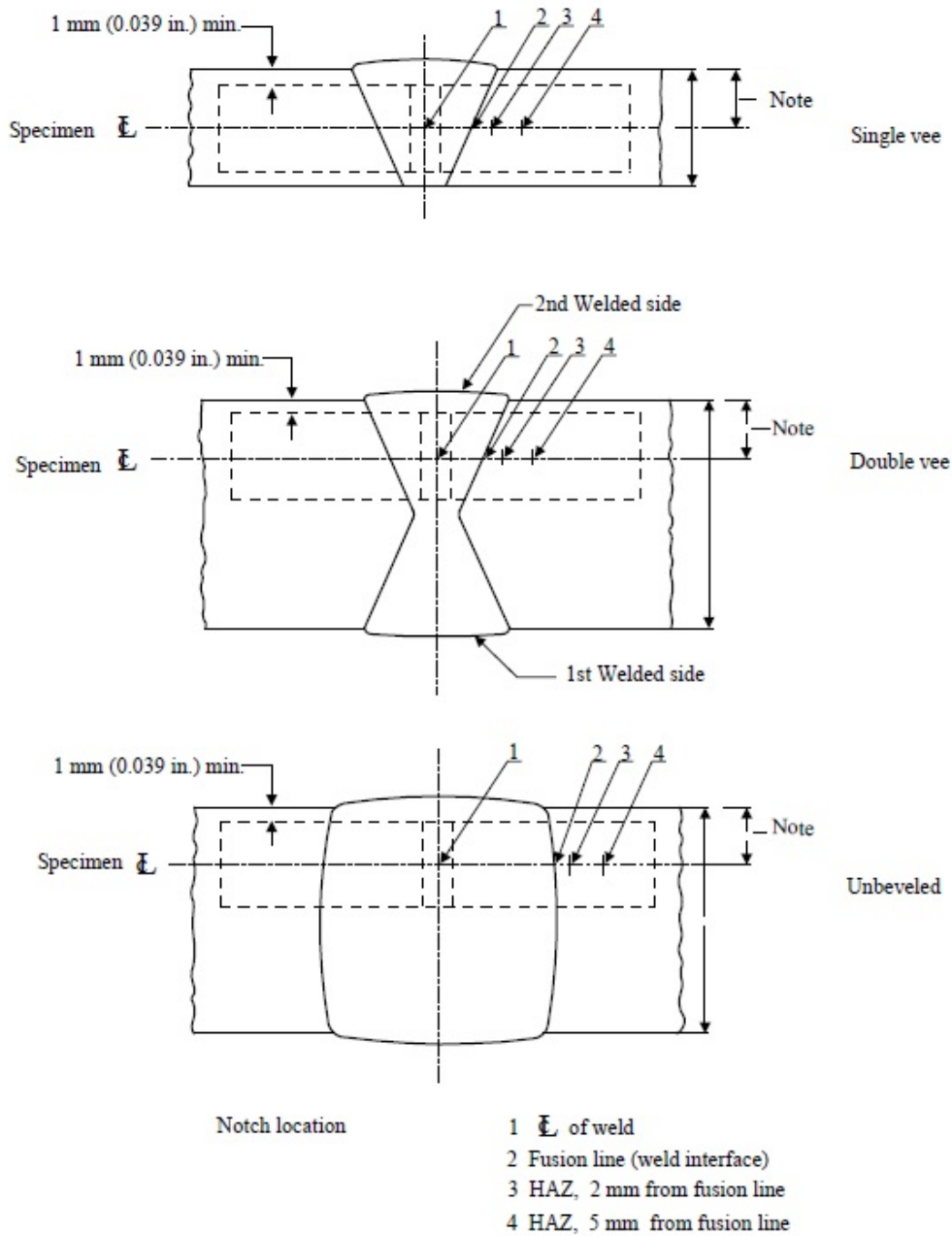


Method of rupturing specimen

**Notes:**

- 1 3.2 mm ( $1/8$  in.) diameter electrodes are to be used to make a 6.4 mm ( $1/4$  in.) maximum size tack weld.
- 2 Welding in the vertical position is to be welded upwards.
- 3 The tack weld is to present a reasonably uniform appearance and is to be free of overlap, cracks and excessive undercut. There is to be no visible surface porosity.
- 4 The fractured surface of the tack weld is to be free of incomplete fusion or porosity larger than 2.4 mm ( $3/32$  in.)

**FIGURE 13**  
**Orientation and Location of Charpy V-notch Specimens for Weld and Heat Affected Zone Properties (2013)**



The largest size Charpy specimens possible for the material thickness are to be machined with the center of the specimen located as near as practicable to a point midway between the surface and the center of the thickness. In all cases, the distance from the surface of the material to the edge of the specimen should be approximately 1 mm (0.039 in.) or greater. For double-vee butt welds, specimens are to be machined closer to the surface of the second welded side.

(2013) Where CVN impact tests for weld metal and HAZ may be required as per 2-4-3/5.9, 5C-8-6/5.3.4 of the *Marine Vessel Rules*, or 4/5.5 of the *ABS Guide for Application of Higher-strength Hull Structural Thick Steel Plates in Container Carriers*, the minimum weld metal and HAZ CVN impact values for ABS grade steels are as indicated in 2-4-3/11.5

TABLE 2. Weld metal and HAZ CVN testing of non-ABS steels is to comply with weld metal limitations indicated in 2-4-1/1.7.3.

**TABLE 2**  
**Minimum Average Weld Metal and HAZ CVN Impact Values for ABS Grade Steels (2020)**

<i>Manual and Semiautomatic Welding Processes, F, H, and OH Positions Energy Absorbed J (ft-lb)</i>	<i>Automatic Welding Processes in all Positions and Manual and Semiautomatic Welding Processes in Vertical Position, Energy Absorbed J (ft-lb)</i>	<i>CVN Test Temperature °C (°F)</i>	<i>Hull Steel Grade</i>
34 (25)	27 (20)	20 (68)	A > 50mm,
34 (25)	27 (20)	20 (68)	B > 25mm
34 (25)	34 (25)	20 (68)	AH32/36 to 12.5 mm (1/2 in.) inclusive
34 (25)	34 (25)	0 (32)	AH32/36 over 12.5 mm (1/2 in.)
47 (35)	34 (25)	0 (32)	D, DH32/36
47 (35)	34 (25)	-20 (-4)	E, EH32/36
47 (35)	34 (25)	-40 (-40)	FH32/36
47 (35)	41 (30)	20 (68)	AH40,
47 (35)	41 (30)	0 (32)	DH40
47 (35)	41 (30)	-20 (-4)	EH40
47 (35)	41 (30)	-40 (-40)	FH40
64 (48)	64 (48)	20 (68)	AH47,
64 (48)	64 (48)	0 (32)	DH47
64 (48)	64 (48)	-20 (-4)	EH47
64 (48)	64 (48)	-40 (-40)	FH47
27 (20)	27 (20)	0 (32)	AQ43
27 (20)	27 (20)	-20 (-4)	DQ43
27 (20)	27 (20)	-40 (-40)	EQ43
27 (20)	27 (20)	-60 (-76)	FQ43
31 (23)	31 (23)	0 (32)	AQ47,
31 (23)	31 (23)	-20 (-4)	DQ47
31 (23)	31 (23)	-40 (-40)	EQ47

<i>Manual and Semiautomatic Welding Processes, F, H, and OH Positions Energy Absorbed J (ft-lb)</i>	<i>Automatic Welding Processes in all Positions and Manual and Semiautomatic Welding Processes in Vertical Position, Energy Absorbed J (ft-lb)</i>	<i>CVN Test Temperature °C (°F)</i>	<i>Hull Steel Grade</i>
31 (23)	31 (23)	-60 (-76)	FQ47
33 (24)	33 (24)	0 (32)	AQ51,
33 (24)	33 (24)	-20 (-4)	DQ51
33 (24)	33 (24)	-40 (-40)	EQ51
33 (24)	33 (24)	-60 (-76)	FQ51
37 (27)	37 (27)	0 (32)	AQ56,
37 (27)	37 (27)	-20 (-4)	DQ56
37 (27)	37 (27)	-40 (-40)	EQ56
37 (27)	37 (27)	-60 (-76)	FQ56
41 (30)	41 (30)	0 (32)	AQ63,
41 (30)	41 (30)	-20 (-4)	DQ63
41 (30)	41 (30)	-40 (-40)	EQ63
41 (30)	41 (30)	-60 (-76)	FQ63
46 (34)	46 (34)	0 (32)	AQ70
46 (34)	46 (34)	-20 (-4)	DQ70
46 (34)	46 (34)	-40 (-40)	EQ70
46 (34)	46 (34)	-60 (-76)	FQ70

*Abbreviations (2016):*

F: Flat  
 H: Horizontal

V: Vertical  
 OH: Overhead

**Note:** For XQ91 and XQ98, Weld Metal & HAZ CVN values are to be specially agreed.



# PART 2

## CHAPTER 4 Welding and Fabrication

### SECTION 4 Piping (1 July 2021)

**Note:**

\* (2016) This Section is applicable only to piping for installation on vessels to be built in accordance with the ABS Rules for Building and Classing Marine Vessels (MVR), the ABS Rules for Building and Classing Mobile Offshore Units (MOU), and the ABS Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels (LHSNV). Piping intended for all other applications is to comply with Section 2-4-2.

## 1 General

### 1.1 Application

The provisions of this section are intended for welding of steel pipes in systems covered in Part 4, Chapter 6 of the Rules for Building and Classing Marine Vessels, (MVR). Additional provisions, as may be specified for piping systems of specialized carriers in Part 5C and Part 5D of the Rules for Building and Classing Marine Vessels, where applicable, are also to be complied with. Consideration will be given to compliance with a recognized national or international welding standard that is considered equally effective.

### 1.3 Pipe Classes

Pipe classes are as defined in 4-6-1/5 TABLE 1, (MVR). Classes I and II pipes are to comply with all the provisions of this Section. Class III pipes are to comply at least with 2-4-4/1.7, 2-4-4/3, 2-4-4/5 and 2-4-4/11.1 of this Section.

### 1.5 Materials

For purpose of determining welding requirements, steel pipe materials are grouped as follows:

Material group	Description	Representative standards <sup>(1)</sup>	
		ABS grade	ASTM grade
C and C/Mn	Carbon; carbon manganese	1, 2, 3, 4, 5; 8, 9	A53, A106; A135
0.5 Mo 0.5 Mo/0.5 Cr	Up to 0.5% Molybdenum; 0.5% Molybdenum & 0.5% Chromium	6; 7	A335 P1; A335 P2



Material group	Description	Representative standards <sup>(1)</sup>	
		ABS grade	ASTM grade
1Cr/0.5Mo	1.0 - 1.25% Chromium & 0.5% Molybdenum	11; 12	A335 P11; A335 P12
2.25Cr/1Mo	2.25% Chromium and 1.0% Molybdenum	13	A335 P22
1) Other materials complying with recognized national or international standards are also acceptable.			

### 1.7 Welding Filler Metals

All welding filler metals are to be certified by their manufacturers as complying with appropriate recognized national or international standards. Welding filler metals tested, certified and listed by ABS in its publication *Approved Welding Consumables* for meeting such a standard may be used in all cases. See Part 2, Appendix 2 for approval of filler metals. Welding filler metals not so listed may also be accepted provided that:

- They are of the same type as that proven in qualifying the welding procedure; and
- They are of a make acceptable to the surveyor; and
- For welding of Class I piping, representative production test pieces are to be taken to prove the mechanical properties of the weld metal.

## 3 Welding Procedures and Welders

### 3.1 Welding Procedures

Before proceeding with welding, the responsible fabricator is to prove to the satisfaction of the Surveyor that the intended welding process, welding filler metal, preheat, post weld heat treatment, etc., as applicable, have been qualified for joining the base metal. In general, the intended welding procedure is to be supported by a welding procedure qualification record (PQR) conducted in the presence of the Surveyor. Properly documented PQR, certified by a recognized body may be submitted to the Surveyor for acceptance. The PQR is to be conducted in accordance with a recognized standard, such as the ASME Boiler and Pressure Vessel Code, Section IX. The PQR may be used to support those welding procedures whose welding variables (e.g., base metal thickness, welding current, etc.) are within the ranges defined in the recognized welding standard being used.

### 3.3 Welders and Welding Operators

Before proceeding with welding, the responsible fabricator is to prove to the satisfaction of the Surveyor that the welder or the welding operator is qualified in performing the intended welding procedure. In general, welders and welding operators are to be qualified in accordance with 2-4-3/11 in the presence of the Surveyor. Properly documented welder performance qualification records (WPQ) conducted in accordance with a recognized welding standard being used (such as the ASME Boiler and Pressure Vessel Code, Section IX) and certified by a recognized body may be presented to the Surveyor for acceptance as evidence of qualification. Once deemed qualified, the welder or the welding operator is permitted to perform the welding as qualified, as well as other welding, provided the welding variables (e.g., position, with or without backing, pipe size, etc.) of such welding are within specified ranges defined by the recognized welding standard being used.

## 5 Types of Welded Joints

### 5.1 Full Penetration Butt Joints

#### 5.1.1 General

Full penetration butt joints for pipes are to have welds deposited on properly prepared single vee, double vee or other suitable types of grooves, with or without backing rings. The edge preparation and fit-up tolerances are to be as indicated in 2-4-4/5.1.2 and 2-4-4/5.1.3. Joints welded without backing rings are to assure complete root penetration and fusion by employing qualified welding procedures and a qualified welder demonstrating that successful joints can be achieved. All full penetration butt joints in Classes I and II piping systems are subject to radiographic examination or equivalent to the extent as indicated in 2-4-4/11 to assure that complete root penetration is achieved and the welds do not contain unacceptable imperfection.

#### 5.1.2 Edge Preparation

Dimensions of the edge-preparation are to be in accordance with recognized standards or that used in the welding procedure qualified by the responsible fabricator. The preparation of the edges shall preferably be carried out by mechanical means. When flame cutting is used, care should be taken to remove the oxide scales and any notch due to irregular cutting by matching grinding or chipping back to sound metal.

#### 5.1.3 Alignment and Fit-up

For pipes to be butt-welded, the alignment of the pipes at the prepared edge is to be within the following maximum offsets:

- i) Pipes of all diameters and thickness welded with permanently fitted backing ring: 0.5 mm (0.02 in.).
- ii) Pipes welded without fitted backing ring:

<i>Nominal pipe size, d</i>	<i>Pipe wall thickness, t</i>	<i>Alignment Tolerance</i>
$d \leq 150 \text{ mm (6 in.)}$	or $t \leq 6.0 \text{ mm (0.24 in.)}$	lesser of 1.0 mm (0.04 in.) or $t/4$
$150 \text{ mm (6 in.)} < d \leq 300 \text{ mm (12 in.)}$	or $6.0 \text{ mm (0.24 in.)} < t \leq 9.5 \text{ mm (0.37 in.)}$	lesser of 1.5 mm (0.06 in.) or $t/4$
$d > 300 \text{ mm (12 in.)}$	or $t > 9.5 \text{ mm (0.37 in.)}$	lesser of 2.0 mm (0.08 in.) or $t/4$

Where pipes of different thicknesses are to be butt welded, and if the difference in thickness is more than  $\frac{1}{4}$  thickness of the thinner section or 3 mm ( $\frac{1}{8}$  in.), whichever is less, a taper transition having a length not less than three times the offset between the abutting sections is to be provided at the joint.

### 5.3 Square-groove Butt Joint

Square groove butt joints may be used in Class III piping systems for low pressure systems which are open to atmosphere, such as tank vent and overflow pipes. In general, such joints should not be made on pipes having wall thickness greater than 4.8 mm ( $\frac{3}{16}$  in.).

### 5.5 Fillet-welded Joints

#### 5.5.1 Socket Welded Joints

Socket welded joints employing sockets complying with recognized standards are to be welded using single fillet weld with leg size not less than 1.1 times the nominal thickness of the pipe. See

also 4-6-2/5.5.2 (*MVR*) for limitation of its use and 4-6-2/5.5.3 FIGURE 1 (*MVR*) for fit up details.

### 5.5.2 Slip-on Welded Sleeves Joints

Sleeves meeting dimensional and fit-up requirements in 4-6-2/5.5.3 (*MVR*) and 4-6-2/5.5.3 FIGURE 1 (*MVR*) may be used for joining pipes with limitations as indicated therein. The fillet weld attaching the sleeve to the pipe is to have a leg size not less than 1.1 times the nominal thickness of the pipe.

## 5.7 Flange Attachment Welds (2022)

A weld neck flange is to be welded to the pipe with a full penetration butt weld conforming to 2-4-4/5.1. Slip-on welded flange and socket welded flange are to be attached to pipes with double fillet and single fillet welds respectively. The external fillet weld for a slip-on flange or a socket-welded flange is to have a leg size not less than 1.4 times the nominal thickness of the pipe or thickness of the hub, whichever is less. For Class II and Class III flange joints, the size of the external fillet weld need not exceed 13 mm (0.531 in.) maximum. The internal weld for a slip-on welded flange is to have a leg size not less than the smaller of 6.0 mm ( $\frac{1}{4}$  in.) or the nominal thickness of the pipe.

## 5.9 Branch Connections

Pipe branches made by welding branch pipe to a hole cut in the run pipe are to be designed in accordance with 4-6-2/5.3 (*MVR*). In general, the attachment weld is to be a full penetration groove weld through the thickness of the run pipe or of the branch pipe, with ample finished fillet weld.

## 5.11 Tack Welding

Tack welds, where used, are to be made with filler metal suitable for the base metal. Tack welds intended to be left in place and form part of the finished weld are to be made by qualified pipe welders using process and filler metal the same as or equivalent to the welding procedure to be used for the first pass. When preheating is required by 2-4-4/7, the same preheating should be applied prior to tack welding.

## 5.13 Brazing (2005)

When brazed pipe joints are tested in tension, the joint strength is not to be less than the tensile strength of the pipe material.

# 7 Preheat

In general, dryness is to be assured before welding; this may be achieved with suitable preheating, as necessary. Where ambient temperatures are below 10°C (50°F), for Classes I and II pipes, the welded parts are to be heated, prior to welding, to at least 10°C (50°F). In addition, preheating is required depending on base metal thickness and chemical composition as indicated in the following table. The values given in the table below are based on the use of low hydrogen processes; consideration is to be given to using higher preheating temperatures when low hydrogen processes are not used. Consideration will be given to alternative preheat requirements based on a recognized standard and welding procedure qualification conducted thereto.

Material group	Thickness of the thicker joining base metal	Minimum preheat temperature
C and C/Mn C+Mn/6 ≤ 0.4 C+Mn/6 > 0.4	≥ 20 mm (0.79 in.) ≥ 20 mm (0.79 in.)	50°C (122°F) 100°C (212°F)
0.5 Mo 0.5 Mo/0.5 Cr	> 13 mm (0.51 in.)	100°C (212°F)

<i>Material group</i>	<i>Thickness of the thicker joining base metal</i>	<i>Minimum preheat temperature</i>
1Cr/0.5Mo	< 13 mm (0.51 in.)	100°C (212°F)
	≥ 13 mm (0.51 in.)	150°C (302°F)
2.25Cr/1Mo	< 13 mm (0.51 in.)	150°C (302°F)
	≥ 13 mm (0.51 in.)	200°C (392°F)

## 9 Post-weld Heat Treatment

### 9.1 Procedure

Post-weld heat treatments are to be conducted according to a procedure acceptable to the Surveyor. They can be carried out in furnaces or locally. Where conducted locally, the weld is to be heated in a circumferential band around the pipe having a width of at least three times the wall thickness. For fabricated branch connections, the band is to extend at least two times the run pipe wall thickness beyond the branch weld. Suitable temperature and time recording equipment is to be provided.

The welded joint is to be heated slowly and uniformly to a temperature within the range indicated in the table in 2-4-4/9.3 and soaked at this temperature for a period of 1 hour per 25 mm (1 in.) of thickness, with a minimum of half an hour. Thereafter, it is to be cooled slowly and uniformly in the furnace or under insulation to a temperature not more than 400°C and subsequently cooled in a still atmosphere.

### 9.3 Requirement

Post-weld heat treatment is to be conducted on welded joints depending on base metal thickness and compositions as indicated in the following table. Consideration will be given to alternative post-weld heat treatment requirements based on a recognized standard, provided that such requirements are also applied to the welding procedure qualification.

<i>Material group</i>	<i>Thickness of the thicker joining base metal</i>	<i>Post-weld heat treatment soaking temperature <sup>(1)</sup></i>
C and C/Mn	≥15 mm <sup>(2)</sup> (0.59 in.)	550-620°C (1022-1148°F)
0.5 Mo 0.5Mo/0.5Cr	≥15 mm (0.59 in.)	580-640°C (1076-1184°F)
1 Cr/0.5Mo	> 8 mm (0.32 in.)	620-680°C (1148-1256°F)
2.25Cr/1Mo	All <sup>(3)</sup>	650-720°C (1202-1328°F)
<i>1)</i>	Maximum temperature is to be at least 20°C (65°F) below the tempering temperature of the base metal.	
<i>2)</i>	PWHT may be omitted for Class III pipes of thickness ≤ 30 mm (1.2 in.) subject to special consideration of base metal, welding process, preheat, and welding procedure qualification.	
<i>3)</i>	PWHT may be omitted for pipes having thickness ≤ 8 mm (0.31 in.) and nominal size ≤ 100 mm (4 in.) and with a service temperature of 450°C (842°F) and above.	

## 11 Nondestructive Examination

### 11.1 Visual Examination

All welded joints, including the root side, wherever possible, are to be visually examined. All visible defects, such as cracks, excessive weld reinforcement, undercuts, lack of fusion on surface, incomplete penetration where the inside is accessible, deficient size for fillet welds, etc. are to be repaired, as provided for in 2-4-4/13.

### 11.3 Butt Weld Joints

#### 11.3.1 Radiographic Examination

##### 11.3.1(a) Extent of examination.

Butt joints are to be radiographically examined as follows:

<i>Pipe class</i>	<i>Nominal size, d / wall thickness, t</i>	<i>Extent</i>
I	$D > 65 \text{ mm (2.5 in.)}$ or $t > 9.5 \text{ mm (3/8 in.)}$	100%
II	$d > 90 \text{ mm (3.5 in.)}$	10%
III	All	None

Radiographic examination is to be performed with techniques and by qualified operators meeting a recognized standard and acceptable to the Surveyor. Radiographic films are to be of acceptable image quality according to a recognized standard and are to be submitted, along with interpretation of the results, to the Surveyor for review.

##### 11.3.1(b) Acceptance criteria.

Welds shown by radiography to have any of the following types of imperfections are to be judged unacceptable and are to be repaired, as provided in 2-4-4/13.

- i)* Any type of crack, or zones of incomplete fusion or penetration.
- ii)* Any elongated slag inclusion which has length greater than
  - $6.0 \text{ mm (} \frac{1}{4} \text{ in.)}$  for  $t \leq 19.0 \text{ mm (} \frac{3}{4} \text{ in.)}$ ,
  - $t/3$  for  $19.0 \text{ mm (} \frac{3}{4} \text{ in.)} < t \leq 57.0 \text{ mm (} 2\frac{1}{4} \text{ in.)}$
  - $19.0 \text{ mm (} \frac{3}{4} \text{ in.)}$  for  $t > 57.0 \text{ mm (} 2\frac{1}{4} \text{ in.)}$

where  $t$  is the thickness of the thinner portion of the weld.

- iii)* Rounded indications in excess of an acceptance standard, such as ASME Boiler and Pressure Vessel Code, Section VIII, Div. 1.

##### 11.3.1(c) Re-examination.

If the radiograph disclosed unacceptable imperfections, the weld is to be repaired and thereafter re-examined by radiography. For Class II pipe joints subjected to 10% radiographic examination only, if unacceptable imperfections were disclosed to such an extent that quality of welds is in doubt, more joints are to be examined at the discretion of the Surveyor.

### 11.3.2 Ultrasonic Examination

Ultrasonic examination may be used in lieu of radiographic examination required by 2-4-4/11.3.1. Such examination technique is to be conducted in accordance with procedures and by qualified operators meeting a recognized standard and acceptable to the Surveyor.

## 11.5 Fillet Weld Joints

In Class I piping, all fillet welds attaching pipes to flanges, sockets, slip-on sleeves, pipe branches, etc. are to be examined by the magnetic particle method or other appropriate nondestructive methods. All surfaces examined and found to have any of the following indications are to be repaired.

- Crack or relevant linear indication (having a length greater than three times the width);
- Relevant rounded indication (circular or elliptical shape with a length equal to or less than three times its width) greater than 5 mm ( $3/16$  in.); or
- Four or more relevant rounded indications in a line separated by 2.0 mm ( $1/16$  in.) or less, edge to edge.

## 13 Weld Repair

Any weld joint imperfection disclosed by examination in 2-4-4/11 and deemed unacceptable is to be removed by mechanical means or thermal gouging processes, after which the joint is to be welded using the appropriate qualified welding procedure by a qualified welder. Preheat and post-weld heat treatment is to be performed as indicated in 2-4-4/7 and 2-4-4/9, as applicable. Upon completion of repair, the repaired weld is to be re-examined by the appropriate technique that disclosed the defect in the original weld.

## 15 Pipe Forming and Bending

### 15.1 Cold Forming

Where pipe is cold bent to a mean bending radius of less than or equal to four times the outside diameter of the pipe, it is to be subjected to a stress relieving heat treatment at least equivalent to that specified in 2-4-4/9.3, except for C and C/Mn steels with ultimate tensile strength of 410 MPa (42 kgf/mm<sup>2</sup>, 60,000 psi) or less.

### 15.3 Hot Forming (2013)

Hot forming is to be carried out in the temperature range 850–1000°C for all material groups; however, the temperature may decrease to 750°C during the forming process. When hot forming is carried out within this temperature range, no stress relieving heat treatment is required for C, C/Mn, 0.5Mo, 0.5Mo/0.5Cr material groups, while stress relieving heat treatment equivalent to that specified in 2-4-4/9.3 is required for 1-1.25Cr/0.5Mo and 2.25Cr/1Mo material groups.

When hot forming is carried out outside this temperature range, the following post-forming heat treatment is to be performed.

<i>Material group</i>	<i>Heat treatment and temperature</i>
C and C/Mn	Normalizing 880–940°C (1616–1724°F)
0.5 Mo 0.5 Mo/0.5 Cr	Normalizing 900–940°C (1652–1724°F)
1Cr/0.5Mo	Normalizing 900–960°C (1652–1760°F) Tempering 640–720°C (1184–1328°F)
2.25Cr/1Mo	Normalizing 900–960°C (1652–1760°F) Tempering 650–780°C (1202–1436°F)

## 17 Additional Requirements for Low Temperature Piping [below -10°C (14°F)]

### 17.1 Application

These requirements are intended for piping operating at below -10°C (14°F) that forms part of the cargo piping of specialized carriers covered in Part 5C, Chapter 8 of the *Rules for Building and Classing Marine Vessels (MVR)*.

### 17.3 Welding Procedure

Welding procedures proposed for piping intended to operate below -10°C (14°F) are, in addition to the provisions of 2-4-4/3.1, to be qualified with Charpy V-notch tests as provided for in 5C-8-6/5.4 (*MVR*).

### 17.5 Pipe Joints

All welded pipe joints are to be in accordance with 2-4-4/5.1, 2-4-4/5.5 and 2-4-4/5.9 and are subject to the limitations indicated in the table below [see also 5C-8-5/8.2 (*MVR*)].

<i>Type of joint</i>	<i>Temperature/ pressure limitation</i>	<i>Size limitation</i>
Full penetration butt joint	None	None
Full penetration butt joint with backing ring retained	10 bar (145 psi) max	None
Socket welded joint	Socket fitting rating	NS 50 mm (2 in.) max
Slip-on welded joint	≤ -55°C (-67°F), open-ended systems	NS 40 mm (1.5 in.) max
Weld neck flange	Flange rating	None
Socket welded flange	Flange rating	NS 50 mm (2 in.) max
Slip-on welded flange	Flange rating	NS 100 mm (4 in.) max

### 17.7 Post-weld Heat Treatment

All butt-welded joints are to be post-weld heat-treated. Exemption from post-weld heat treatment can be considered for butt-welded and fillet-welded joints based on consideration of material, thickness, weld sizes, and design pressure and temperature, see 5C-8-5/9.2 (*MVR*).

### 17.9 Nondestructive Examination

Butt-welded joints are to be radiographically examined as for Class I pipes indicated in 2-4-4/11.3.1(a). Butt-welded joints of smaller diameter or thickness are to have at least 10% of the joints radiographed. See also 5C-8-5/9.3 (*MVR*).

## **1 General**

### **1.1 Hull Welding**

Welding in aluminum hull construction is to comply with the requirements of this Section, unless specially approved otherwise. It is recommended that appropriate permanent welded markings be applied to the side shell of welded craft to indicate the location of bulkheads for reference. In all instances, welding procedures and filler metals are to be applied which will produce sound welds that have strength in accordance with 2-4-5/17 TABLE 2; the chemical compositions of the filler metals are to be generally in accordance with 2-4-5/17 TABLE 3. The selection of filler metals for welding various aluminum alloys is to be in accordance with 2-4-5/Tables 4 and 5.

### **1.3 Plans and Specifications**

The plans submitted are to clearly indicate the extent to which welding is proposed to be used. The welding process, filler metal and joint design are to be shown on the detail drawings or in separate specifications submitted for approval, which are to distinguish between manual, semi-automatic and automatic welding. The shipbuilders are to prepare and file with the Surveyor a planned procedure to be followed in the erection and welding of the important structural members.

### **1.5 Workmanship and Supervision**

It shall be the responsibility of the contractor to insure that personnel, procedures and NDT equipment used for fabrication and inspection comply with these requirements. However, the Surveyor is to satisfy himself that all welders and welding operators to be employed in the construction of craft to be classed are properly qualified and are experienced in the type of work proposed and in the proper use of the welding processes and procedures to be followed. The Surveyor is to be satisfied with the employment of a sufficient number of skilled supervisors to ensure a thorough supervision and control of all welding operations.

### **1.7 Welding Procedures (2020)**

Procedures for the welding of all joints are to be established in writing for each welding test, process, type of electrode, edge preparation, welding technique and position proposed. Details of proposed welding procedures and sequences are required to be submitted for review. Procedure qualifications previously prepared and approved by ABS may be submitted for consideration for the current designs, if applicable.



Welding procedures qualified to equivalent recognized codes and standards such as AWS, EN, ISO, ASME, MIL and JIS may also be considered.

### 3 Preparation for Welding

#### 3.1 Edge Preparation and Fitting

The edge preparation is to be accurate and uniform and the parts to be welded are to be fitted in accordance with the approved welding detail. Joint edges may be prepared by mechanical means, such as saws, millers and routers and by plasma arc cutting. Thermal cutting methods may be employed, provided it can be demonstrated to the satisfaction of the Surveyor that their use does not have deleterious effects on the base material or completed weld.

All means for correcting improper fitting are to be to the satisfaction of the Surveyor. Where excessive root openings of butt weld connections are encountered, weld build up of the plate edges may be allowed, at the discretion of the Surveyor, before welding the plates together. Unless specially approved otherwise, such build up of each plate edge, where permitted, is not to exceed  $0.5t$  or 12.5 mm ( $1/2$  in.) whichever is less, where  $t$  is the thickness of the thinner plate being welded. Where sections to be joined differ in thickness and have an offset on either side of more than 3 mm ( $1/8$  in.), a transition having a length not less than three times the offset is to be provided. The transition may be formed by tapering the thicker member or by specifying a weld joint design which will provide the required transition.

#### 3.3 Alignment

Means are to be provided for maintaining the parts to be welded in correct position and alignment during the welding operation. In general, strong backs or other appliances used for this purpose are to be arranged so as to allow for expansion and contraction during production welding. The removal of such items is to be carried out to the satisfaction of the Surveyor.

##### 3.3.1 Plate Alignment Tolerances

###### 3.3.1(a) Butt Welds.

Where plates are tacked in preparation for butt welding, the deviation of alignment of surfaces at the weld joint shall meet the requirements specified below:

<i>Plate Thickness</i>	<i>Maximum Allowable Deviation</i>
Less than 9.5 mm (0.375 in.)	1.5 mm (0.0625 in.)
9.5 mm (0.375 in.) to 19 mm (0.75 in.)	3 mm (0.125 in.)
19 mm (0.75 in.) to 38 mm (1.5 in.)	5 mm (0.1875 in.)
38 mm (1.5 in.)	6 mm (0.25 in.)

###### 3.3.1(b) Fillet Welds.

When the opening between elements of a fillet welded joint exceeds 1.5 mm ( $1/16$  in.) but not more than 5 mm ( $3/16$  in.) as a nominal condition along the joint, the fillet size shall be increased by an amount equal to the excess of the opening above 1.5 mm ( $1/16$  inch). Where the gap between members exceeds 5 mm ( $3/16$  in.) as a nominal condition along the joint fillet, methods outlined below shall be used. Fillet welds shall be extended around the ends of members to form closed loops, where possible.

- i) *Buttering and Buildup.* Buttering or buildup by welding on the weld joint surface to correct oversized root opening or errors in joint preparation is allowed, provided such buildup of each joint edge shall not exceed  $t$  or 12 mm (0.5 in.), whichever is less, where  $t$

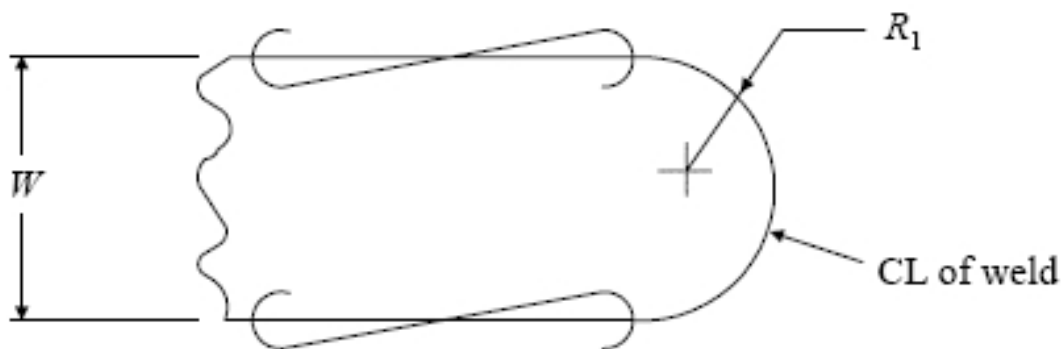
is the thickness of the thinner member being welded. Where one side of a joint may not be accessible, the total buttering or buildup (that is  $2t$  or 25 mm (1 in.), whichever is less) may be deposited on one member. Temporary backing may be used to assist in the buttering or buildup. When root openings cannot be corrected within this limitation, repair shall be made using patches, make-up plates and so forth, in accordance with *ii*) and *iii*) below.

Buttering or buildup may be employed for fairing or for other corrections over or adjacent to welds, provided the above restrictions are not exceeded. This buildup shall be considered part of the involved weld.

- ii*) *Make-up Plates.* Make-up plates welded into primary structure shall have a minimum width of three (3) inches and shall have full penetration, 100 percent efficient butt welds.
- iii*) *Access and Closure Plates.* Boundaries of access and closure plates shall be located between principal boat framing or bulkheads, and shall be at least 75 mm (3 in.) from any of these members. When variance from this 75 mm (3 in.) minimum is required by special circumstances, such variances shall be subject to approval by the Surveyor. The boundaries of access and closure plates should land on existing butts or seams, wherever practical. See 2-4-5/Figures 1A and 1B below.

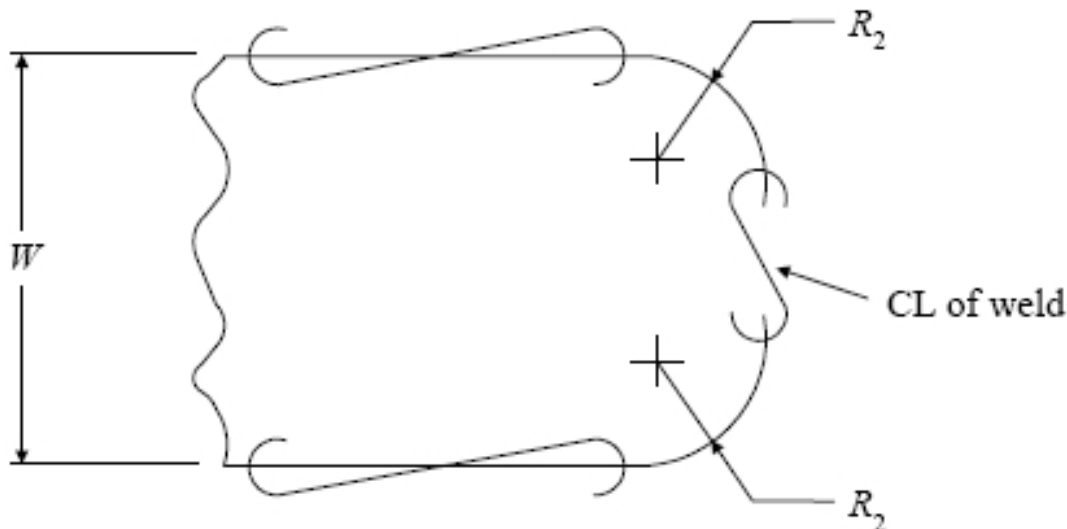
Corners of access or closure plates shall have a minimum radius of 75 mm (3 in.), except when a boundary lands on an existing hull longitudinal or transverse butt joint. In the latter instance, the corners shall intersect the weld at an angle of  $90 \pm 15$  degrees (see 2-4-5/Figures 1A and 1B below). Closure plate weld joints shall be full penetration 100 percent efficient butt welds.

**FIGURE 1A**  
**Inserts and Patches in Plating**



WHEN  $W = 3''$  min.  
 Then  $R_1 = W/2$

**FIGURE 1B**  
**Inserts and Patches in Plating**



WHEN  $W = 6''$  min.  
Then  $R_2 = 3''$  or  $2t$ , whichever is larger

### 3.5 Cleanliness (2012)

Suitable solvents or mechanical means are to be used to remove oil, grease, indelible markings, and all other contaminants from the vicinity of all joints prior to welding. -Oxide films that cannot be removed by the specific welding process, including any water stains (hydrated alumina oxide) are to be removed from the groove surfaces that are to be welded, including joint and faying surfaces as well as adjacent surfaces within one inch of the weld. Removal may be by mechanical means, such as a power driven, clean stainless steel wire brush, sanding with a 36-100 grit aluminum oxide sanding disk or by approved chemical means. Welding shall take place within eight hours of removal of oxide films except in way of faying surfaces of fillet welds. Interpass cleaning to remove slag, soot, overlap conditions, spatter, etc., is required. Degreasers are not to be used when the joint is such that the degreaser can collect in crevices such as faying surfaces between plate and backing bars or in way of lapped connections. Fusion welding is not to be performed on anodically-treated aluminum, except when the surface oxide is removed from the joint areas to be welded.

### 3.7 Tack Welds

Tack welds shall be made with the same type of electrode as the final weld and should be deposited to facilitate incorporation into the final weld. Tack welds of poor quality or workmanship shall be removed.

### 3.9 Stud Welding

The attachment of pins, hangers, studs and other related items by stud welding may be approved at the discretion of the Surveyor. At the Surveyor's discretion, trial stud welds should be tested to demonstrate that stud welds and base material in way of stud welds are sufficiently sound for the intended application,

prior to actual production work. The use of stud welding for structural attachments is subject to special approval and may require special procedure tests appropriate to each application.

### 3.11 Temporary Back-up Plates and Tapes

A temporary back-up plate may be applied to the opposite side of the joint during welding to assist in reducing distortion and to decrease heat concentration. Anodized “hard” aluminum back-up plates are recommended for this purpose, although clean stainless steel or rust-free mild steel plates may also be used. Back-up plates when used are to be free of contaminants and oxides which would interfere with welding. Welding is to be controlled so as not to allow arcing of the aluminum filler metal to the temporary back-up plate. Any accidental arcing to the back-up plate is to be corrected by removal of all contaminated weld or base metal. Approval of procedures involving the use of backing tapes may be considered, provided it is demonstrated to the Surveyor’s satisfaction that their use results in satisfactory welding and that plate distortion is not excessive.

### 3.13 Run-on and Run-off Tabs

When used, run-on and run-off tabs are to be designed to minimize the possibility of high-stress concentrations and cracking of the base metal and weld metal.

### 3.15 Forming

Cold forming of 5000 series aluminum alloys is to be conducted at temperatures below 52°C (125°F), except for the 5454 alloy, where the maximum temperature may be 149°C (300°F). See 2-4-5/3.15 TABLE 1 below for minimum cold-forming radii. When the extent of cold forming is such that base plate properties are changed beyond acceptable limits, appropriate reheat or stress relief treatments are to be used to reestablish acceptable properties. Hot forming of 5000 series aluminum alloys is generally conducted at temperatures between 260°C and 425°C (500°F and 800°F). Hot or cold forming is not to be performed in structures of any aluminum alloy unless supporting data is presented to the Surveyor’s satisfaction indicating that significant material property changes will not result. Appropriate temperature control methods are to be used in all hot forming and stress relieving operations. In hot forming or stress relieving, exposure of the 5000 series alloys to the 65°C (150°F) to 200°C (400°F) temperature range is to be minimized by the use of appropriate cooling techniques. Typically, 6000 series aluminum is not to be formed. For 6000 series aluminum to be considered for forming, supporting technical data is to be submitted for review and approval prior to forming.

**TABLE 1**  
**Minimum Cold-forming Radii for Aluminum Alloys <sup>(1, 2, 3)</sup> (2022)**

<i>Alloy and temper</i>	<i>3 mm (0.125 in.)</i>	<i>5 mm (0.1875 in.)</i>	<i>6 mm (0.25 in.)</i>	<i>9.5 mm (0.375 in.)</i>	<i>12 mm (0.50 in.)</i>
5083-0	1t	1, 2t	1, 2t	2t	2t
H113	1, 1½t	1, 2t	1, 2t	1½, 2t	2, 3t
H116	1½t	1½t	1½t	2t	2½
H321	1½t	1½t	1½t	2t	2½
H323	1½, 3t	1½, 3½t	2, 4t	-----	-----
H343	1½, 3t	2, 4t	2½, 4½t	-----	-----
5052-0	1t	1t	1t	1, 1½t	1, 2t
H32	1, 1½t	1, 1½t	1, 1½t	1, 2t	1½, 2½t
H34	1½, 2½t	1½, 2½t	2, 3t	2, 3t	2½, 3½t
H36	1½, 3t	2, 4t	2, 4t	2½, 5t	3½, 5½t
H38	2, 4t	3, 5t	4, 6t	4, 7t	5, 8t

<i>Alloy and temper</i>	<i>3 mm (0.125 in.)</i>	<i>5 mm (0.1875 in.)</i>	<i>6 mm (0.25 in.)</i>	<i>9.5 mm (0.375 in.)</i>	<i>12 mm (0.50 in.)</i>
5086-0	1t	1t	1t	1, 1 <sup>1</sup> / <sub>2</sub> t	1, 2t
H32,H116,H117	1, 2t	1, 2t	1 <sup>1</sup> / <sub>2</sub> , 2 <sup>1</sup> / <sub>2</sub> t	2, 2 <sup>1</sup> / <sub>2</sub> t	2 <sup>1</sup> / <sub>2</sub> , 3t
H34	1 <sup>1</sup> / <sub>2</sub> , 2 <sup>1</sup> / <sub>2</sub> t	2, 3t	2, 3t	2 <sup>1</sup> / <sub>2</sub> , 3 <sup>1</sup> / <sub>2</sub> t	3, 4t
H36	2, 3 <sup>1</sup> / <sub>2</sub> t	2 <sup>1</sup> / <sub>2</sub> , 4t	3, 4 <sup>1</sup> / <sub>2</sub> t	3, 5t	3 <sup>1</sup> / <sub>2</sub> , 5 <sup>1</sup> / <sub>2</sub> t
H112			1, 2t	1, 2t	1 <sup>1</sup> / <sub>2</sub> , 2 <sup>1</sup> / <sub>2</sub> t
5456-0	1t	1, 2t	1, 2t	2t	2t
H116,H117	2, 3t	2, 3t	2, 3t	3, 4t	3, 4t
H323	1 <sup>1</sup> / <sub>2</sub> , 3t	1 <sup>1</sup> / <sub>2</sub> , 3 <sup>1</sup> / <sub>2</sub> t	2, 4t	-----	-----
H343	1 <sup>1</sup> / <sub>2</sub> , 3t	2, 4t	2 <sup>1</sup> / <sub>2</sub> , 4 <sup>1</sup> / <sub>2</sub> t	-----	-----

**Notes:**

- 1 Where two radii are shown, the larger radius is applicable when the bend is parallel to the direction of rolling.
- 2 These bending radii are applicable to aluminum alloys which are free of visible oxide coating.
- 3 The radii shall be the mandrel radii or inside radii.

## 5 Production Welding

### 5.1 Environment

Proper precautions are to be taken to insure that all welding is done under conditions where the welding site is protected against deleterious effects of moisture, wind and severe cold. Paint or oil mist and other contaminants which tend to cause weld porosity are to be excluded from the vicinity where welding is in progress.

### 5.3 Preheat

Preheating is not generally required for aluminum alloys. The use of preheat may be desirable when welding materials of thick cross section, materials subject to high restraint, and when welding is performed under high humidity conditions or when the temperature of the aluminum alloy is below 0°C (32°F). When preheating is used, appropriate production controls are to be used to maintain the specified temperatures, in accordance with accepted procedures and to the satisfaction of the Surveyor. Preheating temperatures which sensitize an alloy to corrosion are to be avoided. For the 5000 series alloys, it is generally recommended to avoid prolonged exposure to the 65°C to 200°C (150°F to 400°F) temperature range. Preheat and interpass temperatures shall be verified by temperature sticks, small contact thermometer, pyrometer, etc. a minimum of 25 mm (1 in.) away from the weld area.

### 5.5 Postheating

Weldments of work hardenable 5000 series aluminum alloys are not to be postweld heat treated unless the procedures have been specially approved. Where use of a heat-treatable alloy has been approved, any postweld heat treatment proposed is to be as established in procedure qualification tests. Post weld heat treatment is not required on 5000 series aluminum materials, stainless steels, copper alloys or nickel alloys.

### 5.7 Accessibility

Assembly and welding is to be arranged to provide sufficient accessibility to the joint by the welder, the welding equipment and for inspection.

### 5.8 Avoiding Joint Corrosion (2020)

For guidance, refer to D3.7/6.11 of the AWS Guide for Aluminum Hull Welding.

## 5.9 Sequence

Welding is to be planned to progress symmetrically so that shrinkage on both sides of the structure will be equalized. The ends of frames and stiffeners are to be left unattached to the plating at the sub-assembly stage for a distance of about 300 mm (12 in.) until connecting welds are made in the intersecting systems of plating, framing and stiffeners at the erection stage. Welds are not to be carried across an unwelded joint or beyond an unwelded joint which terminates at the joint being welded unless especially approved.

## 5.11 Back Gouging

Chipping, routing, milling, grinding or other suitable methods are to be employed at the root or underside of the weld to obtain sound metal before applying subsequent beads for all full-penetration welds.

## 5.13 Fairing and Flame Shrinking

Shrink welds may be used, but fairing by heating or flame shrinking to correct distortion or defective workmanship in fabrication of main strength members within the midships portion of the craft and other plating which may be subject to high stresses is not generally recommended. If intended to be used, it is to be carried out only with the expressed approval of the Surveyor. For the 5000 series alloys, it is generally recommended that heating and cooling through the sensitizing range of 65°C-200°C (150°F-400°F) is to be as rapid as practicable.

## 5.15 Inspection of Welds

### 5.15.1 Visual Inspection

Visual inspection during construction is to consist of inspecting the surface appearance of welds for the existence of flaws or defects, as stated below. The inspection zone includes the weld face and 12 mm (0.5 in.) of adjacent base metal. The surface of the welds is to be regular and uniform with proper contour, a minimum amount of reinforcement and reasonably free from undercut and overlap, slag, paint and weld splatter.

#### 5.15.1(a) Appearance. (1 July 2021)

Welds shall be free of cracks, incomplete fusion and burn-through. Visible arc-strikes on welds and the adjacent base metal are not allowed and shall not exceed 1 mm ( $\frac{1}{32}$  in.) in depth after removal. Weld spatter greater in diameter than 1 mm ( $\frac{1}{32}$  in.) is not acceptable. Gouge marks, nicks and other fabrication scars in the weld inspection zone shall not exceed the requirements for undercut. Weld surfaces shall be free of slag to the extent that there is no interference with visual or other required nondestructive test. Crater pits are not acceptable and shall be filled to the full cross section of the weld.

#### 5.15.1(b) Melt-through.

Melt-through and repaired burn-through areas are acceptable, provided the areas do not contain cracks, crevices, excessive oxidation or globules, and provided that the root convexity and concavity limits are not exceeded.

#### 5.15.1(c) Suckback.

Suckback is unacceptable in a weld or base metal when it occurs as a sharp notch or where the depth reduces the weld thickness below the minimum base metal thickness.

#### 5.15.1(d) Undercut.

The maximum undercut shall be 1 mm ( $\frac{1}{32}$  in.) or 10% of the adjacent base metal thickness, whichever is less. For base metal thickness 12 mm (0.5 in.) and greater, undercut from 1 mm ( $\frac{1}{32}$  in.) to 1.5 mm ( $\frac{1}{16}$  in.) is allowed if the accumulated length of undercut does not exceed 15% of the joint length or 300 mm (12 in.), whichever is less.

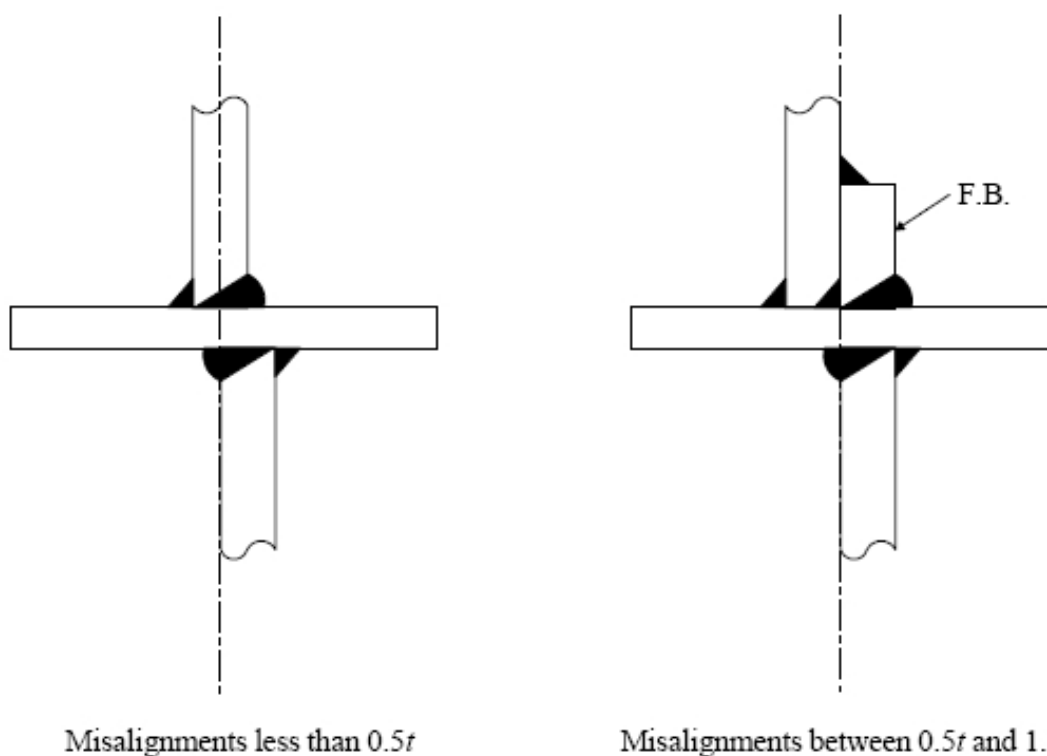
#### 5.15.1(e) Welded Joint Offset.

The maximum offset for all welded joints shall be as follows:

<i>Base Metal Thickness</i>	<i>Maximum Offset</i>
$\frac{1}{4}$ in. and less	25% of joint thickness
Over $\frac{1}{4}$ in. to $\frac{3}{4}$ in.	25% of joint thickness, but not to exceed $\frac{1}{8}$ in.
Over $\frac{3}{4}$ in. to $1\frac{1}{2}$ in.	$\frac{3}{16}$ in.
Over $1\frac{1}{2}$ in.	$12\frac{1}{2}\%$ of joint thickness, but not to exceed $\frac{1}{4}$ in.

For misalignments that exceed the table above and less than  $0.50t$ , the structure may be fixed by using deep penetration welds. For misalignments that exceed  $0.50t$  and are less than  $1.0t$ , the structure may be fixed by aligning flat bar doubling strips. Misalignments greater than  $1.0t$  are to be corrected by realignment of the structure. See 2-4-5/5.15.1(e) FIGURE 2.

**FIGURE 2**  
**Repairs of Misalignments**



### 5.15.2 Dye Penetrant

Dye penetrant inspection is to be used when investigating the outer surface of welds or may be considered for use as a check of intermediate weld passes, such as root passes and also to check back-chipped, ground or gouged joints prior to depositing subsequent passes. Any dye penetrant used is to be thoroughly removed from the area before re-welding. Dye penetrant is not to be used where complete removal of the dye penetrant materials cannot be assured.

#### 5.15.2(a) Type of Dye Penetrant.

Penetrant materials consist of solvent-removable, visible dye penetrant with associated penetrant remover (solvent) and nonaqueous wet developer.

#### 5.15.2(b) Surface Preparation.

Surfaces to be inspected shall be free from scale, slag and adhering or imbedded sand or other extraneous materials. With the exception of undercuts which are within allowances, the contour of welds shall blend smoothly and gradually into the base metal. Weld surface irregularities shall be removed to the extent that they will not interfere with interpretation of the test results. The final liquid penetrant inspection shall be performed in the final surface condition, as specified herein.

Peening, shot, sand, grit and vapor blasting shall not be performed on surfaces before liquid penetrant inspection.

Surfaces for which a specific finish is required shall be given this surface finish prior to the final liquid penetrant inspection.

*5.15.2(c) Test Procedure Requirements.*

All surfaces being tested shall be thoroughly cleaned of extraneous material. If a nonvolatile liquid is used for cleaning, the surface shall be heated or dried with hot air to assure complete removal of the cleaner. As a final cleaning operation, each surface shall be dipped, sprayed, wiped or brushed with an acceptable solvent and thoroughly dried by removing the excess with a clean dry cloth or absorbent paper, and allowing the remainder to evaporate for a minimum of five minutes. Prior to liquid penetrant inspection, the surface to be tested and any adjacent area within one (1) inch of the surface to be tested shall be dry and free of any dirt, grease, lint, scale and salts, coatings or other extraneous matter that would obscure surface openings or otherwise interfere with the test.

Maximum penetration into extremely small openings requires that the penetrant and the test surface be maintained at the temperature recommended by the penetrant manufacturer, but in no case shall be less than 50°F. The temperature of the penetrant and the test surface shall not exceed 100°F. Due to the flammable nature of liquid penetrant inspection materials, the use of an open flame for heating purposes shall be prohibited. Special conditions requiring deviation from the above requirement requires approval of the Surveyor.

The surface to be tested shall be thoroughly and uniformly coated with penetrant by flooding, brushing, immersion or spraying. Unless otherwise recommended by the manufacturer and approved by the Surveyor, dwelling time for the penetrant shall be not less than 15 minutes and no greater than 20.

The excess penetrant shall be removed from all surfaces as follows:

- i)* As much excess penetrant as possible shall be removed by wiping the surface thoroughly with a clean dry cloth or absorbent paper.
- ii)* The remaining excess penetrant shall be removed by wiping the surface with a clean cloth or absorbent paper dampened with a penetrant remover specified by the penetrant material manufacturer.

Flushing of the surface with any liquid following application of the penetrant and prior to developing is prohibited.

The drying of the test surface after the removal of the excess penetrant shall be accomplished only by normal evaporation, or by blotting with absorbent paper or clean, lint-free cloth. Forced air circulation in excess of normal ventilation in the inspection area shall not be used. Unless otherwise specified by the penetrant manufacturer, the time for surface drying after removal of excess penetrant and prior to application of the developer shall be limited to a maximum of ten (10) minutes.

A nonaqueous wet developer specified by the penetrant manufacturer shall be used. Immediately prior to application, the developing liquid shall be kept agitated in order to prevent settling of solid



particles dispersed in the liquid. The developer shall be uniformly applied in a thin coating to the test surfaces by spraying. Pools of wet developer in cavities on the inspection surface is not permitted since these pools will dry to an excessively heavy coating in such areas resulting in the masking of indications. Inspection shall be made a minimum of seven (7) minutes and not later than 30 minutes after the developer has dried.

When the inspection is concluded, the penetrant materials shall be removed as soon as possible by means of wiping, water-wetted clean cloth or solvents, as described above, and with applicable cleaning procedures.

### 5.15.3 Radiographic or Ultrasonic Inspection

Radiographic or ultrasonic inspection or both may be used when the overall soundness of the weld cross section is to be evaluated. Finished welding is to be sound and thoroughly fused throughout its cross section and to the base material. Production welds are to be crack free. Other discontinuities, such as incomplete fusion or incomplete penetration, slag and porosity, are only to be present to the degree permitted by the pertinent inspection standard. The procedures and standards for radiographic and ultrasonic inspection is to be in accordance with ABS's separately issued publication, *Guide for Nondestructive Inspection*, or other approved acceptance standards.

### 5.15.4 Weld Plugs or Samples

The practice of taking weld plugs or samples by machining or cutting from the welded structure is not recommended and is to be considered only in the absence of other suitable inspection methods and is to be subject to the special approval of the Surveyor. When such weld plugs or samples are removed from the welded structure, the holes or cavities formed are to be properly prepared and welded, using a suitable welding procedure approved by the Surveyor and as established for the original joint

## 5.17 Workmanship Requirements

The workmanship requirements include the visual acceptance criteria stated in 2-4-5/5.15.2 above plus the following structural fairness requirements provided below. In addition, welded attachments shall be removed to a minimum of 1.5 mm (0.0625 in.) away from the permanent member to which they are attached by chipping, sawing or cutting, followed by grinding or sanding to restore the plate surface.

### 5.17.1 Structural Fairness for Plating

Unfairness (deviation from the design molded line) of welded plating shall not exceed the tolerances shown on 2-4-5/Figures 3 and 4. Permissible unfairness should result in a generally fair curve across the panel, except that an additional deviation of 3 mm (1.8 in.) from the fair curve is permitted in way of welded butts and seams. Sharp knuckling or bend in way of stiffeners shall be avoided. A procedure for measuring fairness and taking corrective actions shall be developed and be available for review by the surveyor.

If aid is necessary in determining the acceptability of the fairness of welded structure, a measurement of the unfairness of plating may be made in the area of interest. In such cases, the measurement shall be made across the minor dimension of the panel. The tolerances specified on 2-4-5/Figures 3 and 4 are plus or minus the dimensions from a fair line.

For stiffener spacings greater or less than those shown on 2-4-5/Figures 3 and 4, the curves shall be extrapolated proportionately.

### 5.17.2 Structural Fairness for Framing and Stiffeners

Frame, beam and stiffener bows in primary strength structure or structure subject to dynamic loading shall be corrected when it varies plus or minus from the designated or molded line in excess of the following:

$$T = C \left( \frac{\ell}{dw} \right) \quad \text{mm(in.)}$$

where

$T$  = tolerance in mm (in.)

$C$  = 530 (0.25)

$l$  = span of member between the fixed ends at the support structure in m (ft)

$dw$  = depth of the stiffening member measured from the underside of the flange in mm (in.)

### 5.17.3 Underwater Exterior Surfaces

In general, weld surfaces shall not extend greater than 1.5 mm (0.0625 in.) above the plate surface.

## 5.19 Quality Control

To maintain quality control, sample welds may be required to be made by welders and operators during each three (3) month period, at the discretion of the Surveyor and at the location of production welding, using the same equipment, material and filler metal as intended for production. The sample welds are to be examined for acceptable workmanship and may be required to be sectioned, etched and examined for weld soundness. When necessary, measures are to be taken to correct unacceptable workmanship.

## 5.21 Repair Welding

Unsatisfactory welding, as determined by visual inspection, nondestructive test methods, or leakage under hydrostatic tests, is to be corrected by the removal of the defective weld or adjacent material or both and corrected by rewelding, using a suitable repair welding procedure consistent with the material being welded. The repair procedures shall be available for the welder. Multiple repairs (weld cycles) to 5000 series aluminum alloys in the same general area are allowed. Removal by mechanical means of minor surface defects such as arc strikes, scratches or shallow gouges may be permitted at the discretion of the attending Surveyor. Repaired welds must meet the inspection requirements for the original weld.

# 7 Butt Welds

## 7.1 Joint Design

Hull plating up to 5.0 mm ( $\frac{3}{16}$  in.) in thickness may be square-butt welded without beveling the abutting plate edges. Plates exceeding 5.0 mm ( $\frac{3}{16}$  in.) may be prepared for welding by similarly beveling the edges of both plates from one or both sides to form a single-Vee or double-Vee butt joint with an included angle from 60 degrees to 90 degrees. For single-Vee butt joints in material 5.0 mm ( $\frac{3}{16}$  in.) and thicker, the root face or land may be up to 3.0 mm ( $\frac{1}{8}$  in.) in depth. Root faces or lands below 1.5 mm ( $\frac{1}{16}$  in.) are not generally recommended. For double-Vee butt joints in material 8.0 mm ( $\frac{5}{16}$  in.) and thicker, the gap may vary from 0 to 5.0 mm ( $\frac{3}{16}$  in.). Joints of other designs and root openings, such as the square butt joints in heavy thicknesses used with automated procedures will be subject to special consideration. In general, use of double-Vee in lieu of single-Vee joints and the narrowest root gap practicable is recommended to minimize distortion.

Butt-type permanent backing strap joints welded from one side shall not be used. For both single-Vee and double-Vee joints, the weld metal at the root on the reverse side of a weld made without permanent backing is to be removed to sound metal by an approved method before applying subsequent weld passes. See 2-4-5/5.11. Welded butt joints made against removable backing and on which the root is inspected in accordance with these requirements shall be considered the equivalent of a joint welded from both sides.

# 9 Fillet Welds (1 July 2021)

See Section 3-2-13 of the *ABS Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels*.

## 11 Filler Metals

### 11.1 General

Filler metals are to be of a type suitable to produce sound welds that have strength, ductility and corrosion-resistant properties comparable to the materials being welded. Appropriate precautions are to be used to prevent any critical property change of filler wire quality during storage and handling. A list of recommended filler metals for different alloys is given in 2-4-5/Tables 4 and 5.

### 11.3 Approval Basis

Filler metals will be approved and listed, subject to tests conducted at the manufacturer's plant. Upon satisfactory completion of tests, a certificate will be issued for general approval indicating the grade or classification to which the filler metal was tested and the relevant characteristics of the filler metal. Test assemblies are to be prepared in the presence of the Surveyor and all tests are to be attended by and carried out to the satisfaction of the Surveyor. Procedure and testing is to comply with either of the following standards.

- i) Filler metals will be considered for approval based upon tests conducted to standards established by the American Welding Society or other recognized agency.
- ii) Special approvals to manufacturer's specifications.

## 13 Approval of Welding Procedures

### 13.1 Approved Filler Metals

Approval of aluminum alloy filler metals used on ABS-classed weldments will depend on the specific application and alloys for which the filler metal is intended. Procedure tests may be required as a general condition of approval or at the discretion of the attending Surveyor to determine the shipyard's or fabricator's capability in the application of the proposed filler metal to the base material. The extent of such tests may vary depending upon the intended application, but generally would follow those tests outlined in 2-4-5/13.7, and are to be carried out under production conditions.

### 13.3 Surveyor's Acceptance

The Surveyor may, at his discretion, accept a filler metal, welding procedure, or both, in a shipyard or fabricator's plant where it is established to his satisfaction that they have been adequately used for similar work under similar conditions.

### 13.5 New Procedures and Methods

Weld tests, as outlined in 2-4-5/13.7 and 2-4-5/13.9 and 2-4-5/Figure 5 to 2-4-5/Figure 17, using procedures and materials similar to those intended for production welding and carried out under production conditions, may be required to be prepared by each shipyard or fabricator when new or unusual methods, base metals or filler metals are proposed.

All tests are to be made in the presence of the Surveyor and carried out to the Surveyor's satisfaction.

### 13.7 Tests

Tests Nos. 1 and 2 are to be carried out for procedures involving butt welds. Test No. 3 is to be carried out for procedures involving fillet welds. Unless otherwise specified, the number of specimens is to be as indicated. The minimum test results required are stated with the figures:

- *Test No. 1 – Reduced Section Tension Test* (with reinforcement removed) (2-4-5/17 FIGURE 7 or 2-4-5/17 FIGURE 8). Two specimens made in each position involved. The test specimens are to meet or exceed the ultimate tensile strength shown in 2-4-5/3.15 TABLE 1.

- *Test No. 2 – Guided Bend Test* (2-4-5/17 FIGURE 9 or 2-4-5/17 FIGURE 10). For material 12.5 mm (0.5 in.) thick and under, two face-bend and two root-bend specimens for each position; for material over 12.5 mm (0.5 in.) thick, four side-bend specimens for each position involved. The bending jig and test requirements are indicated in 2-4-5/17 FIGURE 11. Equivalent bending jigs, such as wrap around bend test fixtures, may also be used.
- *Test No. 3 – Fillet Weld Test* (2-4-5/17 FIGURE 13).

### 13.9 Special Tests

All-weld-metal tensile, macro-etch, radiographic inspection or other relevant tests may be required for certain applications, and the results submitted for consideration.

## 15 Welder Qualifications

### 15.1 General

The Surveyor is to be satisfied that the welders and operators are proficient in the type of work which they are called upon to perform, either through requiring any or all of the tests outlined in the following paragraphs or through due consideration of the system of employment, training, apprenticeship, plant testing, inspection, etc., employed.

### 15.3 Qualification Tests

The tests, if required for qualification for various welding processes, are given in 2-4-5/17 TABLE 6. Such tests are based on the material thicknesses and welding processes involved. Qualification of welders for a particular alloy may be acceptable for qualification of the welder for other aluminum alloys. Separate qualification tests are to be made for the gas metal arc and gas tungsten arc processes. The tests are referred to by Nos. Q1, Q2, Q4, and Q5, for which specimens are to be prepared and tested in accordance with 2-4-5/17 Figure 14 to 2-4-5/17 Figure 17, respectively. Specimens for qualification tests are to be bent in a bending jig having the profile shown in 2-4-5/17 FIGURE 11 or in a bending jig having an equivalent wrap around design. Alternatively, upon the request of the employer, the welder may be qualified by use of radiography, provided that the complete particulars of the equipment available and the procedures are demonstrated to be satisfactory. Test assemblies for either mechanical testing or radiographic examination are to be prepared according to material thickness and welding position, as indicated in 2-4-5/17 TABLE 6.

## 17 Alternatives

The foregoing are considered minimum requirements for aluminum welding in hull construction, but alternative methods, arrangements and details may be considered for approval.

**TABLE 2**  
**Minimum Mechanical Properties for Butt-Welded Aluminum Alloys**

The adoption of test values higher than given in this table will be subject to special consideration. Filler wires are those recommended in 2-4-5/17 TABLE 3. Values shown are for welds in plate thicknesses up to 38 mm (1.5 in.) unless otherwise noted.

<i>Alloy</i>	<i>Ultimate Tensile Strength (<math>U_a</math>)</i>	<i>Yield Strength (<math>Y_a</math>)<sup>(2)</sup></i>	<i>Shear Strength (<math>\tau_a</math>)<sup>(2)</sup></i>
	<i>N/mm<sup>2</sup> (psi)</i>	<i>N/mm<sup>2</sup> (psi)</i>	<i>N/mm<sup>2</sup> (psi)</i>
5083-H111	269 (39000)	145 (21000)	83 (12000)
5083-H116, H321	276 (40000)	165 (24000)	96 (14000)
5083-H323, H343	276 (40000)	165 (24000)	96 (14000)
5086-H111	241 (35000)	124 (18000)	69 (10000)

Alloy	Ultimate Tensile Strength ( $U_{al}$ )	Yield Strength ( $Y_{al}$ ) <sup>(2)</sup>	Shear Strength ( $\tau_{al}$ ) <sup>(2)</sup>
	N/mm <sup>2</sup> (psi)	N/mm <sup>2</sup> (psi)	N/mm <sup>2</sup> (psi)
5086-H112 6 mm (0.25 in.) –12 mm (0.50 in.)	241 (35000)	117 (17000)	65 (9500)
5086-H112 12 mm (0.5 in.) –25 mm (1.0 in.)	241 (35000)	110 (16000)	62 (9000)
5086-H112 Greater than 25 mm (1.0 in.)	241 (35000)	96.5 (14000)	55 (8000)
5086-H32, H34, H116	241 (35000)	131 (19000)	76 (11000)
5383-O, H111	290 (42000)	145 (21000)	83 (12000)
5383-H116, H321	290 (42000)	165 (24000) <sup>(3)</sup>	83 (12000)
5383-H34	290 (42000)	145 (21000)	83 (12000)
5454-H111	214 (31000)	110 (16000)	65 (9500)
5454-H112	214 (31000)	83 (12000)	48 (7000)
5454-H32, H34	214 (31000)	110 (16000)	65 (9500)
5456-H111	283 (41000)	165 (24000)	96 (14000)
5456-H112	283 (41000)	131 (19000)	76 (11000)
5456-H116, H321	290 (42000)	179 (26000)	103 (15000)
5456-H323, H343	290 (42000)	179 (26000)	103 (15000)
6061-T6 <sup>(1)</sup> under 9.5 mm (0.375 in.)	165 (24000)	138 (20000)	83 (12000)
6061-T6 <sup>(1)</sup> over 9.5 mm (0.375 in.)	165 (24000)	103 (15000)	62 (9000)

**Notes:**

- 1 Values when welded with 4043, 5183, 5356 or 5556 filler wire.
- 2 Yield and shear strength is not required for weld procedure qualification.
- 3 Yield strength values as high as 185 N/mm<sup>2</sup> (27000 psi) have been satisfactorily demonstrated and statistically verified.

**TABLE 3**  
**Aluminum Alloy Filler Metal Composition (2016)**

Composition in percent maximum unless shown as a range or specified. See also AWS A5.10

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Other*		Aluminum
									Each	Total	
4043	4.5-6.0	0.80	0.30	0.05	0.05		0.10	0.20	0.05	0.15	Remainder
4943	5.0-6.0	0.40	0.10	0.05	0.10-0.50		0.10	0.15	0.05	0.15	Remainder
5183	0.40	0.40	0.10	0.50-1.0	4.3-5.2	0.05-0.25	0.25	0.15	0.05	0.15	Remainder
5356	0.25	0.40	0.10	0.05-0.20	4.5-5.5	0.05-0.20	0.10	0.06-0.20	0.05	0.15	Remainder
5554	0.25	0.40	0.10	0.50-1.0	2.4-3.0	0.05-0.20	0.25	0.05-0.20	0.05	0.15	Remainder
5556	0.25	0.40	0.10	0.50-1.0	4.7-5.5	0.05-0.20	0.25	0.05-0.20	0.05	0.15	Remainder

\* The maximum Beryllium content of all filler wires is to be 0.0003%.

**TABLE 4**  
**Filler Metals for Welding Aluminum Alloy – Sheet, Plate and Extrusions (2016)**

Recommendations in this table apply to gas shielded-arc welding processes.

Filler metal alloys 5183, 5356 and 5556 may be used interchangeably, provided that strength, ductility and corrosion resistance are suitable for the service conditions.

<i>Base Metal Alloys</i>	<i>5083</i>	<i>5086</i>	<i>5383</i>	<i>5454<sup>(1)</sup></i>	<i>5456</i>	<i>6061, 6082</i>
5083	5183	5356	5183	5356 <sup>(1)</sup>	5183	5356 <sup>(1)</sup>
5086	5356	5356	5356	5356 <sup>(1)</sup>	5356	5356 <sup>(1)</sup>
5383	5183	5356	5183	5356 <sup>(1)</sup>	5183	5356 <sup>(1)</sup>
5454 <sup>(1)</sup>	5356	5356	5356	5554 <sup>(1)</sup>	5356	5356 <sup>(1)</sup>
5456	5183	5356	5183	5356 <sup>(1)</sup>	5556	5356 <sup>(1)</sup>
6061, 6082	5356	5356	5356	5356 <sup>(2)</sup>	5356	4043, 4943 <sup>(2, 3)</sup>

*Notes:*

- 1 5454 aluminum alloy welded with 5554 filler metal is generally recommended for above 65°C (150°F), such as for smoke stacks and engine room enclosures
- 2 5183 or equivalents may be used.
- 3 In case 4943 is selected, tensile test results are to be submitted for ABS review.

**TABLE 5**  
**Filler Metals for Welding Aluminum Alloy Castings to Castings and Plate**

ASTM American Society for Testing and Materials

AA Aluminum Association

<i>Castings</i>		<i>SG70A SG70B, 357 (Note 1)</i>	<i>5154, 5454, 6061 (Note 2)</i>	<i>5456, 5083, 5086 (Note 3)</i>
<i>ASTM</i>	<i>AA</i>			
SG70A	356.0	4043	4043	5356
SG70B	A356.0	4043	4043	5356
	357.0	4043	4043	5356

*Notes:*

- 1 Filler metal with same analysis as base metal is sometimes used.
- 2 5183, 5356, 5554, 5556 and 5654 may be used. In some cases they may provide higher weld ductility and higher weld strength. 5554 is suitable for elevated temperature service.
- 3 5183, 5356 or 5556 may be used. 4043 may be used for some applications where filler metal properties are not of primary concern.

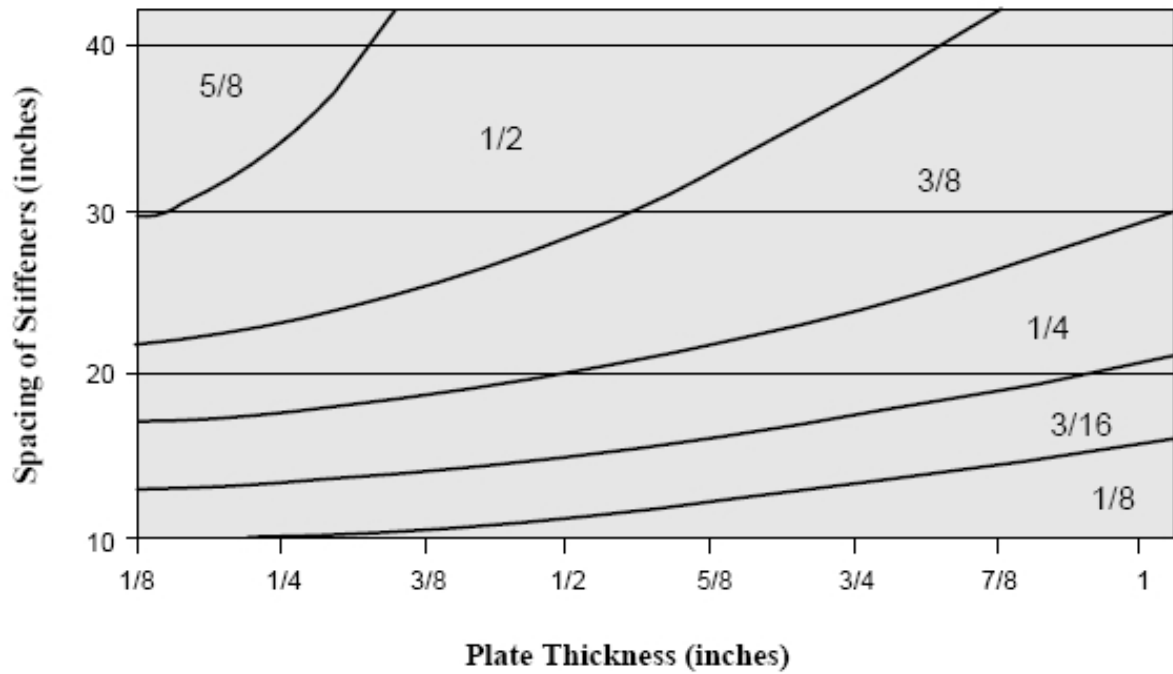
**TABLE 6**  
**Welder Qualification Tests**

<i>Construction Material</i>	<i>Position in Which Welding is to be Done on Job</i>		
	<i>Flat, Horizontal, Vertical and Overhead</i>	<i>Flat and Vertical</i>	<i>Flat Position Only</i>
On material of limited thickness 19.1 mm ( $\frac{3}{4}$ in.) or less. See Note 1.	Test No. Q1 in vertical and overhead positions	Test No. Q1 in vertical position	Test No. Q1 in flat position
On material of unlimited thickness (any thickness) See Notes 1 and 2.	Test No. Q2 in vertical and horizontal positions	Test No. Q2 in vertical position	Test No. Q2 in flat position
On piping or tubing. See Note 3.	Test No. Q3 in horizontal and vertical positions	Test No. Q3 in horizontal and vertical fixed positions	Test No. Q3 in horizontal rolled position
For tack welders	Test No. Q5 in vertical and overhead positions	Test No. Q5 in vertical position	

**Notes:**

- 1 Where the maximum thickness of material on which a welder may have occasion to work throughout the period governed by a test is indeterminate, the Surveyor may, if desired, require the welder to qualify under unlimited thickness requirements.
- 2 Where the maximum plate thickness to be welded is between 19.1 mm ( $\frac{3}{4}$  in.) and 38.1 mm ( $1\frac{1}{2}$  in.) qualification Test No. Q2 may, with the permission of the Surveyor, be conducted on plate of maximum thickness involved.
- 3 Welding operators qualified under the requirements of Test No. Q4 will be considered as qualified to make welds governed by Tests Nos. Q1 and Q2. Welding Operators qualified to weld on plate in the vertical position may be permitted to weld on pipe in the horizontal rolled position.

**FIGURE 3**  
**Permissible Unfairness in Aluminum Welded Structure**

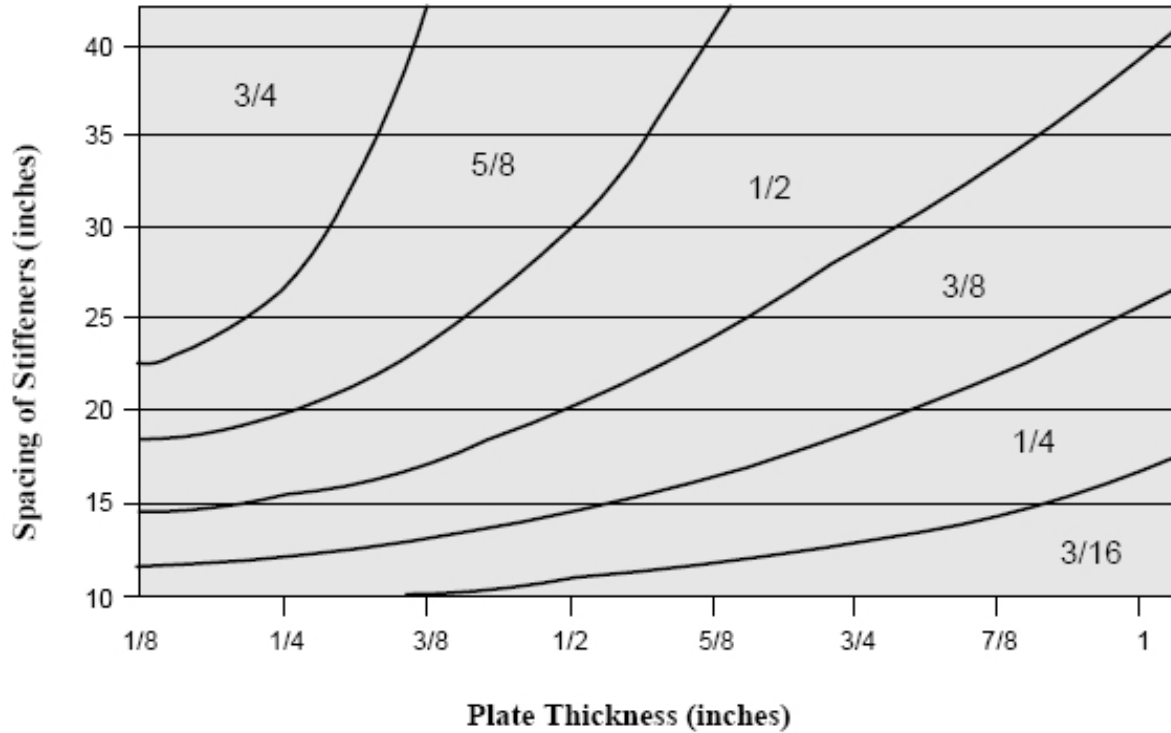


*Applicability of tolerances:*

- 1 Entire shell plating
- 2 Uppermost strength deck
- 3 Longitudinal strength Deck structure which includes inner-bottom tank tops
- 4 Bulwarks and exterior superstructure bulkheads



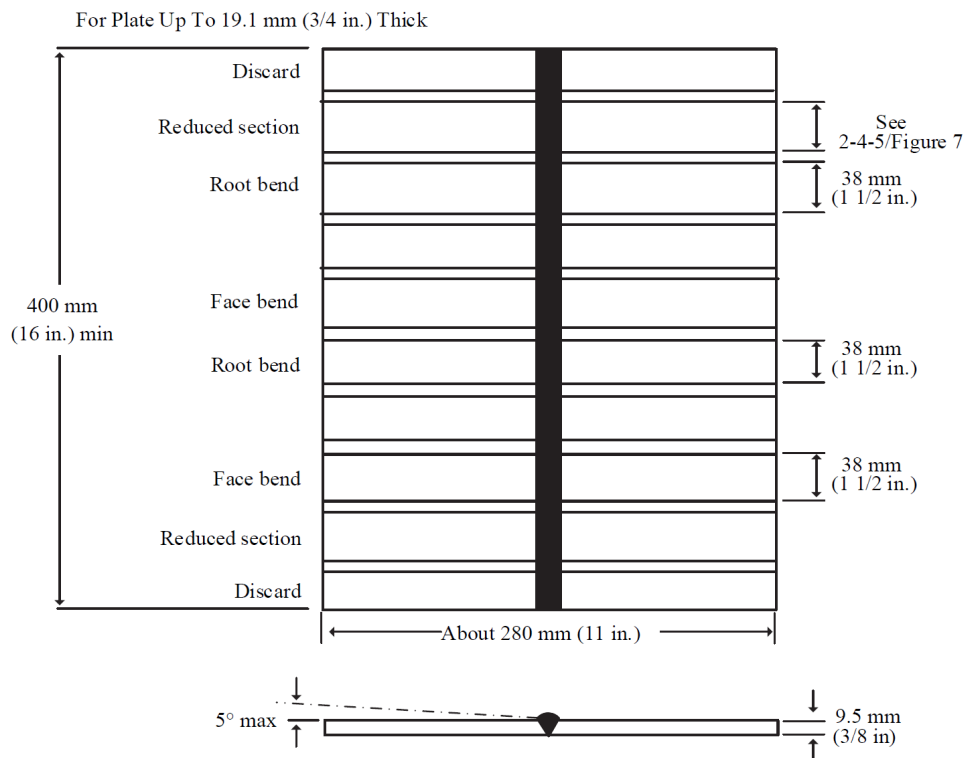
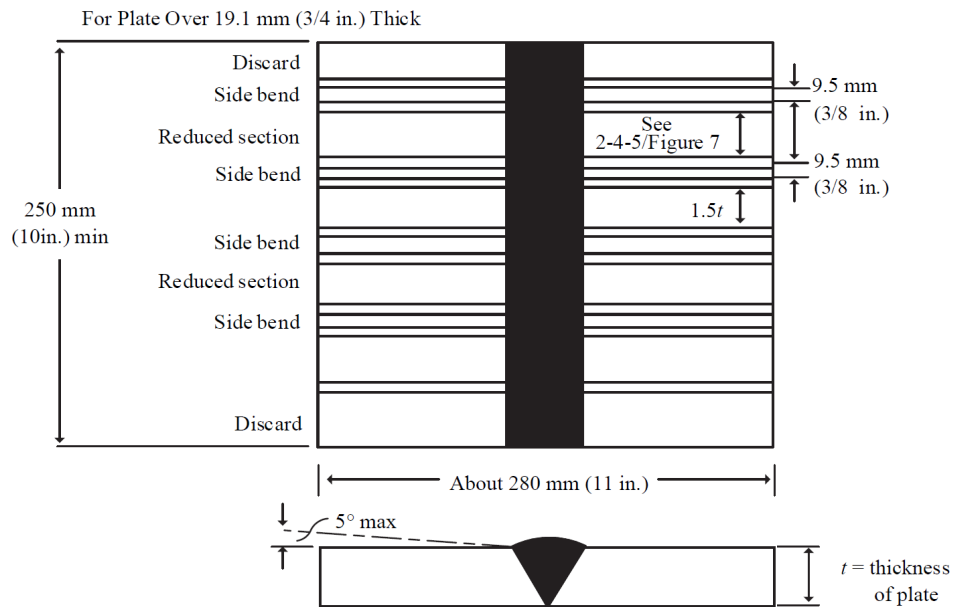
**FIGURE 4**  
**Permissible Unfairness in Other Aluminum Welded Structure**



*Applicability of tolerance:*

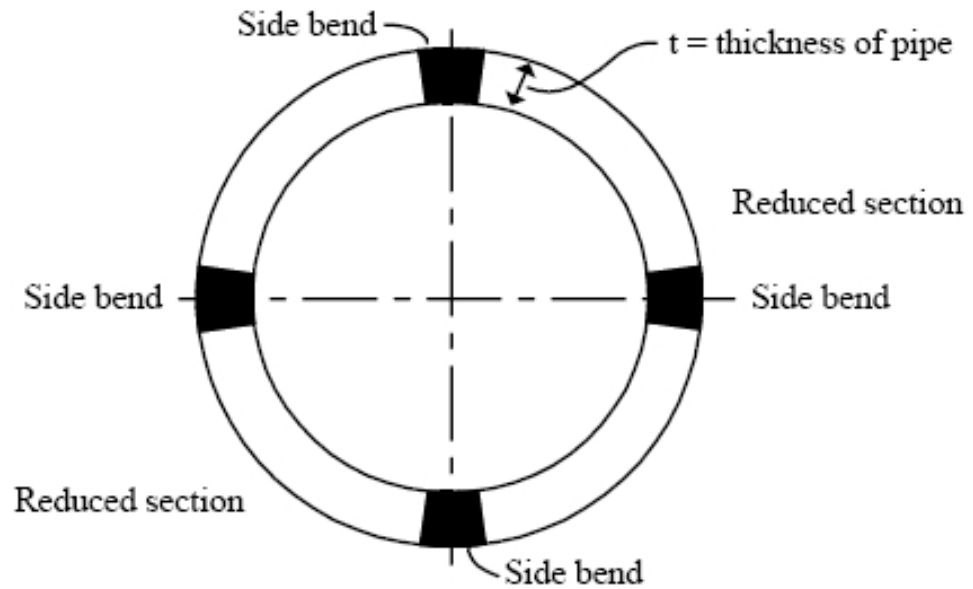
- 1 Structural bulkheads forming a boundary of living space (stateroom, office, berthing, messing or lounge area) and passageways contiguous to such spaces.
- 2 Decks within the hull and superstructure in way of the above living spaces.
- 3 Decks exposed to the weather.
- 4 Tank and main transverse bulkheads
- 5 Inner-bottom plate and longitudinals and transverses.

**FIGURE 5**  
**Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2**

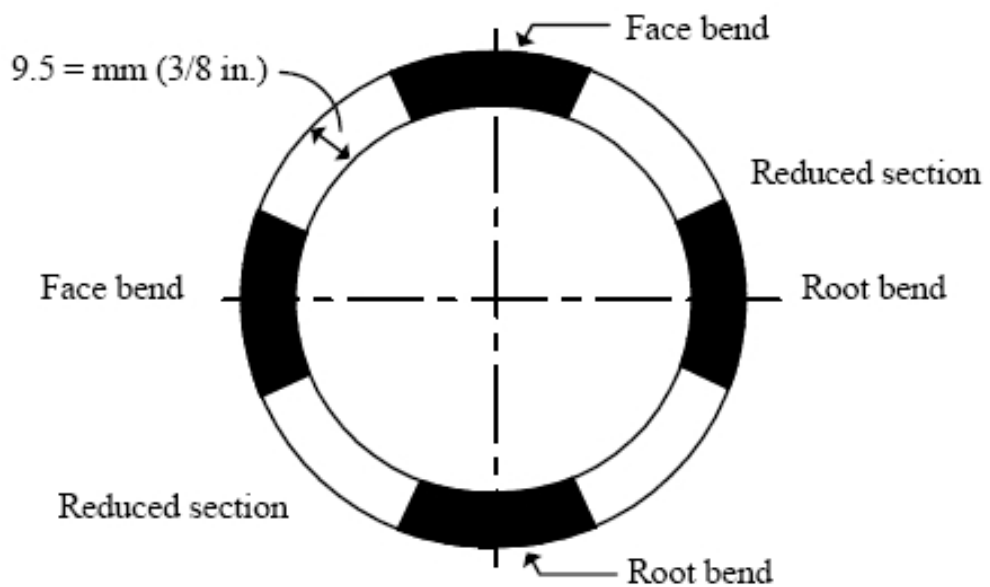


Note: Edge preparation, welding procedure and postweld heat treatment, if any, are to be the same as those for the work represented.

For Pipe Over 19.1 mm (3/4 in.) Thick

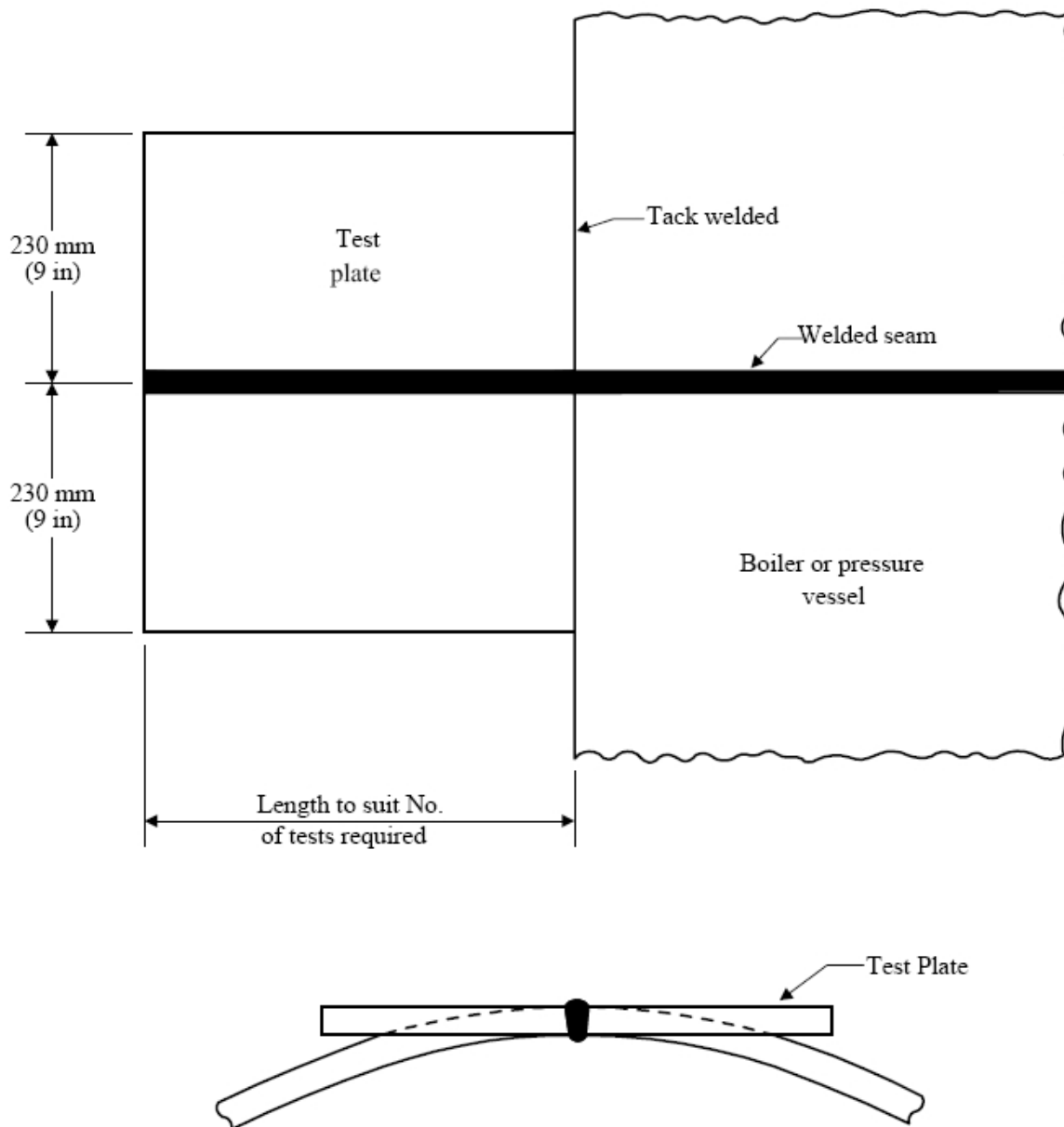


For Pipe Up To 19.1 mm (3/4 in.) Thick



Note: Edge preparation, welding procedure and postweld heat treatment, if any, are to be the same as those for the work represented.

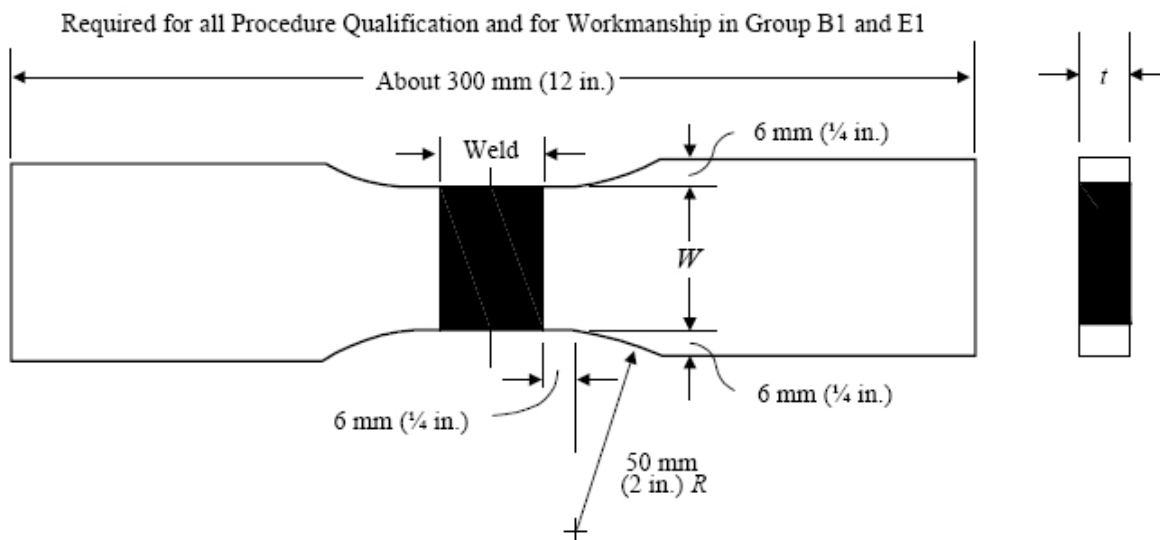
**FIGURE 6**  
**Typical Arrangement of Test Plates for Workmanship Tests in Group B1**



**Note:**

Tack weld test plates together and support test assembly so that warping due to welding does not cause deflection of more than 5 degrees. Should straightening of any test assembly within this limit be necessary to facilitate making test specimens, the test assembly is to be straight-ended after cooling and before any postweld heat treatment.

**FIGURE 7**  
**Test No. 1 – Reduced-section Tension Test for Plate**



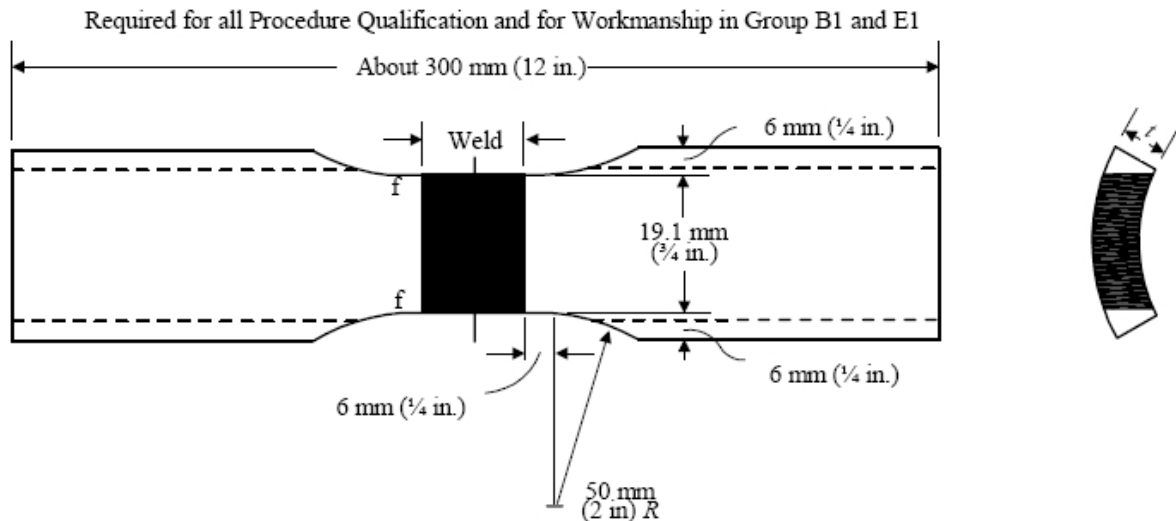
**Notes:**

- 1 Both faces of weld are to be machined flush with base metal.
- 2 For procedure qualification,  $t$  is to be representative of thickness welded in production.
- 3  $W$  = approximately 38 mm (1.5 in.) where  $t$  is 25.4 mm (1 in.) or less.  $w$  = 25.4 mm (1 in.) where  $t$  is more than 25.4 mm (1 in.)
- 4 When the capacity of the available testing machine does not permit testing the full thickness specimen, two or more thinner than full thickness specimens may be prepared by cutting the full thickness specimen into sections, each of which is to meet the requirements.

**Requirement**

The tensile strength of each specimen, when it breaks in or adjacent to the weld, is not to be less than the minimum specified tensile strength, as indicated in 2-4-5/17 TABLE 2.

**FIGURE 8**  
**Test No. 1 – Reduced-section Tension Test for Pipe**



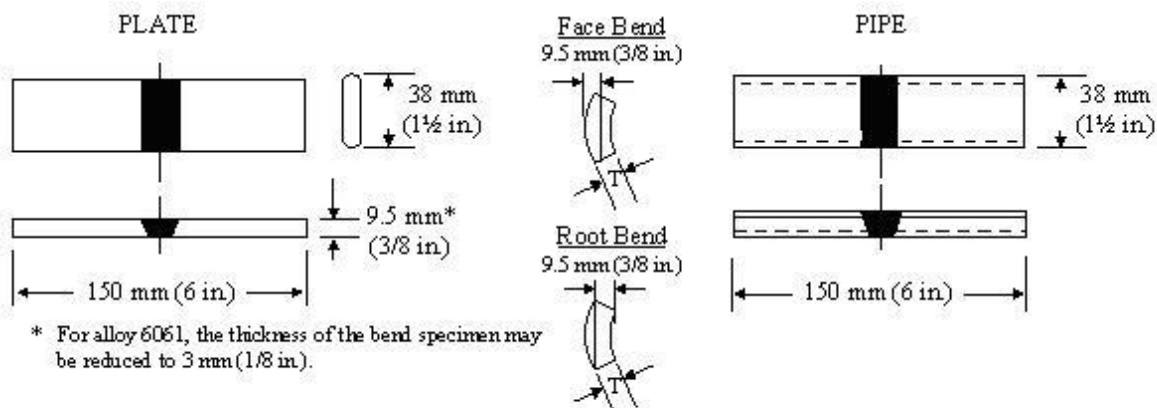
**Notes:**

- 1 Both faces of weld are to be machined flush with base metal. The minimum amount needed to obtain plane parallel faces over 19.1 mm (3/4 in.) wide reduced section may be machined at the option of the testing facility.
- 2 For procedure qualification,  $t = 9.5 \text{ mm}$  (3/8 in.) for construction materials up to 19.1 mm (3/4 in.). For construction material over 19.1 mm (3/4 in.),  $t =$  thickness of material.
- 3 For workmanship tests,  $t =$  thickness in material.
- 4 When the capacity of the available testing machine does not permit testing the full thickness specimen, two or more thinner than full thickness specimens may be prepared by cutting the full thickness specimen into sections, each of which is to meet the requirements.

**Requirements:**

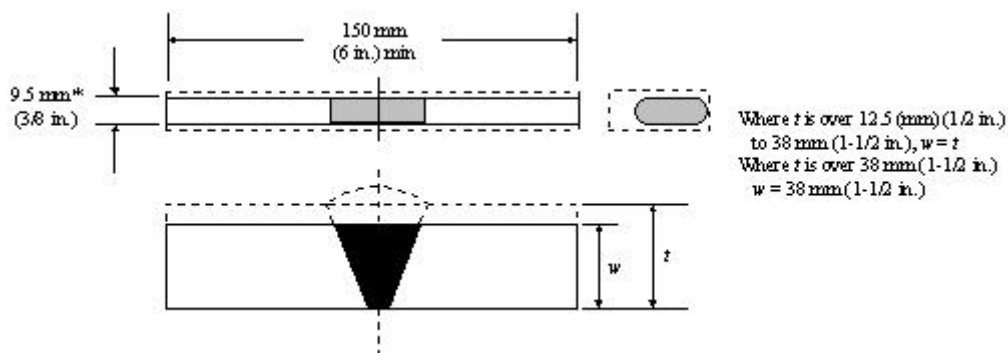
- 1 The tensile strength of each specimen when it breaks in or adjacent to the weld is not to be less than the minimum specified tensile strength, as indicated in 2-4-5/17 TABLE 2.
- 2 The tensile strength of each specimen when it breaks in the base metal and the weld shows no signs of failure is not to be less than 95% of the minimum specified tensile strength of the base material.

**FIGURE 9**  
**Test No. 2 – Guided Bend Test for Root Bend and Face Bend**  
**(Plate or Pipe) (2007)**



*Note:* Both faces of weld to be machined flush with base metal.  
 On test assemblies greater than 9.5 mm (3/8 in.) the opposite side of specimen may be machined as shown.

**FIGURE 10**  
**Test No. 2 – Guided Bend Test for Side Bend (Plate or Pipe)**

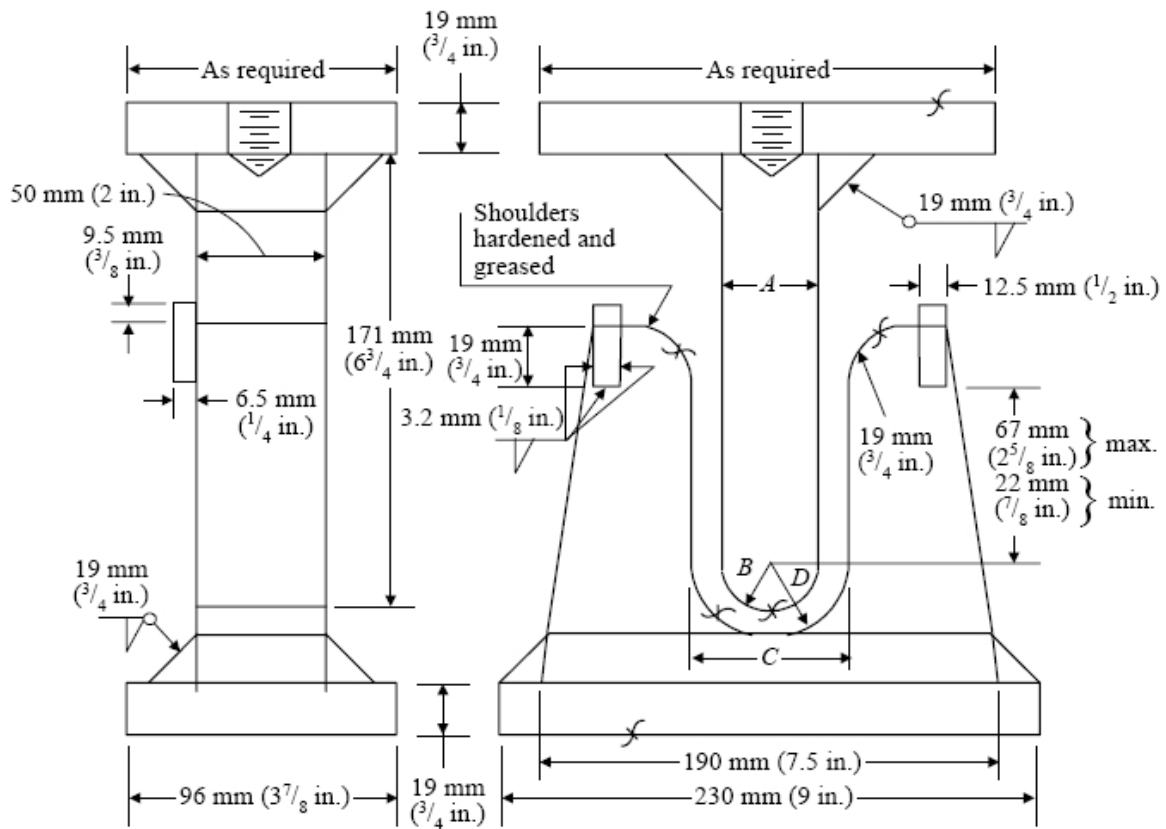


\* For alloy 6061, the thickness of the bend specimen may be reduced to 3 mm (1/8 in.).

*Note:*  
 Both faces of weld to be machined flush with base metal.

**FIGURE 11**  
**Guided Bend Test Jig**

*Test Requirement:* After bending, the specimen is not to show any cracking or other open defects exceeding 3.2 mm (1/8 in.) on the convex side, except at the corners.



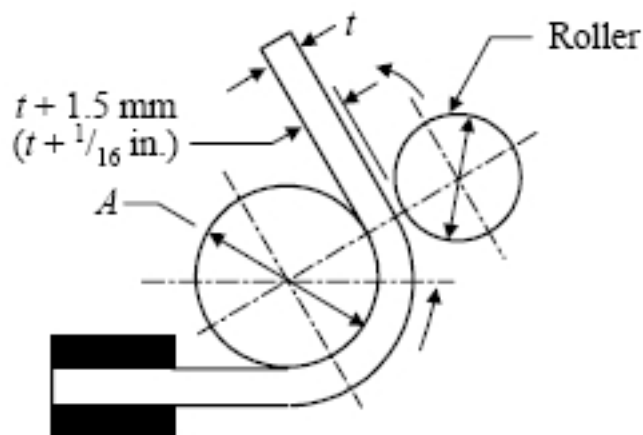
<i>Applicable to material</i>	<i>Thickness of specimens</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
All alloys except 6061	<i>t</i>	$6\frac{2}{3}t$	$3\frac{1}{3}t$	$8\frac{2}{3}t + \frac{1}{8}$	$4\frac{1}{3}t + \frac{1}{16}$
Alloy 6061	3.2 mm ( $\frac{1}{8}$ in.)	51.6 mm ( $2\frac{1}{16}$ in.)	26.2 mm ( $1\frac{1}{32}$ in.)	59.9 mm ( $2\frac{3}{8}$ in.)	30.2 mm ( $1\frac{3}{16}$ in.)

**Note:**

Mandrel radius may be increased up to 8.25t maximum for alloy 6061.



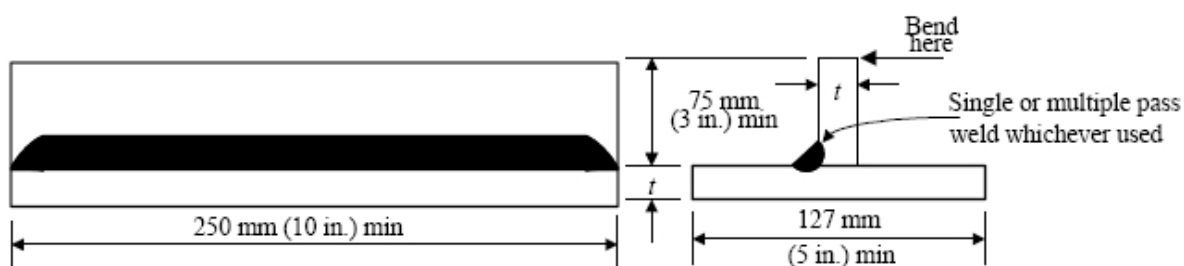
**FIGURE 12**  
**Alternative Guided Bend Test Jig**



*Notes:*

- 1 The dimension  $t$  is the thickness of the material.
- 2 The reduced section is to be parallel within 0.05 mm (0.002 in.) and may have a gradual taper in width from the ends toward the center with the ends not more than 0.13 mm (0.005 in.) wider than the center. The ends of the specimens are to be symmetrical with the centerline of the reduced section within 0.25 mm (0.01 in.).
- 3 Mandrel radius may be increased up to  $8.25t$  maximum for alloy 6061.
- 4 For aluminum alloy bend requirements, see 2-4-5/17 FIGURE 10.

**FIGURE 13**  
**Test No. 3 – Fillet Weld Test (2013)**



*Notes:*

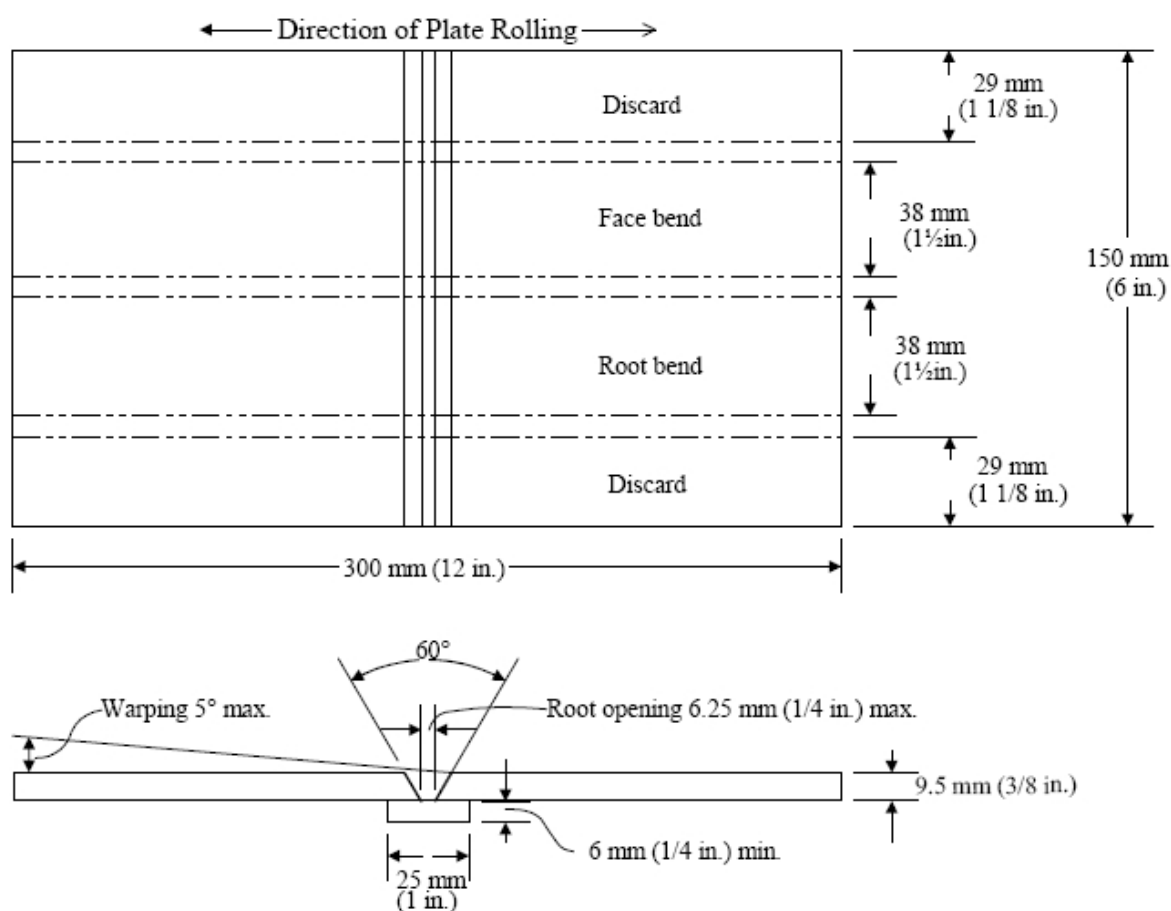
- 1 For procedure qualifications,  $t$  is to be representative of thicknesses welded in production. Base and standing web is to be straight and in intimate contact and securely tacked at ends before fillet-weld is made, to insure maximum restraint.
- 2 (2013) The test plate may be cut into short sections to facilitate breaking open.

Requirement:

The fillet is to be the required contour and size, free from undercutting and overlapping. When broken as indicated, the fractured surface is to be free from cracks, and reasonably free from visible porosity and lack of root infusion, except that porosity or incomplete fusion at the root corners of fillets may be acceptable, provided the total length of the incompletely fused areas is less than approximately 10% of the total length of the weld.

**FIGURE 14**  
**Welder Qualification Test No. Q1**

For plate material 19.1 mm (3/4 in.) or less.

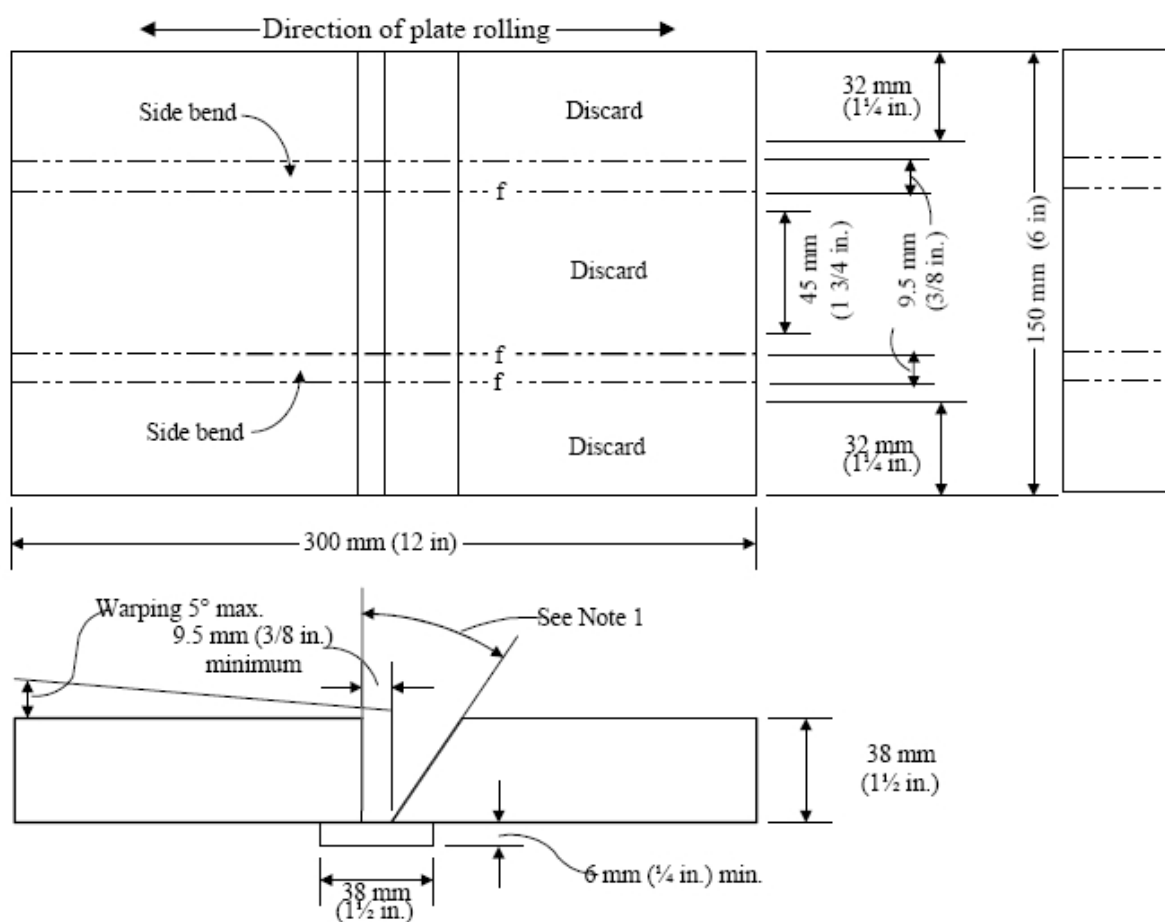


Notes:

- 1 Weld is to be made with the maximum size electrode that will be used in production and a maximum interpass temperature of 66°C (150°F).
- 2 Machine reinforcement and backing strap flush. Do not remove any undercutting.
- 3 Machining is to be done transverse to weld.
- 4 All specimens are to be machined or sawed from plate.
- 5 Backing strap is to be contiguous with plates.
- 6 Joints welded in the vertical position are to be welded upwards.
- 7 Welding is to be done from one side only.
- 8 Bend specimens in Guided Bend Test Jig (2-4-5/17 FIGURE 10 or 2-4-5/17 FIGURE 11).
- 9 1 Face Bend and 1 Root Bend required.

**FIGURE 15**  
**Welder Qualification Test No. Q2**

For material of unlimited thickness.

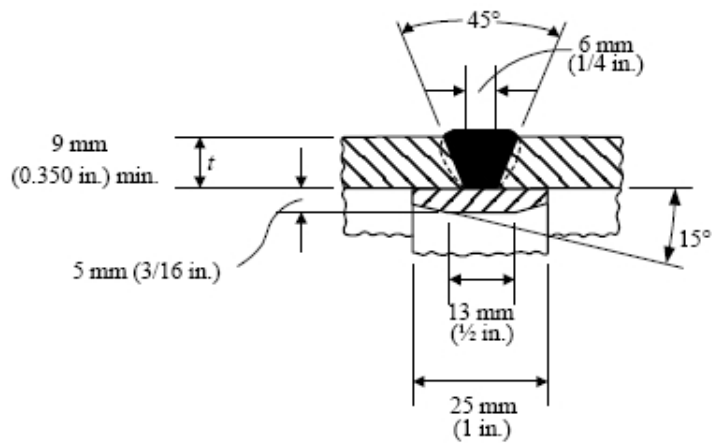
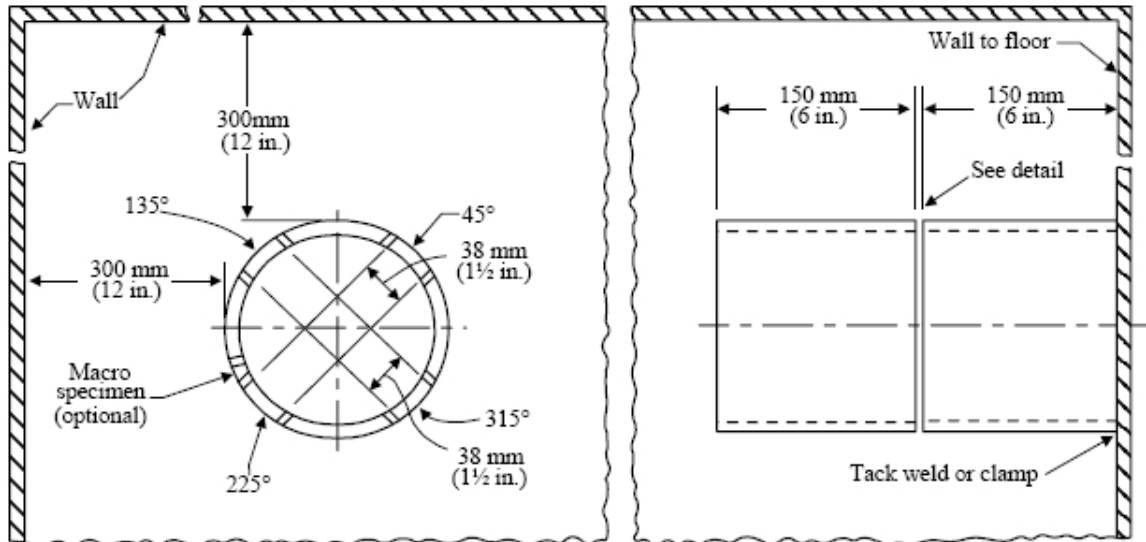


*Notes:*

- 1 When welding in the flat and vertical positions of welding, the groove angle is to be 25 degrees; when welding in the horizontal position, the groove angle is to be 35 degrees and the unbeveled plate is to be located on the top side of the joint.
- 2 Backing strap is to be contiguous with plates.
- 3 Each pass of the weld is to be made with the same size electrode that will be used in production and a maximum interpass temperature of 66°C (150°F).
- 4 Joints welded in the vertical position are to be welded upwards.
- 5 Welding is to be done from one side only.
- 6 Machine reinforcement and backing strap flush. Do not remove any undercutting.
- 7 All specimens are to be machined or sawed from plate.
- 8 Machining is to be done transverse to weld.
- 9 Break edges of specimens to a radius of  $t/6$  maximum.
- 10 Bend Specimen in Guided Bend Test Jig (2-4-5/17 FIGURE 10 or 2-4-5/17 FIGURE 11).
- 11 2 Side Bends required for plate. 4 Side Bends required for pipe.

**FIGURE 16**  
**Welder Qualification Test No. Q4**

For pipe 19.1 mm (3/4 in.) thick or less.



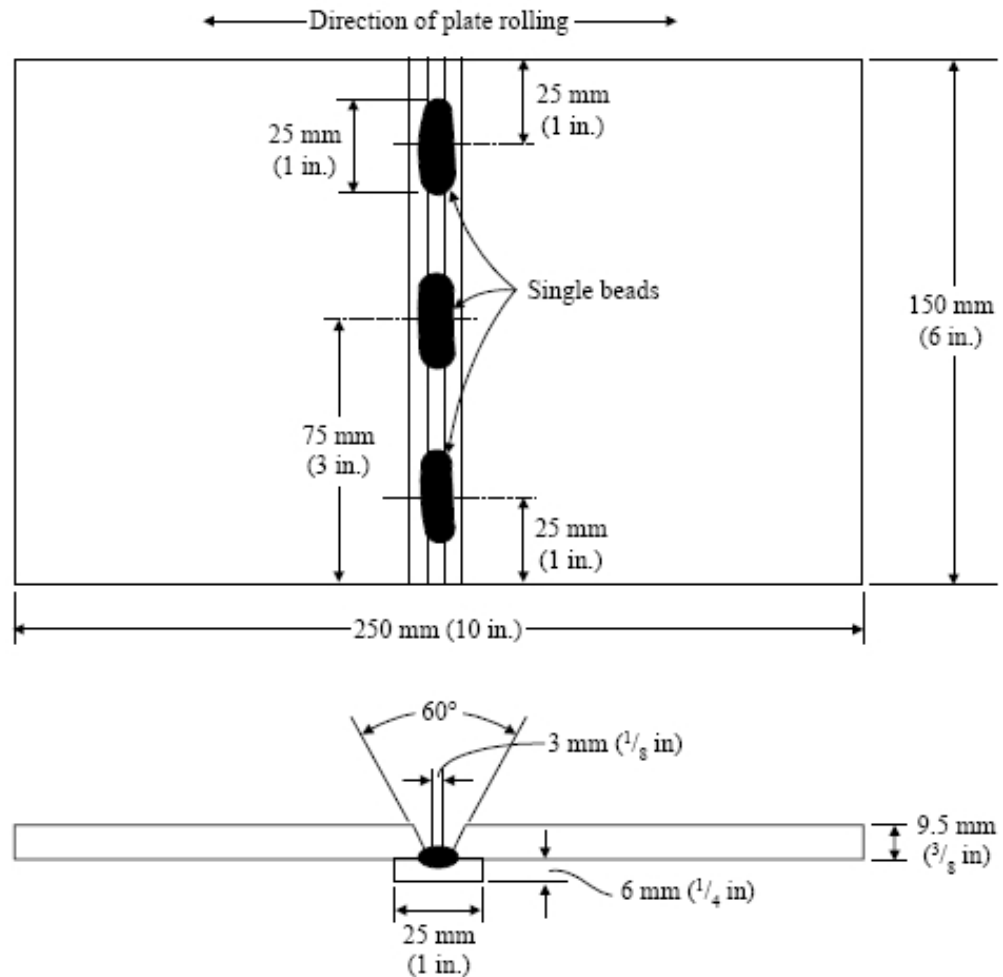
Use 150 mm (6 in.) piping (min.)

*Notes:*

- 1 Each pass of the weld is to be made with the same size electrode that will be used in production and a maximum interpass temperature of 66°C (150°F).
- 2 Machine reinforcement and backing strap flush. Do not remove any undercutting.
- 3 Machining is to be done transverse to weld.
- 4 All specimens are to be machined or sawed from piping.
- 5 Break edges of specimens to a radius of  $t/6$  maximum.
- 6 Mark top and front of piping to insure proper location of specimens.
- 7 Remove face-bend specimens from 45 degree and 225 degree points, and root-bend specimens from 135 degree and 315 degree points, as indicated.
- 8 Welding is to be done from one side only.
- 9 Bend Specimen in Guided Bend Test Jig (2-4-5/17 FIGURE 10 or 2-4-5/17 FIGURE 11).
- 10 Two Root Bends and two Face Bends required.
- 11 For thicknesses over 19.1 mm (3/4 in.),  $t$  is to be a minimum of 1/2 of the thickness to be welded in production.
- 12 For GTA welding, no backing bar need be employed and root opening may be reduced to zero.

**FIGURE 17**  
**Welder Qualification Test No. Q5**

For Tack Welders.



**Notes:**

- 1 Electrode diameter used is to be representative of that used for tack welding in production.
- 2 Backing strap is to be contiguous with plates.
- 3 Joints welded in the vertical position are to be welded upwards.
- 4 Specimen is to be bent in one piece with backing strap in place and face of weld in tension.
- 5 Weld fractures are to exhibit no unfused areas on backing strap or sides of groove throughout length of each tack.
- 6 For GTA welding, no backing bar need be employed and root opening may be reduced to zero.

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General.....</b>	<b>414</b>
	1	Testing and Inspection.....	414
	1.1	General (2014).....	414
	1.3	Witnessed Tests.....	414
	1.5	Rejection of Previously Accepted Material.....	415
	1.7	Calibrated Testing Machines.....	415
	1.9	Referenced Documents (2011).....	415
	3	Defects.....	415
	5	Manufacturer’s Certificates.....	416
	5.1	Form of Certificate (2014).....	416
	5.3	Other Certificates.....	416
	5.5	Dual Certification.....	416
	5.7	Electronic Certification System (2011).....	416
	7	Identification Markings.....	417
	7.1	Marine Grades.....	417
	7.3	Material Identification (2011).....	417
	7.5	Stenciled Material.....	417
<b>SECTION</b>	<b>2</b>	<b>Standard Test Methods.....</b>	<b>418</b>
	1	General (2011).....	418
	1.1	Chemical Analysis.....	418
	1.3	Tension Testing.....	418
	1.5	Shear Testing.....	418
	1.7	Hardness Testing*.....	418
	1.9	Electrical Conductivity Testing*.....	418
<b>SECTION</b>	<b>3</b>	<b>Chemical Composition.....</b>	<b>419</b>
	1	General.....	419
	3	Sampling.....	419
	5	Definition of an Inspection Lot.....	419



	TABLE 1	Chemical Composition Limits of Wrought Aluminum Alloys (2013).....	419
	TABLE 2	Chemical Composition Limits of Cast Aluminum Alloys.....	420
<b>SECTION</b>	<b>4</b>	<b>Heat Treatment.....</b>	<b>421</b>
<b>SECTION</b>	<b>5</b>	<b>Tensile Properties.....</b>	<b>422</b>
	1	General.....	422
	3	Yield Strength.....	422
	5	Standard Test Specimens.....	422
	5.1	General (2011).....	422
	5.3	Full-Section Specimens.....	422
	5.5	Machined Specimens.....	422
	5.7	Dimensions.....	423
	5.9	Test Specimens Orientation and Location (2011).....	424
	7	Retests.....	424
	7.1	Defective Test specimen.....	424
	7.3	Failure to Meet Requirements (2012).....	424
	TABLE 1A	Mechanical Property Limits of Non-Heat-Treatable Sheet and Plate Aluminum Alloys <sup>(2,3)</sup> (2014).....	425
	TABLE 1B	Mechanical Property Limits of Non-Heat-Treatable Marine Grade Sheet and Plate Aluminum Alloys for Hull Construction <sup>(2, 3, 4)</sup> .....	427
	TABLE 2	Long Transverse Mechanical Property Limits of Heat-Treatable Sheet and Plate Aluminum Alloys <sup>(2, 6)</sup> (2011).....	428
	TABLE 3	Longitudinal Mechanical Property Limits of Non-Heat-Treatable Aluminum Alloys for Extruded Bars, Rods, Shapes, and Tubes <sup>(2, 3)</sup> (2011).....	429
	TABLE 4	Mechanical Property Limits of Heat-Treatable Aluminum Alloys for Extruded Products <sup>(2,6)</sup> (2011).....	430
	TABLE 5	Mechanical Property Limits for Die Forgings <sup>(3)</sup> (2011).....	431
	TABLE 6	Mechanical Property Limits for Hand Forgings <sup>(2, 3)</sup> (2011)..	431
	TABLE 7	Mechanical Property Limits for Aluminum Alloy Castings (2011).....	432
	TABLE 8	Cross Reference of Active International Designations with Former Wrought Alloy Designations (2016).....	432
	FIGURE 1	Standard Tension Test Specimen.....	423
<b>SECTION</b>	<b>6</b>	<b>Corrosion Testing.....</b>	<b>434</b>
	1	General (2016).....	434
	3	Reference Photomicrograph (2016).....	434
	5	Batch Microstructural Analysis and Acceptance (2016).....	434
	7	Surveillance of Corrosion Testing (2011).....	435

<b>SECTION</b>	<b>7</b>	<b>Sheet, Plate and Rolled Products.....</b>	<b>436</b>
	1	Scope.....	436
	3	Selection of Tension Test Specimen (2011).....	436
	5	Number of Tension Tests.....	436
	5.1	Sheet.....	436
	5.3	Plate and Rolled Products.....	436
	5.5	Definition of a Batch.....	437
	7	Surface Finish (2014).....	437
	9	Nondestructive Examination (NDE).....	437
	11	Dimensions and Tolerance.....	437
		TABLE 1 Under-thickness Tolerance for Rolled Products (2018).....	437
<b>SECTION</b>	<b>8</b>	<b>Extrusions.....</b>	<b>438</b>
	1	Scope.....	438
	3	Selection of Specimens.....	438
	5	Number of Tests.....	438
	5.1	Tension Tests.....	438
	5.3	Drift Expansion Tests.....	438
	5.5	Definition of a Batch.....	440
	7	Surface Finish (2014).....	440
	9	Nondestructive Examination (NDE).....	440
	11	Dimensions and Tolerance.....	440
		FIGURE 1 Drift Expansion Test.....	439
<b>SECTION</b>	<b>9</b>	<b>Forgings.....</b>	<b>441</b>
	1	Scope .....	441
	3	Selection of Specimens.....	441
	3.1	Location of Specimens.....	441
	3.3	Small Forgings.....	441
	3.5	Test Specimens.....	442
	5	Number of Tests.....	442
	5.1	Large Forgings.....	442
	5.3	Intermediate sized Forgings.....	442
	5.5	Small Forgings.....	442
	5.7	Special Situations.....	442
	5.9	Retests.....	442
	7	Inspection.....	442
	9	Nondestructive Examination (NDE).....	442
	11	Dimensions and Tolerance.....	442
<b>SECTION</b>	<b>10</b>	<b>Castings.....</b>	<b>443</b>

1	Scope (2013).....	443
3	Selection of Specimens.....	443
3.1	Large Castings.....	443
3.3	Small Castings.....	443
3.5	Test Specimens.....	443
5	Number of Tests.....	444
7	Inspection.....	444
9	Welded Repair of Defects.....	444
11	Nondestructive Examination (NDE).....	444
13	Dimensions and Tolerance.....	444
<b>SECTION 11</b>	<b>Rivets.....</b>	<b>445</b>
1	General.....	445
<b>APPENDIX 1</b>	<b>Aluminum/Steel Bi-material Transition Joints (2015).....</b>	<b>446</b>
1	Scope.....	446
3	Supplementary Requirements .....	446
3.1	Reference Documents.....	446
3.3	Process of Manufacture.....	446
3.5	Tensile Strength.....	446
3.7	Bend Test.....	447
3.9	Shear Test.....	447
3.11	Axial Fatigue Strength Test.....	447
3.13	Welded Tensile Test.....	447
3.15	Nondestructive Examination.....	448
3.17	Dimensional Tolerances.....	448
3.19	Sampling Lots.....	448
3.21	Test Sampling.....	448
3.23	Retest Sampling.....	449
3.25	First Article Inspection.....	449
3.27	Ordering Data.....	449
TABLE 1	Fatigue Test Conditions and Requirements (2015).....	447
TABLE 2	Production Lot Testing (2015).....	448
TABLE 3	First Article Testing (2015).....	449
FIGURE 1	Ram Tensile Test Setup (2015).....	450
FIGURE 2	Ram Tensile Specimen (2015).....	451
FIGURE 3	Weld Tensile Test Assembly (2015).....	451
<b>APPENDIX 2</b>	<b>Dissimilar Materials (2015).....</b>	<b>453</b>
1	Material.....	453
1.1	Dissimilar Materials.....	453

**APPENDIX 3 List of Destructive and Nondestructive Tests Required for  
Materials and Responsibility for Verifying (2017)..... 454**

## **1 Testing and Inspection**

### **1.1 General (2014)**

All materials subject to test and inspection, intended for use in the construction of the hulls of craft classed or proposed for classification, are to be tested by the material producer and inspected by the ABS Surveyor in accordance with the following requirements or their equivalent. These requirements are not applicable to the use of aluminum alloys at low temperature for cryogenic applications. Materials, test specimens and mechanical testing procedures having characteristics differing from those prescribed herein may be approved for application, with due regard being given to established practices in the country in which the material is produced and the purpose for which the material is intended, such as the parts for which it is to be used, the type of craft and intended service, and the nature of the construction of the craft. The requirements are based on both metric and U.S. customary units. Each system of units is to be treated as separate and independent from the other. Mixing and matching of units from one system to another are not permitted. The numerical designation (grade) of aluminum alloys and the temper designation are based on those of the Aluminum Association or recognized Standards.

Consideration may be given to aluminum alloys not specified in these requirements, and to alternative temper conditions, subject to prior agreement with ABS further to a detailed study of their properties, including corrosion resistance, and of their conditions of use (in particular welding procedures).

All materials, including semi-finished products are to be manufactured at works which are approved by ABS for the grades and maximum thickness of aluminum alloy supplied.

### **1.3 Witnessed Tests**

All tests are to be carried out by competent personnel and conducted in the presence of the Surveyors at the place of manufacture prior to shipping. Consideration will be given to the acceptance of rolled and extruded products without witnessing of mechanical tests by the Surveyor, on the basis of compliance with ABS's Quality Assurance Program. Testing procedures are to follow established practices in international or national Standards. Test samples are to be taken from material which has undergone the same treatment as the material to be certified. Preparation of specimens is not to involve significant straining or heating. Thermally cut samples are to have excess material to allow a specimen to be machined from material that is unaffected by the cutting process.

### 1.5 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory in the process of being worked, it shall be rejected, notwithstanding any previous certificate of satisfactory testing.

### 1.7 Calibrated Testing Machines

All testing machines shall be maintained in good condition by the manufacturer and to the satisfaction of the attending Surveyor. The measuring equipment and machinery used shall be periodically calibrated by the manufacturer in accordance with ISO standards or any other recognized national/international standards requirements. The validity of calibration certificates shall be verified by the Surveyor before witnessing tests.

### 1.9 Referenced Documents (2011)

The following documents form a part of the overall specification to the extent they are referenced in this ABS Rules document:

ANSI H35.1	Alloy and Temper Designation Systems for Aluminum
ASTM B928/928M	Standard Specification for High Magnesium Aluminum-Alloy sheet and plate for marine Service.
ASTM B221/221M	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B247/247M	Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings
ASTM B316/316M	Standard Specification for Aluminum and Aluminum – Alloy Rivet and Cold-Heading Wire and Rods
ASTM B209/209M	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B26/26M	Standard Specification for Aluminum-Alloy Sand Castings
ASTM B108	Standard Specification for Aluminum-Alloy Permanent Castings
ASTM B918	Standard Practice for Heat Treatment of Wrought Aluminum Alloys
ASTM E34	Test methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys
ASTM E1251	Test Method for optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by Argon Atmosphere, point-to-plane, unipolar self-initiating Capacitor Discharge.
ASTM E8/8M	Standard Test methods for Tension Testing of Metallic Materials
ASTM B557/557M	Standard Test Methods of Tension Testing Wrought and Cast Aluminum – and Magnesium-Alloy Products
ASTM B565	Method for Shear Testing of Aluminum and Aluminum – Alloy Rivet and Cold-Heading Wire and Rods
AWS D1.2/D1.2M	Structural Welding Code – Aluminum
IACS UR W25	Materials and Welding – Aluminum Alloys for Hull Construction and Marine Structure
IACS UR W26	Materials and Welding – Requirements for Welding Consumables for Aluminum Alloys

## 3 Defects

All materials and weldments are to be generally free from linear, planar and volumetric physical defects such as embedded and through thickness flaws, laminations and injurious surface flaws or similar forms of defects that would be detrimental to the use of the materials and weldments in the intended applications. Welding or dressing for the purpose of remedying defects is not permitted unless and until sanctioned by the Surveyor. Discoloration characteristic of proper heat treatment schedules is not cause for rejection.

## 5 Manufacturer's Certificates

### 5.1 Form of Certificate (2014)

Four copies of the mill certificates or the shipping statements of all accepted plate and shape materials indicating the aluminum alloy and temper, the purchaser and order number, the construction project number (if available), the product quantity, dimension and weight, the chemical composition, the batch number (or identifying mark) and mechanical and corrosion test results as applicable, are to be furnished to the Surveyor for his approval; one is to be forwarded to the purchaser, three are to be retained for the use of ABS.

Before the mill certificates or shipping statements are distributed by the local ABS office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been sampled, tested and inspected in accordance with these Rules and that it has met the requirements. The following form of certificate will be accepted if printed on each mill sheet or shipping statement with the name of the firm and initialed by the authorized representative of the manufacturer:

“We hereby certify that the material described herein has been made to the applicable specifications of alloy \_\_\_\_\_; temper \_\_\_\_\_, and the required samples tested in accordance with the requirements of \_\_\_\_\_ (The American Bureau of Shipping Rules or state other specification) in the presence of a Surveyor from the American Bureau of Shipping with satisfactory results.”

At the request of manufacturers, consideration may be given to modifications to the form of certificate, provided it correspondingly indicates compliance with the requirements of these Rules to no less degree than indicated in the foregoing statement.

### 5.3 Other Certificates

Where an aluminum alloy ingot is not produced in the plant where it is rolled, extruded or forged, a certified report is to be supplied to the Surveyor stating the name of the manufacturer, the alloy, ingot or manufacturing and inspection lot identification numbers and certification that the alloy meets the required chemical composition limits.

### 5.5 Dual Certification

Dual certification of aluminum alloys is permitted only when alloy designations involved meet the specified chemical composition and specified minimum mechanical property requirements; provided they have the same ANSI temper designations in order to avoid any differences that may arise in welding and marine corrosion characteristics of the alloys with differing temper designations.

### 5.7 Electronic Certification System (2011)

An electronic certification system may be used to issue certified mill test reports, which may be electronically signed and stamped by an attending Surveyor, subject to the following conditions.

- All relevant information regarding the customer order, including the electronic certification request, is to be provided to the attending Surveyor by the manufacturer.
- Procedures are to be established to control handling and distribution of certified mill test reports among the manufacturer, ABS, and the purchaser.
- In order to implement the electronic certification system, the manufacturer is to be under mandatory ABS-QA program.

## 7 Identification Markings

### 7.1 Marine Grades

Aluminum alloys with ability to resist intergranular and exfoliation forms of corrosion when in direct contact with seawater or when used in marine environment conditions shall be treated as marine grades. Aluminum alloys with magnesium content greater than or equal to 3% are prone to these forms of corrosion and shall be tested, inspected and certified in accordance with ASTM B928 specification by the manufacturer. The acceptance criteria for corrosion tests (ASTM G66 and G67) are to follow ABS Rule requirements. The test results shall be reported on the mill certificates and are to be verified by the Surveyor. The alloy grade shall be suffixed with the letters “MG” while marking as indicated in 2-5-1/7.3.

### 7.3 Material Identification (2011)

All materials which have been sampled, tested and have successfully passed the requirements and have been approved by the Surveyor are to be clearly ink marked or stamped with the manufacturer’s name or trademark and material identification on each finished sheet, plate, shape, bar, rod casing or forging to signify that the material has satisfactorily complied with the tests prescribed. The material identification is to include:

- i) The initials **AB**.
- ii) The aluminum alloy designation according to the Aluminum Association.
- iii) The temper designation according to the Aluminum Association.
- iv) The manufacturers batch number.
- v) The letter “MG” is to be added after the grade and temper designation only if the material has been corrosion tested as per requirements of 2-5-6 of these Rules and ASTM B928. Example: AB/5083 H321 MG.

### 7.5 Stenciled Material

In special cases, when approved, strapped or secured lifts or bundles of light sheet, plates, shapes, bars, rods or tubes of comparatively small size may be marked or stenciled on only the top piece or the marking may be shown on the tag attached to each lift or bundle.



**1 General (2011)**

The latest issue of the following test methods or specifications or their equivalents are considered acceptable:

**1.1 Chemical Analysis**

The chemical analyses are to be carried out in accordance with ASTM E34 or ASTM E716 or ASTM E1251 or equivalent, as may be appropriate to a specific alloy under testing and consideration for certification. The sampling practice for chemical analyses is to be carried out as indicated in 2-5-3/3 and may follow a recognized standard to the extent as may be modified or stated in this document.

**1.3 Tension Testing**

Refer to Section 2-5-5 for requirements for test specimens.

Alternative Standards ASTM E 8/8M or ASTM B557/557M or equivalent may be used.

**1.5 Shear Testing**

Shear tests are to be carried out in accordance with ASTM B769 or ASTM B565 or equivalent.

**1.7 Hardness Testing\***

Hardness tests, if applicable, are to be carried out in accordance with ASTM E18 or equivalent.

**1.9 Electrical Conductivity Testing\***

Electrical Conductivity tests, if applicable, are to be carried out in accordance with ASTM E1004 or equivalent.

**Note:**

\* Hardness and Electrical Conductivity testing are reference only for evaluation of alloys and tempers of heat treatable aluminum products.

**1 General**

The chemical composition of each cast is to be determined by the aluminum manufacturer and is to conform to the applicable requirements of the alloys listed in 2-5-3/Table 1 or 2-5-3/Table 2 or such other requirements as may be specially approved.

**3 Sampling**

A control sample for chemical analysis is to be taken before starting to pour and one additional sample is to be taken during the pouring of each group of ingots poured simultaneously from the same source of molten metal. If not analyzed during pouring samples, it may be taken from semi-finished or finished products. When samples are taken from finished or semi-finished products, one sample is to represent each 1800 kg (4000 lb), or fraction thereof, of each alloy in an inspection lot. The manufacturer's declared analysis will be subject to occasional checks if required by the Surveyor.

Product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

When the aluminum alloys are not cast in the same works in which they are manufactured into semi-finished products, a certificate issued by the works is to be provided to the Surveyor which indicates the reference numbers and chemical composition of the heats.

**5 Definition of an Inspection Lot**

An inspection lot is defined as:

For non-heat treated tempers, an identifiable quantity of material of the same mill form, alloy, temper, section and size submitted for an inspection at one time before shipment. And for heat treated temper an identifiable quantity of material of the same mill form, alloy, temper, section and size traceable to a heat treated lot or lots and submitted for inspection at one time before shipment. Mill forms: sheet and plate, all material of the same thickness is considered to be of the same size.

**TABLE 1**  
**Chemical Composition Limits of Wrought Aluminum Alloys (2013)**

Limits are in weight percent. Single value represents maximum limit, unless shown as a range or indicated as a minimum.

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Others <sup>(1)</sup>		Aluminum
									Each	Total	
5052	0.25	0.40	0.10	0.10	2.2-2.8	0.15-0.35	0.10	–	0.05	0.15	Remainder
5059	0.45	0.50	0.25	0.60-1.2	5.0-6.0	0.25	0.40-0.90	0.20	0.05 <sup>(5)</sup>	0.15 <sup>(5)</sup>	Remainder
5083	0.40	0.40	0.10	0.40-1.0	4.0-4.9	0.05-0.25	0.25	0.15	0.05	0.15	Remainder
5086	0.40	0.50	0.10	0.20-0.7	3.5-4.5	0.05-0.25	0.25	0.15	0.05	0.15	Remainder
5383	0.25	0.25	0.20	0.70-1.0	4.0-5.2	0.25	0.4	0.15	0.05 <sup>(4)</sup>	0.15 <sup>(4)</sup>	Remainder
5454	0.25	0.40	0.10	0.50-1.0	2.4-3.0	0.05-0.20	0.25	0.20	0.05	0.15	Remainder
5456	0.25	0.40	0.10	0.50-1.0	4.7-5.5	0.05-0.20	0.25	0.20	0.05	0.15	Remainder
5754	0.40	0.40	0.10	0.50 <sup>(2)</sup>	2.6-3.6	0.30 <sup>(2)</sup>	0.20	0.15	0.05	0.15	Remainder
6005 A	0.50-0.9	0.35	0.30	0.50 <sup>(3)</sup>	0.4-0.7	0.30 <sup>(3)</sup>	0.20	0.10	0.05	0.15	Remainder
6061	0.40-0.8	0.70	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25	0.15	0.05	0.15	Remainder
6063	0.20-0.6	0.35	0.10	0.10	0.45-0.9	0.10	0.10	0.10	0.05	0.15	Remainder
6082	0.70-1.3	0.50	0.10	0.40-1.0	0.6-1.2	0.25	0.20	0.10	0.05	0.15	Remainder

**Notes:**

- (2011) The term 'Others' includes any other element(s) for which no specific limit is shown in the above table. Other element(s), if added intentionally or analyzed by the alloy producer or specified by the purchaser, are to be reported and not to exceed the limit as given in the 'Others' column.
- Mn + Cr : 0.10 – 0.60
- Mn + Cr : 0.12 – 0.50
- Zr: maximum 0.20. The total for other elements does not include Zirconium.
- Zr: 0.05-0.25. The total for other elements does not include Zirconium.

**TABLE 2**  
**Chemical Composition Limits of Cast Aluminum Alloys**

AA Aluminum Association

Limits are in weight percent. Single value represents maximum limit, unless shown as a range or indicated as a minimum.

AA	Silicon	Iron	Copper	Manganese	Magnesium	Zinc	Titanium	Others		Aluminum
								Each	Total	
356.0	6.5–7.5	0.6 <sup>(1)</sup>	0.25	0.35 <sup>(1)</sup>	0.20–0.45	0.35	0.25	0.05	0.15	Remainder
A356.0	6.5–7.5	0.20	0.20	0.10	0.20–0.45	0.10	0.20	0.05	0.15	Remainder
357.0	6.5–7.5	0.15	0.05	0.03	0.45–0.6	0.05	0.20	0.05	0.15	Remainder

**Note:**

- If the iron content exceeds 0.45%, manganese content shall not be less than one half of the iron.

Alloys 6005A, 6061 and 6082 products are to be suitably **heat** treated to develop the mechanical properties specified in 2-5-5/Tables 2, 4, 5 and 6 for the various tempers. Alternative heat treatments will be specially considered.

- T4 Solution heat treated and then naturally aged.
- T451 For sheet and plate that are stress relieved by stretching after solution heat treatment.
- T4511 For extruded bars, rods or shapes that are stress relieved by stretching after solution heat treatment.
- T5 Cooled from an elevated temperature shaping process and then artificially aged. Usually associated with extruded products.
- T6 Solution heat treated and then artificially aged.
- T651 For sheet and plate that are stress relieved by stretching after solution heat treatment and then artificially aged.
- T6511 For extruded bars, rods or shapes that are stress relieved by stretching after solution heat treatment and then artificially aged.

**1 General**

Tensile properties are to conform to the applicable requirements of the alloys and tempers listed in 2-5-5/ Tables 1 through 7. Mechanical properties for welded joints are lower for strain hardened or heat treated alloys. For as welded properties refer to Section 2-4-5.

**3 Yield Strength**

The yield strength is defined as that determined at 0.2% offset.

**5 Standard Test Specimens****5.1 General (2011)**

Tension test specimens may be the full cross section of the material being tested or they may be machined as indicated for specific product forms. Test specimens in accordance with other recognized standards may be accepted subject to special approval.

**5.3 Full-Section Specimens**

Tension test specimens of the full cross section of the material may be used for wire, rod, bar, shapes and tubular products. It is permissible to reduce the section slightly throughout the section to insure fracture within the gauge marks.

**5.5 Machined Specimens**

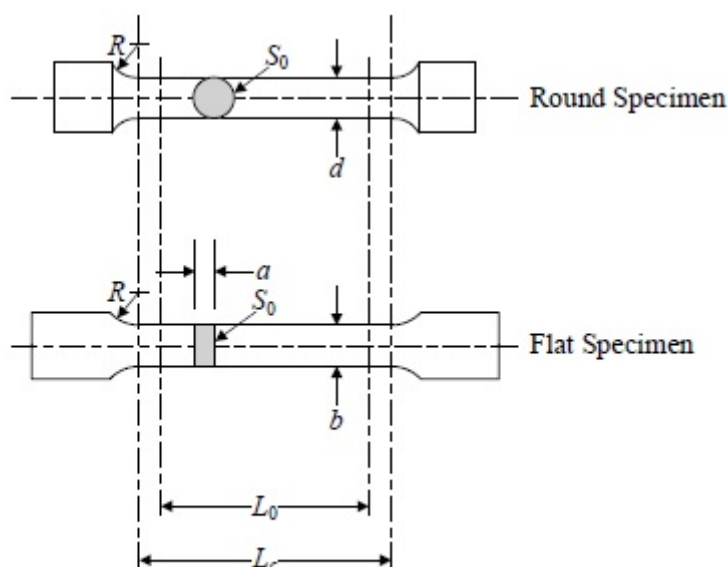
Standard tension test specimens' requirements are indicated in 2-5-5/5.5 FIGURE 1.

The following designations are used:

$d$	=	diameter
$a$	=	thickness
$b$	=	width
$L_0$	=	original gauge length
$L_c$	=	parallel length

- $S_0$  = original cross sectional area
- $R$  = transition radius
- $D$  = external tube diameter
- $t$  = plate thickness

**FIGURE 1**  
**Standard Tension Test Specimen**



## 5.7 Dimensions

Proportional test specimens with a gauge length:

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

can be used or preferably  $5d$  can be used as the gauge length,  $L_0$  should preferably be greater than 20 mm. The gauge length may be rounded off to the nearest 5 mm provided that the difference between this length and  $L_0$  is less than 10% of  $L_0$ .

Flat tensile test specimens shall be used for specified thicknesses up to and including 12.5 mm. The tensile test specimen shall be prepared so that both rolled surfaces are maintained. For thicknesses exceeding 12.5 mm, round tensile test specimens will be used. For thicknesses up to and including 40 mm, the longitudinal axis of the round tensile test specimen shall be located at a distance from the surface equal to half of the thickness. For thicknesses over 40 mm, the longitudinal axis of the round tensile test specimen shall be located at a distance from one of the surfaces equal to one quarter of the thickness.

### 5.7.1 Plates Strips and Sections

Flat specimens are usually to be used with dimensions as specified below

- *Proportional flat specimen*

$$a = t$$

$$b = 25 \text{ mm}$$

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

$$L_c = L_0 + 2\sqrt{S_0}$$

$$R = 25 \text{ mm}$$

- *Non-proportional flat specimen*

$$a = t$$

$$b = 25 \text{ mm}$$

$$L_0 = 200 \text{ mm}$$

$$L_c > 212.5 \text{ mm}$$

$$R = 25 \text{ mm}$$

When the capacity of the available testing machine is insufficient to allow the use of test specimen of full thickness, this may be reduced by machining one of the rolled surfaces.

Alternatively, for materials over 40 mm thick, proportional round test specimens with dimensions as specified below may be used.

- *Round specimen*

$$d \geq 10 \text{ mm to } 20 \text{ mm, preferably } 14 \text{ mm}$$

$$L_0 = 5d$$

$$L_c \geq L_0 + \frac{d}{2}$$

$$R \geq 10 \text{ mm (for materials with a specified elongation less than } 10\%, R \geq 1.5d)$$

The axes of the round test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.

### 5.7.2 Forgings and Castings

Proportional round test specimens with dimensions as specified above in 2-5-5/5.7.1 are usually to be used. For small size bars and similar products the test specimens may consist of a suitable length of bar or other product tested in the full cross-section.

## 5.9 Test Specimens Orientation and Location (2011)

The practice for orientation and location of tension test specimens is to be followed as per ASTM B557/557M or equivalent standard and to the extent as may be modified or stated in this document. The orientation and location of tension test specimens are to be indicated in the test report.

## 7 Retests

### 7.1 Defective Test specimen

If the percentage elongation of a tension test specimen is less than that specified, and if any part of the fracture is outside of the middle half of the gauge length or in a punched or scribed mark within the reduced section, another test specimen may be selected.

### 7.3 Failure to Meet Requirements (2012)

If any tension test specimen selected in accordance with 2-5-7/5, 2-5-8/5 or 2-5-9/5 fails to conform to the requirements, two additional specimens, for each specimen that failed, may be selected from the area that

is adjacent to the area represented by the failure or failures. In the case of separately cast test specimens, for each specimen that failed, two additional cast specimens from the same batch may be selected for retest. If both of these additional tests are satisfactory, the remaining piece and/or the remaining material from the same batch may be accepted.

If one or both of the additional tests referred to above are unsatisfactory, the piece is to be rejected. If the rejected piece is from a batch, the remaining material from the same batch may be accepted provided that two of the remaining pieces in the batch are tested and conform to the requirements. If tension test specimens from either of these two pieces fail to conform to the requirements, the whole batch of material is to be rejected.

If the failure to conform to the requirements is the result of an inadequate thermal treatment, additional aging treatment, as applicable to the material, may be permitted at the discretion of the attending ABS Surveyor. However, no re-solution heat treatment of the alloys and tempers listed in this section is allowed.

In the event of material failing to comply with the test requirements the Classification brand stamp is to be unmistakably defaced by the manufacturer.

**TABLE 1A**  
**Mechanical Property Limits of Non-Heat-Treatable Sheet and Plate Aluminum**  
**Alloys <sup>(2,3)</sup> (2014)**

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	Thickness <sup>(1)</sup>		Ultimate Tensile Strength N/mm <sup>2</sup> (ksi)		Yield Strength 0.2% Offset N/mm <sup>2</sup> (ksi)		Minimum Elongation Percent in		
	millimeters over-through	(inches)	minimum	maximum	minimum	maximum	5d mm	5d	2 in. /4d
5052-O	3.0–6.3	(0.118–0.249)	170 (25.0)	215 (31.0)	65 (9.5)		19	-	20
	6.3–80.0	(0.250–3.000)	170 (25.0)	215 (31.0)	65 (9.5)		18	16	18
5052-H32 <sup>(4)</sup>	3.0–6.3	(0.118–0.249)	215 (31.0)	265 (38.0)	160 (23.0)		7	-	9
	6.3–12.5	(0.250–0.499)	215 (31.0)	265 (38.0)	160 (23.0)		11	-	11
	12.5–50.0	(0.500–2.000)	215 (31.0)	265 (38.0)	160 (23.0)		11	10	12
5052-H34 <sup>(4)</sup>	3.0–6.3	(0.118–0.249)	235 (34.0)	285 (41.0)	180 (26.0)		6	-	7
	6.3–25.0	(0.250–1.000)	235 (34.0)	285 (41.0)	180 (26.0)		10	9	10
5052-H112	6.3–12.5	(0.250–0.499)	190 (28.0)		110 (16.0)		7	-	7
	12.5–40.0	(0.500–2.000)	190 (28.0)		65 (9.5)		-	10	12
	40.0–80.0	(2.001–3.000)	190 (28.0)		65 (9.5)		-	14	16
5059-O	3.0–20.0	(0.118–0.787)	330 (48.0)		160 (23.0)		24	24	24
	20.0–40.0	(0.788–1.575)	330 (48.0)		160 (23.0)		-	20	20
	40.0–50.0	(1.576–2.000)	300 (44.0)		145 (21.0)		-	17	17
5059-H111	3.0–20.0	(0.118–0.787)	330 (48.0)		160 (23.0)		24	24	24
	20.0–40.0	(0.788–1.575)	330 (48.0)		160 (23.0)		-	20	20
5083-O	3.0–50.0	(0.118–2.000)	275 (40.0)	350 (51.0)	125 (18.0)	200 (29.0)	16	14	16
5083-H111	3.0–50.0	(0.118–2.000)	275 (40.0)	350 (51.0)	125 (18.0)	200 (29.0)	16	14	16
5083-H112	3.0–40.0	(0.250–1.500)	275 (40.0)		125 (18.0)		12	10	12
	40.0–50.0	(1.501–2.000)	270 (39.0)		115 (17.0)		-	10	12



Alloy and Temper	Thickness <sup>(1)</sup>		Ultimate Tensile Strength N/mm <sup>2</sup> (ksi)		Yield Strength 0.2% Offset N/mm <sup>2</sup> (ksi)		Minimum Elongation Percent in		
	millimeters over-through	(inches)	minimum	maximum	minimum	maximum	50 mm	5d	2 in. /4d
5086-O	3.0-6.3	(0.118–0.249)	240 (35.0)	305(44.0)	95.0		18	-	18
	6.3-50.0	(0.250–2.000)	240 (35.0)	305 (44.0)	(14.0) 95.0 (14.0)		16	14	16
5086-H111	3.0-6.3	(0.118–0.249)	240 (35.0)	305(44.0)	95.0		18	-	18
	6.3-50.0	(0.250–2.000)	240 (35.0)	305 (44.0)	(14.0) 95.0 (14.0)		16	14	16
5086-H112	3.0-12.5	(0.118–0.499)	250 (36.0)		125 (18.0)		8	-	8
	12.5-40.0	(0.500–1.000)	240 (35.0)		105 (16.0)		-	9	10
	40.0-80.0	(1.001-2.000)	235 (35.0)		95 (14.0)		-	12	14
5383-O	3.0–50	(0.118–2.000)	290 (42.0)		145 (21.0)		-	17	17
5383-H111	3.0–50	(0.118–2.000)	290 (42.0)		145 (21.0)		-	17	17
5454-O	3.0–6.3	(0.118–0.249)	215 (31.0)	285 (41.0)	85 (12.0)		16	-	18
	6.3-80.0	(0.250–3.000)	215 (31.0)	285 (41.0)	85 (12.0)		18	16	18
5454-H32 <sup>(4,5)</sup>	3.0-6.3	(0.118–0.249)	250 (36.0)	305 (44.0)	180 (26.0)		8	-	8
	6.3-50.0	(0.250–2.000)	250 (36.0)	305 (44.0)	180 (26.0)		12	10	12
5454-H34 <sup>(4,5)</sup>	3.0-4.0	(0.118–0.161)	270 (39.0)	325 (47.0)	200 (29.0)		6	-	6
	4.0-6.3	(0.162–0.249)	270 (39.0)	325 (47.0)	200 (29.0)		6	-	7
	6.3-25.0	(0.249–1.000)	270 (39.0)	325 (47.0)	200 (29.0)		10	9	10
5454-H112 <sup>(5)</sup>	6.3–12.5	(0.250–0.499)	220 (32.0)		125 (18.0)		8	-	8
	12.5-40.0	(0.500–2.000)	215 (31.0)		85 (12.0)		-	9	11
	40.0-80.0	(2.001–3.000)	215 (31.0)		85 (12.0)		-	13	15
5456-O	3.0-6.3	(0.118–1.500)	290 (42.0)	365 (53.0)	130 (19.0)	205 (30.0)	16	-	16
	6.3-80.0	(1.501–3.000)	285 (41.0)	360 (52.0)	125 (18.0)	205 (30.0)	16	14	16
5456-H112	6.3-40.0	(0.250–1.500)	290 (42.0)		130 (19.0)		12	10	12
	40.1-80.0	(1.501–3.000)	285 (41.0)		125 (18.0)		-	10	12
5754-O	3.0-12.5	(0.118–0.138)	200 (29.0)	270 (39.0)	80 (12.0)		19	-	19
	12.6-50.0	(0.139-2.000)	190 (27.5)	240 (34.8)	80 (12.0)		18	17	18
5754-H111	3.0-12.5	(0.118–0.138)	200 (29.0)	270 (39.0)	80 (12.0)		19	-	19
	12.6-50.0	(0.139-2.000)	190 (27.5)	240 (34.8)	80 (12.0)		18	17	18

Notes:

- 1 Type of test specimen used depends on thickness of material: (See 2-5-5/5.)
- 2 (2011) Values applicable to longitudinal test specimens.
- 3 (2011) Use of the latest ASTM B209/209M specification may be approved upon application.
- 4 (2011) For the corresponding H2x temper, the maximum tensile strength and minimum yield strength do not apply.
- 5 (2013) 5454 is recommended for service applications where exposed to temperatures exceeding 65°C (150°F).
- 6 (2014) The mechanical properties for the O and H111 tempers are the same. However, they are separated to discourage dual certification as these tempers represent different processing.

**TABLE 1B**  
**Mechanical Property Limits of Non-Heat-Treatable Marine Grade Sheet and Plate Aluminum Alloys for Hull Construction** <sup>(2, 3, 4)</sup> (2021)

Alloy and Temper	Thickness <sup>(1)</sup>		Ultimate Tensile Strength N/mm <sup>2</sup> (ksi)		Yield Strength 0.2% Offset N/mm <sup>2</sup> (ksi)		Minimum Elongation Percent in		
	millimeters over-through	(inches)	minimum	maximum	minimum	maximum	50 mm	5d	2 in. /4d
5059-H116	3.0-20.0	(0.118-0.787)	370 (54.0)	440 (64.0)	270 (39.0)		10	10	10
	20.0-40.0	(0.788-1.575)	360 (52.0)	440 (64.0)	260 (38.0)		-	10	10
5059-H321	3.0-20.0	(0.118-0.787)	370 (54.0)	440 (64.0)	270 (39.0)		10	10	10
	20.0-40.0	(0.788-1.575)	360 (52.0)	440 (64.0)	260 (38.0)		-	10	10
5083-H116	3.0-12.5	(0.118-0.499)	305 (44.0)	385 (56.0)	215 (31.0)		10	-	10
	12.5-40.0	(0.500-1.500)	305 (44.0)	385 (56.0)	215 (31.0)		-	10	12
	40.0-80.0	(1.501-3.000)	285 (41.0)	385 (56.0)	200 (29.0)		-	10	12
5083-H321	3.2-5.0	(0.125-0.187)	305 (44.0)	385 (56.0)	215 (31.0)		10	-	10
	5.0-12.5	(0.188-0.499)	305 (44.0)	385 (56.0)	215 (31.0)		12	-	12
	12.5-40.0	(0.500-1.500)	305 (44.0)	385 (56.0)	215 (31.0)		-	10	12
	40.0-80.0	(1.501-3.000)	285 (41.0)	385 (56.0)	200 (29.0)		-	10	12
5083-H323	3.2-6.4	1/8-1/4	310 (45.0)		230 (34.0)	-	10	-	-
5083-H343	3.2-6.4	1/8-1/4	340 (50.0)		270 (39.0)	-	10	-	-
5083-H128 <sup>(5)</sup>	4.0-12.5	(0.157-0.499)	305 (44.0)	385 (56.0)	215 (31.0)		10	-	10
	12.5-40.0	(0.500-1.500)	305 (44.0)	385 (56.0)	215 (31.0)		-	10	12
	40.0-80.0	(1.501-3.000)	285 (41.0)	385 (56.0)	200 (29.0)		-	10	12
5086-H116	3.0-6.3	(0.118-0.249)	275 (40.0)	360 (52.0)	195 (28.0)		8	-	8
	6.3-50.0	(0.250-2.000)	275 (40.0)	360 (52.0)	195 (28.0)		10	9	10
5086-H321	3.0-6.3	(0.118-0.249)	275 (40.0)	360 (52.0)	195 (28.0)		8	-	8
	6.3-8.0	(0.250-0.320)	275 (40.0)	360 (52.0)	195 (28.0)		9	-	9
5383-H116	3.0-50	(0.118-2.000)	330 (48.0)	400 (58.0)	230 (33.0)		10	10	10
5383-H321	3.0-50	(0.118-2.000)	330 (48.0)	400 (58.0)	230 (33.0)		10	10	10

Alloy and Temper	Thickness <sup>(1)</sup>		Ultimate Tensile Strength N/mm <sup>2</sup> (ksi)		Yield Strength 0.2% Offset N/mm <sup>2</sup> (ksi)		Minimum Elongation Percent in		
	millimeters over-through	(inches)	minimum	maximum	minimum	maximum	50 mm	5d	2 in. /4d
5456-H116	3.0–12.5	(0.118–0.499)	315 (46.0)	405 (59.0)	230 (33.0)		10	-	10
	12.5–30.0	(0.500–1.250)	315 (46.0)	385 (56.0)	230 (33.0)		-	10	12
	30.0–40.0	(1.251–1.500)	305 (44.0)	385 (56.0)	215 (31.0)		-	10	12
	40.0–80.0	(1.501–3.000)	285 (41.0)	370 (54.0)	200 (29.0)		-	10	12
5456-H321	3.0–4.0	(0.118–0.187)	330 (48.0)	405 (59.0)	235 (34.0)		10	-	10
	4.0–12.5	(0.188–0.499)	315 (46.0)	405 (59.0)	230 (33.0)		12	-	12
	12.5–40.0	(0.500–1.500)	305 (44.0)	385 (56.0)	215 (31.0)		-	10	12
	40.0–80.0	(1.501–3.000)	285 (41.0)	370 (54.0)	200 (29.0)		-	10	12

Notes:

- 1 Type of test specimen used depends on thickness of material: (See 2-5-5/5.)
- 2 (2011) Values applicable to longitudinal test specimens.
- 3 (2011) Marine Grade sheet and plate as shown in 2-5-5/7.3 TABLE 1B are to be capable of passing an appropriate test for resistance to exfoliation and intergranular corrosion. Refer to Section 2-5-6 for full details of corrosion test requirements.
- 4 (2013) Use of the latest ASTM B 928/928M specification may be approved upon application.
- 5 The properties for Grade 5083 H128 are indicated as tentative in ASTM B 928/928M-15 and as such may be subject to revision.

**TABLE 2**  
**Long Transverse Mechanical Property Limits of Heat-Treatable Sheet and Plate**  
**Aluminum Alloys <sup>(2, 6)</sup>(2011)**

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	Type	Thickness <sup>(1)</sup>		Minimum Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in		
		millimeters over - through	(inches)	N/mm <sup>2</sup> (ksi)	N/mm <sup>2</sup> (ksi)	4d	5d	2 in. /4d
6061-T4	Sheet	3.0-6.3	(0.118–0.249)	205 (30.0)	110 (16.0)	16	-	16
6061-T451 <sup>(4,5)</sup>	Plate	6.3–25.0	(0.250–1.000)	205 (30.0)	110 (16.0)	18	16	18
		25.0–80.0	(1.001–3.000)	205 (30.0)	110 (16.0)	-	14	16
6061-T6 and T62 <sup>(3)</sup>	Sheet	3.0-6.3	(0.118–0.249)	290 (42.0)	240 (35.0)	10	-	10
6061-T62 <sup>(3)</sup> and -T651 <sup>(4,5)</sup>	Plate	6.3–12.5	(0.250–0.499)	290 (42.0)	240 (35.0)	10	-	10
		12.5–25.0	(0.500–1.000)	290 (42.0)	240 (35.0)	-	8	9
		25.0–50.0	(1.001–2.000)	290 (42.0)	240 (35.0)	-	7	8
		50.0–80.0	(2.001–3.000)	290 (42.0)	240 (35.0)	-	5	6

Notes:

- 1 Type of test specimen used depends on thickness of material; (See 2-5-5/5).
- 2 (2011) Values applicable to long transverse test specimens.
- 3 (2011) These properties apply to samples of material, which are solution heat treated or solution and precipitation treated from O or F temper by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.
- 4 For stress-relieved tempers, characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.
- 5 Upon artificial aging, T451 temper material is to be capable of developing the mechanical properties applicable to the T651 temper.
- 6 (2011) Use of the latest ASTM B209/209M specification may be approved upon application.

**TABLE 3**  
**Longitudinal Mechanical Property Limits of Non-Heat-Treatable Aluminum**  
**Alloys for Extruded Bars, Rods, Shapes, and Tubes <sup>(2, 3)</sup>(2011)**

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	Maximum Diameter or Thickness <sup>(1)</sup>		Maximum Area		Ultimate Tensile Strength N/mm <sup>2</sup> (ksi)		Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in		
	mm	(in.)	mm <sup>2</sup>	(in <sup>2</sup> )	minimum	maximum	N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	4d	5d	2 in. /4 d
5059-H112	50	(2.0)	---	---	330 (48.0)	---	200 (29.0)	-	10	10
5083-O <sup>(4)</sup>						350 (51.0)				
5083-H111 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	270 (39.0)		110 (16.0)	14	12	14
5083-H112 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	275 (40.0)		165 (24.0)	12	10	12
5083-H112 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	270 (39.0)		110 (16.0)	12	10	12
5086-O <sup>(4)</sup>						315 (46.0)				
5086-H111 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	240 (35.0)		95.0 (14.0)	14	12	14
5086-H111 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	250 (36.0)		145 (21.0)	12	10	12
5086-H112 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	240 (35.0)		95.0 (14.0)	12	10	12
5383-O	50	(2.0)	---	---	290 (42.0)	---	145 (21.0)	17	17	17
5383-H111	50	(2.0)	---	---	290 (42.0)		145 (21.0)	17	17	17
5383-H112	50	(2.0)	---	---	310 (45.0)		190 (27.5)	-	13	13
5456-O <sup>(4)</sup>						365 (53.0)				
5456-H111 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	285 (41.0)		130 (19.0)	14	12	14
5456-H111 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	290 (42.0)		180 (26.0)	12	10	12
5456-H112 <sup>(4)</sup>	130.0	(5.0)	20000	(32)	285 (41.0)		130 (19.0)	12	10	12

Notes:

- 1 Type of test specimen used depends on thickness of material; (see 2-5-5/5.)
- 2 (2011) Values applicable to longitudinal test specimens.
- 3 (2011) Use of the latest ASTM B221/221M specification may be approved upon application.
- 4 (2011) Properties not applicable to extruded tube over 70 mm (2.999 inch) wall thickness.

**TABLE 4**  
**Mechanical Property Limits of Heat-Treatable Aluminum Alloys for Extruded Products <sup>(2,6)</sup>(2011)**

Mechanical test specimens are taken as detailed in 2-5-5/5 as specified in ASTM B 557/557M.

Alloy and Temper	Diameter or Thickness <sup>(1)</sup>		Area mm <sup>2</sup> /in <sup>2</sup>	Ultimate Tensile Strength N/mm <sup>2</sup> (ksi)	Yield Strength 0.2% Offset N/mm <sup>2</sup> (ksi)	Minimum Elongation Percent in		
	millimeters over - through	(inches)		minimum	minimum	50 mm	5d	2 in. /4d
6005A-T5	3.0-6.3	(0.118-0.249)	All	260 (38.0)	215 (31.0)	7	-	7
	6.3-50.0	(0.250-2.000)		260 (38.0)	215 (31.0)	9	8	9
6005A-T6	3.0-10.0	(0.118-0.400)	All	260 (38.0)	215 (31.0)	8	-	8
	10.0-50.0	(0.401-2.000)		260 (38.0)	200 (29.0)	8	6	8
6005A-T61	3.0-6.3	(0.118-0.249)	All	260 (38.0)	240 (35.0)	8	-	8
	6.4-25.0	(0.250-0.999)		260 (38.0)	240 (35.0)	10	9	10
6061-T4/T4511 <sup>(4,5)</sup>	All	All	All	180 (26.0)	110 (16.0)	16	14	16
6061-T6 <sup>(4,5)</sup> , -T62 <sup>(3)</sup> and -T6511 <sup>(4,5)</sup>	3.0-6.3	(0.118-0.249)	All	260 (38.0)	240 (35.0)	8	-	8
	6.3 and over	(0.250 and over)		260 (38.0)	240 (35.0)	10	9	10
6063-T6, -T62 <sup>(3)</sup>	3.0-3.2	(0.118-0.124)	All	205 (30.0)	170 (25.0)	8	-	8
	3.2-25.0	(0.125-1.000)		205 (30.0)	170 (25.0)	10	9	10
6082-T5	3.0-50.0	(0.118-2.000)	All	270 (39.0)	230 (33.0)	8	6	8
6082-T6, -T6511	3.0-5.0	(0.118-0.199)	All	290 (42.0)	250 (36.0)	6	-	6
	5.0-50.0	(0.200-2.000)		310 (45.0)	260 (38.0)	10	8	10
	50.0-150.0	(2.001-6.000)		310 (45.0)	260 (38.0)	-	8	8

Notes:

- 1 Type of test specimen used depends on thickness of material; (see 2-5-5/5.)
- 2 (2011) Values applicable to longitudinal test specimens.
- 3 (2011) These properties apply to samples of material, which are solution heat treated or solution and precipitation treated from O or F temper by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.
- 4 For stress-relieved tempers, characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.
- 5 Upon artificial aging, T4 and T4511 temper material are to be capable of developing the mechanical properties applicable to the T6 and T6511 tempers, respectively.
- 6 (2011) Use of the latest ASTM B221/221M specification may be approved upon application.

**TABLE 5**  
**Mechanical Property Limits for Die Forgings<sup>(3)</sup> (2011)**

Alloy and Temper	Thickness	Specimen Axis Parallel to Direction of Grain Flow					Specimen Axis Not Parallel to Direction of Grain Flow				
		Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in <sup>(4)</sup>			Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in <sup>(4)</sup>		
				50 mm	5d	2 in. /4d			50 mm	5d	2 in. /4d
5083-H111	to 100 (4)	290 (42.0)	150 (22.0)	14	12	14	270 (39.0)	140 (20.0)	12	10	12
5083-H112	to 100 (4)	275 (40.0)	125 (18.0)	16	14	16	270 (39.0)	110 (16.0)	14	12	14
5456-H112 <sup>(1)</sup>	to 100 (4)	303 (44.0)	140 (20.0)	16	16	16					
6061-T6	to 100 (4)	260 (38.0)	240 (35.0)	7 <sup>(2)</sup>	6 <sup>(2)</sup>	7 <sup>(2)</sup>	260 (38.0)	240 (35.0)	5	4	5

Notes:

- 1 (2011) Alloy 5456 is not covered in ASTM B247/247M, but use of such forgings meeting these requirements may be considered.
- 2 (2010) When sample is selected from a separately-forged test coupon, an elongation minimum of 10% applies.
- 3 (2011) Use of the latest ASTM B247/247M Specification may be approved upon application.
- 4 (2011) Elongation values apply to test specimens taken from an actual forging or its prolongation.

**TABLE 6**  
**Mechanical Property Limits for Hand Forgings<sup>(2, 3)</sup> (2011)**

Alloy and Temper	Thickness	Axis of Test Specimen	Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in	
	mm (in.)		N/mm <sup>2</sup> (ksi)	N/mm <sup>2</sup> (ksi)	5d	4d
5083-H111	to 100 (4)	Longitudinal	290 (42.0)	150 (22.0)	12	14
		Long transverse	270 (39.0)	140 (20.0)	10	12
5083-H112	to 100 (4)	Longitudinal	275 (40.0)	125 (18.0)	14	16
		Long transverse	270 (39.0)	110 (16.0)	12	14

Alloy and Temper	Thickness	Axis of Test Specimen	Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in	
	mm (in.)		N/mm <sup>2</sup> (ksi)	N/mm <sup>2</sup> (ksi)	5d	4d
5456-H112 <sup>(1)</sup>	to 75 (3)	Longitudinal	305 (44.0)	140 (20.0)	16	16
		Long transverse	290 (42.0)	125 (18.0)	14	14
6061-T6/-T652	to 100 (4)	Longitudinal	260 (38.0)	240 (35.0)	9	10
		Long transverse	260 (38.0)	240 (35.0)	7	8
		Short transverse <sup>(2)</sup>	255 (37.0)	230 (33.0)	4	5
6061-T6/-T652	over 100 (4) to 200 (8)	Longitudinal	255 (37.0)	235 (34.0)	7	8
		Long transverse	255 (37.0)	235 (34.0)	5	6
		Short transverse	240 (35.0)	220 (32.0)	3	4

Notes:

- (2011) Alloy 5456 is not covered in ASTM B247/247M, but use of such forgings meeting these requirements may be considered.
- Requirement applicable to thicknesses of 50 mm (2 in.) and greater.
- (2011) Use of the latest ASTM B247/247M Specification may be approved upon application.

**TABLE 7**  
**Mechanical Property Limits for Aluminum Alloy Castings (2011)**

AA Aluminum Association

Alloy	Temper	Casting	Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.20% Offset	Minimum Elongation in 50 mm (2 in.)
AA			N/mm <sup>2</sup> (ksi)	N/mm <sup>2</sup> (ksi)	percent
356.0	T6	Sand	205 (30.0)	140 (20.0)	3
		Permanent mold	228 (33.3)	152 (22.0)	3
A356.0	T6 T61	Sand	235 (34.0)	165 (24.0)	3.5
			245 (35.0)	180 (26.0)	1.0
A356.0	T-61 Separately cast coupons T-61 Integral coupons	Permanent mold	262 (38.0)	179 (26.0)	5
			230 (33.3)	179 (26.0)	5
357.0	T6	Permanent mold	310 (45.0)		3

**TABLE 8**  
**Cross Reference of Active International Designations with Former Wrought Alloy Designations (2016)**

- |      |   |     |                                 |
|------|---|-----|---------------------------------|
| AA   | Aluminum Association                      | BS  | British Standard                |
| ASTM | American Society for Testing and Material | UNI | Unificazione Nazionale Italiana |
| CSA  | Canadian Standards Association            | JIS | Japanese Industrial Standard    |

NF Normes Francaises  
 ISO International Organization for Standardization  
 GB Chinese National Standard

The chemical composition of wrought aluminum and aluminum alloys is specified in the document International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Aluminum Alloys - Unified North American and International Registration Records, edited by the Aluminum Association (also known as the Teal Sheets). The equivalents shown are former designations and are approximate based on available information.

<i>Active International Designations</i>	<i>Canada CSA</i>	<i>France NF</i>	<i>U.K. BS</i>	<i>Italy UNI</i>	<i>Japan JIS</i>	<i>ISO</i>	<i>China GB/T</i>
5052	GR20		2L, 55, 2L, 56, L80, L81	PA1Mg2.5	A2-1	A1Mg2.5Mn	5A02, 5052
5083	GM41, E54S*		N8		A2-7	A1Mg4.5Mn	5083
5086		AG4MC				A1Mg4	5086
5454	GM31N, 55330*					A1Mg3Mn	5454
5456			N61				
6061	GS11N		H20		A2-4	A1Mg1SiCu	6061

**Note:**

\* Commercial designations.



**1 General (2016)**

Rolled 5xxx-alloys delivered in the H116, H128 and H321 tempers (as listed in 2-5-5/7.3 TABLE 1B) intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance as per requirements of this Section and ASTM B 928/928M. These alloys should not be used for service which provides prolonged exposure (continuous or discontinuous) to temperatures exceeding 65°C (150°F) because of the risk of sensitization and the resulting susceptibility to intergranular corrosion and stress corrosion cracking.

The alloy grades of the 6000 series should not be used in direct contact with seawater unless protected by anodes and/or paint system.

**3 Reference Photomicrograph (2016)**

For 5xxx-alloys delivered in H116 and H321 tempers, the manufacturers shall establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500× [using 40% phosphoric acid etch for 3 minutes at 35°C (50°F)], under the conditions specified in ASTM B928, Section 9.4.1, shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET). The samples shall also have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm<sup>2</sup>, when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by ABS. Production practices shall not be changed after approval of the reference micrographs.

Other recognized test methods may also be accepted at ABS's discretion.

**5 Batch Microstructural Analysis and Acceptance (2016)**

For batch acceptance of 5xxx-alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate may be carried out, provided that surveillance testing as stated in 2-5-6/7 is performed. The microstructure of the sample is to be compared to the reference photomicrograph [taken at 500× after 3 minutes etch in phosphoric acid at 35°C (50°F)] of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination, under the conditions specified in ASTM

B928, Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminum-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation-corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. Acceptance criteria are that the sample shall exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM G66 ASSET test, and the sample shall exhibit resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm<sup>2</sup> (0.0002 lbs/in<sup>2</sup>) when subjected to ASTM G67 NAMLT test. If the results from testing satisfy the acceptance criteria stated in 2-5-6/3 the batch is accepted, else it is to be rejected.

As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 under the conditions specified in ASTM B928, or equivalent standards and accepted if the results satisfy the acceptance criteria stated in 2-5-6/3.

## **7 Surveillance of Corrosion Testing (2011)**

The manufacturer shall perform, each quarter or after any process change, at least one test for exfoliation corrosion resistance and one test for intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards for each approved alloy grade. The manufacturer shall maintain records of all surveillance test results and make them available to the Surveyor for product certification.

**1 Scope**

The following requirements cover non-heat-treatable and heat-treatable aluminum alloys for sheet plate, and rolled products intended to be used in hull construction.

**3 Selection of Tension Test Specimen (2011)**

For rolled products, test samples are taken at one-third of the width from the longitudinal edge. Tension test specimens for non-heat-treatable rolled products are to be taken in the longitudinal direction. For heat-treatable rolled products, generally tests in the long transverse direction are required. If the width is insufficient to obtain long transverse test specimens, and when specified, tests in the longitudinal direction may be permitted. Short transverse testing, when specified, is only applicable to plate having a specified thickness of 40 mm (1.500 in.) or greater. The standard rectangular tension test specimen shown in 2-5-5/5.5 FIGURE 1 is to be used for sheet and plate less than 12.5 mm (0.5 in.) in thickness. For plate 12.5 mm (0.5 in.) and greater in thickness, the round tension test specimen shown in 2-5-5/5.5 FIGURE 1 is to be used. The tension test specimen is to be taken midway between the two plate surfaces for plate in thicknesses of 12.5 mm (0.5 in.) up to 40 mm (1.57 in.). For plate over 40 mm (1.57 in.) in thickness, the specimen shall be taken midway between the center and surface of the plate.

After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

**5 Number of Tension Tests**

Tension test specimens are to be selected as follows.

**5.1 Sheet**

For sheet under 6.3 mm (0.25 in.) in thickness, one tensile test specimen is to be taken from one random sheet representative of 900 kg (2000 pounds) or fraction thereof in each batch.

**5.3 Plate and Rolled Products**

For plate and rolled products 6.3 mm (0.25 in.) and over in thicknesses, one tensile test specimen is to be taken from each batch of the product. If the weight of one batch exceeds 2000 kg (4410 lb), or fraction thereof, one extra tensile test specimen is to be taken from every 2000 kg (4410 lb) or fraction thereof, in each batch.

For single plates or coils weighing more than 2000 kg (4410 lb) each, only one tensile test specimen per plate or coil is to be taken.

### 5.5 Definition of a Batch

The term batch applies to products if they are all:

- The same alloy grade from the same cast;
- The same product form and similar dimensions (for plates, the same thickness);
- Manufactured by the same process, and;
- Submitted simultaneously to the same temper condition.

## 7 Surface Finish (2014)

The material is to be free from injurious defects and have a workmanlike finish. Surface imperfections may be removed by smooth grinding or machining as long as the thickness of the material remains within the tolerances given in 2-5-7/11. It is to be surface inspected at the mill by the surveyors only when specifically requested and so ordered by the purchaser.

## 9 Nondestructive Examination (NDE)

In general NDE of material is not required for acceptance purposes.

However, the manufacturer is expected to employ suitable methods of NDE for maintaining compliance with quality standards.

## 11 Dimensions and Tolerance

It is the Manufacturer’s responsibility to check dimensions and to comply with the following tolerance requirements.

Under-thickness for rolled products are given in 2-5-7/11 TABLE 1. Dimensional tolerances other than under-thickness tolerance are to comply with a recognized national or international standard.

**TABLE 1**  
**Under-thickness Tolerance for Rolled Products (2018)**

<i>Nominal Thickness (t), mm</i>	<i>Thickness Tolerances for Nominal Width (w), mm</i>		
	<i>w ≤ 1500</i>	<i>1500 &lt; w ≤ 2000</i>	<i>2000 &lt; w ≤ 3500</i>
3.0 ≤ t < 4.0	0.10	0.15	0.15
4.0 ≤ t < 8.0	0.20	0.20	0.25
8.0 ≤ t < 12.0	0.25	0.25	0.25
12.0 ≤ t < 20.0	0.35	0.40	0.50
20.0 ≤ t < 50.0	0.45	0.50	0.65

**Note:**

For thicknesses greater than 50.0 mm, tolerances are to be agreed between the purchaser and manufacturer and accepted by ABS.

## **1 Scope**

The following requirements cover extruded non-heat-treatable and heat-treatable aluminum alloy products intended to be used in hull construction.

## **3 Selection of Specimens**

For extruded products tension test specimens are to be taken in the range  $\frac{1}{3}$  to  $\frac{1}{2}$  of the distance from the longitudinal edge to the center of the thickest part.

Tension test specimens are to be taken in the longitudinal direction and are to be of the full section of the material where practicable. Otherwise, the specimens shown in 2-5-5/5.5 FIGURE 1 are to be used. For material 40 mm (1.57 in.) and less in diameter or thickness, the specimen is to be taken from the center of the section. For material greater than 40 mm (1.57 in.) in thickness or diameter the specimen is to be located midway between the center and an edge.

After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation are maintained.

## **5 Number of Tests**

### **5.1 Tension Tests**

For the products with a nominal weight of less than 1 kg/m (0.7 lb/ft), one tensile test specimen is to be taken from each 1000 kg, (2205 lb) or fraction thereof, in each batch. For nominal weights between 1 and 5 kg/m (0.7 and 3.5 lb/ft), one tensile test specimen is to be taken from each 2000 kg (4410 lb) or fraction hereof, in each batch. If the nominal weight exceeds 5 kg/m (3.5 lb/ft), one tensile test specimen is to be taken for each 3000 kg (6615 lb) of the product or fraction thereof, in each batch.

### **5.3 Drift Expansion Tests**

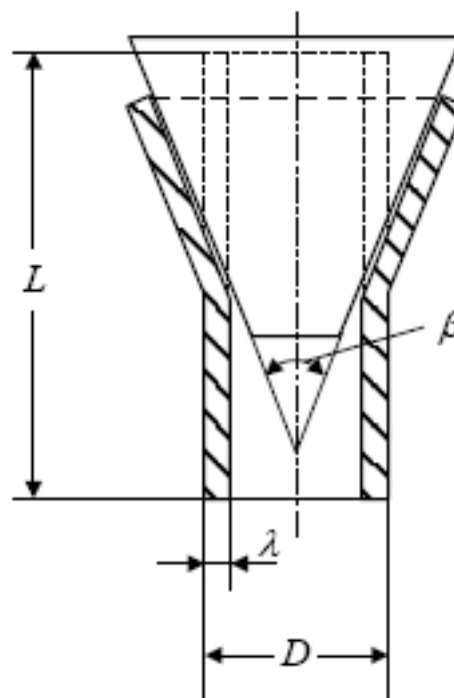
The Manufacturer is to demonstrate by macrosection tests or drift expansion tests of closed profiles performed on each batch of closed profiles that there is no lack of fusion at the press welds.

#### **5.3.1 Drift Expansion Tests (2008)**

- Every fifth profile shall be sampled after final heat treatment.
- Batches of five profiles or less shall be sampled one profile.

- Profiles with lengths exceeding 6 m shall be sampled every profile in the start of the production.
- The number of tests may be reduced to every fifth profile if the results from the first 3-5 profiles are found acceptable.
- Each profile sampled will have two samples cut from the front and back end of the production profile.
- The test specimens are to be cut with the ends perpendicular to the axis of the profile.
- The edges of the end may be rounded by filing.
- The length of the specimen is to be in accordance with 2-5-8/5.3.1 FIGURE 1 or recognized standard such as ISO 8493.
- Testing is to be carried out at ambient temperature and is to consist of expanding the end of the profile by means of a hardened conical steel mandrel having an included angle of at least 60°.
- The sample is considered to be unacceptable if the sample fails with a clean split along the weld line, which confirms lack of fusion.
- The entire batch of closed profiles (press welded) being tested is to be rejected if the sampled profile fails during drift expansion test. However, each profile in the rejected batch may be tested individually and accepted if it passes the test.

**FIGURE 1**  
**Drift Expansion Test**



*Notes:*

- 1  $L$  equal to twice the external diameter  $D$  of the tube if the angle of the drift is  $30^\circ$ , and  $L$  equal to  $1.5D$  if the angle of the drift is  $45^\circ$  or  $60^\circ$ .
- 2 The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than  $0.5D$ .
- 3 The rate of penetration of the mandrel shall not exceed 50 mm/min.

## 5.5 Definition of a Batch

The term batch applies to products if they are all:

- The same alloy grade from the same cast;
- The same product form and similar dimensions (for plates, the same thickness);
- Manufactured by the same process, and;
- Submitted simultaneously to the same temper condition.

## 7 Surface Finish (2014)

The material is to be free from injurious defects and have a workmanlike finish. Surface imperfections may be removed by smooth grinding or machining as long as the thickness of the material remains within the tolerances given in 2-5-8/11. It is to be surface inspected at the mill only when specifically requested and so ordered by the purchaser.

## 9 Nondestructive Examination (NDE)

In general NDE of material is not required for acceptance purposes.

However, the manufacturer is expected to employ suitable methods of NDE for maintaining compliance with quality standards.

## 11 Dimensions and Tolerance

It is the Manufacturer's responsibility to check dimensions and to comply with the following tolerance requirements:

Under-thickness tolerances for extruded products are to be in accordance with recognized national or international standards.

Dimensional tolerances other than under-thickness tolerance are to comply with recognized national or international standards.

**1 Scope (1 July 2019)**

The following requirements cover non-heat-treatable and heat-treatable aluminum alloy die and hand forgings intended to be used in hull construction. The material covered is in substantial agreement with ASTM B247. Forgings differing in chemical composition, mechanical properties or heat treatment will be specially considered.

Forgings are to be made by a manufacturer approved by ABS.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

Raw materials for forgings, such as Aluminum ingots or semi-finished products, are to be manufactured at a facility approved by ABS and manufactured by a process approved by ABS.

**3 Selection of Specimens****3.1 Location of Specimens**

Tension test specimens are to be taken from prolongations having a sectional area not less than that of the body of the forging. Tension test specimens are normally taken parallel to the direction in which the metal is most drawn out (longitudinal) but may be taken transversely. Specimens taken in the longitudinal direction are to be taken from as near to the center of the cross-section of the forging as is practicable. The midpoint of the axes of transverse specimens are to be near to the center of the cross section of the forging.

**3.3 Small Forgings**

In the case of forgings weighing less than 114 kg (250 lb) each, where the foregoing procedures are impracticable, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for testing. In such cases, the special forging should be subjected to the same amount of working and reduction as the forging represented and, if applicable, be heat treated with those forgings. Alternatively, test specimens may be taken from one of the forgings in the lot.



### 3.5 Test Specimens

The tension test specimen shown in 2-5-5/5.5 FIGURE 1 is to be used.

## 5 Number of Tests

### 5.1 Large Forgings

In the case of forgings weighing over 2700 kg (6000 lb) each, one tension test specimen is to be taken from each end of the forging.

### 5.3 Intermediate sized Forgings (1 July 2019)

In the case of forgings weighing less than 2700 kg (6000 lb) each, except as noted in 2-5-9/5.5 and 2-5-9/5.7, one tension test specimen is to be taken from each forging.

### 5.5 Small Forgings

In the case of forgings weighing less than 114 kg (250 lb) each, one tension test specimen may be taken from one forging as representative of 900 kg (2000 lb), provided the forgings are of similar size, of one alloy and temper, are made from the same lot of stock and, if applicable, heat treated in the same furnace charge.

### 5.7 Special Situations

In the case of a number of pieces cut from a single forging, individual tests need not necessarily be made for each piece, but forgings may be tested in accordance with whichever of the foregoing procedures is applicable to the primary forging involved.

### 5.9 Retests (1 July 2019)

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected.

## 7 Inspection

The forgings are to be inspected by the Surveyor after final heat treatment, where applicable, to insure that the forgings are free from injurious defects.

## 9 Nondestructive Examination (NDE)

The manufacturer is to carry out suitable methods of NDE for maintaining compliance with quality standards.

## 11 Dimensions and Tolerance

It is the Manufacturer's responsibility to check dimensions and to comply with tolerance requirements.

**1 Scope (2013)**

The following requirements cover aluminum alloy castings for use in hull construction. The material covered is in substantial agreement with alloys in accordance with ASTM Designations B26 and B108 (Aluminum Association alloys 356.0, A356.0 and AA357.0)-. Except in cases specifically approved otherwise, all aluminum castings are to be furnished in the heat treated condition. Castings differing in chemical composition, mechanical properties or heat treatment from those covered herein will be specially considered.

Castings are to be made by a manufacturer approved by ABS.

ABS approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection.

**3 Selection of Specimens****3.1 Large Castings**

Tensile specimens are to be taken from integral test bars. Integral test bars are not to be detached until the heat treatment of the castings has been completed nor until the coupons have been stamped by the Surveyor for identification.

**3.3 Small Castings**

In the case of castings weighing less than 450 kg (1000 lb) each, test coupons may be cast separately, provided they are poured from the same source of molten metal as the castings represented. When separate coupons are used, the Surveyor is to be furnished an affidavit by the manufacturer stating that the coupons were poured from the same source of molten metal as the castings represented and that they were heat treated with the castings.

**3.5 Test Specimens**

The tension test specimen shown in 2-5-5/5.5 FIGURE 1 is to be used.

## **5 Number of Tests**

At least one tension test is to be made representative of the same source of molten metal and in each heat-treatment charge.

## **7 Inspection**

The castings are to be inspected by the Surveyor after final heat treatment and thorough cleaning to insure that the castings are free from injurious defects, such as cracks, laminations, or embedded porosity. The final machined casting is to be examined to avoid the presence of surface defects.

## **9 Welded Repair of Defects**

Defects in noncritical areas may, with the Surveyor's approval, be repaired by welding using an approved procedure. The welding is to be done before the final heat-treatment.

## **11 Nondestructive Examination (NDE)**

The manufacturer is to carry out suitable methods of NDE for maintaining compliance with quality standards.

## **13 Dimensions and Tolerance**

It is the Manufacturer's responsibility to check dimensions and to comply with tolerance requirements.



# PART 2

## CHAPTER 5

### Materials for Hull Construction – Aluminum

#### SECTION 11

#### Rivets

#### 1 General

Non-heat-treatable and heat-treatable aluminum alloy cold heading rod and wire for use in manufacturing rivets should be in agreement with a specification equivalent to ASTM Designation B316. Material differing from ASTM B316 in chemical composition, mechanical properties or heat-treatment may be specially considered.

## **1 Scope**

The following specification covers metallurgically bonded bimetallic transition joints intended for structural connections between aluminum and steel in an atmospheric or dry environment.

## **3 Supplementary Requirements**

Aluminum/steel bimetallic transition joints are to be produced, tested, inspected and certified in accordance the following supplementary requirements.

### **3.1 Reference Documents**

The following documents of the issue in effect on the date of the material purchase form a part of this specification to the extent referenced herein.

- ASTM A264 Standard Specification for Stainless Chromium-Nickel Steel-Clad Plate, Sheet, and Strip
- MIL-STD-1689 Fabrication, Welding, and Inspection of Ship Structures
- NAVSEA Technical Publication T9074-AS-GIB-010/271, Nondestructive Testing Requirements for Metals

### **3.3 Process of Manufacture**

The bimetallic bond may be produced by explosion-bonding or by roll-bonding. In both cases, the material is to be produced in the form of plate, which will subsequently be cut into bar-like transition joints. Aluminum alloys in accordance with Part 2, Chapter 5 and the steels in accordance with Part 2, Chapter 1, are considered suitable for use as transition joint material.

The use of an intermediate aluminum material at the bond interface is permitted.

### **3.5 Tensile Strength**

The ultimate tensile strength of the bond zone is to be determined by means of the ram tensile test described in 2-5-A1/3.27 FIGURE 1. Test specimens machined to the dimensions in 2-5-A1/3.27 FIGURE 2 are to be loaded in tension to failure. The minimum tensile strength is 75 N/mm<sup>2</sup> (8 kgf/mm<sup>2</sup>, 11 ksi). Tests are to be made in the as-clad condition, and in the simulated welded condition.

### 3.5.1 As-Clad Test

No preliminary treatment is to be given to the specimens which are to represent the as-clad product. The testing is to be carried out at room temperature.

### 3.5.2 Simulated Welded Test

A preliminary heat treatment is to be given to the specimens which are to represent the product after welding. The test specimen is to be heat treated at  $315^{\circ}\text{C} \pm 14^{\circ}\text{C}$  ( $600^{\circ}\text{F} \pm 25^{\circ}\text{F}$ ) for 15 minutes. The testing is to be carried out at room temperature.

## 3.7 Bend Test

The integrity of the bond zone is to be evaluated by means of a full thickness guided bend test. Two bend specimens, see 2-4-3/11.5 FIGURE 5, are to be machined with the bond line transverse to the specimen longitudinal axis and at the approximate mid-length. The specimens are to be bent over ninety degrees to a radius of three times the thickness of the specimen. Openings at the bond line that are visible to the unaided eye and larger in size than 3.2 mm ( $1/8$  in.) are cause for rejection. The total length of permissible openings is not to exceed twenty percent of the bond length tested.

## 3.9 Shear Test

The ultimate shear strength of the bond zone is to be determined by means of the methods for the shear strength test in Figure 1 of ASTM A264, for Stainless Chromium-Nickel Steel-Clad Plate, Sheet, and Strip. Test specimens are to be loaded in shear to failure. The minimum shear strength is  $55 \text{ N/mm}^2$  ( $6 \text{ kgf/mm}^2$ , 8 ksi). Tests are to be made in the as-clad condition, and in the simulated welded condition.

### 3.9.1 As-Clad Test

No preliminary treatment is to be given to the specimens which are to represent the as-clad product. The testing is to be carried out at room temperature.

### 3.9.2 Simulated Welded Test

A preliminary heat treatment is to be given to the specimens which are to represent the product after welding. The test specimen is to be heat treated at  $315^{\circ}\text{C} \pm 14^{\circ}\text{C}$  ( $600^{\circ}\text{F} \pm 25^{\circ}\text{F}$ ) for 15 minutes. The testing is to be carried out at room temperature.

## 3.11 Axial Fatigue Strength Test

The axial fatigue strength of the welded transition joint is to be determined by means of specimens in 2-5-A1/3.27 FIGURE 3, and is to meet the minimum specified loadings and endurance without decohesion at the bond line. The testing is to be repeated if the base metal fails before the specified number of cycles.

**TABLE 1**  
**Fatigue Test Conditions and Requirements (2015)**

<i>Tension Stress, in <math>\text{N/mm}^2</math> (<math>\text{kgf/mm}^2</math>, ksi)</i>	<i>Compressive Stress, in <math>\text{N/mm}^2</math> (<math>\text{kgf/mm}^2</math>, ksi)</i>	<i>Number of Cycles</i>
35 (4, 5)	100 (11, 15)	175,000
7 (0.7, 1)	100 (11, 15)	650,000
20 (2, 3)	70 (7, 10)	1,000,000

## 3.13 Welded Tensile Test

The axial tensile strength of the welded transition joint is to be determined by means of specimens in 2-5-A1/3.27 FIGURE 3. The results are considered satisfactory provided the failure load is above that calculated for one of the web members based on the specified minimum tensile strength of the web material.

### 3.15 Nondestructive Examination

The bond zone is to be examined by means of ultrasonic inspection in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271 to detect areas that lack a bond. Each bimetallic bond is to be continuously scanned. Complete loss of back reflection resulting from a discontinuity at the bond interface is cause for rejection.

### 3.17 Dimensional Tolerances

The transition joint flatness, edge straightness and edge chamfer are to comply with the following.

#### 3.17.1 Flatness

The joints are to be flat to within 1.6 mm (0.062 in.) over any 305 mm (12 in.). The overall flatness is to be within 25.4 mm (1.0 in.) for joints over 2.5 m (8 ft) in length, and 19.1 mm (0.75 in.) for shorter joints.

#### 3.17.2 Edge Straightness

The joints are to be straight at the edge to within 3.2 mm (0.375 in.) over any 305 mm (12 in.). The overall straightness is to be within 12.5 mm (0.50 in.).

#### 3.17.3 Edge Chamfer

The joint edges are to be chamfered to a minimum radius of 1.6 mm (0.062 in.). The edge squareness is to be within 0.8 mm (0.031 in.) for cut ends, and 1.6 mm (0.062 in.) for cut edges.

### 3.19 Sampling Lots

A test lot consists of not more than ten (10) bimetallic bonded plates produced at one time and with the same set of manufacturing parameters. Changes to the manufacturing parameters listed below constitute a different lot.

#### 3.19.1 Common Parameters

Manufacturing parameters common to both explosion-bonding and to roll-bonding are: alloy heat, plate thicknesses, base metal pre-cleaning, bonding agents, and assembly width and length.

#### 3.19.2 Explosion-Bonding Parameters

Manufacturing parameters for explosion-bonding are: charge size, standoff distance, charge type, and process sequencing.

#### 3.19.3 Roll-Bonding Parameters

Manufacturing parameters for roll-bonding are: roll pressure, roll temperature, and number of passes.

### 3.21 Test Sampling

One bonded plate from each lot is to be sampled for mechanical testing. The selected plate is to be sampled at diagonally opposite corners. Each sample is to be used for tensile strength testing, and bend testing. All plates are to 100% ultrasonically inspected, see 2-5-A1/3.15. All transition joints are to be dimensionally inspected, see 2-5-A1/3.17.

**TABLE 2**  
**Production Lot Testing (2015)**

<i>Test</i>	<i>Section</i>	<i>Number of Specimens</i>	<i>Test Specimen Condition</i>
Tensile Strength	2-5-A1/3.5	One	As clad
		One	Simulated welded
Bend	2-5-A1/3.7	Two	As clad

### 3.23 Retest Sampling

Rejected lots may be reconsidered on a plate-by-plate basis provided two tensile tests and two bend tests are carried out with satisfactory results. A plate with any mechanical test failure is not to be reconsidered for acceptance.

### 3.25 First Article Inspection

A first article inspection is to be carried out for each type of bimetallic joint to validate the bond zone properties and the manufacturing process. All bonding practices are to be recorded and to serve as a baseline for production. Where production practices are modified from the baseline, first article inspection may be required. First article testing is to include ultrasonic inspection, 2-5-A1/3.15, and the following production tests and special tests:

**TABLE 3**  
**First Article Testing (2015)**

<i>Test</i>	<i>Section</i>	<i>Number of Specimens</i>	<i>Test Specimen Condition</i>
Tensile Strength	2-5-A1/3.5	One	As clad
		One	Simulated welded
Bend	2-5-A1/3.7	Two	As clad
Shear	2-5-A1/3.9	Three <sup>(1)</sup>	As clad
		Three <sup>(1)</sup>	Simulated welded
Axial Fatigue Strength	2-5-A1/3.11	Three	As welded
Welded Tensile	2-5-A1/3.13	Two	As welded

**Note:**

If the specimen contains three lugs for testing, then one specimen may be used. In this case, each lug is to be tested individually and the specimen suitably cleaned of testing damage so as to not influence testing and results of the subsequent lug.

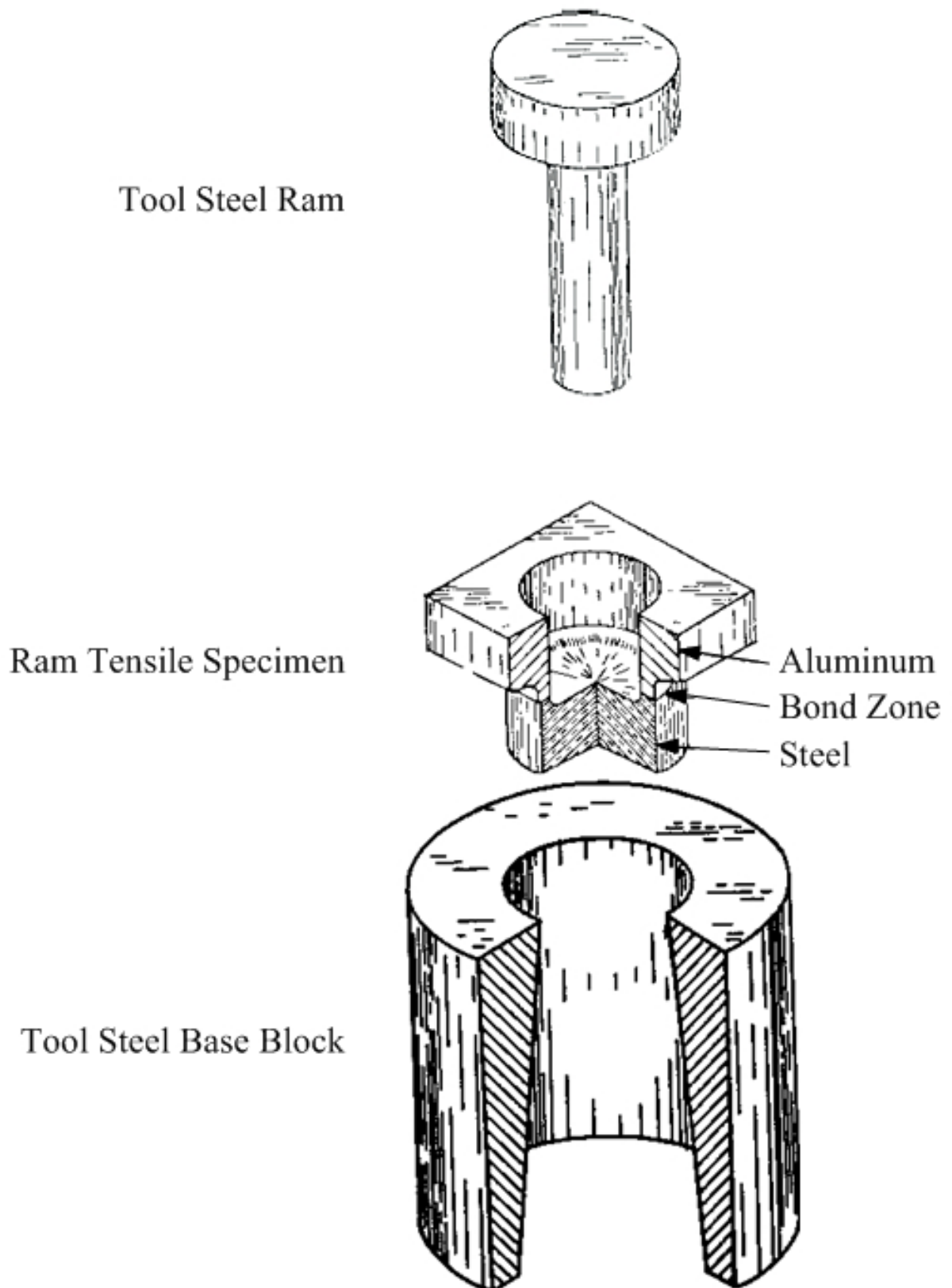
### 3.27 Ordering Data

Procurement documents are to list the following items with appropriate requirements specified:

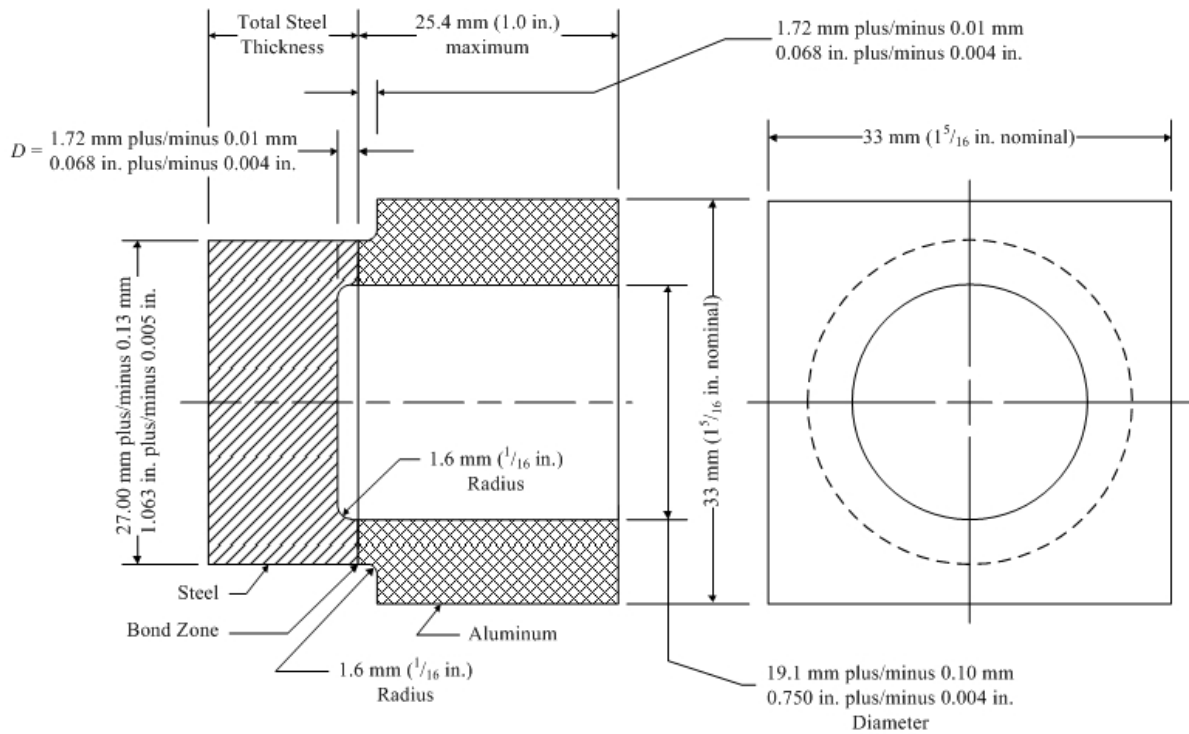
- i)* Title and number of ABS specification.
- ii)* ABS designation and UNS alloy number of bimetallic materials.
- iii)* ASTM specification, if applicable.
- iv)* Dimensions or reference a drawing number.
- v)* ABS certification, if required.
- vi)* Special product marking, if required.
- vii)* First article inspection, 2-5-A1/3.25, if required.



**FIGURE 1**  
**Ram Tensile Test Setup (2015)**



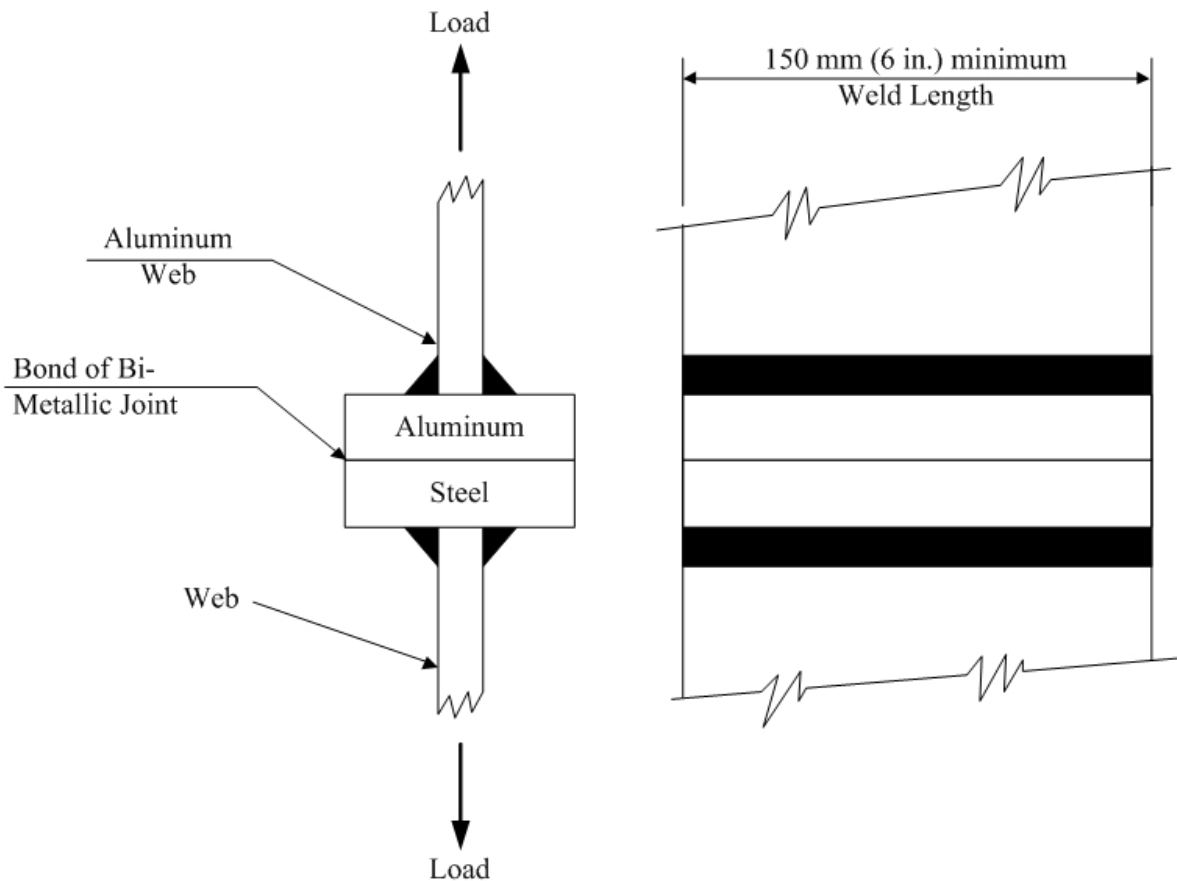
**FIGURE 2**  
**Ram Tensile Specimen (2015)**



**Notes:**

- 1 Sketch dimensions may be appropriately scaled for testing product less than 33 mm (1<sup>5</sup>/<sub>16</sub> in.) in width.
- 2 The hole depth, *D*, below the bond line is to be 1.62 mm (0.064 in.) or greater in all cases.

**FIGURE 3**  
**Weld Tensile Test Assembly (2015)**



*Notes:*

- 1 The web members are to be of the same composition and thickness as those which are to be used for the service application.
- 2 The width of the transition joint is to be the same as the product furnished to the purchaser.
- 3 The welding filler material is to be chosen in accordance with the requirements of MIL-STD-1689. The test assembly is to be cut from the approximate center of the welded assembly and is to be a minimum of 50 mm (2 in) in length. The welded assembly is to incorporate the necessary load tabs.



# PART 2

## CHAPTER 5

### Materials for Hull Construction – Aluminum

## APPENDIX 2

### Dissimilar Materials (2015)

## 1 Material

### 1.1 Dissimilar Materials

Where dissimilar materials such as aluminum and steel, stainless steel and carbon steel, or copper/nickel and carbon steel, are used in combination and exposed to water or weather, measures are to be taken to avoid galvanic corrosion.

## List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying (2017)

### Test and Test Data

- i)* **Witnessed Tests.** The designation (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved under ABS’s Quality Assurance Program.
- ii)* **Manufacturer’s Data.** The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.
- iii)* **Other Tests.** The designation (A) indicates those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with Rule requirements.

<b>2-5-2 Standard Test Methods</b>	
2-5-2/1.1	Chemical Analysis (M)
2-5-2/1.3	Tension Test (W)
2-5-2/1.5	Shear Test (W)
2-5-2/1.7	Hardness Test (W)
2-5-2/1.9	Electrical Conductivity Test (W)
<b>2-5-6 Corrosion Testing</b>	
2-5-6/5	Batch Microstructural Analysis (M)
<b>2-5-7 Sheet, Plate and Rolled Products</b>	
2-5-7/3 and 5	Tension Test (W)
2-5-8/9	Nondestructive Examination (NDE) (A)
<b>2-5-8 Extrusions</b>	
2-5-8/5.1	Tension Test (W)
2-5-8/3	Drift Expansion Test (W)
2-5-8/9	Nondestructive Examination (NDE) (A)

<b>2-5-9 Forgings</b>	
2-5-9/3 and 5	Tension Test (W)
2-5-9/9	Nondestructive Examination (NDE) (A)
<b>2-5-10 Castings</b>	
2-5-10/3 and 5	Tension Test (W)
2-5-10/11	Nondestructive Examination (NDE) (A)

### Materials for Hull Construction – Fiber Reinforced Plastics (FRP)

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General.....</b>	<b>461</b>
	1	Resins.....	461
	1.1	Polyester Resins.....	461
	1.3	Vinylester and Epoxy Resins.....	461
	1.5	Gel Coats.....	461
	1.7	Curing Systems.....	461
	1.9	Phenolic Resins.....	461
	1.11	Resin Properties.....	461
	1.13	Additives.....	462
	1.15	Fillers.....	462
	3	Reinforcing Materials.....	463
	5	Core Materials.....	463
	5.1	PVC Foam Cores.....	463
	5.3	Balsa Wood.....	463
	5.5	Core Bonding Materials.....	463
	7	Laminates.....	464
	7.1	Basic Laminate.....	464
	7.3	Uni-directional Laminates.....	464
	7.5	Bi-Directional Laminates.....	464
	7.7	Sandwich Laminates.....	464
	7.9	Mechanical Properties.....	464
	7.11	Nonstructural Plies.....	465
	7.13	Laminate Thickness.....	465
	7.15	Plywood and Timber Members.....	465
	9	Adhesives.....	466
	9.1	General.....	466
	9.3	Requirements for Structural Application.....	467
	TABLE 1	Properties of Core Materials.....	463
	TABLE 2	FRP Laminate Properties.....	466

<b>SECTION</b>	<b>2</b>	<b>Fabrication.....</b>	<b>468</b>
	1	General.....	468
	3	Fabrication Procedures.....	468
	3.1	General.....	468
	3.3	Laminate Layup.....	468
	3.5	Sandwich Panel Layup.....	468
	3.7	Secondary Bonds.....	469
<b>SECTION</b>	<b>3</b>	<b>Building Process Description.....</b>	<b>470</b>
	1	General.....	470
	3	Building Facilities.....	470
	3.1	Material Storage Premises.....	470
	3.3	Mold Construction.....	471
	3.5	Laminating Premises.....	471
	3.7	Equipment.....	472
	5	Specifications and Data Sheets for Materials.....	473
	5.1	Resins, Gel Coats, Catalysts, Accelerators, Hardeners and Other Additives.....	473
	5.3	Reinforcing Materials.....	473
	5.5	Core Materials.....	473
	7	Receiving Materials.....	474
	7.1	Resins, Gel Coats, Catalysts, Accelerators, Hardeners and Other Additives.....	474
	7.3	Reinforcing Materials.....	474
	7.5	Core Materials.....	474
	9	Laminating Procedure.....	474
	9.1	Start-up.....	474
	9.3	Application of Gel Coat.....	475
	9.5	Lamination of Skin Coat.....	475
	9.7	Main Lamination – Single Skin.....	475
	9.9	Main Lamination – Sandwich Laminate.....	476
	9.11	Release and Curing.....	478
	9.13	Secondary Bonding.....	478
	11	Inspection.....	479
	11.1	General.....	479
	11.3	Voids.....	479
	13	Faults.....	479
	13.1	General.....	479
	13.3	Production Faults.....	480
<b>SECTION</b>	<b>4</b>	<b>Quality Control.....</b>	<b>481</b>
	1	Application.....	481
	3	Definitions.....	481
	3.1	Hull Construction.....	481



3.3	Quality Assurance Standard.....	481
3.5	Quality Assurance.....	481
3.7	Quality Assurance System.....	481
3.9	Building Process Description.....	481
3.11	Quality Control.....	482
3.13	Inspection.....	482
3.15	Assessment.....	482
3.17	Audit.....	482
3.19	System Monitoring.....	482
5	Design.....	482
5.1	Plan Review.....	482
5.3	Revisions.....	482
7	Building Process Description – Quality Control.....	482
9	Certification of Quality Assurance.....	482
11	Documentation of Quality Assurance System.....	483
13	Personnel.....	483
15	Internal Audit.....	483
17	Documentation.....	483
19	Purchase.....	483
19.1	.....	483
19.3	.....	484
19.5	.....	484
19.7	.....	484
21	Material Receipt, Inspection and Storage.....	484
21.1	.....	484
21.3	.....	484
21.5	.....	484
21.7	.....	484
21.9	.....	484
21.11	.....	484
21.13	.....	484
23	Production.....	484
23.1	.....	484
23.3	.....	484
23.5	.....	485
23.7	.....	485
23.9	.....	485
23.11	.....	485
23.13	.....	485
23.15	.....	485
23.17	.....	485
25	Production Inspections and Tests.....	485
27	Final Inspection.....	485
29	Nonconforming Materials and Components.....	485

	29.1	.....	485
	29.3	.....	486
31	Corrective Action.....		486
	31.1	.....	486
	31.3	.....	486
	31.5	.....	486
33	Calibration and Maintenance of Equipment.....		486
	33.1	.....	486
	33.3	.....	486
	33.5	.....	486
	33.7	.....	486
	33.9	.....	486
	33.11	.....	486
35	Training.....		486
37	Records.....		487
	37.1	.....	487
	37.3	.....	487
	37.5	.....	487
<b>SECTION 5</b>	<b>Testing.....</b>		<b>488</b>
1	Gel Time.....		488
3	Barcol Hardness.....		488
5	Burnout and Thickness.....		488
7	Void Content.....		489
9	Laminate Properties.....		489
11	Test Results.....		489
	TABLE 1 Tests for Physical Properties of FRP Laminates.....		489
<b>SECTION 6</b>	<b>Repair.....</b>		<b>490</b>
1	General.....		490
3	Materials.....		490
	3.1 Resins.....		490
	3.3 Fiber Reinforcements.....		490
5	Repair Procedures – Single Skin Laminate.....		490
	5.1 Damage Assessment.....		490
	5.3 Removal of Damaged Laminate.....		491
	5.5 Laminating Procedures.....		492
	5.7 Laminating Process.....		494
7	Repair Procedure – Sandwich Construction.....		503
	7.1 Damage Assessment.....		503
	7.3 Removal of Damaged Laminate.....		503
	7.5 Laminating Procedure and Process.....		503

9	Repair Acceptance.....	503
FIGURE 1	Scarf Joint Preparation.....	492
FIGURE 2	Repair Sequence.....	493
FIGURE 3	Ply Overlap Requirements.....	494
FIGURE 4	Partially Through Thickness Defect Repair.....	495
FIGURE 5	Double Sided Scarf Repair.....	496
FIGURE 6	One Sided Scarf Repair – Backing Plate Installation.....	497
FIGURE 7	Repair Using Defective Section as Backing Plate.....	498
FIGURE 8	Single Sided Scarf Repair on Thin Laminate.....	499
FIGURE 9	Backing Plate Installation – Access from One Sided Repair.....	500
FIGURE 10	Repair in Way of Through Bolt Failure.....	501
FIGURE 11	Stepped Angle Defect Repair.....	502

**1 Resins**

Resins for the basic laminate of these Rules, other than those utilized for gel coats, are to be unsaturated, general-purpose or fire retardant polyesters suitable for marine use, and are to be catalyzed in strict accordance with manufacturers' recommendations.

**1.1 Polyester Resins**

Isophthalic polyester or orthophthalic polyester may be used. The former is often used for gel coat and outer ply lamination; the latter is an effective laminating resin.

**1.3 Vinylester and Epoxy Resins**

Epoxy resins cannot form a primary bond with polyester and vinylester resins. Epoxies can only be used either by themselves or in conjunction with fully cured polyester or vinylester resins.

**1.5 Gel Coats**

All gel coats are to be used in strict accordance with the manufacturers' recommendations. Where a gel coat is not used, details of the proposed water barrier are to be submitted for consideration.

**1.7 Curing Systems**

For polyester and vinylester resins, the level of catalyst and accelerator are to be as recommended by the manufacturer to ensure full polymerization of the resin. In general, the rate of gelation is to be controlled by the amount of catalyst accelerator added to the resin. The amount of catalyst is not to be less than 1% of the base resin, by weight.

**1.9 Phenolic Resins**

Phenolic resins having superior properties for fire resistance may not be suitable for structural applications. Where fire retardant additives to the resin system are used, the type and quantity are to be as recommended by the resin manufacturer. The results of independently tested fire retardant and fire restricting materials are to be submitted. All fire retardant systems are to be used in strict accordance with the resin manufacturer's recommendation.

**1.11 Resin Properties**

The properties of a resin are to be for the final form of the resin actually used in production with all additives and fillers included. The amount of silicon dioxide or other material added to provide thixotropy

is to be the minimum necessary to resist flowing or draining. The following liquid and cured condition properties of resins are to be provided for the gel coat resin and laminating resin, and if different, for the skin coat:

- Liquid Properties (at 25°C)
  - Monomer Content %
  - Viscosity – Brookfield (Spindle No. & RPM) CPS
  - Thixotropic Index, Minimum
  - Specific Gravity
  - Flash Point, Closed Cup
  - Fillers (type and amount)
- Cure Characteristics (at 25°C)
  - Gel Time, Minutes (indicate initiator (catalyst) and activator (promoter) and %)
  - Gel to Peak, Minutes
  - Peak Exotherm
- Cured Properties for Resin Clear Casting
  - Barcol Hardness
  - Heat Deflection Temperature
  - Tensile Strength and Tensile Modulus
  - Tensile Elongation at Break, %
  - Flexural Strength & Modulus
  - Volume Shrinkage
  - Water Absorption
- Chemical analysis and shelf life.

For polyester resins, the tensile elongation at break is generally not to be less than 1.0% for laminating resins and is to be generally not less than 2.0% for gel coat resins. Elongation of other resins will be specifically considered.

### 1.13 Additives

Additives are only to be added by the resin manufacturer in accordance with the agreed procedure and tested accordingly. Where a resin contains an ingredient that can settle within the resin system, it is the builder's responsibility to ensure that the resin manufacturer's recommendations regarding mixing and conditioning are complied with prior to use.

### 1.15 Fillers

All fillers added by a builder are to be of the dispersed type. The amount of filler that may be added to a resin is to be recommended by the resin manufacturer and is not to significantly alter the viscosity of the resin nor is it to affect the overall strength properties of the laminate. Recommendations by the resin

manufacturer to adopt amounts of fillers in excess of 13% by weight of the base resin will be subject to individual approval and testing. Pigments, thixotropes and fire retardant additives are to be considered as fillers in the calculation of total filler content. Fillers are to be carefully and thoroughly mixed into the base resin that is then to be allowed to stand to ensure that the entrapped air is released. The resin manufacturer’s recommendations regarding the method of mixing are to be followed. Details of all fillers are to be submitted.

### 3 Reinforcing Materials

Fiber reinforcement includes E glass fiber, S or R glass, carbon and aramid (Kevlar) fibers. The use of hybrid reinforcing materials is also acceptable. To be considered a reinforced plastic, the properties of the cured laminate of resin and fiber must exceed those of the cured clear resin without fiber. Where coupling agents are used, they are to be of the silane type, and are to be compatible with the laminating resins.

### 5 Core Materials

Expected shear strengths of core materials are shown in 2-6-1/5.5 TABLE 1. Core materials other than those shown will be subject to special consideration. Polyester fiber or vinylester mat is not considered a lightweight structural core, and use will be subject to special consideration. Shear strength for use in the design is to be verified by test, as required in Section 2-6-5. Construction methods and procedures for core materials are to be in strict accordance with core manufacturer’s recommendations.

#### 5.1 PVC Foam Cores

Foam cores are to be of the closed cell types and impervious to water, fuel and oils. Foam cores are to be compatible with the resin system and have good aging ability. Foam cores are to have good strength retention at 60°C (140°F). If the foam core is manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble with the laminating resin. Where necessary, foam core materials are to be conditioned in accordance with the manufacturer’s recommendations. Conditioning at an elevated temperature in excess of that which may be experienced in service may be necessary to ensure the release of entrapped residual gaseous blowing agents from the cells of the foam core.

#### 5.3 Balsa Wood

Balsa wood is to be end-grained. Balsa wood is to be treated chemically against fungal and insect attack and kiln-dried shortly after felling, and is to be sterilized and homogenized. Balsa wood is to have an average moisture content of 12%. If the balsa wood is manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

#### 5.5 Core Bonding Materials

Core bonding materials are to be used in accordance with the manufacturer’s instructions. The proposed core bonding to be used with the core material is to be indicated on the Material Data Sheet and the construction plans.

**TABLE 1**  
**Properties of Core Materials**

<i>Material</i>	<i>Density</i>		<i>Minimum Shear Strength</i>		
	<i>kg/m<sup>3</sup></i>	<i>lb/ft<sup>3</sup></i>	<i>N/mm<sup>2</sup></i>	<i>kgf/mm<sup>2</sup></i>	<i>psi</i>
Balsa, end-grain	104	6.5	1.6 <sup>(1)</sup>	0.16 <sup>(1)</sup>	225 <sup>(1)</sup>
Balsa, end-grain	144	9	2.5 <sup>(1)</sup>	0.25 <sup>(1)</sup>	360 <sup>(1)</sup>
PVC, crosslinked	80	5	0.9	0.09	122

<i>Material</i>	<i>Density</i>		<i>Minimum Shear Strength</i>		
	<i>kg/m<sup>3</sup></i>	<i>lb/ft<sup>3</sup></i>	<i>N/mm<sup>2</sup></i>	<i>kgf/mm<sup>2</sup></i>	<i>psi</i>
PVC, crosslinked	100	6.25	1.4	0.14	200
PVC, linear <sup>(2)</sup>	80–96	5–6	1.2	0.12	170

**Notes:**

- 1 These values are for Ecuadorian balsa.
- 2 Caution is to be taken when linear PVC cores are used in areas that are susceptible to high temperatures because of their low heat distortion temperature.

## 7 Laminates

### 7.1 Basic Laminate

The basic laminate consists of an unsaturated general-purpose polyester resin and alternate plies of E-glass, fiberglass mat and fiberglass-woven roving fabricated by the contact or hand lay-up process. The minimum glass content of this laminate is 35% by weight.

### 7.3 Uni-directional Laminates

Lay-up details showing the thickness and weight of the plies are to be indicated on the drawings.

A sufficient balance of properties in the warp and fill directions is to be maintained to prevent laminate failure in any direction. The ratios of the verified minimum laminate strengths in the fill direction to those in the warp direction are to be not less than the following:

<i>Member</i>	<i>Fill Strength/Warp Strength</i>
Panel, aspect ratio = 1.0	0.80
Panel, aspect ratio > 2.0	0.61
Stiffening member	0.25

For panels with aspect ratios between 1.0 and 2.0, the ratios are to be obtained by interpolation.

The values of  $E_F/F$ ,  $E_T/T$  and  $E_C/C$  in the fill direction are not to exceed the same ratios in the warp direction.

### 7.5 Bi-Directional Laminates

Lay-up details showing the thickness and weight of the plies are to be indicated on the drawings.

### 7.7 Sandwich Laminates

All core materials are to be effectively bonded to their laminated skins.

### 7.9 Mechanical Properties

The mechanical properties used in design for all laminates are to be verified by approved material tests. See Section 2-6-5.

2-6-1/7.15 TABLE 2 gives the average mechanical properties for various laminating materials. Thickness, strength and stiffness vary from the type of construction (hand lay-up, vacuum bagging, RTM or resin infusion) and the quality of the builder. These values are minimum for hand lay-up construction and are to be used for guidance only. For sandwich construction, the core to skin bond line is to be tested in tension

(flatwise tension test, see 2-6-1/5.5 TABLE 1) to determine its integrity. The bondline is considered acceptable if failure occurs in the cored region of the sample or within the laminate skins. The properties to be used for a particular laminate are subject to verification by approved material tests, as required in Section 2-6-5.

### 7.11 Nonstructural Plies

Gel coats and skin coats of either fiber mat or fiber cloth weighing less than 30 grams per square meter (0.1 ounce per square foot) are considered to be nonstructural. They are not to be included when assessing laminate strength and stiffness.

### 7.13 Laminate Thickness

The average thicknesses given below are provided only as guidance to the designer for mat and woven plies laid-up separately. Thickness indicated on the submitted plans for use with the guide are to be verified by the Surveyor and approved material tests.

The cured resin-and-mat plies may be taken to have average thickness equal to 0.25 millimeters per 100 grams of mat in each square meter (0.03 inches per ounce of mat in each square foot) of the basic laminate. The cured resin-and-woven roving plies may be taken to have an average thickness equal to 0.12 millimeters per 100 grams of woven roving in each square meter (0.0016 inches per ounce of woven roving in each square yard) of the basic laminate.

For mat and woven roving laminates differing in glass content from the basic laminate, the average cured laminate thickness,  $t$ , (excluding nonstructural plies) can be obtained from the following equation:

$$t = \frac{Wk}{c} \left( \frac{305}{f_g} - 2.69 \right) \quad \text{mm(in)}$$

where

$k$  = 0.35 mm (0.0138 inches)

$f_g$  = glass content, percentage by weight, of one ply of the mat and one ply of the woven-roving of the laminate to be used

$c$  = glass content per pair of composite fiberglass reinforcement of basic laminate,  
 = 1272 g/m<sup>2</sup> (4.17 oz/ft<sup>2</sup>)

$W$  = total weight of fiberglass reinforcement of the laminate in g/m<sup>2</sup> (oz/ft<sup>2</sup>), of the laminate thickness,  
 $t$

### 7.15 Plywood and Timber Members

Where plywood and timber members are to be used in structural applications and are to be laminated onto, or encapsulated within the laminate, the surface of the wood is to be suitably prepared and primed prior to laminating.



**TABLE 2**  
**FRP Laminate Properties**

**SI Units:**

	<i>Basic Laminate</i> <i>kgf/mm<sup>2</sup></i>	<i>“S” Glass</i> <i>kgf/mm<sup>2</sup></i>	<i>Kevlar</i> <i>kgf/mm<sup>2</sup></i>	<i>Carbon</i> <i>kgf/mm<sup>2</sup></i>
Flexural Strength, <i>F</i>	17.5	45.9	23.5	51
Flexural Modulus, <i>E<sub>f</sub></i>	773	1835	2236	4500
Tensile Strength, <i>T</i>	12.6	36.4	39.4	43.4
Tensile Modulus, <i>E<sub>t</sub></i>	703	1920	2314	4500
Compressive Strength, <i>C</i>	11.9	30.5	14.4	30
Compressive Modulus, <i>E<sub>c</sub></i>	703	1828	2285	4430

**MKS Units:**

	<i>Basic Laminate</i> <i>N/mm<sup>2</sup></i>	<i>“S” Glass</i> <i>N/mm<sup>2</sup></i>	<i>Kevlar</i> <i>N/mm<sup>2</sup></i>	<i>Carbon</i> <i>N/mm<sup>2</sup></i>
Flexural Strength, <i>F</i>	172	450	230	500
Flexural Modulus, <i>E<sub>f</sub></i>	7580	18000	22000	43800
Tensile Strength, <i>T</i>	124	357	386	425
Tensile Modulus, <i>E<sub>t</sub></i>	6890	18800	22700	43800
Compressive Strength, <i>C</i>	117	299	142	284
Compressive Modulus, <i>E<sub>c</sub></i>	6890	18000	22500	43700

**U.S. Customary Units:**

	<i>Basic Laminate</i> <i>psi</i>	<i>“S” Glass</i> <i>psi</i>	<i>Kevlar</i> <i>psi</i>	<i>Carbon</i> <i>psi</i>
Flexural Strength, <i>F</i>	25000	65300	33400	72500
Flexural Modulus, <i>E<sub>f</sub></i>	1100000	2610000	3180000	6400000
Tensile Strength, <i>T</i>	18000	51800	56000	61700
Tensile Modulus, <i>E<sub>t</sub></i>	1000000	2730000	3290000	6400000
Compressive Strength, <i>C</i>	17000	43400	20500	41100
Compressive Modulus, <i>E<sub>c</sub></i>	1000000	2600000	3250000	6300000

## 9 Adhesives

### 9.1 General

Adhesives for structural applications are to be used in accordance with the manufacturer’s recommendations. The details of all structural adhesives are to be specified on the Material Data Sheet and

on the construction plans submitted. Details concerning the handling, mixing and application of adhesives are to form part of the Builders Process Instruction. Particular attention is to be given to the surface preparation and cleanliness of the surfaces to be bonded. Where excessive unevenness of the faying surfaces exists, a suitable gap-filling adhesive is to be used or local undulations removed by the application of additional reinforcements. The Builder Process Description is to identify the level of training required for personnel involved in the application of structural adhesives.

### 9.3 Requirements for Structural Application

For adhesive materials to be acceptable for use in structural applications, they are to comply with the following requirements:

- i)* The minimum shear strength of the adhesive is to be between 6.9 N/mm<sup>2</sup> (1000 psi) and 10 N/mm<sup>2</sup> (1500 psi). This shear strength is to be achieved in temperatures ranging from ambient to 49°C (120°F). The testing is to be performed to ASTM D1002 or ASTM D3165 using FRP substrates. All failures of test samples are to be either cohesive or fiber tear.
- ii)* The adhesive is to be tested in fatigue using ASTM D3166 (note: the test substrates may be metallic). The test is to be conducted at 50% of the ultimate tensile strength and is to last for a minimum of one million cycles at 30 Hz.
- iii)* The process for the application of the adhesive is to be submitted for review and is to include the maximum bondline thickness, nondestructive testing methods and maximum creep.
- iv)* The elastic modulus of the adhesive is to be considerably less than that of the FRP skin to which it is being adhered
- v)* The strain of failure ratio of the adhesive is to be much larger than the surrounding structure.
- vi)* The mechanical properties of the adhesive are achieved rapidly, such that the use of screws or bolts will not be necessary to hold the substrates together while the adhesive cures.
- vii)* The adhesive is to be compatible with the lamination resin.

**1 General**

The use of fabricating procedures differing from those given below will be specially considered.

**3 Fabrication Procedures****3.1 General**

The laminate is to be lay-up by one of the following methods:

- Hand layup or contact process
- Vacuum Bagging
- Resin Impregnation
- Resin Transfer Molding (RTM)
- Resin Infusion
- Pre-preg

**3.3 Laminate Layup**

A layer or ply of reinforcing material may consist of a number of pieces. The pieces are to be lapped along their edges and ends. The width of each lap is to be not less than 50 mm (2 in.). Unless otherwise specifically approved, no laps in the various plies of a laminate are to be closer than 100 mm (4 in.) to each other.

Transitions in laminate thickness are to be tapered over a length not less than three times the thickness of the thicker laminate. A gradual transition in fiber reinforcement is to be provided between bidirectional and unidirectional laminates.

**3.5 Sandwich Panel Layup**

Sandwich panels may be laminated with cores that either are effective in resisting bending; tension, compression, shear and deflection (e.g., plywood) or are essentially ineffective in resisting bending, tension, compression and deflection, but are capable of carrying shear loads, (e.g., balsa wood and plastic foam).

All cores are to be effectively bonded to the skins in accordance with the manufacturer's recommendation (e.g., vacuum bag techniques with an approved bedding putty). Joints in core materials are to be scarphed and bonded or connected by similar effective means.

Where sandwich panels with ineffective cores are used in way of mechanically connected structures, gears and equipment, a core effective in resisting bearing, shear, flexure and compression is to be inserted. The inserts are to be bonded to the skins or faces of the sandwich and to the adjacent core.

The ply of skin laminate in contact with each face of a core material is to be chopped-strand mat. The mat is to be thoroughly impregnated with resin and the core is to be coated with resin before lay-up. For foam cores, the resin is to be applied and sufficiently rolled to ensure that all voids are filled, and the coat of resin for wood cores should be substantial enough to seal the grain of the wood.

### 3.7 Secondary Bonds

In general, secondary bonds should only be used when a primary bond cannot be achieved. Where ever possible, peel-ply should be applied to the outer layer of the surface requiring the secondary bond. When preparing for a secondary bond, the following criteria along with the manufacturer's recommendations should be adhered to:

- i)* The area is to be clean and free from all foreign particles such as wax, grease, dirt and dust.
- ii)* When grinding is required, the grinding is not to damage any of the structural glass fibers, thus weakening the laminate, especially in highly stressed areas.

In general, the first ply of the secondary lay-up is to be chopped-strand mat. The final ply of laminate along the bond line of the cured laminate is preferably to be chopped-strand mat.

Where methods other than conventional secondary bonding are proposed, the shipyard is to demonstrate that the proposed method is equivalent in strength to a conventional secondary bond.

**1 General**

The building process description is to be submitted for review by the builder before construction starts. Information on the following items is to be included.

- i)* Description of construction facilities, including environmental control and material storage and handling.
- ii)* Specifications for resins, reinforcing products and core materials including the manufacturer's recommendations.
- iii)* Lay-up procedures, including type, orientation of reinforcements, sequence, resin mixing methods and resin pot-life limits.
- iv)* Secondary bonding procedures.
- v)* Inspection and quality control systems
- vi)* Laminate properties derived from destructive qualification testing including sample check sheets, forms and guides.

**3 Building Facilities****3.1 Material Storage Premises**

The premises are to be equipped and arranged so that the material manufacturer's recommendations for storage and handling can be followed:

**3.1.1**

Premises are to be enclosed, protected from the sun, clean, dry, ventilated as necessary and sufficiently free of dust so that materials are not contaminated or degraded. Materials are to remain sealed in storage as recommended by the manufacturer.

**3.1.2**

Before use, fiber reinforcements are to be stored for at least 48 hours at a temperature and humidity similar to that of the laminating premises.

### 3.1.3

Resins, catalysts, hardeners and accelerators are to be stored in a well-ventilated space at temperatures recommended by the manufacturer. The storage period is not to exceed the shelf lives. Fillers and additives are to be stored in closed containers impervious to humidity and dust. Resin tanks are to be arranged so that they can be stirred at the frequency and time recommended by the manufacturer.

### 3.1.4

Core materials are to be stored in a dry space and protected against damage; they are to be contained in their protective packaging until immediately prior to use.

### 3.1.5

Materials that may be considered hazardous to each other are to be stored separately. Catalyst is to be stored in a cool, dry location away from manufacturing facility in accordance with fire and insurance codes.

## 3.3 Mold Construction

Molds are to be constructed to the following criteria:

### 3.3.1

Molds are to be constructed of a suitable material and are to be adequately stiffened to maintain their overall shape and fairness of form.

### 3.3.2

The materials used in the construction of molds are not to affect the resin cure.

### 3.3.3

The finish on a mold is to be such that the moldings produced are suitable for the purpose intended. The resultant aesthetic appearance of the molding is not part of ABS Survey and approval.

### 3.3.4

Where multiple section molds are used, the sections are to be carefully aligned to the attending Surveyor's satisfaction prior to molding. Mismatch between mold sections is to be avoided.

### 3.3.5

The release agent (e.g., mold wax, etc.) is to be of a type recommended by the resin manufacturer and is not to affect the cure of the resin.

### 3.3.6

Prior to use, all molds are to be conditioned to the workshop temperature.

### 3.3.7

Lifting arrangements are to be designed such that moldings are subjected to minimal distortion and unnecessary stressing. Moldings are to be adequately supported to avoid distortion during final cure.

## 3.5 Laminating Premises

Premises are to be arranged and equipped so that the material manufacturer's recommendations and builder's standards for handling, laminating and curing can be followed:

### 3.5.1

Premises are to be fully enclosed, dry, clean, shaded from the sun and adequately ventilated to remove fumes, overspray and dust from the molds and laminating area and properly and adequately lighted. Precautions are to be taken to avoid any effects on the resin cure due to direct sunlight or artificial lighting.

### 3.5.2

Temperature is to be maintained adequately constant at a temperature between 16°C and 32°C (60°F and 90°F). The humidity is to be kept adequately constant to prevent condensation and is not to exceed 80%. Where spray molding is taking place, the humidity is not to be less than 40%. Temperature and humidity are to be within limits recommended by the manufacturer of the materials. Departures from the foregoing will be considered, provided the temperatures and humidity are within the limits recommended by the manufacturer and are reviewed by ABS prior to laminating.

### 3.5.3

The laminating temperature in the premises is to be attained at least 24 hours before commencement of lamination, and is to be maintainable, regardless of the outdoor temperature.

### 3.5.4

Sufficient temperature and humidity monitoring equipment is to be provided, and detailed records are to be kept in accordance with the Quality Assurance system.

### 3.5.5

Laminating areas are to be remote from operations creating dust.

### 3.5.6

Scaffolding is to be provided, where necessary, to avoid standing on cores or on laminated surfaces. Such arrangements are to conform to the National Authority requirements and are not, in general, to be connected to the molding or impinge on the mold surface.

### 3.5.7

It is the responsibility of the builder to ensure that the ventilation and working conditions, together with discharges into the atmosphere, are such that levels of substances are within the limits specified in any pertinent National or International legislation.

## 3.7 Equipment

All equipment is to be well maintained and operated to the specifications underlined by the equipment manufacturer's recommendations and the following guidelines:

### 3.7.1

Production equipment, hose connections, gauge faces, spray guns, meters and pumps are to be kept clean and properly serviced.

### 3.7.2

Floors and work tables are to be regularly cleaned and reasonably free of accumulation of resin and reinforcing materials.

### 3.7.3

Compressed air for air operated equipment is to be clean, dry and free from contaminants such as oil, moisture or dirt. The system should include traps that are cleaned and serviced frequently.

#### 3.7.4

The catalyst injection accelerator of the spray gun is to introduce the catalyst into the resin or gel coat in a precise ratio and to result in a thoroughly homogeneous mixture. This accelerator is to be checked and calibrated frequently.

#### 3.7.5

Chopper guns are to be maintained properly adjusted to ensure the desired fiber to resin ratio, fiber length and fiber distribution.

#### 3.7.6

Resin delivery systems, both portable and fixed, are to be readily accessible for service and maintenance, including the cleaning of lines to prevent contamination.

#### 3.7.7

For spray laminating, the weight of resin and reinforcement used is to be continuously monitored to check the glass/resin ratio. Samples are also to be taken on a regular basis to validate the calibration equipment.

#### 3.7.8

All measuring equipment is to be certified and suitable for the quantity of material being measured. Valid certificates of calibration are to form part of the quality control documentation.

## 5 Specifications and Data Sheets for Materials

Material specifications and data sheets are to be provided to the builders by the material manufacturers. In general, these data sheets are to include the cured, mechanical properties of sample laminates as guidance to the designer. The material specification and data sheets are to also include information indicating the safe use and treatment of operators in the case of contamination.

### 5.1 Resins, Gel Coats, Catalysts, Accelerators, Hardeners and Other Additives

The specifications are to indicate the contents of the resin and gel coats, type and amount of catalyst, accelerators, hardeners and other additives, as well as recommendations for storage, handling and use.

Data sheets are to provide liquid and cured form physical and mechanical properties, as well as curing characteristics at a specified temperature indicating the gel time variation with air temperature and amount of catalyst and accelerator, or amount of hardener. Cured mechanical properties are to be given for unreinforced resin. Batch data sheets are to be supplied with each delivery, indicating the physical and mechanical properties of the particular delivered batch. All resins are to be used within 90 days of their specified “batch date,” unless acceptable by the manufacturer of the material. Batch data sheets are to be retained.

### 5.3 Reinforcing Materials

For reinforcing material, the specification is to indicate the fiber type and form, weave, fiber orientation, weight, physical data and mechanical properties.

Detailed storage records are to be maintained as part of the quality control documentation.

### 5.5 Core Materials

Core material specifications are to indicate the material specification number, material type, density and recommendations for storage, handling and use.



## 7 Receiving Materials

### 7.1 Resins, Gel Coats, Catalysts, Accelerators, Hardeners and Other Additives

The builder is to have a range of acceptance criteria for properties. The builder is to sample and test each batch to verify properties. Cured samples should be retained for future reference in the event of subsequent problems such as rapid yellowing, sun blistering and print through. All incoming raw materials are to be tested and inspected on receipt. Following testing, the drums or containers are to be labeled “Approved” or “Rejected.” “Rejected” material is to be immediately returned to the manufacturer. See Section 2-6-5.

### 7.3 Reinforcing Materials

Testing on incoming materials should include a weight check and a visual inspection of a sample of the material for its physical condition. Batch data sheets are to be retained.

### 7.5 Core Materials

Check tests on density and moisture content for core materials are required. Batch data sheets are to be retained.

## 9 Laminating Procedure

This laminating procedure is for a standard hand lay-up technique. Different laminating techniques will be specially considered.

### 9.1 Start-up

Before laminating, the following items are to be checked and complied with:

#### 9.1.1

Clean, dry, contaminant free air is delivered to equipment.

#### 9.1.2

All materials are at laminating premise temperature.

#### 9.1.3

Resins and gel coats are to be agitated to ensure a uniform mix. Manufacturer’s recommendations are to be adhered to, do not over agitate. Curing agents, fillers and pigments are to be added in strict accordance with the resin manufacturer’s recommendations.

#### 9.1.4

The condition of the resin, gel coat and catalyst delivery system is to be checked to ensure proper pump operations, tips are clean, clear and in good condition, seals and lines are free of leaks and that the filters are clean.

#### 9.1.5

The equipment is to be calibrated in accordance with the equipment manufacturer’s instructions. Set delivery rates, ratios and mix to the material manufacturer’s instructions. Check the gel and cure times to verify calibration.

#### 9.1.6

Record temperature, flow rates and catalyst ratios and maintain.

#### 9.1.7

Catalyst amount is to be determined in accordance with the manufacturer’s instructions.

#### 9.1.8

Inspect the mold to ensure that there is adequate mold release agent, that the surface is dry and clean and that the mold temperature is the same as the laminating premise temperature.

### 9.3 Application of Gel Coat

#### 9.3.1

Apply the catalyzed gel coat, typically using multiple uniform passes of six to eight mils to build up a uniform wet thickness of 25 to 30 mils. Recommended time between passes is 15 to 30 seconds; consult the manufacturer for optimum time and for optimum gel coat thickness.

#### 9.3.2

Commence lamination of skin coat as soon as adequate film cure has occurred in accordance with gel coat manufacturer's specification.

### 9.5 Lamination of Skin Coat

#### 9.5.1

Exposed surface of gel coat is to be kept clean, free of dust and contaminants.

#### 9.5.2

Wet film of catalyzed resin is applied by pouring, brushing or spraying to the entire gel coat surface. Apply at least 300 g/m<sup>2</sup> (1 oz/ft<sup>2</sup>) chopped strand or other skin coat, as indicated on the approved plans, into wet resin and apply sufficient additional resin to complete wet-out of glass, i.e., resin encirclement of each individual fiber or complete impregnation of the mat, roving or cloth.

#### 9.5.3

Roll-out skin coat to ensure saturation of fibers and elimination of air and voids in the skin coat. The consolidation is to be done with gentle rolling and with care not to damage the gel coat.

### 9.7 Main Lamination – Single Skin

#### 9.7.1

Laminating is to be carried out by skilled workers trained and qualified to the level required by the Quality Control Plan.

#### 9.7.2

Carry out lay-up in accordance with the lay-up schedule on the approved plans giving particular attention to type of reinforcing ply and their orientation.

#### 9.7.3

Wet film of catalyzed resin is applied by pouring, brushing or spraying to the entire skin-coated surface. Apply next reinforcing ply as required, and apply it to sufficient resin to completely saturate the glass fibers. Carefully roll-out the laminate to remove air pockets and void spaces.

#### 9.7.4

Continue as indicated in the lay-up schedule. Time between plies is to be in accordance with the material manufacturer's recommendations.

#### 9.7.5

The approved laminate schedule is to be carefully followed with respect to the particular ply type, weight and orientation. Ply overlaps along edges and at ends and ply staggering are to be in accordance with the approved plan.

### 9.7.6

During lay-up, guidance on gel time is to be strictly followed with regard to laminating premise temperature and the amount of catalyst. The gelation time is to be suitable for the proposed application such that full wet-out of the reinforcement can be obtained without unnecessary drainage on vertical surfaces or excessive loss of the monomer.

### 9.7.7

The degree of laminate cure is established by the Barcol Hardness Test. The hardness meter is to be regularly checked for calibration during use. A value of 40 or more indicates a satisfactory degree of cure for polyester resin. Lesser values may be used for vinylester and epoxy resins. These are to be in accordance with the manufacturer's recommendations.

### 9.7.8

Excessive exothermic heat generation caused by thick laminate construction is to be avoided. Where thick laminates are to be laid, the builder is to demonstrate to the Surveyor's satisfaction that the number of plies can be laid wet on wet and that the resultant temperature during the cure cycle does not have any adverse effect on the mechanical properties of the cured laminate.

### 9.7.9

Laminating is to be carried out in a sequence and documented in the quality control procedure for the particular resin system. Similarly, the time lapse between the forming and bonding of structural members is to be kept within the limits recommended by the resin manufacturer. Where this is not practicable, the surface of the laminate is to be prepared to improve the bond in accordance with the resin manufacturer's instructions.

### 9.7.10

Particular attention is to be given to localized thinning of the laminate in way of chines, coamings, knuckles and openings. Further deposition may be required in such areas to compensate for any reduction in thickness. Alternatively, layers of other equivalent reinforcements may be laid to achieve the required local thickness.

### 9.7.11

The exposed edges of all openings cut in single skin laminate panels are to be suitably sealed. Where such edges are in wet spaces or under water, the edges of such openings are to have rounded edges and are to be sealed by two plies of 450 g/m<sup>2</sup> (1.5 oz/ft<sup>2</sup>) chopped strand mat (or equivalent) reinforcement.

## 9.9 Main Lamination – Sandwich Laminate

### 9.9.1

For sandwich laminates, where applicable, single skin requirements are to be adhered to.

### 9.9.2

The ply before the core is to be chopped strand mat. Mat is to be thoroughly wet-out with a generous application of resin. Alternatively, core manufacturer's putty or compound may be used. Core is to be laid-up in strict accordance with the core manufacturer's instructions and approved plans. A generous coat of resin or putty, etc. is to be applied to the core and subsequent ply, generally chopped strand mat, applied and thoroughly wet-out and rolled out. The core is to be vacuum bagged to the skins. Where it is not practicable, alternative lamination will be considered.

### 9.9.3

Where the core material is to be laid onto a pre-molded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.

#### 9.9.4

Where the core is applied to a laminated surface, particular care is to be taken to ensure that a uniform bond is obtained. Where a core is to be applied to an uneven surface, additional building up of the surface or contouring of the core is required.

#### 9.9.5

Where other than epoxy resins are being used, the reinforcement against either side of the core is to be of the chopped strand mat type. No additional flow coating is to be applied to the foam core prior to laminating.

#### 9.9.6

Prior to bonding, the core is to be cleaned and primed (sealed) in accordance with the manufacturer's recommendations. The primer is to be allowed to cure and is not to inhibit the subsequent cure of the materials contained within the manufacturer's recommended bond process. The primer is to seal the panels, including all surfaces between the blocks of contoured material, without completely filling the surface cells.

#### 9.9.7

Where panels of rigid core materials are to be used, the vacuum bagging techniques are to be adopted. The core is to be prepared by providing "breather" holes to ensure efficient removal of air under the core. Bonding paste is to be visible at such breather holes after vacuum bagging. The number and pitch of such "breather" holes is to be in accordance with the core manufacturer's application procedure and any specific requirements of the core bonding paste manufacturer.

#### 9.9.8

Thermoforming of core material is to be carried out with the core manufacturer's recommendations. Maximum temperature limits are to be observed.

#### 9.9.9

Where panels of controllable core material are to be used, it is necessary to ensure that the core is cut/scored through the entire thickness such that the panels will conform to the desired shape of the molding. The builder is to demonstrate that the quantity of bonding material indicated in the core manufacturer's application procedure is sufficient to penetrate the full depths of the core between the blocks. It is recommended that grid-scored panels using a carrier scrim cloth are adopted.

#### 9.9.10

In all application procedures, cured excess bonding material is to be removed and the panel cleaned and primed prior to the lamination of the final sandwich skin.

#### 9.9.11

Inserts in sandwich laminates are to be of a material capable of resisting crushing. Inserts are to be well bonded to the core material and to the laminate skins in strict accordance with the approved plans.

#### 9.9.12

The level of vacuum applied for initial consolidation and during the cure period is not to be higher than that recommended by the relevant manufacturer of the materials being used, to avoid the possibility of evaporative boiling and excessive loss of monomer.

#### 9.9.13

Exposed edges of openings cut in sandwich panels are to be suitably sealed. The cut edges are, in general, to be sealed with a weight of reinforcement not less than that required for the outer skin

of the sandwich. Where other than an epoxy resin system is used, the first layer of such reinforcement is to be chopped strand mat with a weight not exceeding 450 g/m<sup>2</sup> (1.5 oz/ft<sup>2</sup>).

#### 9.9.14

Scored core material should be avoided whenever possible. However, when necessary, only single cut core material should be used in all external panels. When scored core material is used, the scores are to be properly filled with the bedding putty. The layer of bedding putty between the core material and the FRP skins should be between 0.5 mm and 2 mm (0.02 in. and 0.08 in.) thick.

### 9.11 Release and Curing

#### 9.11.1

After completion of the lay-up, the molding is to be left in the mold for a period to allow the resin to cure before being removed. This period is not to be less than 12 hours or that recommended by the resin manufacturer.

#### 9.11.2

Care is to be exercised during removal from the mold to ensure that the hull, deck and other large assemblies are adequately braced and supported to avoid damage and to maintain the form of the molding.

#### 9.11.3

Where female molds are adopted, all primary stiffening and transverse bulkheads are to be installed prior to the removal from the mold unless agreed otherwise.

#### 9.11.4

Moldings are not to be stored outside of the workshop environment until they have attained the stage of cure recommended by the resin manufacturer for that particular resin. Provision is to be made for moldings to be protected against adverse weather conditions.

#### 9.11.5

Moldings are, in general, to be stabilized in the molding environment for at least 24 hours, or that recommended by the resin manufacturer, before the application of any special cure treatment, details of which are to be submitted for approval.

### 9.13 Secondary Bonding

#### 9.13.1

Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies. Where a secondary bond is to be made, it is to be carried out with the resin manufacturer's recommendation, details of which are to be incorporated into the builder's quality assurance plan.

#### 9.13.2

Internal stiffening members, internal structural bulkheads, etc. are generally secondary bonded to the hull. Secondary bonding is the application of a resin wet ply to an already fully cured surface.

#### 9.13.3

The cured surface is to be sanded and thoroughly cleaned and dry. A generous coat of resin is to be applied to the cured surface and the first ply laid-on and further resin applied. The first ply is generally chopped strand mat. An alternative method is to use a peel ply on the cured laminate, which is to be removed and the laminate is to be lightly abraded prior to the secondary bond.

#### 9.13.4

The overlap of the resin wet plies to the cured laminate are to be in accordance with the approved plans.

## 11 Inspection

### 11.1 General

Inspection is to be carried out by the builders and Surveyors, as indicated and approved in the building process description and building quality control manual. A constant visual inspection of the laminating process is to be maintained by the builder. If improper curing or blistering of the laminate is observed, immediate remedial action is to be taken. Inspections of the following are to be carried out:

- i)* Check the mold to ensure it is clean and releasing agent is properly applied.
- ii)* Gel coat, check thickness, uniformity and application and cure before applying laminating resin first layer of reinforcement.
- iii)* Check resin formulation and mixing. Check and record amounts of base resin, catalysts, hardeners, accelerators, additives and fillers.
- iv)* Check that reinforcements are uniformly impregnated and well wet-out, and that lay-up is in accordance with approved drawings and the approved standards of overlaps are complied with. All variation in materials should be brought to the attention of the appropriate ABS Technical Department.
- v)* Check and record resin/fiber ratios.
- vi)* Check that curing is occurring as specified. Immediate remedial action is to be taken when improper curing or blistering is noted.
- vii)* Visual overall inspection of completed lay-up for defects that can be corrected before release from the mold. The laminated parts are to be free of open voids, pits, cracks or protruding fibers.
- viii)* Check and record hardness of cured hull prior to release from mold.
- ix)* The ambient temperature, humidity and gel time is to be monitored and recorded.

### 11.3 Voids

Excessive void content can reduce the overall strength of the laminate, and therefore, the laminate is to be inspected for the following:

- i)* There are to be no voids extending through more than one ply of laminate.
- ii)* There are to be no voids larger than 12 mm (0.50 in.) in their greatest dimension.
- iii)* There are to be no voids larger than 3 mm (0.125 in.) on each ply in any 150 mm × 150 mm (6 in. × 6 in.) area, with a maximum of six (6) total voids in this area.
- iv)* There are to be no more than three (3) voids larger than 3 mm (0.125 in.) on each ply in any 300 mm × 300 mm (12 in. × 12 in.) area, with a maximum of twenty (20) total voids in this area.

Note that interconnected voids are to be considered a single void, and spaces occupied by foreign matter in the laminate are to be considered as voids.

## 13 Faults

### 13.1 General

All faults are to be classified according to their severity and recorded, together with the remedial action taken, under the requirements of the Quality Assurance systems.

### 13.3 Production Faults

Production faults are to be brought to the attention of the attending Surveyor and a rectification system is to be agreed upon.

## **1 Application**

A quality assurance system is to be set up in association with the building process description. The objective of the system is to measure and record compliance with approved plans and the building process description. Quality control records are to be carefully kept, and are to be available at all times for review and routine verification by the ABS Surveyor. Compliance with the quality assurance system is required, in general, for craft that are obtaining ABS classification.

## **3 Definitions**

### **3.1 Hull Construction**

Hull construction consists of construction of the hull, deck, deckhouse and all other structure that affects the structural, weathertight and watertight integrity of the craft. Included are windows, doors, hatches, rudders, skegs and keels.

### **3.3 Quality Assurance Standard**

The quality assurance requirements of ABS for the hull construction of small craft.

### **3.5 Quality Assurance**

All activities and procedures concerned with the attaining of quality, including records and documents to verify attainment.

### **3.7 Quality Assurance System**

The organization indicating responsibilities, activities, resources and events that provide the procedures from which data and records originate to verify the builder's capability to comply with quality requirements. It includes the building process description.

### **3.9 Building Process Description**

A description of the building process, covering building facilities, material receiving procedures, laminating process, inspection and testing. Monitoring and recording of the building process description implements quality control.



### 3.11 Quality Control

The operational means and functions used to measure and regulate the quality of construction to the required standards.

### 3.13 Inspection

The process of measuring, examining, testing and comparing an item with the approved plans, approved building process and approved builder's standards.

### 3.15 Assessment

The initial inspection of the quality system at the builder's facilities to verify that all requirements are met and that the facilities are in accordance with the approved building process description and quality control procedures.

### 3.17 Audit

Verification that the building process and quality control process continue to be as effectively maintained as they were at the initial assessment.

### 3.19 System Monitoring

The checking by ABS Surveyors on a regular basis the processes, activities and necessary documentation to verify that the builder's quality system continues to be effectively carried out in accordance with the ABS quality assurance standard.

## 5 Design

### 5.1 Plan Review

The plans showing scantlings and arrangements and details of materials, building process description and quality assurance manual, as listed below, are to be submitted for review prior to start of production. All review amendments are to be included on the working plans.

### 5.3 Revisions

Any revisions made after approval are to be submitted to the attending Surveyor, who, at his discretion, may agree to the revision or require the plans to be resubmitted for approval. Where the Surveyor agrees to the revision, he is to provide the Technical Office responsible for plan approval with the details.

## 7 Building Process Description – Quality Control

A building process description is to be submitted for review. It is to cover in detail the building facilities, receipt of materials process, manufacture, inspection and testing. The relevant stages in the building process description are to be monitored and recorded as given in the quality assurance manual. It is to be agreed upon at which stages the Surveyor will carry out quality control monitoring and direct inspection. Direct inspection will include, but will not be limited to, final inspection on completion of construction.

## 9 Certification of Quality Assurance

At the request of the builder, ABS will carry out plan approval of the craft to be constructed and review of the Building Process Description and Quality Assurance Manual. On satisfactory completion of this and subsequent inspection by an ABS Surveyor to verify the building process and quality assurance system are in accordance with the reviewed documents, a Quality Assurance Certificate will be issued.

The certificate is valid for one year and will be reissued each year, subject to a satisfactory audit.

All information and data submitted by a builder for approval or review under the ABS Quality Assurance program will be treated with strictest confidence and will not be shown to or discussed with any third party without the written consent of the builder.

Builders receiving ABS Quality Assurance Certificates will be published by ABS, together with information on whether the craft are receiving classification or type approval.

## **11 Documentation of Quality Assurance System**

The builder is to establish, document and maintain an effective quality assurance system to ensure and verify that the material, processes and procedures used comply with the applicable requirements.

This documentation is to be in the form of a quality assurance manual that provides the policies, and fully details procedures adopted to comply with the applicable requirements.

## **13 Personnel**

A representative of the builder will be named to have the necessary authority and responsibility to ensure the requirements of this standard are complied with. Unless specifically approved otherwise, the quality assurance representative is to have no other duties or functions. This representative is to have the authority to stop production in the event of a serious quality problem.

The builder is to have an adequately staffed quality control group whose duties are carried out free of production priorities. This group will generally be supervised by the builder's quality assurance representative.

Other staff whose duties affect quality, including production management, are to have specified responsibility and authority to identify, control and assess quality. In process, inspections may be done by production staff, provided it is checked by the builder's quality control group representative on staff.

## **15 Internal Audit**

Internal audits of the quality assurance system in all production areas and other areas concerned with product quality, as given in this standard, are to be carried out under the supervision of the builder's quality assurance representative. The audits are to be at an agreed frequency and the results are to be evaluated at a management review meeting attended by the builder's quality assurance representative and the production and testing management.

## **17 Documentation**

The approved quality assurance manual, building process description, approved plans, material specifications, material bunch data sheets, completed quality control forms, material sample and test results are to be prepared and maintained readily available for inspection by the Surveyor.

## **19 Purchase**

### **19.1**

Materials and components incorporated into the hull construction that affect quality are to be obtained from recognized manufacturers and suppliers. Recognition may be on the following:

- i)* Documented records of previous satisfaction in supply.
- ii)* Approval by a recognized independent organization to a suitable quality assurance standard.
- iii)* Batch sample inspection and testing against batch data sheets and approval by ABS.
- iv)* Satisfactory assessment and evaluation of the manufacturer's/supplier's capability or quality assurance system at the manufacturer's/supplier's plant by the builder's quality assurance representative.

### 19.3

Records of manufacturers and suppliers are to be kept to monitor their performance. Those with a poor record are to be considered for replacement.

### 19.5

Purchase requisitions are to contain all of the necessary technical specification details.

### 19.7

Purchase orders are to be precise and clear, giving revision status of all referenced documents, standards, etc. and are to include any requirements for certification. Purchase orders are to be reviewed for accuracy prior to issue.

## 21 Material Receipt, Inspection and Storage

### 21.1

The material is to be kept separate prior to receiving inspection.

### 21.3

All materials are to be confirmed as identifiable to a purchase order, and that they are in a satisfactory condition, having no damage or contamination. Data batch sheets are to be provided with each delivery, and where required, certificates of conformity. Batch sample test may be required.

### 21.5

The temperature, humidity and cleanliness of the storage spaces for resin system materials, fiber reinforcing materials and core materials are to be monitored and recorded at a suitable frequency.

### 21.7

Materials with a limited shelf life are to be used before the expiration date and in full compliance with the manufacturer's recommendations.

### 21.9

Where the ambient temperature of the production area differs from that of the storage area, and the material performance is affected by this temperature difference, the material is to be placed in the production area in time to allow the necessary temperature change to occur before the material is used.

### 21.11

All material is to be fully identifiable in storage and is to be maintained from issue to use in production.

### 21.13

All material known or thought to be nonconforming is to be segregated from acceptable material.

## 23 Production

### 23.1

The necessary plans and other instructions are to be available to the manufacturing staff in all work areas. Instructions are to include control of equipment and method of working.

### 23.3

All material, parts, hulls and decks during construction are to be specifically identified and are to be traceable to the applicable plans, work instructions, etc.

### 23.5

Work during the manufacturing stages is to be carried out strictly in accordance with the applicable building process description and monitored and recorded on documents that are part of the building process description. The builder's staff member responsible for each stage is to sign to accept responsibility as soon as the stage is satisfactorily completed.

### 23.7

Production areas are to have the means of controlling the ambient temperature and humidity. The respective values are to be monitored and recorded at regular intervals. The working areas are also to be kept adequately clean and dust free.

### 23.9

Materials are to be taken from the stores in sufficient quantities so that they can be processed without delay. Materials waiting to be used are to be kept in conditions that will not lead to contamination, such as moisture absorption or deterioration.

### 23.11

The production staff is to have ready access to instructions on mold preparation, resin mixing, laminating, curing and release processes.

### 23.13

The time of application of gel coat, laminating and other time sensitive processes is to be monitored and recorded.

### 23.15

All equipment and tools in the laminating process such as gel coat and resin application systems, catalyst mixing systems, spray lay-up equipment, compressed air systems, etc. are to be maintained, serviced and calibrated at suitable intervals to ensure that they are in good working order.

### 23.17

The list of personnel trained in the laminating processes is to be readily available.

## 25 Production Inspections and Tests

Inspection and tests are to be carried out at the appropriate stages of manufacture in accordance with the building process description. The acceptance/rejection criteria are also to be in accordance with the building process description. Inspections and tests are to be carried out and recorded by authorized personnel and each inspection and test is to be signed for when satisfactorily completed. Subject to prior agreement, certain inspections may be carried out by production personnel, provided there is a system for monitoring by the quality control staff.

## 27 Final Inspection

Final inspection of each completed hull is to be carried out by the quality control staff. It is to include verification that the construction processes and inspections have been completed satisfactorily, documented and that no outstanding nonconforming items remain.

## 29 Nonconforming Materials and Components

### 29.1

All materials and components considered to be nonconforming are to be clearly labeled as such and kept separated from accepted materials.

### 29.3

There is to be a system of recording a nonconformance, for documenting the authorized corrective measures and for confirmation, where applicable, that the nonconformance has been eliminated by corrective measures.

## 31 Corrective Action

### 31.1

Guarantee claims and other customer complaints are to be recorded, together with the agreed method of rectification.

### 31.3

Records of guarantee claims and customer complaints, cases of nonconformance and inspection test results are to be analyzed at suitable intervals to detect trends and introduce corrective measures to reduce the probability of any recurrence.

### 31.5

Corrective actions are to be kept under surveillance until their effectiveness and suitability are proven satisfactory by experience.

## 33 Calibration and Maintenance of Equipment

### 33.1

Production and inspection equipment is to be calibrated and maintained to ensure the procedures and criteria for workmanship and inspection can be carried out with the necessary precision and quality. Whenever available, the manufacturers' calibrations are to be used.

### 33.3

A list of all such equipment is to be maintained with each item specifically identified and its required calibration/maintenance marked on the item.

### 33.5

The calibration/maintenance interval and the method and accuracy of the calibration/maintenance of each type of equipment are to be established.

### 33.7

Records of the calibration/maintenance process are to be maintained and are to include details of any adjustment or repairs.

### 33.9

Calibration is to be carried out against master instruments of known accuracy based on national or international standards or in accordance with the manufacturer's instructions.

### 33.11

The interval, method and results of calibration/maintenance are to be reviewed at internal audits.

## 35 Training

The necessary basic training, qualifications or experience for, as a minimum, the quality assurance, inspection and test personnel, and those performing the laminating and forming processes, calibration, maintenance and internal or external auditing/assessing, are to be prescribed by the builder.

## **37 Records**

### **37.1**

The builder is to develop and maintain records that show achievement of the required quality and the effective operation of the quality system. The following categories of documents, as a minimum, are to be retained as records after their use:

#### **37.1.1**

Superseded versions of the quality assurance manual, documented procedures, generally applicable work instructions and workmanship standards, internally produced standards, accept/reject criteria and representative samples, procedure approval tests and lists of recognized suppliers.

#### **37.1.2**

Working drawings and their revision history, copies of purchase orders, records of incoming, in-process and final inspections and tests, certificates of conformity for the raw materials used, records of temperature and humidity, completed nonconformance reports, guarantee claims, customer complaints, training records, internal audit reports, corrective action analysis and minutes of management review meetings.

### **37.3**

All records are to be kept for a defined period of time. Product related records are to be kept for a statutory period of time.

### **37.5**

All records are to be efficiently collated, held in secure storage and systematically identified and indexed to enable retrieval.

**1 Gel Time**

The builder is to establish and implement a resin gel-time control system for the gel-time desired in production. This gel time is to be within the gel time upper and lower limits recommended by the resin manufacturer. Resin mixes are to be monitored and recorded to assure proper gel times. During layup, the temperature and humidity in the laminating area is to be recorded at regular intervals. The catalyst and gel time are to be adjusted to suit any changing conditions.

**3 Barcol Hardness**

Prior to removal from the mold, the laminate is to be checked with a Barcol hardness tester at a suitable number of locations to determine the degree of cure. The Barcol hardness number of the cured laminate measured on the surface without the gel coat is to be not less than 40. When using a Barcol hardness tester, the minimum thickness is  $\frac{1}{32}$  inch, and the following should be applied:

- i)* For a Barcol reading between 0-30: 25 readings, discard high and low and average the rest.
- ii)* For a Barcol reading between 30-40: 12 readings, discard high and low and average the rest.
- iii)* Barcol hardness tester cannot generally be used with epoxy.

**5 Burnout and Thickness**

The builder is to conduct and record the results of a predetermined, sufficient number of tests for glass/fiber content and thickness checks on cutouts or plugs that have been removed from laminates to make way for through-hull and through-deck fittings. The plugs are to be identified by their location in hull. Each burnout test for glass-reinforced laminates is to be made on a sample that is at least 25 mm (1 in.) in diameter. A record is to be made of the cured laminate thickness and the glass content by weight. Fiber content measurements for carbon and aramid (Kevlar) fiber reinforced laminates are to be carried out by acid tests.

Additionally, a visual inspection of the residue may be required to determine the types and the number of layers of reinforcement used in the laminate.

The cured laminate thickness, in general, is not to differ more than 15% from the thickness indicated on the approved plans.

## 7 Void Content

Where the extent of voids in the laminate has been deemed suspect by the attending Surveyor, the void content of the laminate is to be tested in accordance with ASTM D2734.

The void content is not to exceed 4%. Where the void content is in excess of 2%, additional testing may be required.

## 9 Laminate Properties

Determination of laminate properties (specific gravity, glass content, tensile strength and modulus, flexural strength and modulus, shear strength, and, where glass content is less than 40% or more than 60%, interlaminar shear strength) is to be made on the basis of destructive qualification tests of panels assembled by the fabricator under environmental conditions and using resin formulations and process techniques simulating the conditions, formulations and techniques to be used in actual production.

The fabricator is to lay up the test panels at an angle of about 45°. All panels are to be tested in the as-cured condition. All test results are to be reported. ABS review of laminate design will be predicated on the quality of laminate produced by the fabricator. Laminate properties derived from qualification testing of sample panels, which are to be witnessed as necessary by the Surveyor are to be included in the process description.

Test panels may be either laid up as a qualification test sample at the time of craft lay-up or may be taken from hull cut-outs or hull laminate extension tabs.

The tests associated with the laminate properties are shown in 2-6-5/9 TABLE 1.

**TABLE 1**  
**Tests for Physical Properties of FRP Laminates**

<i>Type of Laminate</i>	<i>Properties</i>	<i>Test</i>
Single Skin	Flexural Strength and Modulus	ASTM D790 or D790M or ISO 178
Single Skin	Shear Strength, perpendicular and parallel to Warp	ASTM D732 85
Single Skin and Sandwich	Glass Content and Ply-by-Ply Analysis	ASTM D2584 or ISO 1172
Single Skin and Sandwich –Both Skins	Compressive Strength and Modulus	ASTM D695 or D695M or ISO 604
Single Skin and Sandwich –Both Skins	Tensile Strength and Modulus	ASTM D3039 or D638 or D638M or ISO 3268
Single Skin and Sandwich –Both Skins	Interlaminar Shear Strength	ASTM D3846
Sandwich –Core to Skin Bondline	Flatwise Tensile Test	ASTM C297
Sandwich –Core Material	Shear Strength and Modulus	ASTM C273

## 11 Test Results

One complete copy of the laboratory test report is to be promptly forwarded to the ABS Technical Office doing hull plan approval. Where test results are less than the laminate design properties, this is to be drawn to the attention of the Technical Office. One copy of all test results is to be filed in the classification survey report or hull certification report.

In the case of advanced composites, one copy of all test results is to be forwarded to the ABS Technical Office plan approval staff.



## **1 General**

This Section specifies the requirements for repairs of defects during construction. These details are also applicable for repair of damaged laminates due to collisions, allisions or other extreme forces.

All repair work relies on the use of proper secondary bonding technique (see 2-6-3/9.13). Therefore, additional replacement material is required to achieve the original strength of the laminate. Details of the area to be repaired, the materials to be used (resins, reinforcing materials, cores, etc.) and the repair process is to be submitted for review. Damage to the gel-coat and/or skin coat is not part of the ABS survey unless it has an adverse effect on the laminate structural layers.

## **3 Materials**

### **3.1 Resins**

In general, isophthalic polyester, vinyl ester or epoxy resins are to be used for all repairs. Special consideration will be given for the use of other resins, provided they are used in accordance with the manufacturer's recommendations. In all cases, the shipyard is to demonstrate to the satisfaction of the attending Surveyor that the resin is capable of bonding to the cured laminate of the craft being repaired.

### **3.3 Fiber Reinforcements**

The original, primary fiber reinforcement is to be used in repair, whenever practical. Where alternative reinforcements are used, they are to be similar in type and weight to those being replaced. Dissimilar fiber types are not to be used in a repair unless they were part of the original laminate.

## **5 Repair Procedures – Single Skin Laminate**

### **5.1 Damage Assessment**

Damages can be found either by visual inspection, probing or hammer sounding of the structure. Damage can be found from indicators such as the following:

- i)* Cracked or chipped paint or abrasion of the surface
- ii)* Distortion of a structure or support member
- iii)* Unusual build-up or presence of moisture, oil or rust
- iv)* Structure that appears blistered or bubbled and feels soft to the touch

- v) Surface and penetrating cracks, open fractures and exposed fibers
- vi) Gouges
- vii) Debonding of joints

For the proper inspection of suspect areas, the removal of insulation, outfitting or equipment may be required. The extent of damage is to be clearly indicated on the hull and is to be agreed upon by all parties prior to removal.

Where water is found in the laminate or core, the area is to be rinsed by fresh water and be allowed to dry for a minimum of 48 hours. Work is not to be performed on the laminate until the moisture is 0.5% by weight or less.

### **5.3 Removal of Damaged Laminate**

#### **5.3.1 Damage Partially Through the Thickness**

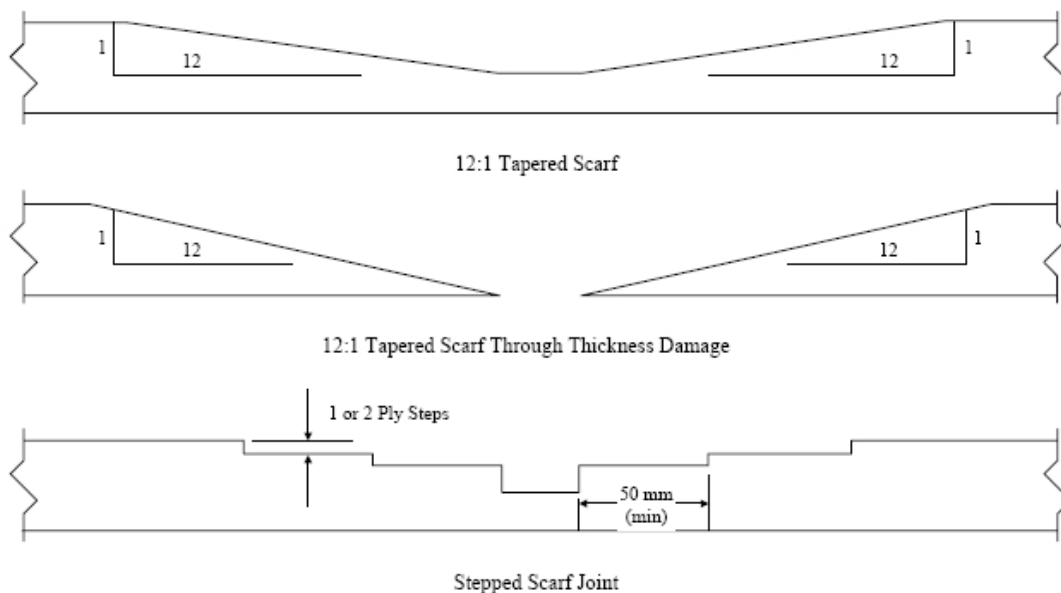
For damage extending partially through the thickness of a laminate, the damaged laminate can be removed using a course grit grinder. The damaged area is then to be shaped for repair using a fine grit grinder. See 2-6-6/5.3.2 FIGURE 1 for preparation details.

#### **5.3.2 Damage Through the Thickness**

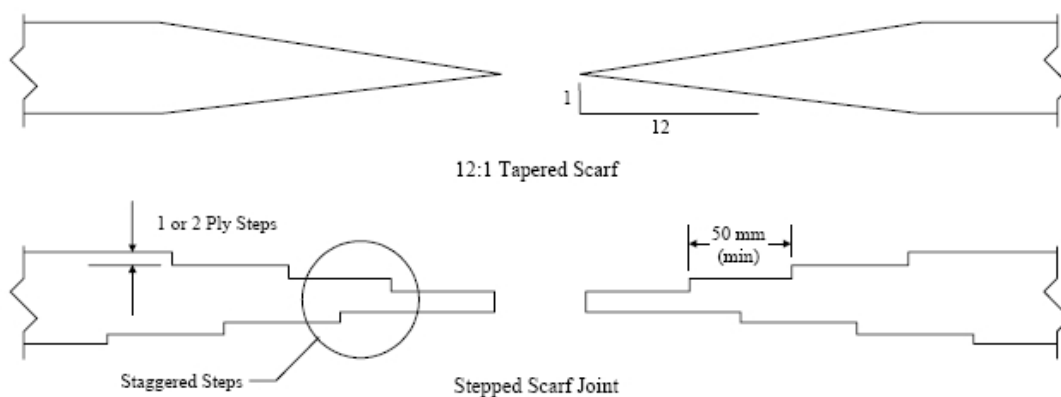
For damage that extends through the thickness of the laminate, the damaged area can be cut away. The laminating surfaces are to be prepared as indicated in 2-6-6/5.3.1 and 2-6-6/5.3.2 FIGURE 1.

**FIGURE 1**  
**Scarf Joint Preparation**

a) SINGLE-SIDED SCARF



b) DOUBLE-SIDED SCARF



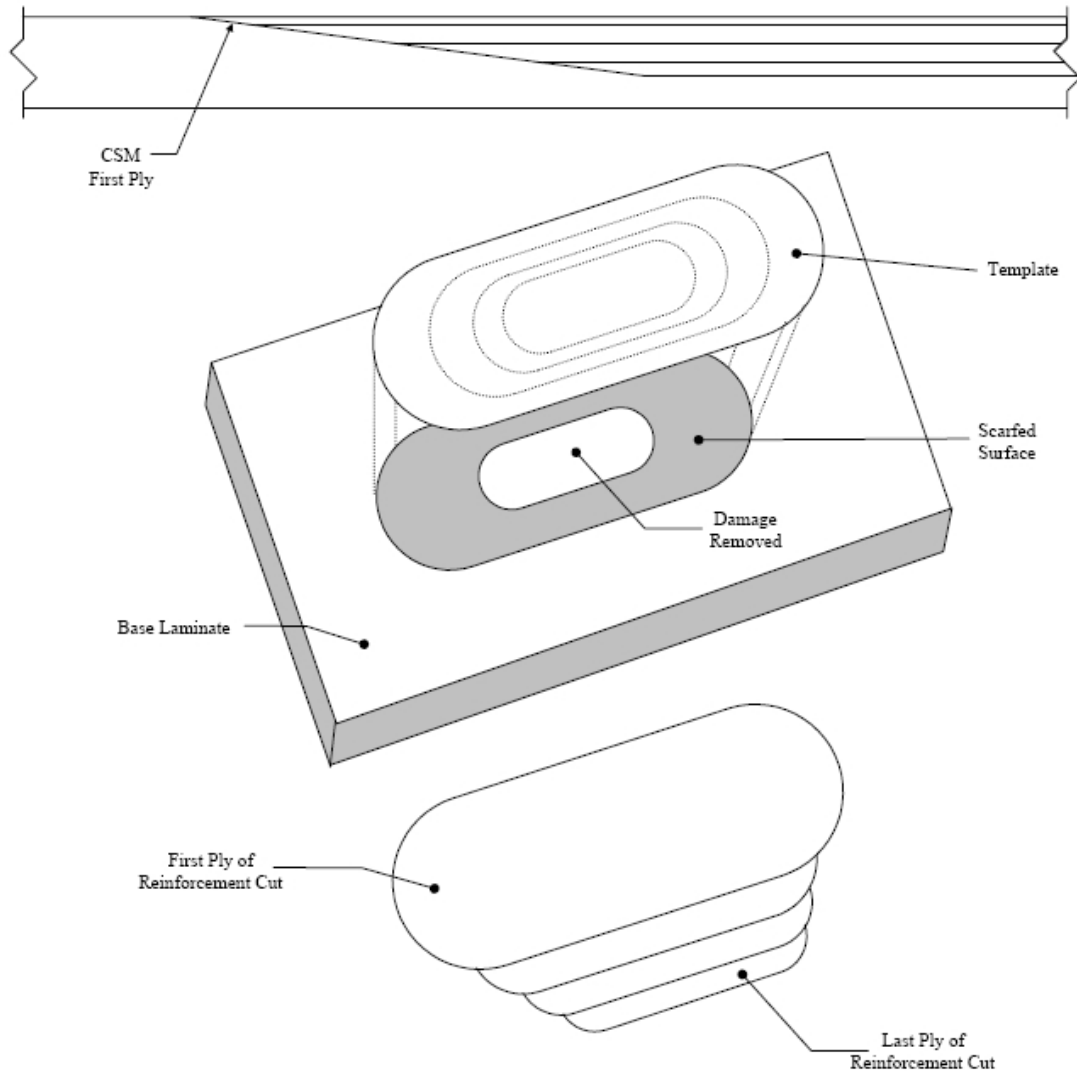
**5.5 Laminating Procedures**

**5.5.1 General**

All laminating procedures consist of using secondary bonding and the requirements in 2-6-3/9.13 are applicable. Generally, the lay-up is to have the smallest ply first with each successive ply being larger, as indicated in 2-6-6/5.5.1 FIGURE 2. Each of the successive plies are to be slightly oversized and trimmed as it is being laminated in place. Care is to be taken in using undersized plies as this may create a resin pocket along the bond line. The fiber orientation is to be maintained during lamination. Alternative methods for laminating will be subject to special consideration.

**FIGURE 2**  
**Repair Sequence**

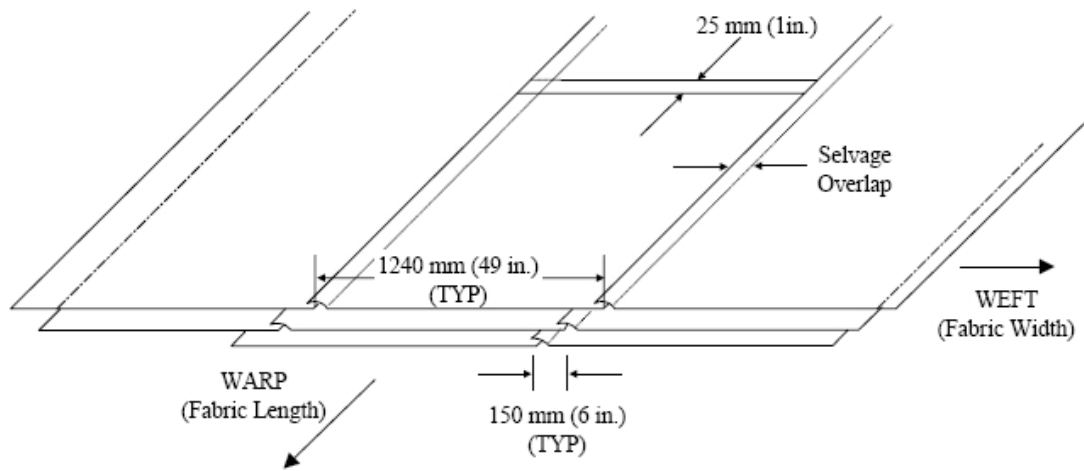
BUTTED LAY-UP



**5.5.2 Overlap Requirements**

Adjacent plies of reinforcement are to be overlapped when fitted with a selvage edge. Other reinforcements may be butt jointed. Edge joints in successive layers are to offset 150 mm (6 in.) relative to the underlying ply. Lengthwise joints are also to be staggered 150 mm (6 in.). The ply overlap is to be a minimum of 25 mm (1 in.). See 2-6-6/5.5.2 FIGURE 3.

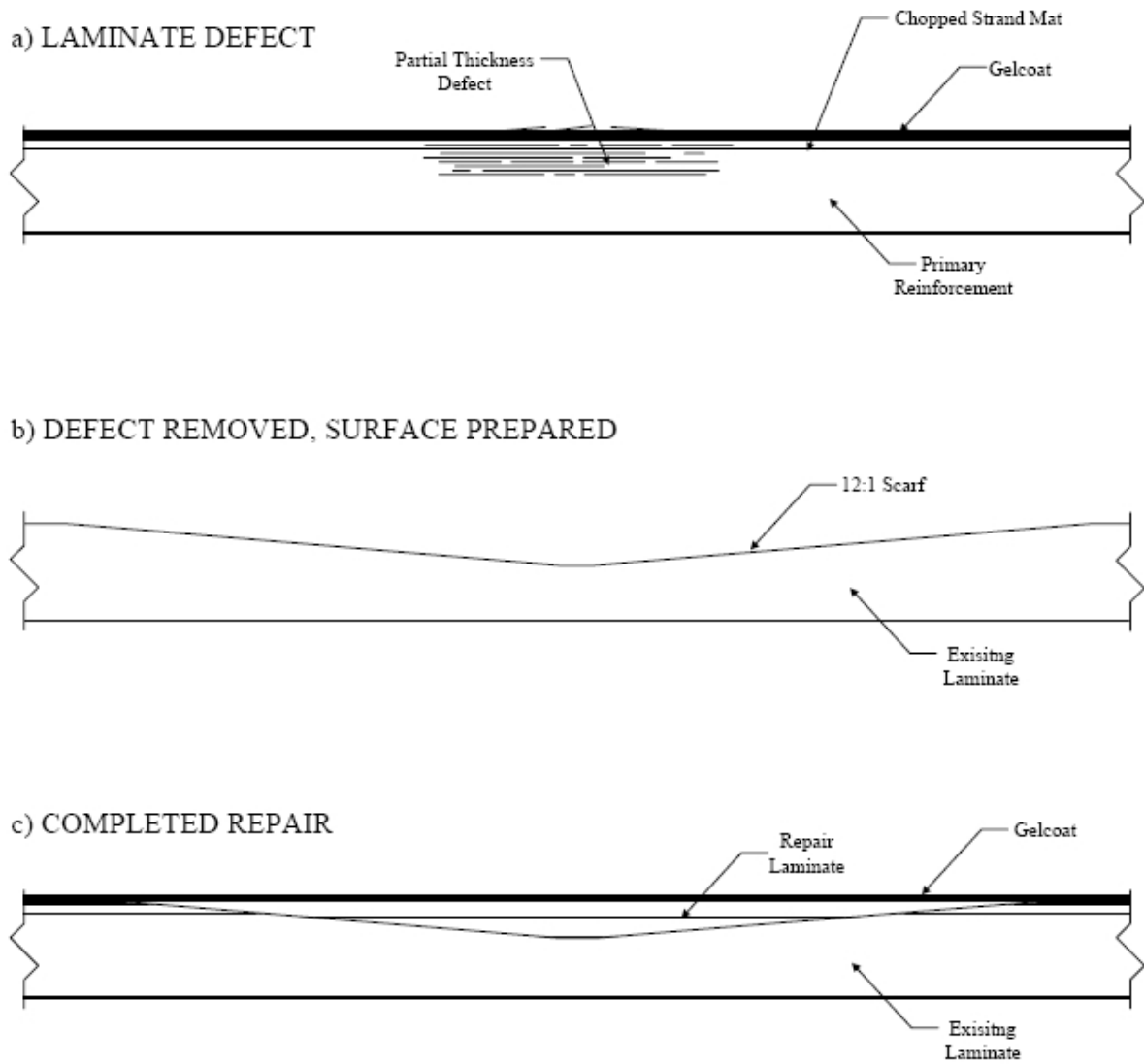
**FIGURE 3**  
**Ply Overlap Requirements**



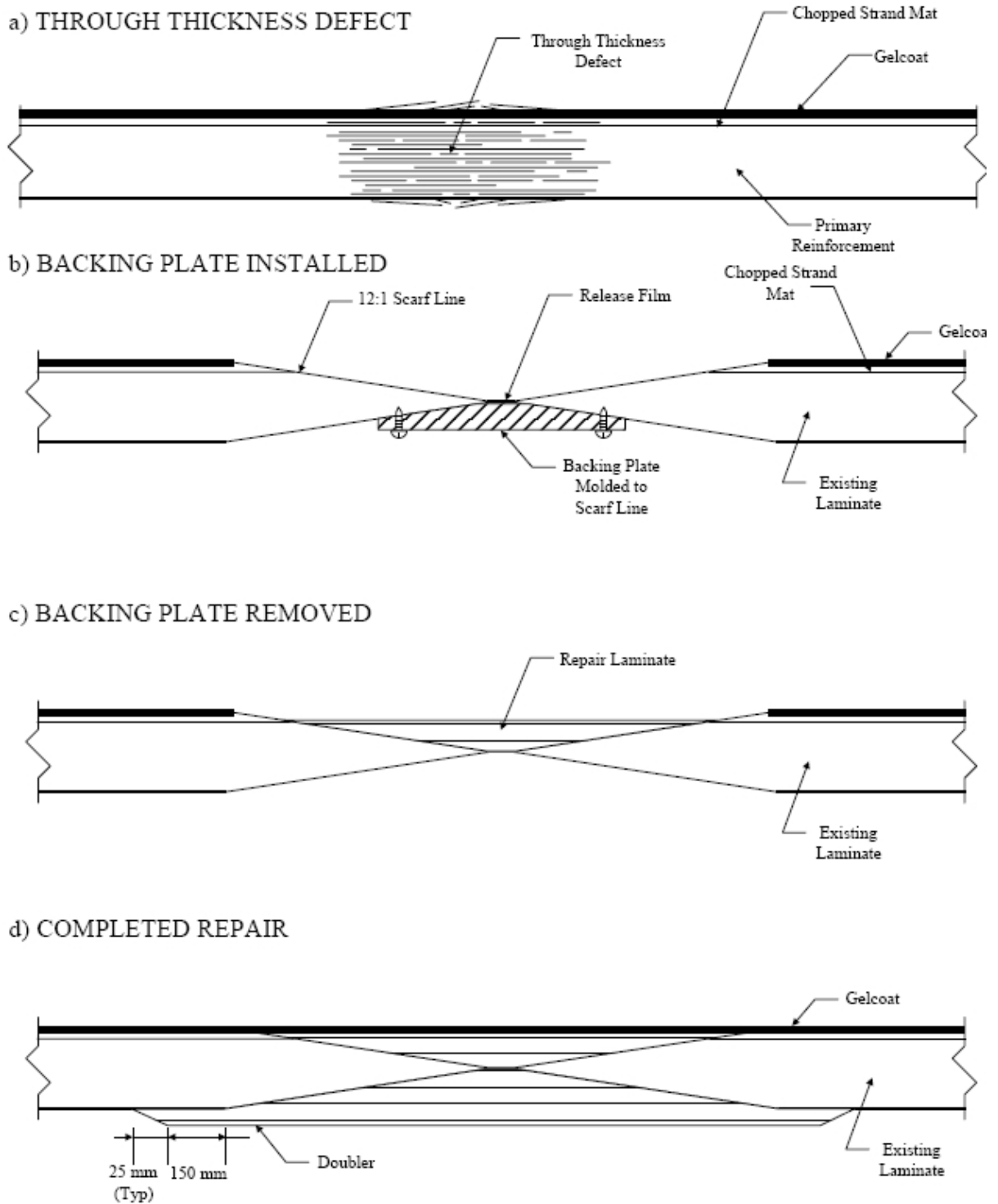
### 5.7 Laminating Process

In all cases, the first ply applied to the existing surface is to be chopped strand mat. This layer is to cover the entire faying surface and is to be saturated in the laminating resin. The laminating procedures, as outlined in 2-6-3/9.7, are to be followed. When lamination is required on an inclined or overhead surface, precautions are to be taken so that the wet reinforcements do not fall. Acceptable laminating repairs can be seen in 2-6-6/Figures 4 through 11.

**FIGURE 4**  
**Partially Through Thickness Defect Repair**

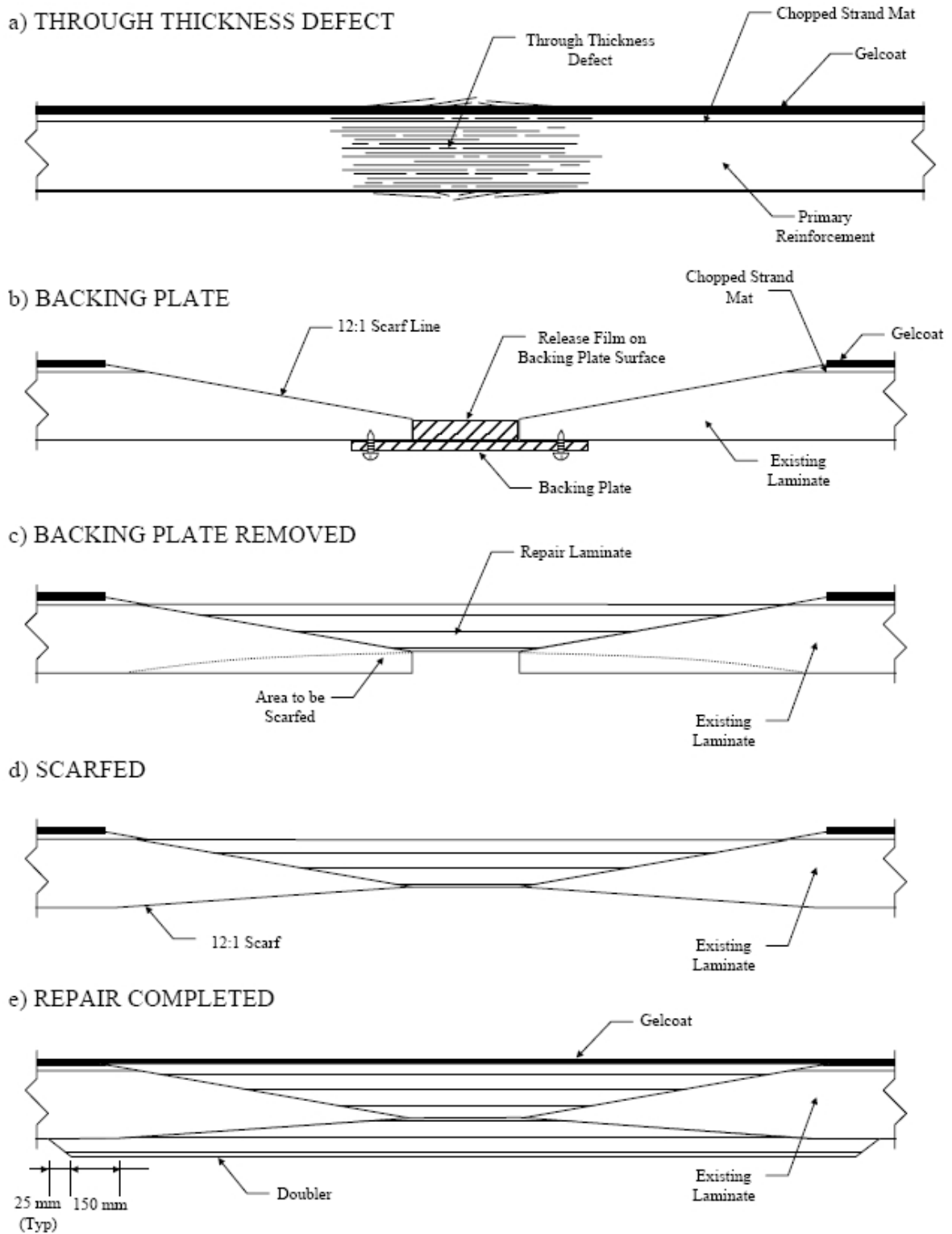


**FIGURE 5**  
**Double Sided Scarf Repair**



Note: Repair shown with additional plies onto non-molded side.

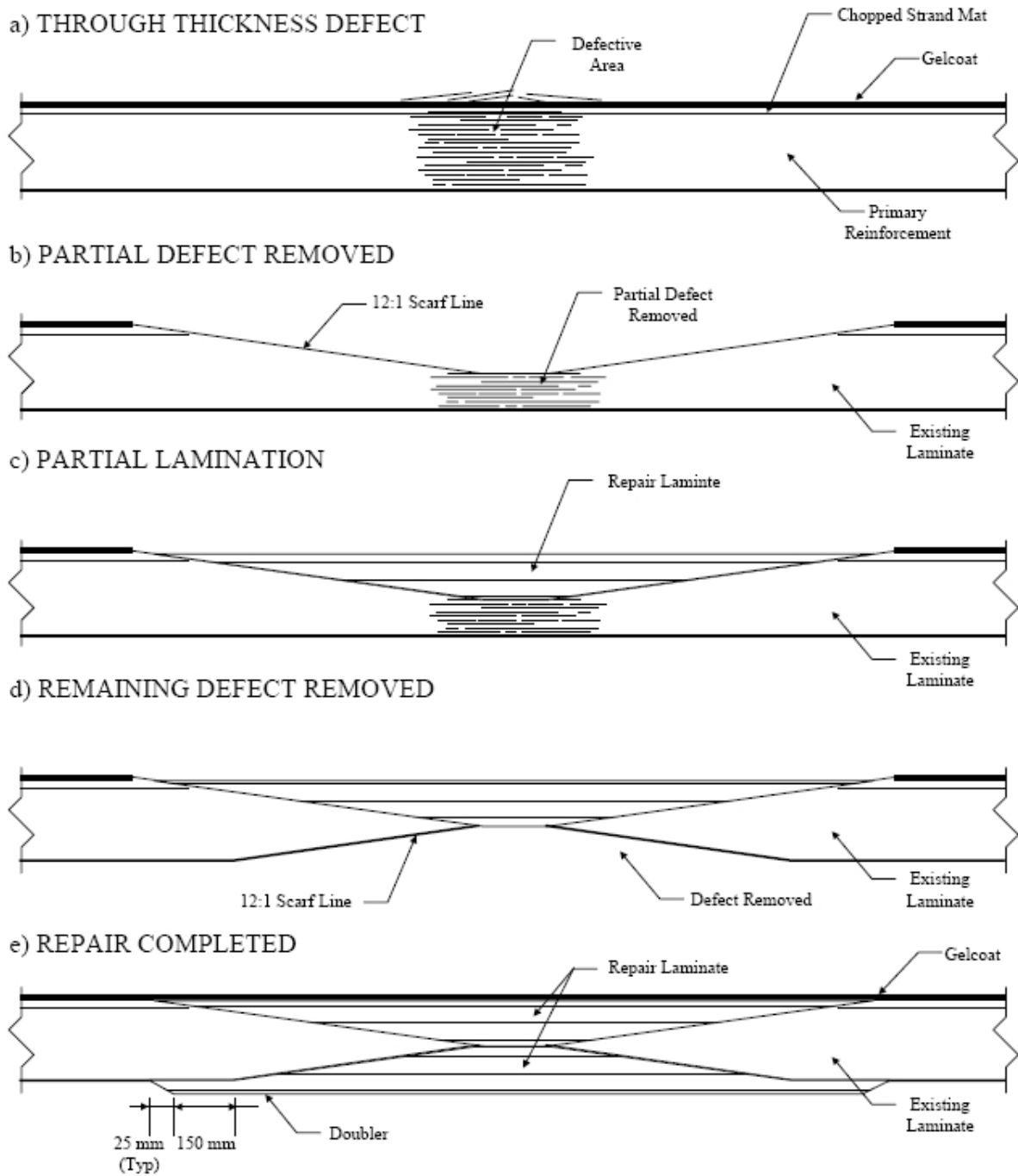
**FIGURE 6**  
**One Sided Scarf Repair – Backing Plate Installation**



Note: Repair shown with additional plies onto non-molded side.



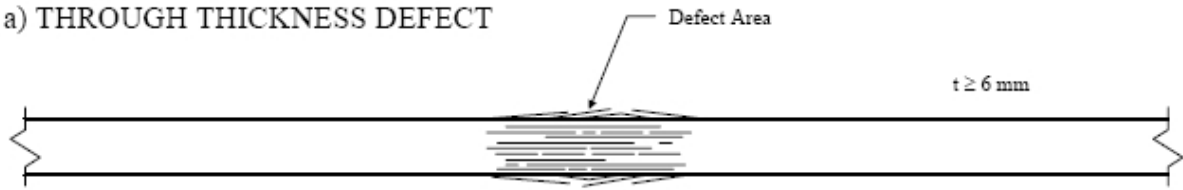
**FIGURE 7**  
**Repair Using Defective Section as Backing Plate**



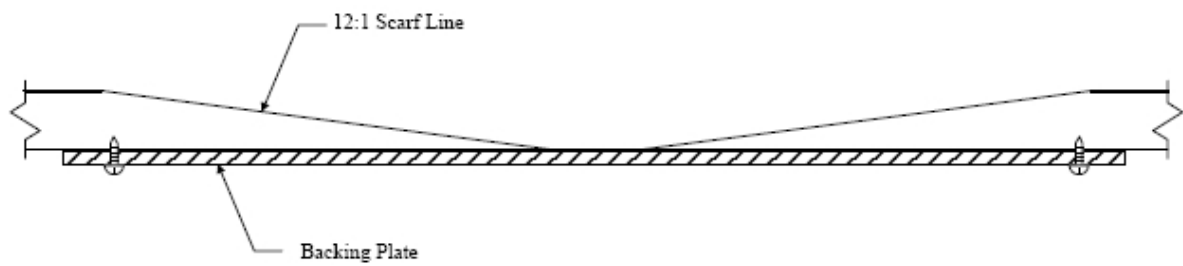
Note: Repair shown with additional plies onto non-molded side.

**FIGURE 8**  
**Single Sided Scarf Repair on Thin Laminate**

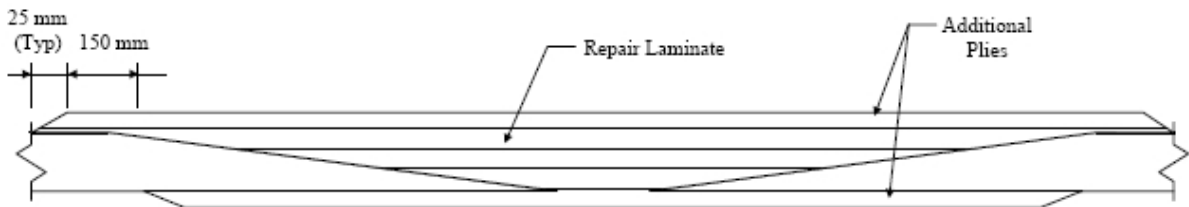
a) THROUGH THICKNESS DEFECT



b) BACKING PLATE INSTALLATION



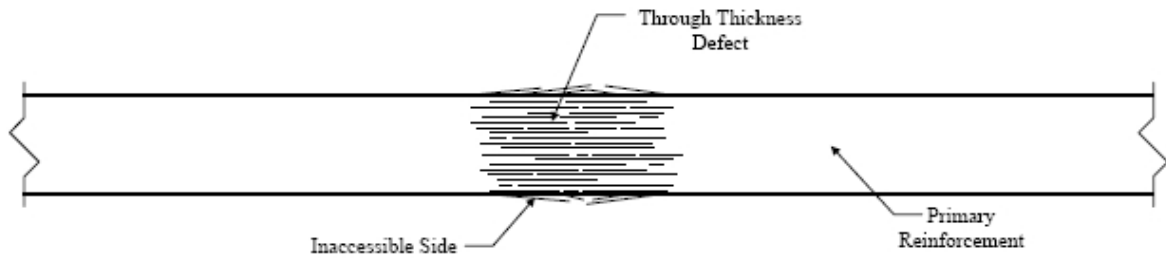
c) COMPLETED REPAIR



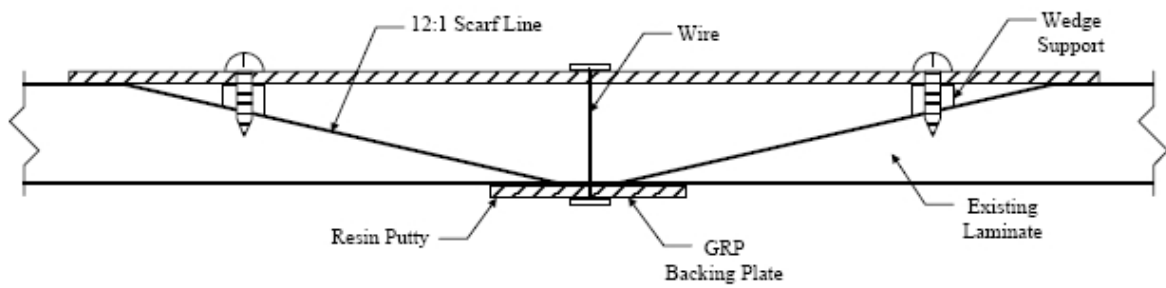
*Note:* Repair shown with additional plies onto non-molded side.

**FIGURE 9**  
**Backing Plate Installation – Access from One Sided Repair**

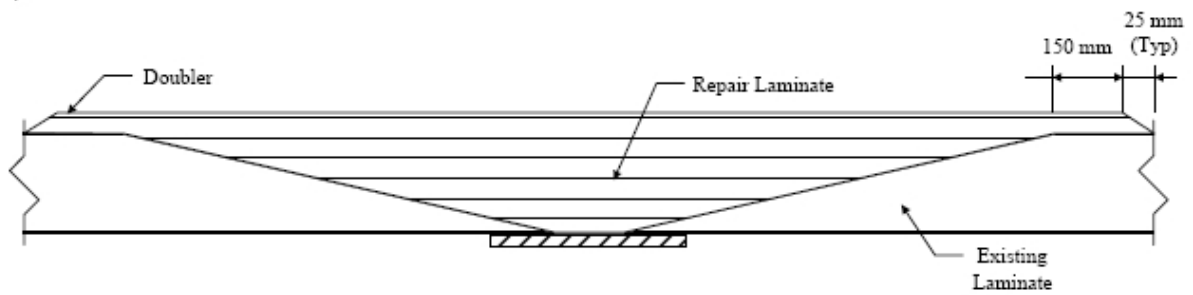
a) DEFECTIVE LAMINATE



b) BACKING PLATE INSTALLATION



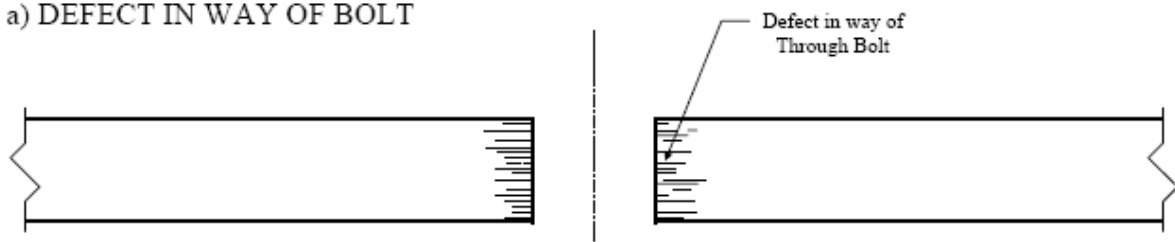
c) COMPLETED REPAIR



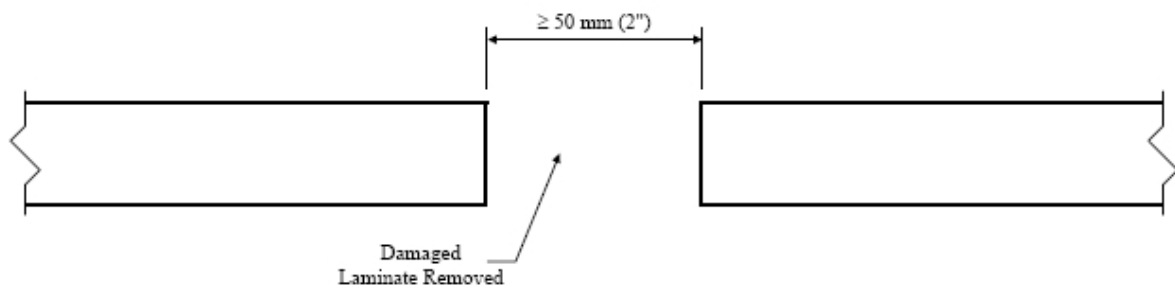
Note: Repair shown with additional plies onto non-molded side.

**FIGURE 10**  
**Repair in Way of Through Bolt Failure**

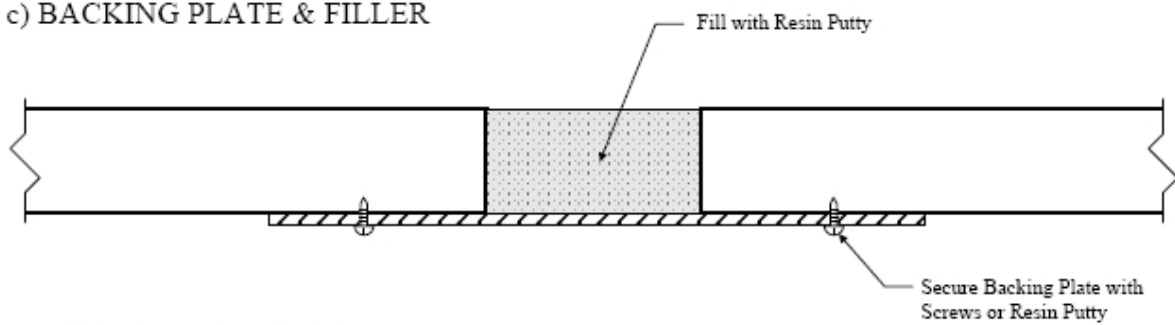
a) DEFECT IN WAY OF BOLT



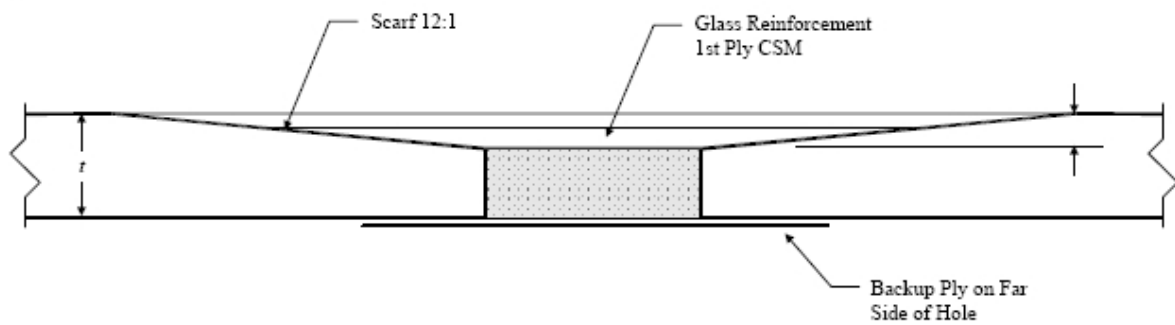
b) LAMINATE REMOVAL



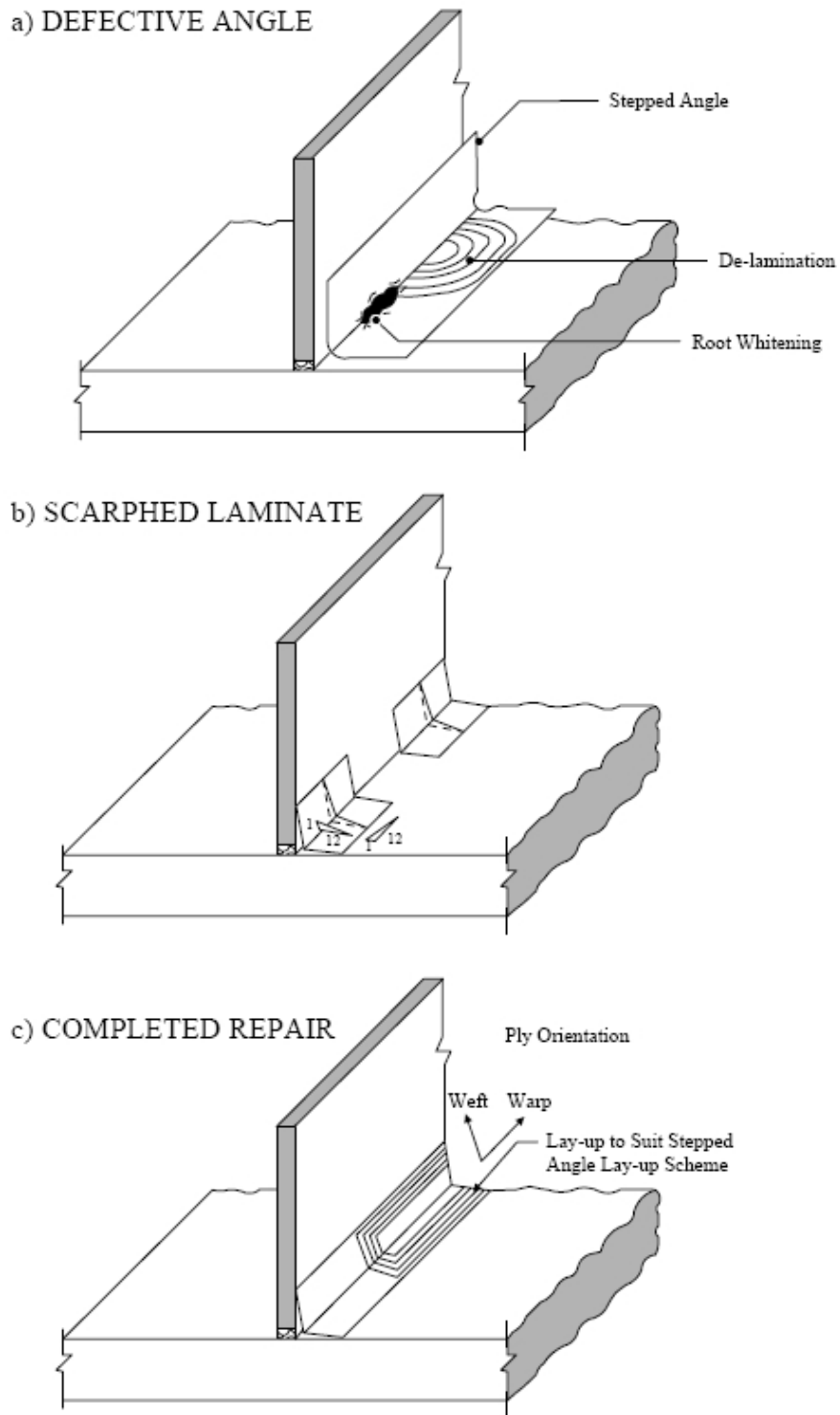
c) BACKING PLATE & FILLER



d) COMPLETED REPAIR



**FIGURE 11**  
**Stepped Angle Defect Repair**



## 7 Repair Procedure – Sandwich Construction

### 7.1 Damage Assessment

The techniques outlined in 2-6-6/5.1 are to be applied to sandwich laminate. However, the extent of damage may extend far beyond the area of visible damage.

### 7.3 Removal of Damaged Laminate

The requirements in 2-6-6/5.3 are, in general, applicable to sandwich laminates. The cut back area will be increasingly larger, proceeding from the outer skin to the inner skin.

### 7.5 Laminating Procedure and Process

In general, the skins of a sandwich laminate are to be as indicated in 2-6-6/5.5 and 2-6-6/5.7. The new core is to be similar in type and density to the core that is being replaced. The new core will need to be slightly thinner than the existing core to accommodate the additional repair laminate thickness. The laminating procedure outlined in 2-6-3/9.9 is to be followed.

## 9 Repair Acceptance

Prior to the acceptance and painting of the repair, the area is to be inspected for the following:

- i)* There are to be no open voids, pits, cracks, crazing, delaminations or embedded contaminants in the laminate.
- ii)* There is to be no evidence of resin discoloration or other evidence of extreme exotherm.
- iii)* There is to be no dry reinforcement as indicated by white laminate
- iv)* There are to be no wrinkles in the reinforcement and no voids greater than 12 mm ( $\frac{1}{2}$  in.)

The surface of the repair is to be smooth and conform to the surrounding surface contour. The degree of cure is to be within 10% of the required BARCOL hardness, as indicated in 2-6-5/3.



# PART 2

## APPENDIX 1

### Tests Required for Materials, and Responsibility for Verifying

#### CONTENTS

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SECTION	1	List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying.....	505
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# PART 2

## APPENDIX 1

### Tests Required for Materials, and Responsibility for Verifying

#### SECTION 1

### List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying (2018)

#### Test and Test Data

- i)* **Witnessed Tests.** The designation (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved under ABS's Quality Assurance Program.
- ii)* **Manufacturer's Data.** The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.
- iii)* **Other Tests.** The designation (A) indicates those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with Rule requirements.

2-1-1 General	
2-1-1/17	Through Thickness Properties (W)
2-1-2 Ordinary-Strength Hull Structural Steel	
2-1-2/5.1	Ladle Analysis (M)
2-1-2/5.3	Product Analysis (M)
2-1-2/5.7.1	McQuaid - Ehn (M)
2-1-2/9.1	Tension Test (W)
2-1-2/11.1	Charpy V-notch Impact Test (W)
2-1-3/1 Higher-Strength Hull Structural Steel	
2-1-3/3	Ladle Analysis (M)
2-1-3/3	Tension Test (W)
2-1-3/3	Charpy V-notch Impact Test (W)
2-1-3/3	Product Analysis (M)
2-1-3/5	McQuaid - Ehn (M)



<b>2-1-4 Materials for Low Temperature Service</b>	
2-1-4/5.1	Charpy V-notch Impact Test (W)
2-1-4/5.3	Drop-weight Test (NDTT) (W)
<b>2-1-5 Hull Steel Castings</b>	
2-1-5/7	Tension Test (W)
2-1-5/13.11	Magnetic Particle Inspection (A)
2-1-5/13.11	Dye Penetrant Inspection (A)
2-1-5/13.11	Ultrasonic Inspection (A)
<b>2-1-6 Hull Steel Forgings</b>	
2-1-6/1.7	Ladle Analysis (M)
2-1-6/7	Tension Test (W)
2-1-6/11.3	Brinell Hardness Test (BHN) (W)
<b>2-1-7 Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks (2017)</b>	
2-1-7/7	Ladle Analysis (M)
2-1-7/11	Tension Test (W)
2-1-7/11	Charpy V-notch Impact Test (W)
2-1-7/7	Product Analysis (M)
2-1-7/7	McQuaid-Ehn (M)
2-1-7/3.3 and 3.5	Corrosion Tests (A)
<b>2-1-8 Extra High Strength Quenched and Tempered Steel (2018)</b>	
2-1-8/3	Ladle Analysis (M)
2-1-8/5	Tension Test (W)
2-1-8/5	Charpy V-notch Impact Test (W)
2-1-8/3	Product Analysis (M)
2-1-8/2	McQuaid-Ehn (M)
2-1-8/11	Ultrasonic Inspection (W)
<b>2-2-1 Anchors</b>	
2-2-1/7.1	Proof Test (W)
2-2-1/7.3	Product Test (W) - See 2-2-1/7.3.1 TABLE 1 and 2-2-1/7.3.1 TABLE 2
<b>2-2-2 Anchor Chain</b>	
2-2-2/11.1.2	Ladle Analysis (M)
2-2-2/13.5, 2-2-2/19.5 and 2-2-2/23.3	Tension Test (W)
2-2-2/13.7 and 2-2-2/23.3	Bend Test (W)

2-2-2/13.9, 2-2-2/19.5 and 2-2-2/23.3	Charpy V-notch Impact Test (W)
2-2-2/17.1, 2-2-2/19.1 and 2-2-2/23.13	Breaking Test (W)
2-2-2/17.1, 2-2-2/19.3 and 2-2-2/23.15	Proof Test (W)
2-2-2/23.9	Magnetic Particle Inspection (A)
2-2-2/23.11	Brinell Hardness Test (W)
<b>2-2-2/25 Unstudded Short-link Chain</b>	
2-2-2/25.1	Ladle Analysis (M)
2-2-2/25.1	Tension Test (W)
2-2-2/25.1	Bend Test (W)
2-2-2/25.3	Breaking Test (W)
2-2-2/25.3	Proof Test (W)
<b>2-3-2 General Requirements for All Grades of Steel Plates for Machinery, Boilers, and Pressure Vessels</b>	
2-3-2/1.7.1	Ladle Analysis (M)
2-3-2/1.7.2	Product Analysis (M)
2-3-2/1.9.1, 2-3-2/1.9.2, and 2-3-2/1.9.3	Test Specimens (W)
2-3-2/1.11.1, 2-3-2/1.11.2, and 2-3-2/1.11.3	Tensile Properties (W)
<b>2-3-2/3 Steel Plates for Intermediate Temperature Service</b>	
2-3-2/3.5	Chemical Composition (M)
2-3-2/3.9	Tensile Properties (W)
<b>2-3-2/5 Steel Plates for Intermediate and Higher-Temperature Service</b>	
2-3-2/5.7	Chemical Composition (M)
2-3-2/5.11	Tensile Properties (W)
<b>2-3-2/7 Steel Plates for Intermediate and Lower-Temperature Service</b>	
2-3-2/7.1	McQuaid-Ehn (M)
2-3-2/7.7	Chemical Composition (M)
2-3-2/7.11	Tensile Properties (W)
<b>2-3-2/9 Materials for Low Temperature Service [Below -18C (0°F)]</b>	
Those listed in Section 2-1-4 and 2-3-2/9	
<b>2-3-3 Seamless Forged-Steel Drums</b>	
2-3-3/1	Tension Tests (W)
<b>2-3-4 Seamless-Steel Pressure Vessels</b>	
2-3-4/3	Tension Test (W)
2-3-4/5	Flattening Test (W)

2-3-4/7	Hydrostatic Test (W)
2-3-4/9	Thickness Test (W)
<b>2-3-5 Boiler and Superheater Tubes</b>	
2-3-5/9	Chemical Composition (M)
2-3-5/11	Product Analysis (M)
2-3-5/17	Tensile Properties (W)
2-3-5/19	Flattening Test (W)
2-3-5/21	Reverse Flattening Test (W)
2-3-5/23	Flange Test (W)
2-3-5/25	Flaring Test (W)
2-3-5/27	Crush Test (W)
2-3-5/29	Hardness Test (W)
2-3-5/31	Hydrostatic Test (W)
2-3-5/33	Nondestructive Electric Test (NDET) (A)
2-3-5/39	Thickness Test (A)
<b>2-3-6 Boiler Rivet and Staybolt Steel and Rivets</b>	
2-3-6/5	Tensile Properties (W)
2-3-6/7	Bending Properties (Bars) (W)
2-3-6/13.1	Bending Properties (Rivets) (W)
2-3-6/13.3	Flattening Test (W)
<b>2-3-7 Steel Machinery Forgings</b>	
2-3-7/1.1.2, 2-3-7/3.1.2, 2-3-7/5.1.2, 2-3-7/7.1.2	Chemical Composition (M)
2-3-7/1.7, 2-3-7/3.7, 2-3-7/5.7, 2-3-7/7.7	Tensile Properties (W)
2-3-7/1.13.1, 2-3-7/5.11.1	Surface Inspection of Tailshaft Forgings (W)
2-3-7/1.13.3, 2-3-7/5.11.2	Ultrasonic Examination of Tail Shaft Forgings (A)
2-3-7/1.11.2, 2-3-7/3.7.2, 2-3-7/5.9.4, 2-3-7/7.7.2	Hardness Test (W)
<b>2-3-8 Hot-rolled Steel Bars for Machinery</b>	
2-3-8/1	Those listed in Section 2-3-7 above
<b>2-3-9 Steel Castings for Machinery, Boilers, and Pressure Vessels (2013)</b>	
2-3-9/1.3	Chemical Composition (M)
2-3-9/7	Tensile Properties (W)
2-3-9/15 and 2-3-9/17	Magnetic Particle or Dye Penetrant Inspection (W)

<b>2-3-10 Ductile (Nodular) Iron Castings</b>	
2-3-10/11	Tension Tests (W)
2-3-10/7	Chemical Composition (M)
<b>2-3-11 Gray-iron Castings</b>	
2-3-11/13	Tension Test (W)
<b>2-3-12 Steel Piping</b>	
2-3-12/5	McQuaid-Ehn (M)
2-3-12/9	Chemical Composition (M)
2-3-12/13	Product Analysis (M)
2-3-12/23	Tension Tests (W)
2-3-12/25	Bend Test (W)
2-3-12/27	Flattening Test (W)
2-3-12/29	Hydrostatic Test (W)
2-3-12/37	Thickness Test (A)
<b>2-3-13 Piping, Valves and Fittings for low Temperature Service [Below -18 °C (0 °F)]</b>	
2-3-13/5	McQuaid-Ehn (M)
2-3-13/11	Chemical Composition (M)
2-3-13/13	Mechanical Test (M) [(W) for Piping]
2-3-13/15	Impact Properties (M) [(W) for Piping]
<b>2-3-13 Valves on Vessels Intended to Carry Liquefied Gases in Bulk for Low Temperature Service [at or Below -55°C (-67°F)] (2006)</b>	
2-3-13/5	McQuaid-Ehn (M)
2-3-13/11	Chemical Composition (M)
2-3-13/13	Mechanical Test (W)
2-3-13/15	Impact Properties (W)
<b>2-3-13 Valves on Vessels Intended to Carry Liquefied Gases in Bulk for Low Temperature Service [Above -55°C (-67°F)] (2006)</b>	
2-3-13/5	McQuaid-Ehn (M)
2-3-13/11	Chemical Composition (M)
2-3-13/13	Mechanical Test (M)
2-3-13/15	Impact Properties (M)
<b>2-3-14 Bronze Castings</b>	
2-3-14/3.3	Chemical Composition (M)
2-3-14/3.9	Tensile Properties (W)
2-3-14/3.21	Dye Penetrant Inspection (W)

<b>2-3-15 Austenitic Stainless Steel Propeller Castings</b>	
2-3-15/3	Dye Penetrant Inspection (W)
2-3-15/5	Chemical Composition (M)
2-3-15/7	Tensile Properties (W)
<b>2-3-16 Seamless Copper Piping</b>	
2-3-16/9	Chemical Composition (M)
2-3-16/11	Tension Test (W)
2-3-16/13	Expansion Test (W)
2-3-16/15	Flattening Test (W)
2-3-16/17	Hydrostatic Test (W) (M)
2-3-16/23	Thickness Test (A)
<b>2-3-17 Seamless Red-brass Piping</b>	
2-3-17/7	Chemical Composition (M)
2-3-17/9	Expansion Test (W)
2-3-17/11	Flattening Test (W)
2-3-17/13	Mercurous Nitrate Test (M)
2-3-17/15	Bend Test (W)
2-3-17/17	Hydrostatic Test (W) (M)
2-3-17/23	Thickness Test (A)
<b>2-3-18 Seamless Copper Tube (2013)</b>	
2-3-18/9	Chemical Composition (M)
2-3-18/11	Tension Test (W)
2-3-18/13	Expansion Test (W)
2-3-18/15	Flattening Test (W)
2-3-18/17	Hydrostatic Test (W) (M)
2-3-18/23	Thickness Test (A)
<b>2-3-19 Condenser and Heat Exchanger Tube (2013)</b>	
2-3-19/9	Chemical Composition (M)
2-3-19/11	Tension Test (W)
2-3-19/13	Expansion Test (W)
2-3-19/15	Flattening Test (W)
2-3-19/17	Nondestructive Electric Test (NDET) (A)
2-3-19/19	Hydrostatic Test (W) (M)
2-3-19/27	Dimensions (A)

<b>2-3-20 Copper-Nickel Tube and Pipe (2013)</b>	
2-3-20/9	Chemical Composition (M)
2-3-20/11	Tension Test (W)
2-3-20/13	Expansion Test (W)
2-3-20/15	Flattening Test (W)
2-3-20/17	Nondestructive Electric Test (NDET) (A)
2-3-20/17	Radiographic Examination (A)
2-3-20/19	Hydrostatic Test (W) (M)
2-3-20/27	Dimensions (A)
<b>2-3-21 Monel Pipe and Tube (2013)</b>	
2-3-21/9	Chemical Composition (M)
2-3-21/11	Tension Test (W)
2-3-21/13	Flattening Test (W)
2-3-21/15	Flare Test (W)
2-3-21/17	Flange Test (W)
2-3-21/21	Hydrostatic Test (W) (M)
2-3-21/23	Nondestructive Electric Test (NDET) (A)
2-3-21/29	Dimensions (A)

# PART 2

## APPENDIX 2

### Requirements for the Approval of Filler Metals

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General.....</b>	<b>517</b>
	1	Scope .....	517
	1.1	Condition of Approval.....	517
	1.3	Approval Procedure (1 October 1993).....	517
	1.5	Aluminum Filler Metals.....	517
	3	Grading .....	517
	3.1	ABS Grades.....	517
	3.3	Other Standards.....	518
	3.5	Special Properties.....	518
	5	Manufacturer's Guarantee (1 October 1994) .....	518
	7	Plant Inspection .....	518
	7.1	Initial Inspection.....	518
	7.3	Annual Inspection (2015).....	518
	9	Test Requirements .....	519
	9.1	General.....	519
	9.3	Test Plate Material.....	519
	11	Welding Conditions .....	520
	13	Chemical Analysis (2009).....	520
	15	Deposited Metal Tension Test .....	520
	15.1	Specimen Type and Preparation.....	520
	15.3	Hydrogen Removal.....	520
	15.5	Test Requirements (1 October 1994).....	520
	17	Butt Weld Tension Test .....	520
	17.1	Specimen Type and Preparation.....	520
	17.3	Test Requirements (1 October 1994).....	520
	19	Impact Test .....	521
	19.1	Specimen Type and Preparation (2015).....	521
	19.3	Test Requirements (2015).....	521
	19.5	Retest.....	521
	21	Butt Weld Bend Test .....	521
	21.1	Specimen Type and Preparation.....	521

	21.3	Test Requirements.....	521
	21.5	Alternative Test for YQ-Grades (1997).....	522
23		Diffusible Hydrogen Test (1997) .....	522
	23.1	Optional or Required Test.....	522
	23.3	Test Methods (2005).....	522
	23.5	Alternative Test Method.....	522
	23.7	Test Requirements (2005).....	523
25		Special Tests .....	523
	25.1	Nondestructive Testing.....	523
	25.3	Additional Tests.....	523
27		Licensee Approvals (2007).....	523
29		Annual Check Tests (2015) .....	524
	29.1	Upgrading and Uprating (1 October 1993).....	524
31		Quality Assurance Program (1 October 1993) .....	524
33		Retests (2006) .....	524
TABLE 1 Tension Test Requirements .....			527
TABLE 2 Impact Test Requirements.....			528
FIGURE 1 Deposited Metal Tension Test Specimen (2014).....			525
FIGURE 2 Butt Weld Tension Test Specimen (2005).....			525
FIGURE 3 Charpy V-Notch Impact Test Specimen.....			526
FIGURE 4 Bending Elongation Test (1997).....			527

<b>SECTION</b>	<b>2</b>	<b>Electrodes for Shielded Metal Arc Welding.....</b>	<b>531</b>
	1	General .....	531
	3	Chemical Analysis .....	531
	5	Deposited Metal Test Assemblies .....	531
	5.1	Test Assembly (2005).....	531
	5.3	Test Specimens (1 October 1994).....	531
	7	Butt Weld Test Assemblies .....	531
	7.1	Test Assemblies.....	531
	7.3	Welding Procedure (1996).....	532
	7.5	Test Specimens (2008).....	532
	9	Fillet Weld Test Assemblies .....	532
	9.1	General (2005).....	532
	9.3	Test Assemblies.....	533
	9.5	Welding Procedure.....	533
	9.7	Test Specimens.....	533
	11	Low Hydrogen Approval (1997) .....	533
	11.1	Ordinary-Strength Filler Metals (1997).....	533
	11.3	Higher-Strength Filler Metals (2009).....	533
	11.5	YQ Grade Filler Metals (2005).....	534



13	Annual Check Tests .....	534
13.1	General (1 October 1993).....	534
13.3	Upgrading and Uprating (2008).....	534
FIGURE 1	Deposited-Metal Test Assembly for Manual and Gas-Metal Arc Welding.....	535
FIGURE 2	Butt-Weld Test Assembly for Manual and Gas-Metal Arc Welding.....	536
FIGURE 3	Fillet-Weld Test Assembly.....	537
FIGURE 4	Fillet Weld Hardness Test Locations.....	537
<b>SECTION 3</b>	<b>Wire-Flux Combinations for Submerged Arc Welding.....</b>	<b>538</b>
1	General (1997) .....	538
3	Chemical Analysis .....	538
5	Deposited Metal Test Assemblies for Multi-run Technique .....	538
5.1	Test Assembly (2005).....	538
5.3	Test Specimens (1 October 1994).....	538
7	Butt Weld Test Assemblies for Multi-run Technique .....	539
7.1	Test Assembly.....	539
7.3	Test Specimens.....	539
9	Butt Weld Assemblies for Two-run Technique .....	539
9.1	Test Assemblies (2005).....	539
9.3	Test Specimens (1 October 1994).....	539
9.5	Longitudinal All-Weld-Metal Tension Test (1 October 1994).....	539
11	Fillet Weld Tests .....	539
13	Low Hydrogen Approval (1997) .....	540
13.1	YQ Grade Wires -Flux Combination (2005).....	540
15	Annual Check Tests .....	540
15.1	General (1996).....	540
15.3	Upgrading and Uprating (2008).....	540
17	Multiple Electrodes .....	540
19	Electroslag Welding (1996) .....	540
19.1	General (1997).....	540
19.3	Annual Tests (1996).....	541
19.5	Upgrading and Uprating (1996).....	541
FIGURE 1	Deposited-Metal Test Assembly for Submerged Arc Welding -Multi-runTechnique and Automatic Gas-Metal Arc Welding.....	542
FIGURE 2	Butt-Weld Test Assembly for Submerged Arc Welding – Multi-run Technique (2008).....	543
FIGURE 3	Butt-Weld Test Assembly for Submerged Arc Welding - Two-run Technique (2009).....	544

FIGURE 4	Butt-Weld Impact Specimen Location for Submerged and Gas-Metal Arc Welding -Two-run Technique.....	546
----------	--	-----

<b>SECTION 4</b>	<b>Wire and Wire Gas Combinations for Gas Metal Arc Welding and Flux Cored Wires for Flux Cored Arc Welding.....</b>	<b>547</b>
1	General (1997) .....	547
3	Chemical Analysis and Shielding Gas Compositions (2008).....	547
5	Deposited Metal Test Assemblies for Semi-automatic and Automatic Testing .....	548
5.1	Semi-automatic Test Assemblies (2009).....	548
5.3	Test Specimens for Semi-automatic.....	548
5.5	Automatic Test Assembly (2008).....	548
5.7	Test Specimens for Automatic.....	549
7	Butt Weld Test Assemblies for Semi-automatic and Automatic Techniques .....	549
7.1	Test Assemblies.....	549
7.3	Welding Procedure (2009).....	549
7.5	Test Specimens (2005).....	549
9	Butt Weld Test Assemblies for Two-run Technique .....	549
9.1	Test Assemblies.....	549
9.3	Test Specimens (1996).....	550
9.5	Longitudinal All-Weld-Metal Tension Test.....	550
11	Fillet Weld Tests .....	550
11.1	General (2018).....	550
11.3	Test Assemblies.....	550
11.5	Welding Procedure.....	550
11.7	Test Requirements.....	550
13	Low Hydrogen Approval .....	550
13.1	Flux Cored Wire.....	550
15	Annual Check Tests .....	551
15.1	General (2011).....	551
15.3	Upgrading and Uprating (2008).....	551
17	Electrogas Welding (1996) .....	552
17.1	General (1997).....	552
17.3	Annual Tests (1996).....	552
17.5	Upgrading and Uprating (1996).....	552

TABLE 1	Compositional Limits of Designated Groups of Gas Types and Mixtures (2008).....	548
---------	---	-----

FIGURE 1	Butt-Weld Test Assembly for Gas-Metal Arc Welding - Two-run Technique.....	553
----------	--	-----

FIGURE 2	Contact Tip to Work Distance (2005).....	554
----------	--	-----

<b>SECTION</b>	<b>5</b>	<b>Requirements for the Approval of Aluminum Filler Metals (2018)</b> .....	<b>555</b>
	1	General.....	555
		1.1 Scope.....	555
		1.3 Grading, Designation.....	555
		1.5 Manufacture, Testing and Approval Procedure.....	556
	3	Testing and Required Properties.....	557
		3.1 Testing of the Deposited Weld Metal.....	557
		3.3 Testing of Butt Weld Assemblies.....	557
	5	Annual Check Tests.....	560
	TABLE 1	Consumable Grades and Base Materials for the Approval Test (2009).....	555
	TABLE 2	Compositional Limits of Shielding Gases and Mixtures to be Used.....	556
	TABLE 3	Requirements for the Transverse Tensile and Bend Tests (2009).....	560
	FIGURE 1	Deposited Weld Metal Test Assembly.....	557
	FIGURE 2	Butt Weld Test Assembly for Out-of-position Welding.....	557
	FIGURE 3	Butt Weld Test Assembly in Flat Position.....	558

## **1 Scope**

### **1.1 Condition of Approval**

The scope and conditions of classification contained in Part 1, Chapter 1 of the *ABS Rules for Conditions of Classification (Part 1)* are applicable to the approval of welding filler metals, insofar as they are appropriate. Approval will be for each plant of each manufacturer carrying out its own quality control inspection and certification.

### **1.3 Approval Procedure (1 October 1993)**

Welding filler metals intended for hull construction will be approved by ABS, subject to compliance with the requirements and test schedules as outlined herein. The requirements are based on the following:

#### **1.3.1**

Guarantee by the manufacturer of the minimum properties

#### **1.3.2**

Inspection of the manufacturing facility by an ABS Surveyor

#### **1.3.3**

Testing of selected samples

The test assemblies are to be prepared and tested in the presence of an ABS Surveyor. The Surveyor is to be satisfied that the manufacturer's plant and method of filler metal production are capable of ensuring reasonable uniformity in production. ABS is to be notified of any alterations proposed to be made in the production of filler metals.

### **1.5 Aluminum Filler Metals**

Approval of aluminum filler metals is covered in Section 2-A2-5.

## **3 Grading**

### **3.1 ABS Grades (1 July 2019)**

Filler metals are divided into three groups based on the steel for which they are intended.

Ordinary-Strength Steel (2-1-2/Table 1 through 2-1-2/Table 4)	No suffix.
Higher-Strength Steel (2-1-3/Table 1 through 2-1-3/Table 4)	Suffix Y and Y400
Extra High-Strength Steel (2-1-8/Tables 4A and 5A)	Suffix YQ420 through YQ960

Each group is further divided into multiple levels based on the strength and/or toughness, the latter being represented by the toughness digit 1 through 5. Exact combination of digit/suffix and corresponding tensile and impact requirements are indicated in 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2.

### 3.3 Other Standards

At the option of the manufacturer, filler metals may be approved to a recognized standard. The required tests and procedures for such approval are to be in accordance with the specified standard. In addition, annual inspection and testing are to be carried out for continued approval.

### 3.5 Special Properties

Welding filler metals may be approved to the manufacturer's guaranteed minimum properties over and above or in addition to the requirements for the applicable standard. Notations indicating guaranteed minimum properties will be added, as appropriate, upon verification by test.

## 5 Manufacturer's Guarantee (1 October 1994)

Each plant of the manufacturer is to file an application for each filler metal indicating the following:

- Specification and Grade/Classification
- Electrode (wire) size and welding position
- Flux or shielding gas
- Current/Polarity
- Recommended volts and amperage
- Guaranteed all-weld-metal chemical and mechanical properties
- Guaranteed hydrogen content (for H15, H10, H5, Y or Y400 designation)

## 7 Plant Inspection

### 7.1 Initial Inspection

Before marketing the product, each plant manufacturing welding filler metals submitted for ABS approval is to be inspected by an ABS Surveyor to satisfy himself that the facilities, production method, quality assurance procedures, etc., in that plant are adequate to maintain uniform and acceptable quality in production.

The Surveyor is also to satisfy himself that the testing machines are maintained in an accurate condition and that a record of periodical calibration is maintained up to date.

Where a plant approved by ABS intends to commence production of a new product, plant inspection may be required for the facilities, production methods, and quality control procedures for the new product.

### 7.3 Annual Inspection (2015)

Each plant manufacturing ABS-approved welding filler metals is to be inspected by an ABS Surveyor annually. These inspections are to be completed and reported within one year after the initial approval date,

and repeated annually so as to provide at least an average of one annual inspection per year. The extent of the inspection is as indicated in 2-A2-1/7.1. Special consideration for equivalent arrangements may be accepted subject to special agreement with ABS.

## 9 Test Requirements

### 9.1 General

When the plant inspection required in 2-A2-1/7 is completed, representative filler metal samples will be selected by the Surveyor for welding and testing in his presence. The preparation of the test assemblies and test specimens are to be in accordance with the following:

### 9.3 Test Plate Material

#### 9.3.1 Deposited Metal Test and Diffusible Hydrogen Test (2010)

Except as indicated below, any grade of ordinary-strength or higher-strength hull structural steel may be used for the preparation of all test assemblies.

For the deposited metal test assemblies of YQ Grades, fine grain structural steel compatible with the properties of the weld metal is to be used. Alternatively, other steel may be used, provided the groove is buttered with the filler metal or, if deposited metal testing is carried out with a process not suitable for buttering, buttering may be carried out using another process and a filler metal of equivalent chemical composition.

#### 9.3.2 Butt Weld Test and Fillet Weld Test (1 July 2019)

For butt weld test assembly and fillet weld test assembly, as applicable, one of the grades of steel as listed below, or equivalent IACS grade or other classification society grade, for the individual grade of filler metals is to be used

Grade 1	A
Grade 2	A, B, D
Grade 3	A, B, D, E
Grade 1Y	AH32, AH36
Grade 2Y	AH32, AH36, DH32, DH36
Grade 3Y	AH32, AH36, DH32, DH36, EH32, EH36
Grade 4Y	AH32, AH36, DH32, DH36, EH32, EH36, FH32, FH36
Grade 2Y400	AH36, AH40, DH36, DH40
Grade 3Y400	AH36, AH40, DH36, DH40, EH36, EH40
Grades 4Y400, 5Y400	AH36, AH40, DH36, DH40, EH36, EH40, FH36, FH40
Grade 3 YQXXX :	AQZZ, DQZZ
Grade 4 YQXXX	AQZZ, DQZZ, EQZZ
Grade 5 YQXXX	AQZZ, DQZZ, EQZZ, FQZZ

(XXX/ZZ = 420/43, 460/47, 500/51, 550/56, 620/63, 690/70, 890/91, and 960/98)

For Y grade filler metals, the tensile strength of the base metal is to be at least 490 N/mm<sup>2</sup> (50 kgf/mm<sup>2</sup>, 71 ksi).

### 9.3.3 Ordinary and Higher-strength Filler Metals (Dual Approvals) (1 October 1994)

The required deposit metal test assemblies may be made using either ordinary or H32/36 higher-strength hull structural steel. The required butt weld test assemblies are to be made using steel with a tension strength of 490 N/mm<sup>2</sup> (50 Kgf/mm<sup>2</sup>, 71 ksi) or greater. The test results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade.

Dual approval of Y400 grade filler metals will be specially considered.

### 9.3.4 Electroslag or Electrogas Welding for Higher-Strength Steel (2005)

For unrestricted approval, the test plate should contain niobium close to its maximum allowable limit of 0.05%. Where such a plate is not used, the filler metal approval may be restricted to plates other than niobium treated.

## 11 Welding Conditions

The welding conditions used, such as amperage, voltage, travel speed, etc., are to be held within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the welding of the test assemblies, unless specified otherwise by the applicable standard of 2-A2-1/3.3.

## 13 Chemical Analysis (2009)

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer and is to include the content of all significant alloying elements (e.g., those identified in an AWS filler metal specification). Results of the analysis shall not exceed the limit values specified in the standard or by the manufacturer, the narrower tolerances being applicable in each case.

## 15 Deposited Metal Tension Test

### 15.1 Specimen Type and Preparation

The deposited metal tension test specimens are to be machined to the dimensions indicated in 2-A2-1/33 FIGURE 1, care being taken that the longitudinal axis coincides with the center of the weld and the mid-thickness of the plate.

### 15.3 Hydrogen Removal

The tension test specimen may be subjected to a temperature not exceeding 250°C (482°F) for a period not exceeding 16 hours for hydrogen removal, prior to testing.

### 15.5 Test Requirements (1 October 1994)

The values of tensile strength, yield stress and elongation are to be recorded. The results are to conform to the requirements of 2-A2-1/33 TABLE 1.

## 17 Butt Weld Tension Test

### 17.1 Specimen Type and Preparation

The butt weld tension test specimens are to be machined to the dimensions indicated in 2-A2-1/33 FIGURE 2. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

### 17.3 Test Requirements (1 October 1994)

The results are to conform to the tensile strength requirement of 2-A2-1/33 TABLE 1. The position of the fracture is to be reported.

## 19 Impact Test

### 19.1 Specimen Type and Preparation (2015)

The impact test specimens are to be of the Charpy V-notch type and machined to dimensions indicated in 2-A2-1/33 FIGURE 3. The test specimens are to be cut with their longitudinal axis perpendicular to the weld and are to be taken from the middle of the plate thickness for multi-pass welds, from the middle of the second (2<sup>nd</sup>) run for two-run technique welds and from 2 mm ( $\frac{5}{64}$  in.) maximum below one surface for electroslag or electrogas welds. The notch is to be positioned in the center of the weld, unless specified otherwise in 2-A2-3/19 and 2-A2-4/17. The notch is to be cut perpendicular to the surface of the plate. Where the test temperature is other than ambient, the test temperature of the test pieces at the moment of breaking is to be controlled to within  $\pm 2^{\circ}\text{C}$  ( $\pm 3.6^{\circ}\text{F}$ ) of the required temperature.

### 19.3 Test Requirements (2015)

The average value of three specimens is to equal or exceed the required average value indicated in 2-A2-1/33 TABLE 2, according to the applicable grade and welding technique. Only one individual value may be below the required average value, provided it is not less than 70% of the required average value.

### 19.5 Retest

When the results fail to meet the above requirements but conditions (2-A2-1/19.5.2) and (2-A2-1/19.5.3) below are complied with, three additional specimens may be taken from the same assembly and the results added to those previously obtained to form a new average. The retest is acceptable, if for the six specimens, all of the following conditions are met.

#### 19.5.1

The new average is not less than the required average.

#### 19.5.2

No more than two individual values are below the required average.

#### 19.5.3

No more than one individual value is below 70% of the required average.

If the test is unsatisfactory, further tests may be made, at the discretion of the Surveyor, on a new assembly. In such cases, all required tests, including those previously found satisfactory, are to be carried out.

## 21 Butt Weld Bend Test

### 21.1 Specimen Type and Preparation

The butt weld face and root bend test specimens are to be 30 mm (1.2 in.) in width. The upper and lower surfaces of the weld are to be filed, ground, or machined flush with the surface of the plate. The corners of the specimens may be rounded to a radius not exceeding 2 mm ( $\frac{5}{64}$  in.).

### 21.3 Test Requirements (1 July 2019)

The test specimens are to be bent through an angle of 120 degrees around a pin or mandrel having the following diameter:

Ordinary Strength	Three times the thickness of the specimen
Y and Y400	Three times the thickness of the specimen
YQ420, YQ460 & YQ500	Four times the thickness of the specimen
YQ550, YQ620 & YQ690	Five times the thickness of the specimen.



YQ890	Six times the thickness of the specimen.
YQ960	Seven times the thickness of the specimen.

For a face bend, the face of the weld is to be in tension during testing and for a root bend, the root of the weld is to be in tension during testing. The specimens are to withstand bending without developing any crack or discontinuity greater than 3.2 mm ( $\frac{1}{8}$  in.) in length on the tension surface of the specimen. For electroslag or electrogas welded test assemblies, side bend tests are to be used in lieu of root and face bend tests.

### 21.5 Alternative Test for YQ-Grades (1997)

For YQ-Grade, a bending elongation test in accordance with 2-A2-1/33 FIGURE 4 may be accepted. For this alternative, the bending elongation on gauge length  $Lo = Ls + t$  ( $Ls$  = width of weld,  $t$  = specimen thickness) is to meet the minimum elongation requirements in 2-A2-1/33 TABLE 1.

## 23 Diffusible Hydrogen Test (1997)

### 23.1 Optional or Required Test (1 July 2019)

Any ABS grade welding consumables not required to undergo diffusible hydrogen testing as specified below may, at the option of the manufacturer, be submitted for testing. A suffix indicating the hydrogen amount will be added to those welding consumables to indicate compliance with the hydrogen test requirements specified in 2-A2-1/23.7.

Higher-strength, shielded metal arc welding electrodes and flux cored wires, and YQ grade shielded metal arc welding electrodes, submerged arc welding wire-flux combinations, and flux-cored wires are to be submitted to a hydrogen test. Test results are to meet the requirements for the following notations, except that Y-grade electrodes with a diffusible hydrogen content greater than H10 and Y-grade flux-cored wires with a diffusible hydrogen content greater than H15 will be specially identified, as indicated in 2-A2-1/23.7, 2-A2-2/11.3, and 2-A2-4/13.1.3.

Y-Grade shielded metal arc electrodes	H10
Y-Grade flux-cored wires	H15
YQ420/460/500 Grades	H10
YQ550/620/690/890/960 Grades	H5

### 23.3 Test Methods (2005)

The diffusible hydrogen content of the weld metal is to be determined in accordance with the test methods prescribed in ISO 3690 or AWS A4.3, or any other method such as the gas chromatographic method that correlates with ISO 3690 with respect to cooling rate and delay times during preparation of the weld samples and hydrogen volume determinations.

The thermal conductivity deduction (TCD) method, such as that described in BS-6693 Appendix C, is also acceptable provided the equipment is calibrated against another standard such as AWS A4.3 or ISO 3690.

### 23.5 Alternative Test Method

In lieu of the test methods indicated in 2-A2-1/23.3, a recognized alternate procedure may be considered for Grades other than YQ. The following glycerine method will be acceptable.

Four test specimens are to be prepared measuring approximately  $12 \times 25$  mm ( $\frac{1}{2} \times 1$  in.) in cross section by 125 mm (5 in.) in length. The test specimens may be any grade of hull structural steel and are to be weighed to the nearest 0.1 gm before welding. On the wider surface of each test specimen, a single bead of welding is to be deposited about 100 mm (4 in.) in length with a 4 mm ( $\frac{5}{32}$  in.) electrode, using about 150

mm (6 in.) of the electrode. The welding is to be carried out with as short an arc as possible and with a current of approximately 150 amperes.

The electrodes, prior to welding, can be subjected to the normal drying process recommended by the manufacturer. Within thirty seconds of the completion of the welding of each specimen, the slag is to be removed and the specimen quenched in water having a temperature of approximately 20°C (68°F). After an additional 30 seconds the specimens are to be cleaned and placed in an apparatus suitable for the collection of hydrogen by displacement of glycerin. The glycerin is to be kept at a temperature of 45°C (113°F) during the test. All four test specimens are to be welded and placed in the hydrogen collecting apparatus within 30 minutes.

The specimens are to be kept immersed in the glycerin for a period of 48 hours and after removal are to be cleaned in water or suitable solvent, dried, and weighed to the nearest 0.1 gram to determine the amount of weld deposited. The amount of gas evolved is to be measured to the nearest 0.01 ml and corrected for temperature and pressure to 0°C (32°F) and 760 mm (30 in.) Hg.

### 23.7 Test Requirements (2005)

The individual and average diffusible hydrogen content of the four specimens is to be reported and the average value in milliliters (ml) per 100 grams is not to exceed the following:

<i>Suffix</i>	<i>AWS A4.3 or ISO 3690</i>	<i>Glycerin Method</i>
H15	15	10
H10	10	5
H5	5	-

All higher-tensile strength steel grade shielded metal arc electrodes with an average value above the H10 requirement and flux cored wires with an average value above the H15 requirement are to be identified with “non-low hydrogen electrode, requires special approval for use with higher-strength steel”.

## 25 Special Tests

### 25.1 Nondestructive Testing

The welded assemblies may be subjected to radiographic or ultrasonic examination to ascertain any discontinuities in the weld prior to testing.

### 25.3 Additional Tests

ABS may specify any additional tests as may be necessary.

## 27 Licensee Approvals (2007)

When a filler metal is manufactured in more than one plant of the same company or by a licensee company, a complete set of approval tests is to be carried out on the samples selected from products of the main plant. In the other plants, a reduced test program equivalent to annual check tests plus diffusible hydrogen test may be permitted, if the main plant and licensee can certify that the materials used, the fabrication process and final products by the licensee are identical to those in the main plant. Affidavits from both the main plant and licensee are to be submitted attesting to this fact. However, should there be any doubt, a complete test series may be required.

*Note:*

Wire-flux combinations for submerged arc welding. If a unique flux is combined with different wires coming from several factories belonging to the same firm, it is acceptable, after initial approval, to perform only one test series if the various wires conform to the same technical specification.

## 29 Annual Check Tests (2015)

The facilities and associated quality control systems, where approved filler metals are manufactured, are subject to an annual inspection in accordance with 2-A2-1/7.3. Annual check tests are to be conducted in accordance with 2-A2-2/13;2-A2-3/15 and 2-A2-3/19.3;2-A2-4/15; or 2-A2-4/17.3, whichever is applicable for the welding process. Test data are to conform to the applicable requirements, whichever is applicable for the welding process. Test data are to conform to the applicable requirements. These annual check tests are to be completed and reported within the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year. Special consideration for equivalent arrangements may be accepted subject to special agreement with ABS.

### 29.1 Upgrading and Uprating (1 October 1993)

Upgrading and uprating of welding filler metals will be considered at the manufacturer's request. Generally, tests from butt weld assemblies and, where applicable, a diffusible hydrogen test will be required in addition to the normal annual check tests. The data is to conform to the applicable requirements. See also 2-A2-2/13.3, 2-A2-3/15.3, 2-A2-3/19.5, 2-A2-4/15.3 and 2-A2-4/17.5.

#### 29.1.1 Upgrading

Upgrading refers to notch toughness and, consequently, Charpy V-notch impact tests are required from butt weld and deposited metal test assemblies. The impact tests are to be conducted at the upgraded temperature.

#### 29.1.2 Uprating (2010)

Uprating refers to the extension of approval to also cover the welding of higher-strength steels (dual approvals). For this purpose, butt-weld tests are to be carried out as required in 2-A2-1/9.3.3. For uprating to YQ grades of SMAW electrodes, fillet testing is to be conducted per 2-A2-2/9.

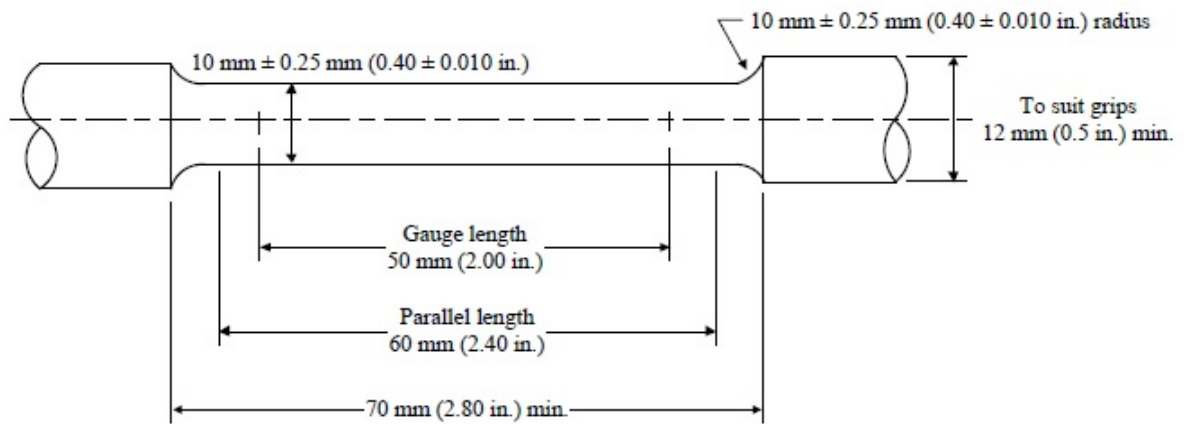
## 31 Quality Assurance Program (1 October 1993)

Where an ABS-approved Quality Assurance Program is maintained and a periodical audit is carried out satisfactorily, the attendance of the Surveyor at the annual check test may be waived, provided the results of the annual check test are examined by the Surveyor and found in accordance with the applicable requirements.

## 33 Retests (2006)

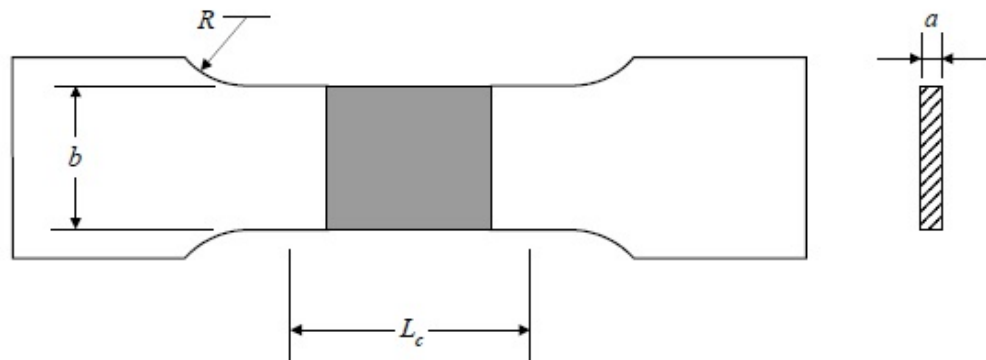
Where the result of a tension or bend test does not comply with the requirements, two test specimens of the same type are to be prepared and tested from the original test assembly, if possible. A new assembly may be prepared using welding consumables from the same batch. The new assembly is to be made with the same procedure (particularly number of runs) as the original assembly. Testing of the new assembly is to include CVN testing. See 2-A2-1/19.5 for impact retests.

**FIGURE 1**  
**Deposited Metal Tension Test Specimen (2014)**



**Note:** The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1% larger in diameter than the center (controlling dimension)

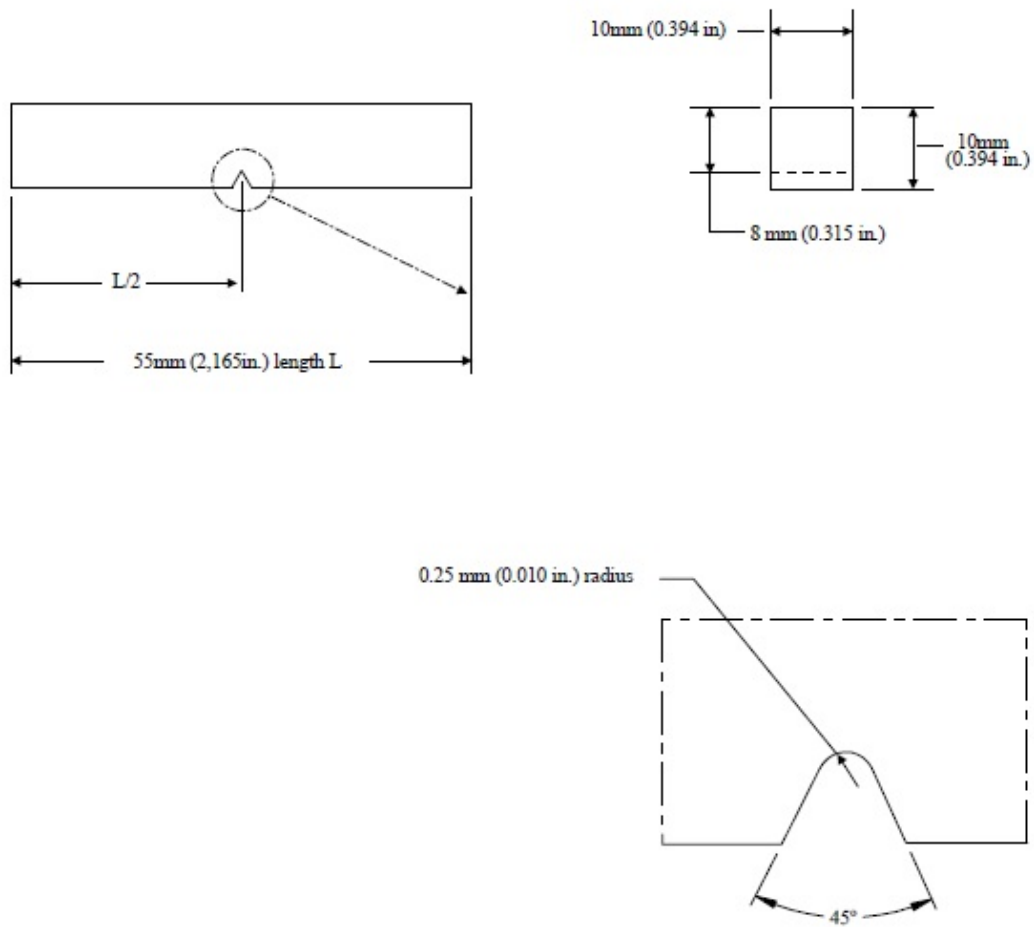
**FIGURE 2**  
**Butt Weld Tension Test Specimen (2005)**



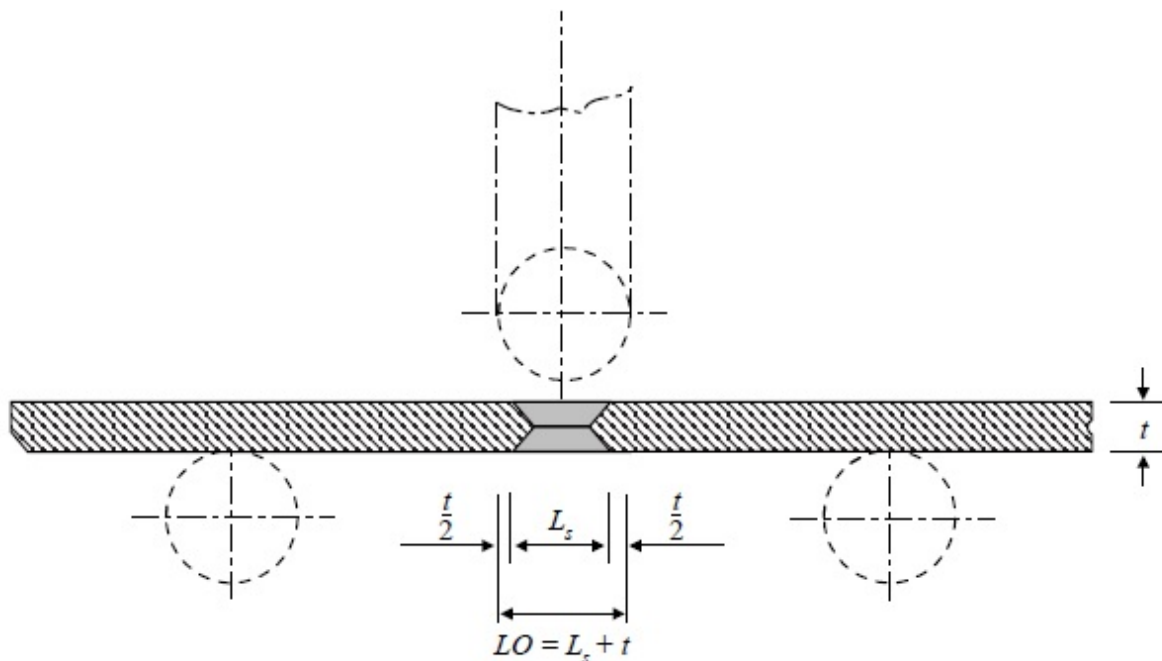
Flat specimen, the weld to be machined (or ground) flush with the surface of the plate, with the following dimensions is to be used:

- $a = t$
- $b = 12 \text{ mm}$  for  $t \leq 2 \text{ mm}$
- $b = 25 \text{ mm}$  for  $t > 2 \text{ mm}$
- $L_c = \text{width of weld} + 60 \text{ mm}$
- $R > 25 \text{ mm}$

**FIGURE 3**  
**Charpy V-Notch Impact Test Specimen**



**FIGURE 4**  
**Bending Elongation Test (1997)**



**TABLE 1**  
**Tension Test Requirements (1 July 2019)**

The tensile requirements are based on the type of test specimen (longitudinal or transverse) specified elsewhere in these Requirements for the particular combination of weld process and the type of required test.

To find the required tension test properties, first locate in the “process” column the welding process for which the filler metal is intended (e.g., wire-flux). Then locate in that line under “applicable test” column the test in question (e.g., DM/M).

The required properties are found below the box in which the particular test is located (longitudinal specimen for the example chosen).

Process	Applicable Tests			
MW	DM			BW
WF	DM/M, DM/TM, BW/T, BW/TM			BW/M, BW/T, BW/TM
WG/SA	DM			BW
WG/A	DM/M, DM/TM, BW/T, BW/TM			BW/M, BW/T, BW/TM
ESEG	BW			BW
Required Properties				
Grade* <sup>3</sup>	Longitudinal Specimen			Transv. Specimen(1999)
	Tensile Strength N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Yield Point, min. N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)	Elongation min. %	Tensile Strength, min. N/mm <sup>2</sup> (kgf/mm <sup>2</sup> , ksi)
1, 2 & 3 (2006)	400/560 (41/57, 58/82)	305 (31, 44)	22	400 (41, 58)
1Y <sup>(1)</sup> , 2Y, 3Y & 4Y	490/660 (50/67, 71/95)	375 (38, 54)	22	490 (50, 71)

2Y400, 3Y400, 4Y400 & 5Y400	510/690 (52/70, 74/100)	400 (41, 58)	22	510 (52, 74)
XYQ420 <sup>(4)</sup>	530/680 54/69, 77/98)	420 (43,61)	20	530 (54, 77)
XYQ460 <sup>(4)</sup>	570/720 (58/73, 83/104)	460 (47, 67)	20	570 (58, 83)
XYQ500 <sup>(4)</sup>	610/770 (62/78, 88/112)	500 (51, 73)	18	610 (62, 88)
XYQ550 <sup>(4)</sup>	670/830 (68/85, 97/120)	550 (56, 80)	18	670 (68, 97)
XYQ620 <sup>(4)</sup>	720/890 (73/91, 104/129)	620 (63, 90)	18	720 (73, 104)
XYQ690 <sup>(4)</sup>	770/940 (78/96, 112/136)	690 (70, 100)	17	770 (78, 112)
XYQ890 <sup>(4)</sup>	940/1100 (96/112, 136/160)	890 (91, 129)	14	940 (96, 136)
XYQ960 <sup>(4)</sup>	980/1150 (100/117, 142/167)	960 (98, 139)	13	980 (100, 142)

Abbreviations:

MW:	Covered Electrode for Manual Welding	A:	Automatic
WF:	Wire-flux Combination	M:	Multi-run
WG:	Wire-gas Combination	T:	Two run* <sup>2</sup>
ESEG:	Electroslag or Electro gas	TM:	Two run & Multi-run* <sup>2</sup>
SA:	Semi-automatic	DM:	Deposited Metal Test
		BW:	Butt Weld Test

Notes:

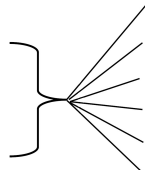
- Grade 1Y not applicable to MW and WG/SA.
- Two run not applicable to YQ Grades.
- X = 3, 4 or 5. See 2-A2-1/33 TABLE 2. (1999)
- X = 3, 4 or 5. See . (1999)
- Specifications for extra high strength steels, for which these XYQ grades of welding consumables are intended, may be found in Section 2-1-8.

**TABLE 2**  
**Impact Test Requirements (1 July 2019)**

There are two levels of energy requirements depending upon the particular combination of weld process, types of required test and, where applicable, welding position.

To find the required energy, first locate under “process” column the welding process for which the filler metal is intended (e.g., wire-gas, semi-automatic). Then locate in that line under “applicable test” column the test/position in question (e.g., BW/F). The required energy is found in the box under the particular test/position combination for respective grade (47J for the example chosen if it is Grade 2Y or 3Y).

Process	Applicable Tests	
MW	DM, BW/F/H/OH	BW/V
WF	—	DM, BW
WG/SA	DM, BW/F/H/OH	BW/V
WG/A	—	DM, BW

ESEG		—	BW/V	
<i>Required Temperature/Energy</i>				
<i>Temp °C (°F)</i>	<i>Grade</i>	<i>Av. Absorbed Energy J (kgf-m, ft-lbf)</i>	<i>Av. Absorbed Energy J (kgf-m, ft-lbf)</i>	
20 (68)	1	47 (4.8, 35)	34 (3.5, 25)	
0 (32)	2	47 (4.8, 35)	34 (3.5, 25)	
-20 (-4)	3	47 (4.8, 35)	34 (3.5, 25)	
20 (68)	1Y <sup>(1)</sup>	See Note 1	34 (3.5, 25)	
0 (32)	2Y	47 (4.8, 35)	34 (3.5, 25)	
-20 (-4)	3Y	47 (4.8, 35)	34 (3.5, 25)	
-40 (-40)	4Y	47 (4.8, 35)	34 (3.5, 25)	
0 (32)	2Y400	47 (4.8, 35)	41 (4.2, 30)	
-20 (-4)	3Y400	47 (4.8, 35)	41 (4.2, 30)	
-40 (-40)	4Y400	47 (4.8, 35)	41 (4.2, 30)	
-60 (-76)	5Y400	47 (4.8, 35)	41 (4.2, 30)	
-20 (-4) X=3 -40 (-40) X=4 -60 (-76) X=5		XYQ420 <sup>(2)</sup>	47 (4.8, 35)	47 (4.8, 35)
		XYQ460 <sup>(2)</sup>	47 (4.8, 35)	47 (4.8, 35)
		XYQ500 <sup>(2)</sup>	50 (5.1, 37)	50 (5.1, 37)
		XYQ550 <sup>(2)</sup>	55 (5.6, 41)	55 (5.6, 41)
		XYQ620 <sup>(2)</sup>	62 (6.3, 46)	62 (6.3, 46)
		XYQ690 <sup>(2)</sup>	69 (7.0, 51)	69 (7.0, 51)
		XYQ890 <sup>(2)</sup>	69 (7.0, 51)	69 (7.0, 51)
		XYQ960 <sup>(2)</sup>	69 (7.0, 51)	69 (7.0, 51)
<i>Alternate Temperature and Energy</i>				
-10 (14)	3	61 (6.2, 45)	44 (4.5, 33)	
10 (50)	1Y	—	40 (4.1, 30)	
0 (32)	1Y	27 (2.8, 20)	—	
-10 (14)	2Y	—	27 (2.8, 20)	
-20 (-4)	2Y	27 (2.8, 20)	—	
-10 (14)	3Y	68 (6.9, 50)	52 (5.3, 38)	
-30 (-22)	3Y	—	27 (2.8, 20)	
-40 (-40)	3Y	27 (2.8, 20)	—	

**Notes:**

- 1 Grade 1Y not applicable to MW and WG/SA.
- 2 Specifications for extra high strength steels, for which these XYQ grades of welding consumables are intended, may be found in Section 2-1-8.



*Abbreviations (2016):*

F: Flat

V: Vertical

H: Horizontal

OH: Overhead

(See also 2-A2-1/33 TABLE  
1.)

# PART 2

## APPENDIX 2

### Requirements for the Approval of Filler Metals

#### SECTION 2

#### Electrodes for Shielded Metal Arc Welding

### 1 General

The annual check test shall consist of two deposited metal test assemblies welded and tested in accordance with 2-A2-2/5.

### 3 Chemical Analysis

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer.

### 5 Deposited Metal Test Assemblies

#### 5.1 Test Assembly (2005)

Two deposited metal test assemblies, as indicated in 2-A2-2/13.3 FIGURE 1, are to be welded in the flat position, one using 4 mm ( $\frac{5}{32}$  in.) electrodes or the smallest size manufactured, whichever is greater, and the other using the largest size manufactured. If an electrode is produced in one size only or if the largest size produced is 4 mm ( $\frac{5}{32}$  in.) or less, one test assembly is sufficient. The weld metal is to be deposited in single or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm ( $\frac{5}{64}$  in.) and not more than 4 mm ( $\frac{5}{32}$  in.) thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

#### 5.3 Test Specimens (1 October 1994)

One tension and one set of three impact specimens are to be prepared from each deposited metal test assembly, as indicated in 2-A2-2/13.3 FIGURE 1 and the results are to conform to the requirements of of 2-A2-1/33 TABLE 1 and 2-A2-1/33.1 TABLE 2 for the applicable grade and welding technique.

### 7 Butt Weld Test Assemblies

#### 7.1 Test Assemblies

One butt weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 2 is to be welded in each position (flat, vertical-up, vertical-down, overhead and horizontal) for which the electrode is recommended by the manufacturer, except that those electrodes meeting the requirements for flat and vertical positions will be

considered as also complying with the requirements for the horizontal position. Where the electrode is only to be approved in the flat position, one additional test assembly is to be welded in that position.

### 7.3 Welding Procedure (1996)

In general, the following welding procedure is to be adopted in making the test assemblies:

*Flat.* First run using 4 mm ( $\frac{5}{32}$  in.) electrodes; remaining runs except last two layers with 5 mm ( $\frac{3}{16}$  in.) or above according to the normal welding practice with the electrodes; the runs of the last two layers with the largest size electrodes manufactured. When a second flat assembly is required, the runs of the last three layers are to be welded with the largest size electrode manufactured.

*Horizontal.* First pass with 4 mm ( $\frac{5}{32}$  in.) or 5 mm ( $\frac{3}{16}$  in.) diameter electrode. Subsequent passes with 5 mm ( $\frac{3}{16}$  in.) diameter electrode.

*Vertical-up and Overhead.* The first run with 3.25 mm ( $\frac{1}{8}$  in.) electrodes; remaining runs with the largest diameter recommended by the manufacturer for the position concerned.

*Vertical down.* The electrode diameter used is to be as recommended by the manufacturer.

For all assemblies, the back weld is to be made with 4 mm ( $\frac{5}{32}$  in.) electrodes in the welding position appropriate to each test sample, after removing the root run to clean metal. For electrodes suitable only for flat position welding, the test assemblies may be turned over to carry out the back weld.

Normal welding practice is to be used, and between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F) but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After welding, the test assemblies are not to be subjected to any heat treatment.

### 7.5 Test Specimens (2008)

One tension, one face bend, one root bend are to be prepared from each butt weld test assembly together with one set of three impact specimens from the flat and vertical test assemblies, as indicated in 2-A2-2/13.3 FIGURE 2. The results of tension and impact tests are to conform to the requirements of 2-A2-1/33 FIGURE 1 and 2-A2-1/33 TABLE 1 for the applicable grade, position and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

## 9 Fillet Weld Test Assemblies

### 9.1 General (2005)

For gravity fillet welding electrodes (including combination gravity/manual electrodes), fillet weld testing is required in addition to deposited metal testing. Butt weld testing is not required. For gravity welding electrodes (including combination gravity/manual electrodes) intended for both fillet and butt welding, fillet weld testing is required in addition to deposited metal and butt weld testing. Gravity welding equipment is to be used in welding fillet weld test assemblies. Such fillet weld tests are to be carried out and tested in accordance with 2-A2-2/9.3 through 2-A2-2/9.7 using gravity welding equipment and the longest size electrode manufactured.

The following applies to SMAW electrodes other than gravity electrodes: An electrode other than YQ Grades is considered approved for fillet welding in position for which the butt weld test of 2-A2-2/7 was satisfactory. Electrodes meeting the flat butt weld requirements will be considered as complying with the requirements for horizontal fillet (HF) welds. Where an electrode is submitted for approval for fillet welds only, the butt weld tests indicated in 2-A2-2/7 may be omitted and fillet weld tests are to be carried out and tested in accordance with 2-A2-2/9.3 through 2-A2-2/9.7.

### 9.3 Test Assemblies

One fillet weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 3, is to be welded in each position for which the electrode is recommended by the manufacturer.

### 9.5 Welding Procedure

The length  $L$  of the fillet test assemblies is to be sufficient to allow for the tests required in 2-A2-2/9.7 and is to provide for at least the deposition of the entire length of the electrode being tested. One side is to be welded using the maximum size electrode manufactured and the second side using the minimum size of electrode manufactured that is recommended for fillet welds. The fillet size will, in general, be determined by the electrode size and the welding current employed during testing. The fillet weld is to be carried out with the longest size electrode using the welding equipment and technique recommended by the manufacturer. The current used while conducting the test, and the manufacturer's recommended current range are to be reported for each electrode size and welding position.

### 9.7 Test Specimens

#### 9.7.1 Macrographs and Hardness Tests (1 October 1994)

Each fillet weld test assembly is to be sectioned, as indicated in 2-A2-2/13.3 FIGURE 3 to form three macro-sections. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity, undercut and slag inclusions. Hardness readings are to be made on each section. The number and location of hardness readings are to approximate those indicated in 2-A2-2/13.3 FIGURE 4. The hardness of the weld is to be determined and is to meet the following listed equivalent values.

<i>Load</i>	<i>Grade 1, 2, 3</i>	<i>Grades Y, Y400 and YQ</i>
Diamond Pyramid (Vickers) Hardness-10 kg (98 N)	To be reported for information	150 min.
Rockwell B-100 kg (980 N)		80 min.

The hardness of the heat affected zone (HAZ) and base metal are also to be determined and reported for information only.

#### 9.7.2 Breaking Test

One of the remaining sections of the fillet weld is to have the weld, on the side welded first, gouged or machined to facilitate breaking the fillet weld on the other side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the side welded second is to be gouged or machined and the section fractured using the above procedure. The fractured surfaces are to be examined and there is to be no evidence of incomplete penetration or internal cracking and they are to be reasonably free from porosity.

## 11 Low Hydrogen Approval (1997)

### 11.1 Ordinary-Strength Filler Metals (1997)

Electrodes which have satisfied the requirements of Grades 2 and 3 may, at the option of the manufacturer, be subjected to a hydrogen test, as specified in 2-A2-1/23.3. A suffix indicating the hydrogen amount will be added to the grade number of those electrodes to indicate compliance with the hydrogen test requirements specified in 2-A2-1/23.7.

### 11.3 Higher-Strength Filler Metals (2009)

Electrodes which are submitted for approval according to Grades 2Y, 3Y, 4Y, 2Y400, 3Y400, 4Y400, or 5Y400 are to be subjected to a hydrogen test and are to meet the requirement specified in 2-A2-1/23.7 for the H10 suffix. Such suffix, however, will not be added to the grade. Electrodes meeting H5 requirements will be so identified. Electrodes meeting the higher-strength requirements, except for hydrogen test, will

require special approval for use on higher strength steel for each user and will be so identified in the list of approved electrodes.

### 11.5 YQ Grade Filler Metals (2005)

Electrodes which are submitted for approval according to YQ Grades are to be subjected to a hydrogen test, as specified in 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

## 13 Annual Check Tests

### 13.1 General (1 October 1993)

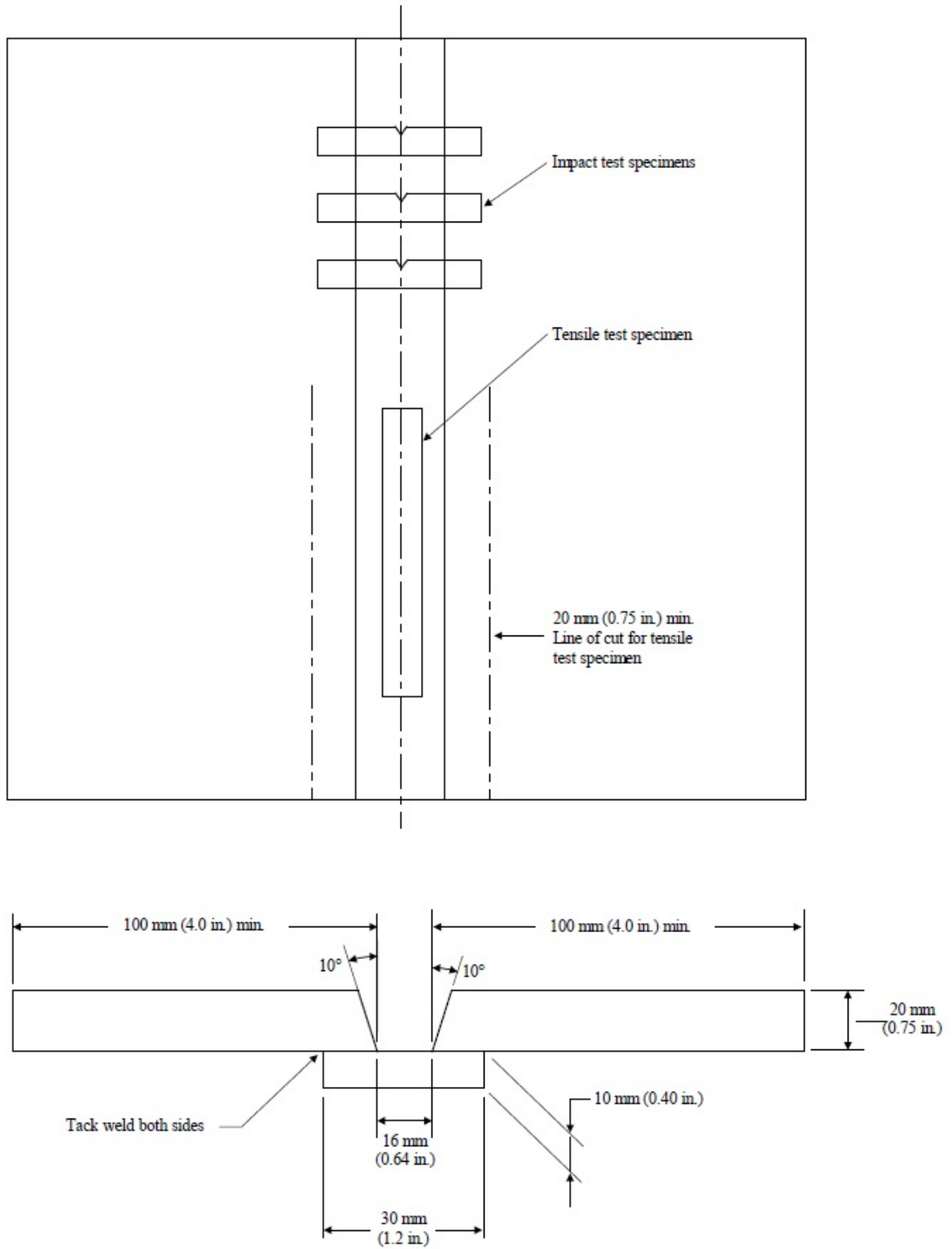
The annual check test shall consist of two deposited metal test assemblies welded and tested in accordance with 2-A2-2/5.

### 13.3 Upgrading and Up-rating (2008)

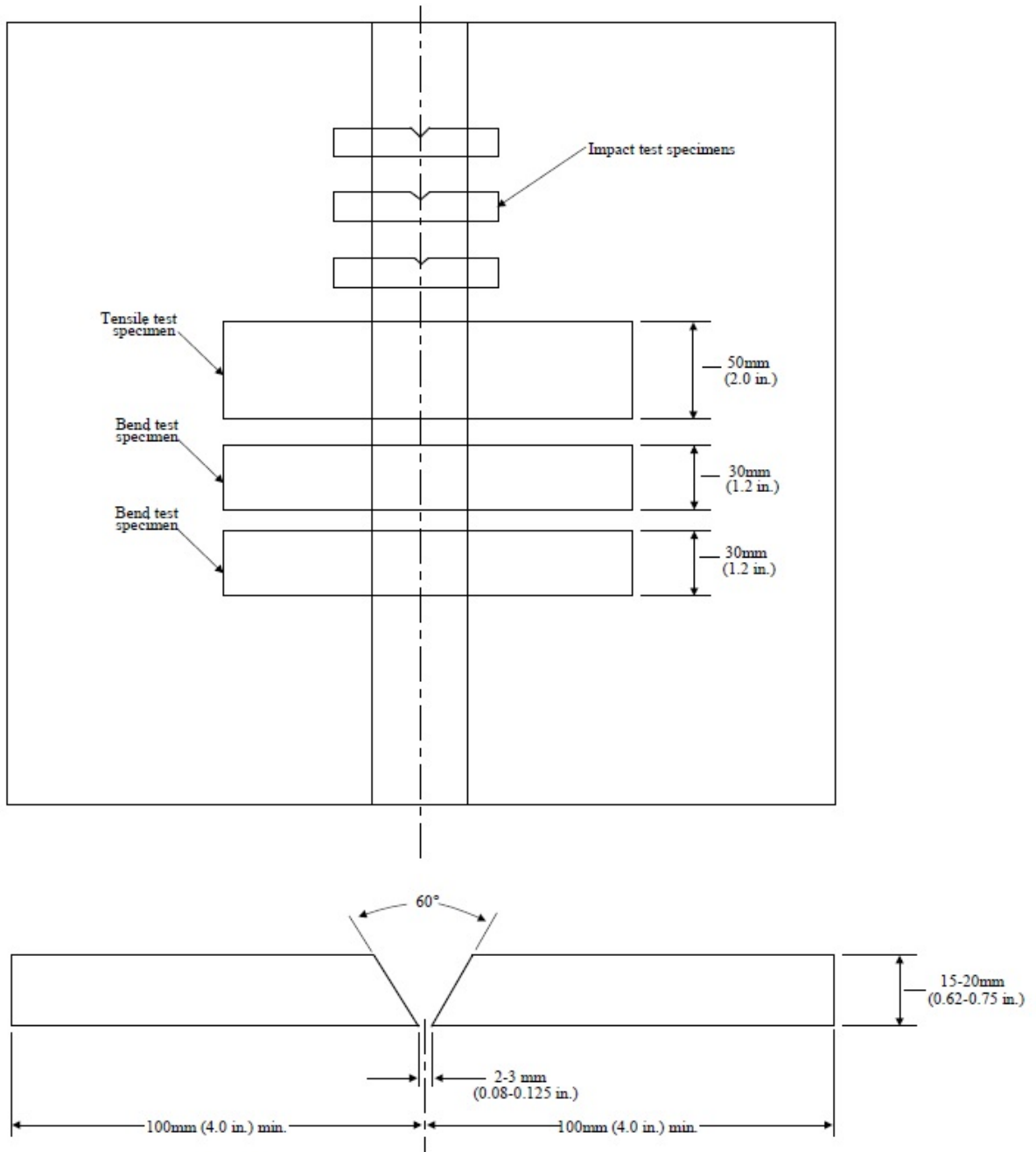
Upgrading of electrodes will be considered at the manufacturer's request. In addition to the two deposited metal tests indicated in 2-A2-2/13.1, a butt weld test assembly is to be welded as indicated in 2-A2-2/7 for each position initially tested, and sets of three impact specimens from each test assembly are to be tested at the upgraded temperature.

Up-rating refers to the extension of approval to also cover the welding of higher-strength steels (dual approvals). For this purpose, butt weld tests are to be carried out, as required in 2-A2-1/9.3.3 and 2-A2-2/7. In addition, the diffusible hydrogen test required by the grade or suffix referred to in 2-A2-2/11.1 and 2-A2-2/11.3 is to be conducted.

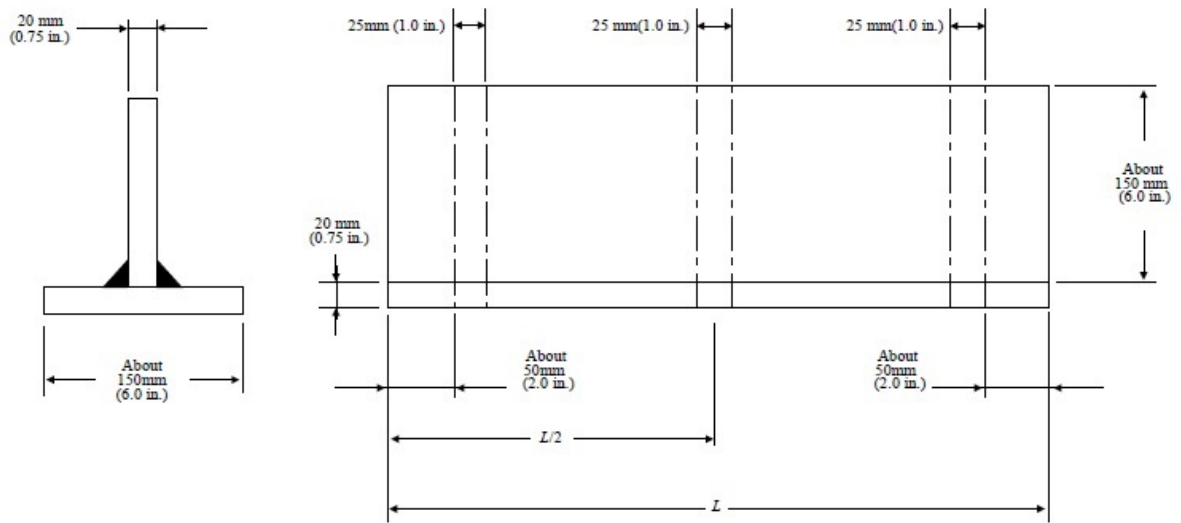
**FIGURE 1**  
**Deposited-Metal Test Assembly for Manual and Gas-Metal Arc Welding**



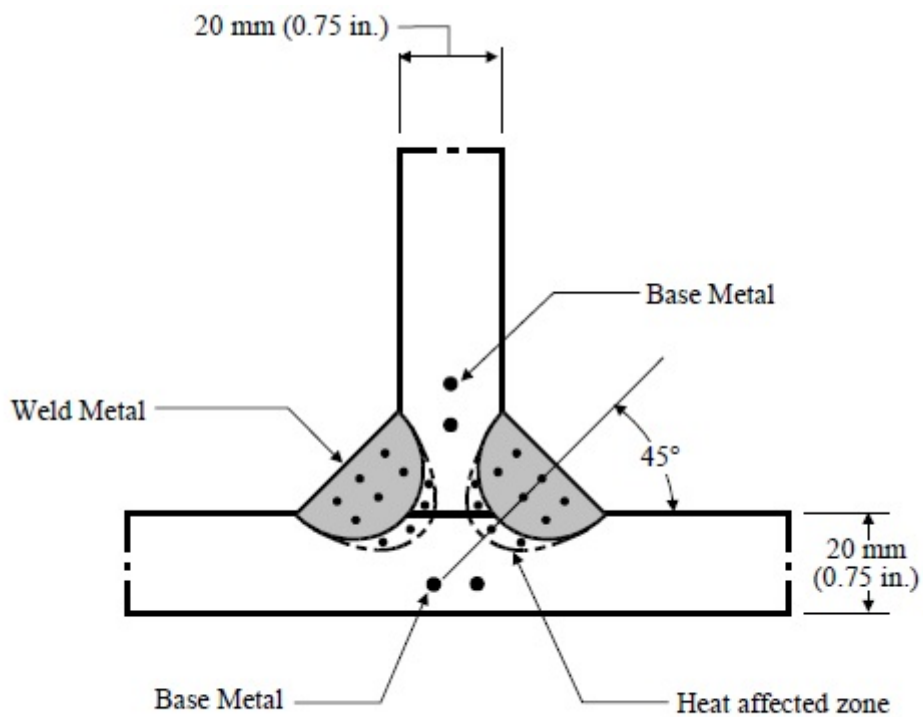
**FIGURE 2**  
**Butt-Weld Test Assembly for Manual and Gas-Metal Arc Welding**



**FIGURE 3**  
**Fillet-Weld Test Assembly**



**FIGURE 4**  
**Fillet Weld Hardness Test Locations**





**1 General (1997)**

This test program is intended for the approval of automatic or semi-automatic, single-electrode submerged arc welding. Provisions are made for the testing of weld metal deposited by multi-run and two-run (one pass each side) techniques. For YQ Grades automatic welding, a multi-run technique is contemplated. Application for high heat input process, such as automatic welding two-run technique, may be considered under 2-A2-1/3.5 and approval by a technical office. Where a manufacturer states that a particular wire-flux combination is suitable for welding with both techniques, both series of tests are to be carried out. The suffix **T**, **M**, or **TM** will be added to the grade to indicate two-run technique, multi-run technique, or both techniques, respectively.

**3 Chemical Analysis**

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer.

**5 Deposited Metal Test Assemblies for Multi-run Technique****5.1 Test Assembly (2005)**

One deposited metal test assembly, as indicated in 2-A2-3/19.5 FIGURE 1 is to be welded in the flat position using the wire size recommended by the manufacturer. The direction of deposition of each run is to alternate from each end of the plate and after completion of each run, the flux and welding slag are to be removed. The thickness of each layer is not to be less than the size of the wire, or 4 mm ( $\frac{5}{32}$  in.), whichever is the greater. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. The welding conditions (amperage, voltage, and travel speed) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding. The welded test assembly is not to be subjected to heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

**5.3 Test Specimens (1 October 1994)**

Two tension and one set of three impact specimens are to be prepared from the deposited metal test assembly, as indicated in 2-A2-3/19.5 FIGURE 1 and the results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33.1 TABLE 2 for the applicable grade and welding technique.

## 7 Butt Weld Test Assemblies for Multi-run Technique

### 7.1 Test Assembly

One butt weld test assembly, as indicated in 2-A2-3/19.5 FIGURE 3 is to be welded in the flat position using the wire size recommended by the manufacturer. The welding conditions are to be essentially the same as those indicated in 2-A2-3/5.1 for deposited metal test assembly. The back weld is to be applied in the flat position after removing the root run to clean metal. After being welded, the test assembly is not to be subjected to any heat treatment.

### 7.3 Test Specimens

Two tension, two face bend and two root bend together with one set of three impact specimens are to be prepared from the butt weld test assembly, as indicated in 2-A2-3/19.5 FIGURE 3, and the results of tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

## 9 Butt Weld Assemblies for Two-run Technique

### 9.1 Test Assemblies (2005)

Two butt weld test assemblies, as indicated in 2-A2-3/19.5 FIGURE 3 are to be welded in the flat position. The maximum size of wire, grades of steel plate, and the edge preparation to be used are also to be in accordance with 2-A2-3/19.5 FIGURE 3. At the request of the manufacturer, small deviations in the edge preparation may be allowed. The root gap is not to exceed 1.0 mm (0.04 in.). Each test assembly is to be welded in two runs, one from each side, using welding conditions (amperage, voltage, and travel speed) which are in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to 100°C (212°F) or less, the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any treatment.

### 9.3 Test Specimens (1 October 1994)

Two tension, one face bend, one root bend, and one set of three impact specimens are to be prepared from each butt weld assembly, as indicated in 2-A2-3/19.5 FIGURE 3 and 2-A2-3/19.5 FIGURE 4, and the results of tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/23.1. The edges of all test specimens and also the discards are to be examined to ensure complete fusion and interpenetration of the welds.

### 9.5 Longitudinal All-Weld-Metal Tension Test (1 October 1994)

Where the combination is to be approved for two-run technique only, one longitudinal all-weld-metal tension specimen is to be cut from the thicker butt weld test assembly, as indicated in 2-A2-3/19.5 FIGURE 3, and machined to the dimensions indicated in 2-A2-1/33 FIGURE 1, care being taken that the longitudinal axis coincides with the center of the weld and is approximately 7 mm (0.28 in.) below the plate surface on the side from which the second run is made. The test specimen may be subjected to a temperature not exceeding 250°C (482°F) for up to 16 hours for hydrogen removal, prior to testing. The results of the tests are to conform to the requirements of 2-A2-1/33 TABLE 1.

## 11 Fillet Weld Tests

Where a wire-flux combination is submitted for approval for fillet welds only, then the butt weld tests may be omitted, and fillet weld tests are to be carried out and tested in accordance with the applicable parts of 2-A2-4/11.3 to 2-A2-4/11.7.

## 13 Low Hydrogen Approval (1997)

### 13.1 YQ Grade Wires -Flux Combination (2005)

All wire-flux combination of this grade are to be submitted to the diffusible hydrogen test, as required by 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

## 15 Annual Check Tests

### 15.1 General (1996)

The annual check tests for each approved technique shall consist of the following.

*Multi-run Technique.* One deposited metal test assembly is to be welded in accordance with 2-A2-3/5.1. One tension and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-3/5.3.

*Two-run Technique.* One butt weld test assembly of 20 mm (0.75 in.) thickness is to be welded in accordance with 2-A2-3/9.1. One transverse tension, one face bend, one root bend, and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-3/9.3 and 2-A2-3/9.5. One longitudinal tension test specimen is also to be prepared where wire-flux combination is approved solely for the two-run technique.

### 15.3 Upgrading and Up-rating (2008)

Upgrading of wire-flux combinations will be considered at the manufacturer's request. For multi-run technique, in addition to the deposited metal test indicated in 2-A2-3/15.1, one butt weld test assembly is to be welded, as indicated in 2-A2-3/7 and one set of three impact specimens is to be tested at the upgraded temperature. For the two-run technique, butt weld testing is to be carried out as indicated in 2-A2-3/15.1, except the test assembly is to be fabricated using the maximum thickness approved.

Up-rating refers to the extension of approval to also cover welding of higher-strength steels (dual approvals). For this purpose butt weld tests are to be carried out as required in 2-A2-3/7 and 2-A2-3/9, and 2-A2-1/9.3.3, as applicable.

## 17 Multiple Electrodes

Wire-flux combinations for multiple electrode submerged arc welding will be subject to separate approval tests. They are to be carried out generally in accordance with the requirements of this section.

## 19 Electroslag Welding (1996)

### 19.1 General (1997)

Where approval is requested for wire-flux combinations other than YQ Grades, (with or without consumable nozzles) for use in electroslag welding, two test assemblies of 20–25 mm (0.75–1.0 in.) and 35–40 mm (1.38–1.58 in.) or more in thickness are to be prepared with a minimum root opening of 16 mm (0.63 in.), or with another joint design sufficient to allow the selection of the following test specimens. The chemical composition of the plates including the content of grain refining elements is to be reported.

- 2 longitudinal tension specimens from the axis to the weld,
- 2 transverse tension specimens,
- 2 side bend specimens,
- 3 Charpy-V specimens notched at the center of the weld,
- 3 Charpy-V specimens with their notches in the weld metal at 2 mm ( $\frac{5}{64}$  in.) from the fusion line,

- 2 macro-sections.

The results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

### 19.3 Annual Tests (1996)

One butt test assembly of 20–25 mm (0.75–1.0 in.) or more in thickness is to be prepared. One longitudinal tension, one transverse tension, two side bend and two sets of three Charpy V-notch specimens are to be prepared and tested. The notch of the impact specimens is to be located at the center of the weld and 2 mm (0.08 in.) from the fusion line in the weld. One macro-section is also to be examined.

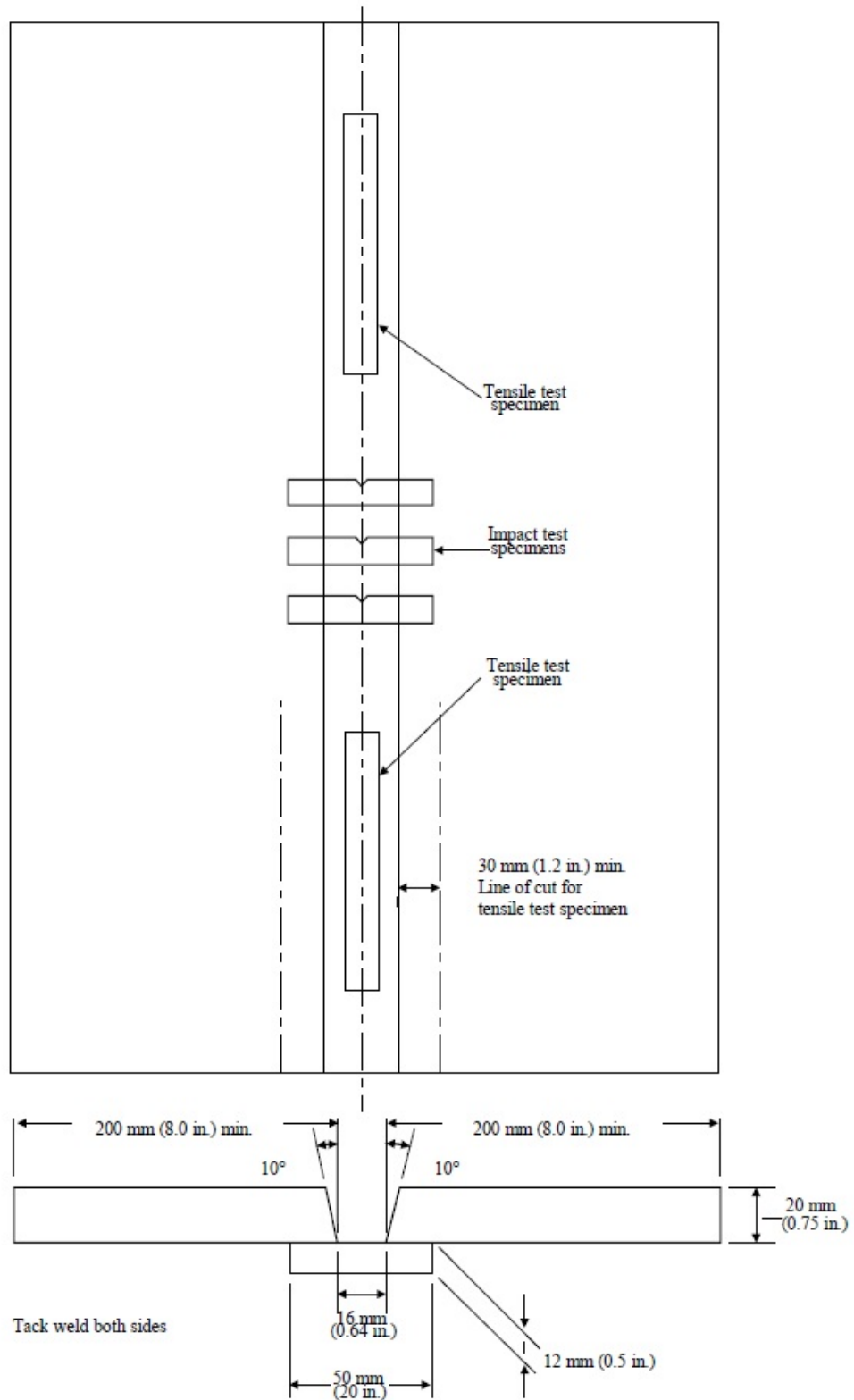
The test results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

### 19.5 Upgrading and Uprating (1996)

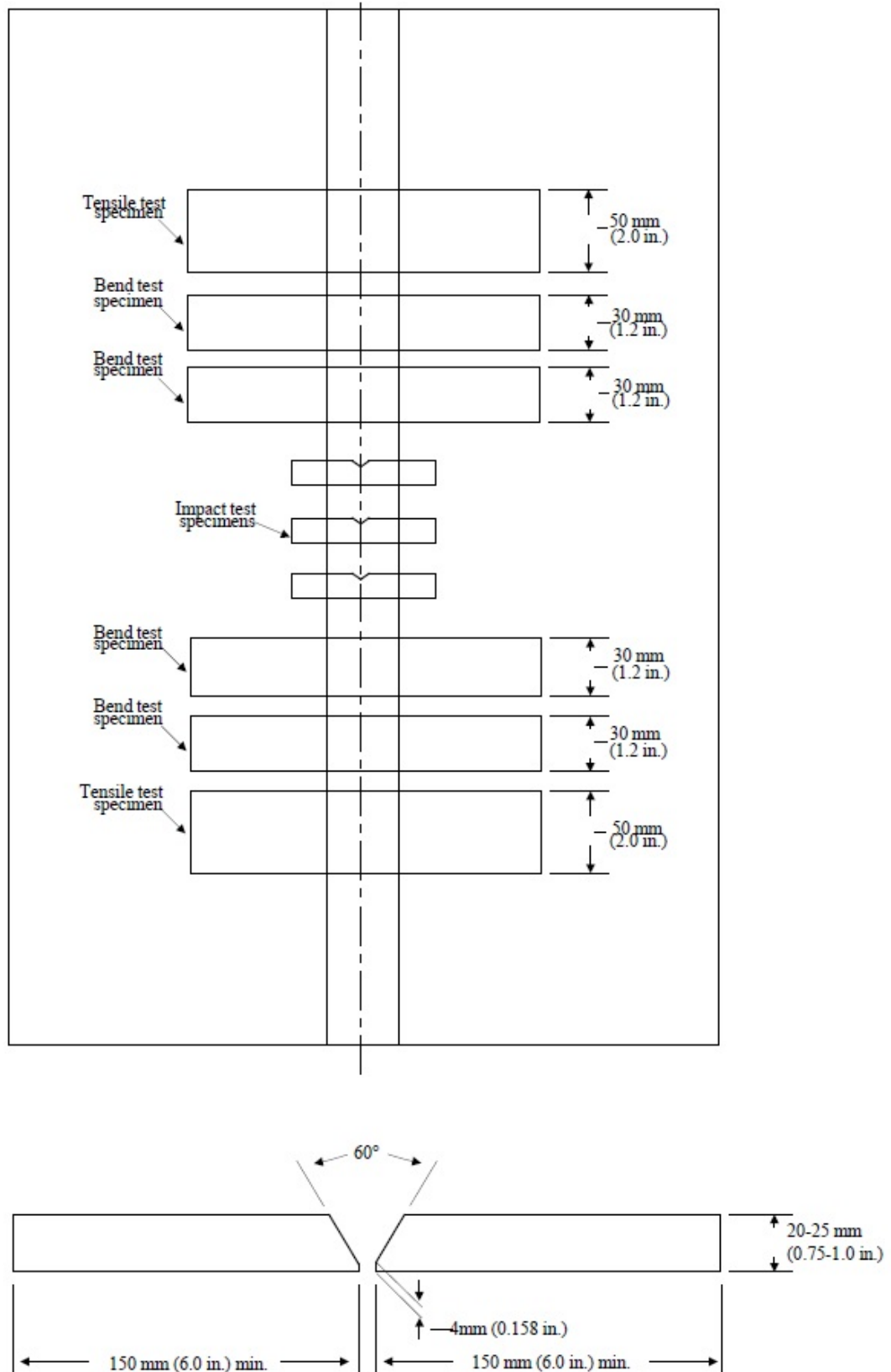
Upgrading and uprating will be considered at the manufacturer's request. Full tests as indicated in 2-A2-3/19.1 will be required.

The test results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

**FIGURE 1**  
**Deposited-Metal Test Assembly for Submerged Arc Welding -Multi-run**  
**Technique and Automatic Gas-Metal Arc Welding**



**FIGURE 2**  
**Butt-Weld Test Assembly for Submerged Arc Welding – Multi-run Technique**  
**(2008)**



**FIGURE 3**  
**Butt-Weld Test Assembly for Submerged Arc Welding -Two-run Technique**  
**(2009)**

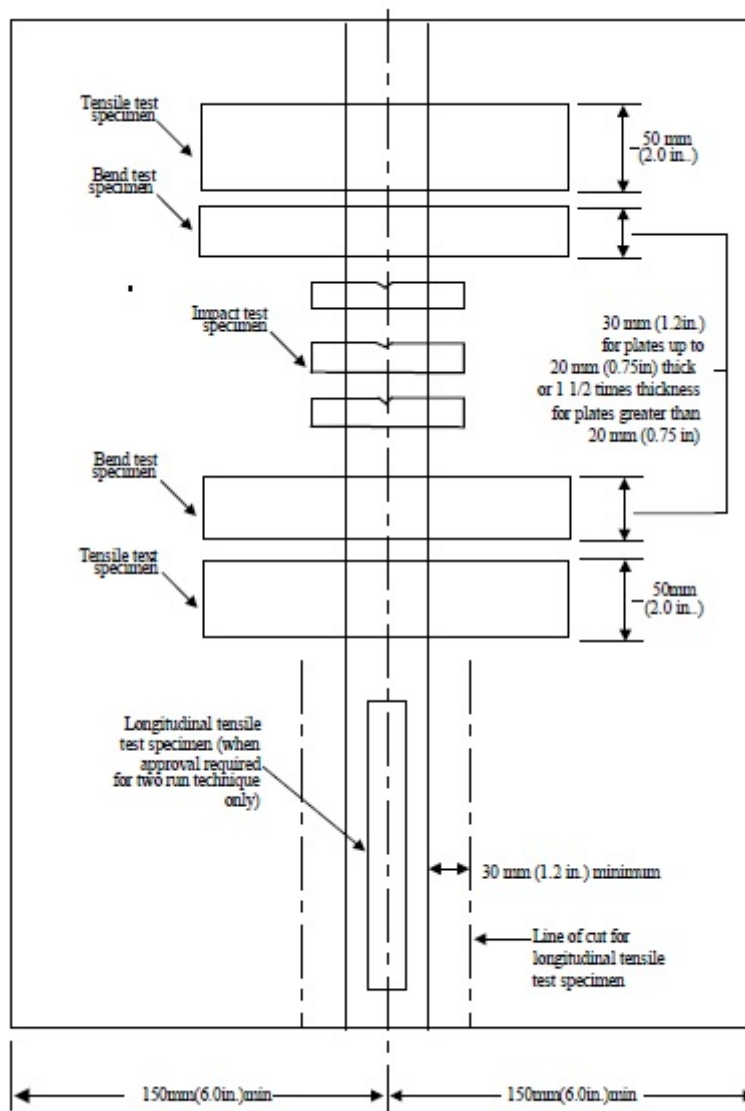
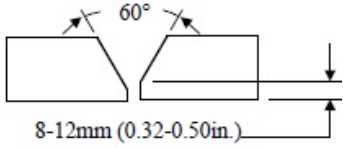
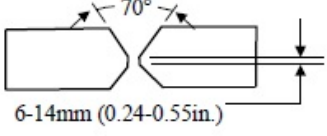
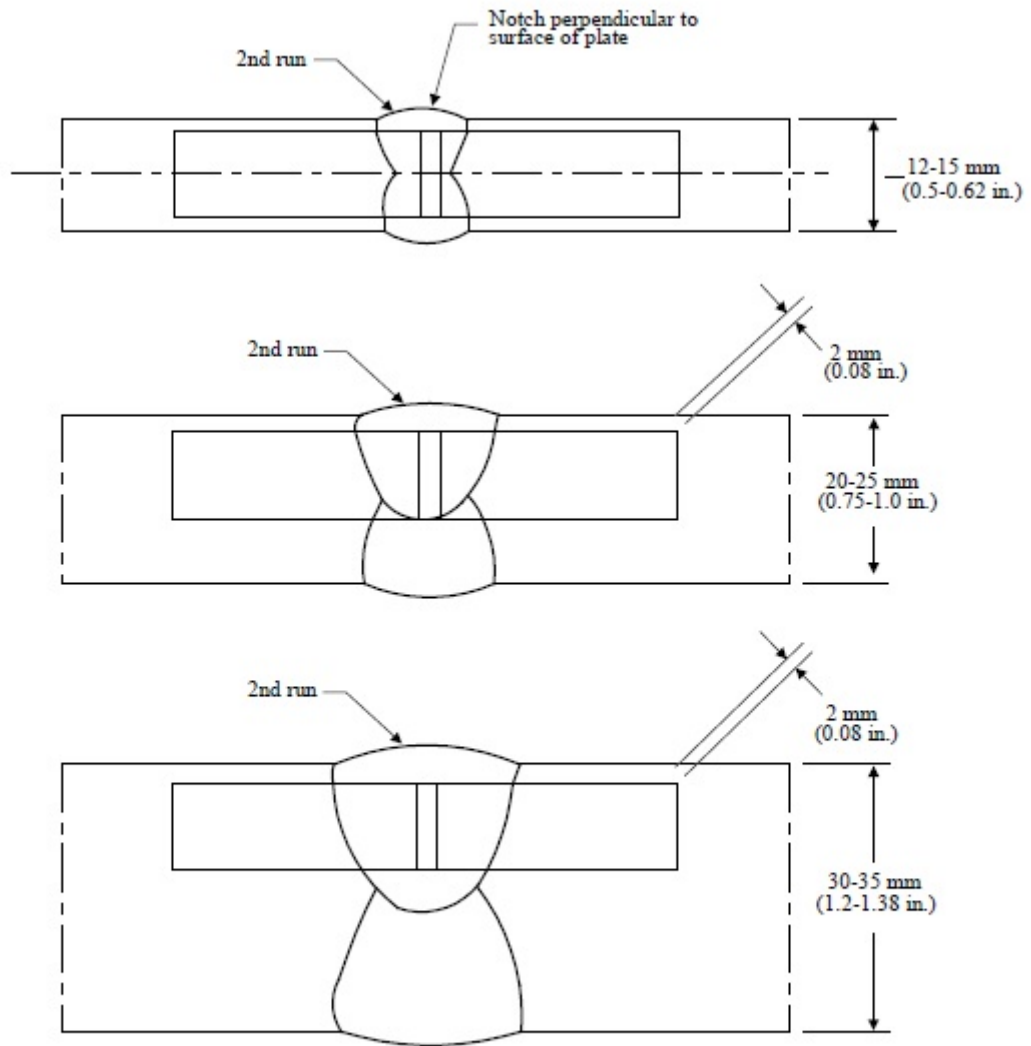


Plate Thickness	Preparation	Maximum sizes of wire	Wire Flux Grade	Grades of Steel	
				Ordinary Strength	Higher Strength
12-15 mm (0.5-0.62 in)		5 mm (0.20 in)	1, 1Y	A	AH32/36

20-25 mm (0.75-1.0 in)		6 mm (0.25 in)	1, 1Y	A	AH332/36
			2, 2Y	A/B/D	AH/DH32/36
			2Y400	-	AH/DH40
			3, 3Y	A/B/D/E	AH/DH/EH32/36
			3Y400	-	AH/DH/EH40
			4Y	-	AH/DH/EH/FH32/36
			4Y400, 5Y400	-	AH/DH/EH/FH40
30-35 mm (1.2-1.38 in)		7 mm (0.28 in)	2, 2Y	A/B/D	AH/DH32/36
			2Y400	-	AH/DH40
			3, 3Y	A/B/D/E	AH/DH/EH32/36
			3Y400	-	AH/EH/EH40
			4Y	-	AH/DH/EH/FH32/36



**FIGURE 4**  
**Butt-Weld Impact Specimen Location for Submerged and Gas-Metal Arc**  
**Welding -Two-run Technique**



## PART 2

### APPENDIX 2

#### Requirements for the Approval of Filler Metals

### SECTION 4

#### Wire and Wire Gas Combinations for Gas Metal Arc Welding and Flux Cored Wires for Flux Cored Arc Welding

##### 1 General (1997)

This test program is intended for the approval of wire-gas combinations and flux cored wires with or without shielding gas intended for semi-automatic or automatic arc welding techniques. For both techniques, the welding gun provides continuous wire feed; for semi-automatic welding, the welding gun is held manually, and for automatic welding, the welding gun is machine held with various degrees of controlled motion provided by the machine. The impact requirements for the semi-automatic welding technique and those for the automatic welding technique are indicated separately in 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 1 according to the applicable grade. The suffix **SA** will be added to the grade to indicate approval for manual semi-automatic or machine-automatic gas-metal arc welding. The suffix **A** will be added to the Grade to indicate approval for machine automatic welding only. An additional suffix **T** will be added to the grade to indicate approval for two-run (one pass each side) technique for machine automatic welding. Wire-gas combinations and flux cored wires approved for semi-automatic welding may be used for automatic welding under the procedure recommended by the manufacturer, except that for the two-run automatic technique, testing in accordance with 2-A2-4/9 is required. For YQ Grades semi-automatic or automatic welding, a multi run technique is contemplated. Application for high heat input process, such as semi-automatic or automatic welding two-run technique, may be considered under 2-A2-1/3.5 and approval by technical office.

##### 3 Chemical Analysis and Shielding Gas Compositions (2008)

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer. The trade name of the shielding gas, when used, as well as its composition, is to be reported. The approval of a wire in combination with any particular gas can be applied or transferred to any combination of the same wire and any gas in the same numbered group as defined in 2-A2-4/3 TABLE 1.

**TABLE 1**  
**Compositional Limits of Designated Groups of Gas Types and Mixtures (2008)**

Group		Gas composition (Vol.%)			
		CO <sub>2</sub>	O <sub>2</sub>	H <sub>2</sub>	Ar
M1	1	>0 to 5	--	>0 to 5	Rest <sup>(1,2)</sup>
	2	>0 to 5	--	--	Rest <sup>(1,2)</sup>
	3	--	>0 to 3	--	Rest <sup>(1,2)</sup>
	4	>0 to 5	>0 to 3	--	Rest <sup>(1,2)</sup>
M2	1	>5 to 25	--	--	Rest <sup>(1,2)</sup>
	2	--	>3 to 10	--	Rest <sup>(1,2)</sup>
	3	>5 to 25	>0 to 8	--	Rest <sup>(1,2)</sup>
M3	1	>25 to 50	--	--	Rest <sup>(1,2)</sup>
	2	--	>10 to 15	--	Rest <sup>(1,2)</sup>
	3	>5 to 50	>8 to 15	--	Rest <sup>(1,2)</sup>
C	1	100	--	--	--
	2	Rest	>0 to 30	--	--

**Notes:**

- 1 Argon may be substituted by Helium up to 95% of the Argon content.
- 2 Approval covers gas mixtures with equal or higher Helium contents only.

## 5 Deposited Metal Test Assemblies for Semi-automatic and Automatic Testing

### 5.1 Semi-automatic Test Assemblies (2009)

Two deposited metal test assemblies, as indicated in 2-A2-2/13.3 FIGURE 1, are to be welded in the flat position, one using the smallest size wire intended for approval, and the other using the largest size intended for approval. If a wire is produced in one size only or if the largest size produced is 1.2 mm (0.045 in.) or less, one test assembly is sufficient. The weld metal is to be deposited in single or multi-run layers according to recommended practice and the thickness of each layer of weld metal is to be between 2 mm (<sup>5</sup>/<sub>64</sub> in.) and 6 mm (<sup>15</sup>/<sub>64</sub> in.). Between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

### 5.3 Test Specimens for Semi-automatic

One tension and one set of three impact specimens are to be prepared from each deposited metal test assembly, as indicated in 2-A2-2/13.3 FIGURE 1 and the results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade.

### 5.5 Automatic Test Assembly (2008)

For automatic welding one test assembly, as indicated in 2-A2-3/19.5 FIGURE 1 is to be welded in the flat position using 2.4 mm (<sup>3</sup>/<sub>32</sub> in.) wire or the largest size manufactured. The thickness of each layer is not to be less than 3 mm (<sup>1</sup>/<sub>8</sub> in.). Between each run, the assembly is to be left in still air until it has cooled to

250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assembly is not to be subjected to any heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3

## 5.7 Test Specimens for Automatic

Two tension and one set of three impact specimens are to be prepared from the test assembly, as indicated in 2-A2-1/33 FIGURE 1, and the results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade.

## 7 Butt Weld Test Assemblies for Semi-automatic and Automatic Techniques

### 7.1 Test Assemblies

One butt weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 2, is to be welded in each position (flat, vertical-up, vertical-down, overhead, and horizontal) for which the wire is recommended by the manufacturer, except that wires meeting the requirements for flat and vertical positions will be considered as also complying with the requirements for horizontal position. Where the wire is only to be approved in the flat position, one additional test assembly is to be welded in that position.

### 7.3 Welding Procedure (2009)

In general, the following welding procedure is to be adopted in making the test assemblies:

*Flat.* First run using the smallest size wire intended for; remaining runs with the largest size intended for approval. Where a second flat assembly is required, it is to be prepared using wires of different sizes.

*Vertical-up, Vertical-down, Overhead and Horizontal.* First run with the smallest size wire intended for approval; remaining runs using the largest size wire intended for approval recommended by the manufacturer for the position involved.

In all cases, the back weld is to be made with the smallest size wire intended for approval, after removing the root run to clean metal. Normal welding practice is to be used and between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment.

### 7.5 Test Specimens (2005)

One tension, one face bend, one root bend, and one set of three impact specimens are to be prepared from each butt-weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 2. The results of tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade, position and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

## 9 Butt Weld Test Assemblies for Two-run Technique

### 9.1 Test Assemblies

Two butt weld test assemblies, as indicated in 2-A2-4/17.5 FIGURE 1 are to be welded in the flat position. One test assembly is to be welded using 1.2 mm (0.045 in.) wire or the smallest size manufactured, whichever is greater and one test assembly using 2.4 mm ( $\frac{3}{32}$  in.) wire or the largest size wire recommended by the manufacturer for two-run technique. Each test assembly is to be welded in two runs, one from each side. Between each run, the assembly is to be left in still air until it has cooled to 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment.

### 9.3 Test Specimens (1996)

Two tension, one face bend, one root bend and one set of three impact specimens are to be prepared from each butt weld test assembly, as indicated in 2-A2-4/17.5 FIGURE 1 and 2-A2-3/19.5 FIGURE 4. If approval is requested for welding plate thicker than 25 mm (1.0 in.), one assembly is to be prepared using plates approximately 20 mm (0.75 in.) in thickness and the other using plates of the maximum thickness for which approval is requested. For assemblies using plates over 25 mm (1.0 in.) in thickness, the edge preparation is to be reported for information. The results of tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade. The results of bend tests are to meet the requirements of 2-A2-1/21.3. The edges of all test specimens and also the discards are to be examined to ensure complete fusion and interpenetration of the welds.

### 9.5 Longitudinal All-Weld-Metal Tension Test

Where the wire is to be approved for two-run technique only, one longitudinal all-weld-metal tension specimen is to be cut from the thicker butt weld test assembly, as indicated in 2-A2-4/17.5 FIGURE 1 and machined to the dimensions indicated in 2-A2-1/33 FIGURE 1 care being taken that the longitudinal axis coincides with the center of the weld and is about 7 mm (0.28 in.) below the plate surface on the side from which the second run is made. The test specimen may be subjected to a temperature not exceeding 250°C (482°F) for a period not exceeding 16 hours for hydrogen removal, prior to testing. The results of the test are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade.

## 11 Fillet Weld Tests

### 11.1 General (2018)

A wire-gas combination or flux cored wire is considered approved for fillet welding in the welding position for which the butt weld test of 2-A2-4/7 was satisfactory. A wire-gas combination or flux cored wire meeting the flat butt weld requirements will be considered as complying with the requirements for horizontal fillet (HF) welds. Where a wire-gas combination or a flux cored wire is submitted for approval for fillet welding only, the butt weld tests indicated in 2-A2-4/7 and 2-A2-4/9 may not be required, and fillet weld tests are to be carried out and tested in accordance with 2-A2-4/11.3 through 2-A2-4/11.7.

### 11.3 Test Assemblies

One fillet weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 3, is to be welded in each welding position for which the wire is recommended by the manufacturer.

### 11.5 Welding Procedure

The length  $L$  of the fillet weld test assemblies is to be sufficient to allow for the tests prescribed in 2-A2-2/9.5. One side is to be welded using the maximum size wire manufactured and the second side is to be welded using the minimum size wire manufactured and recommended for fillet welding. The fillet size will in general be determined by the wire size and the welding current employed during testing. The fillet welding is to be carried out with the welding equipment and technique recommended by the manufacturer. The manufacturer's recommended current range is to be reported for each wire size and welding position.

### 11.7 Test Requirements

The results of hardness and breaking tests are to meet the requirements 2-A2-2/9.7.

## 13 Low Hydrogen Approval

### 13.1 Flux Cored Wire

#### 13.1.1 Welding Conditions for Test Assemblies (2005)

When flux cored wires undergo diffusible hydrogen testing as indicated in 2-A2-4/13.1.2, 2-A2-4/13.1.3 and 2-A2-4/13.1.4 below, the following apply unless otherwise specified by the

diffusible hydrogen test standard. Welding of diffusible hydrogen test assemblies is to be carried out using the same welding conditions (including contact tip to work distance) that were used in welding the deposited metal test assembly. The travel speed may be adjusted to give a weight of weld deposit per sample similar to manual electrodes.

#### **13.1.2 Ordinary Strength Wires (2005)**

A flux-cored wire which has satisfied the requirements of grade 2 or 3 may, at the manufacturer's option, be submitted to the diffusible hydrogen test, as detailed in 2-A2-1/23.3 or 2-A2-1/23.5. A suffix indicating the hydrogen amount will be added to the grade number to indicate compliance with the hydrogen test requirements specified in 2-A2-1/23.7.

#### **13.1.3 YQ-Grade Wires (2005)**

All flux-cored wires of this grade are to be submitted to the diffusible hydrogen test, as required by 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

#### **13.1.4 Higher Strength Wires (2009)**

Flux-cored wires submitted for approval according to Grades 2Y, 3Y, 4Y, 2Y400, 3Y400 4Y400 or 5Y400 are to be subjected to a hydrogen test, as detailed in 2-A2-1/23.3 or 2-A2-1/23.5. Diffusible hydrogen test results are to meet the requirement specified in 2-A2-1/23.7 for the H15 suffix. Such suffix, however, will not be added to the grade. Flux cored wires meeting H5 or H10 requirements will be so identified. Electrodes meeting the higher-strength requirements, except for the hydrogen test, will require special approval for use on higher strength steel for each user and will be so identified in the list of approved consumables.

## **15 Annual Check Tests**

### **15.1 General (2011)**

The annual check tests for each approved technique shall consist of the following:

*Semi-automatic and Automatic.* One deposited metal test assembly is to be welded using a wire of diameter within the range approved in accordance with 2-A2-4/5.1 or 2-A2-4/5.5 as applicable. One tension and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-4/5.3 or 2-A2-4/5.7, as applicable.

*Two-run Automatic Technique.* One butt weld test assembly of 20 mm (0.75 in.) thickness is to be welded in accordance with 2-A2-4/9.1. The wire diameter used is to be reported. One longitudinal tension, one face bend, one root bend and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-4/9.3 and 2-A2-4/9.5. A longitudinal tension test will not be required for wires also approved for multi-run technique.

### **15.3 Upgrading and Uprating (2008)**

Upgrading of wire-gas combinations and flux cored wires will be considered at the manufacturer's request. For semi-automatic and automatic welding, in addition to the deposited metal test indicated in 2-A2-4/15.1, butt weld test assembly is to be welded as indicated in 2-A2-4/7 for each position initially tested, and sets of three impact specimens from each test assembly are to be tested at the upgraded temperature.

Uprating refers to the extension of approval to also cover welding of higher-strength steels (dual approvals). For this purpose butt weld tests are to be carried out as required in 2-A2-4/7 or 2-A2-4/9, and 2-A2-1/9.3.3, as applicable. In addition, the diffusible hydrogen test required by the grade or suffix referred to 2-A2-4/13.1.2 and 2-A2-4/13.1.4 is to be conducted.

## 17 Electrogas Welding (1996)

### 17.1 General (1997)

Where approval is requested for wire-gas combinations other than YQ Grades, (with or without consumable nozzles or self-shielding gas) for use in electrogas welding, two test assemblies of 20-25 mm (0.75-1.0 in.) and 35-40 mm (1.38-1.58 in.) or more in thickness are to be prepared with a minimum root opening of 16 mm (0.63 in.), or with another joint design sufficient to allow the selection of the following test specimens. The chemical composition of the plates including the content of grain refining elements is to be reported.

- 2 longitudinal tension specimens from the axis to the weld.
- 2 transverse tension specimens,
- 2 side bend specimens,
- 3 Charpy-V specimens notched at the center of the weld,
- 3 Charpy-V specimens with their notches in the weld metal at 2 mm ( $\frac{5}{64}$  in.) from the fusion line,
- 2 macro-sections.

The results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

### 17.3 Annual Tests (1996)

One butt test assembly of 20–25 mm (0.75–1.0 in.) or more in thickness is to be prepared. One longitudinal tension, one transverse tension, two side bend and two sets of three Charpy V-notch specimens are to be prepared and tested. The notch of the impact specimens is to be located at the center of the weld and 2 mm (0.08 in.) from the fusion line in the weld. One macro-section is also to be examined.

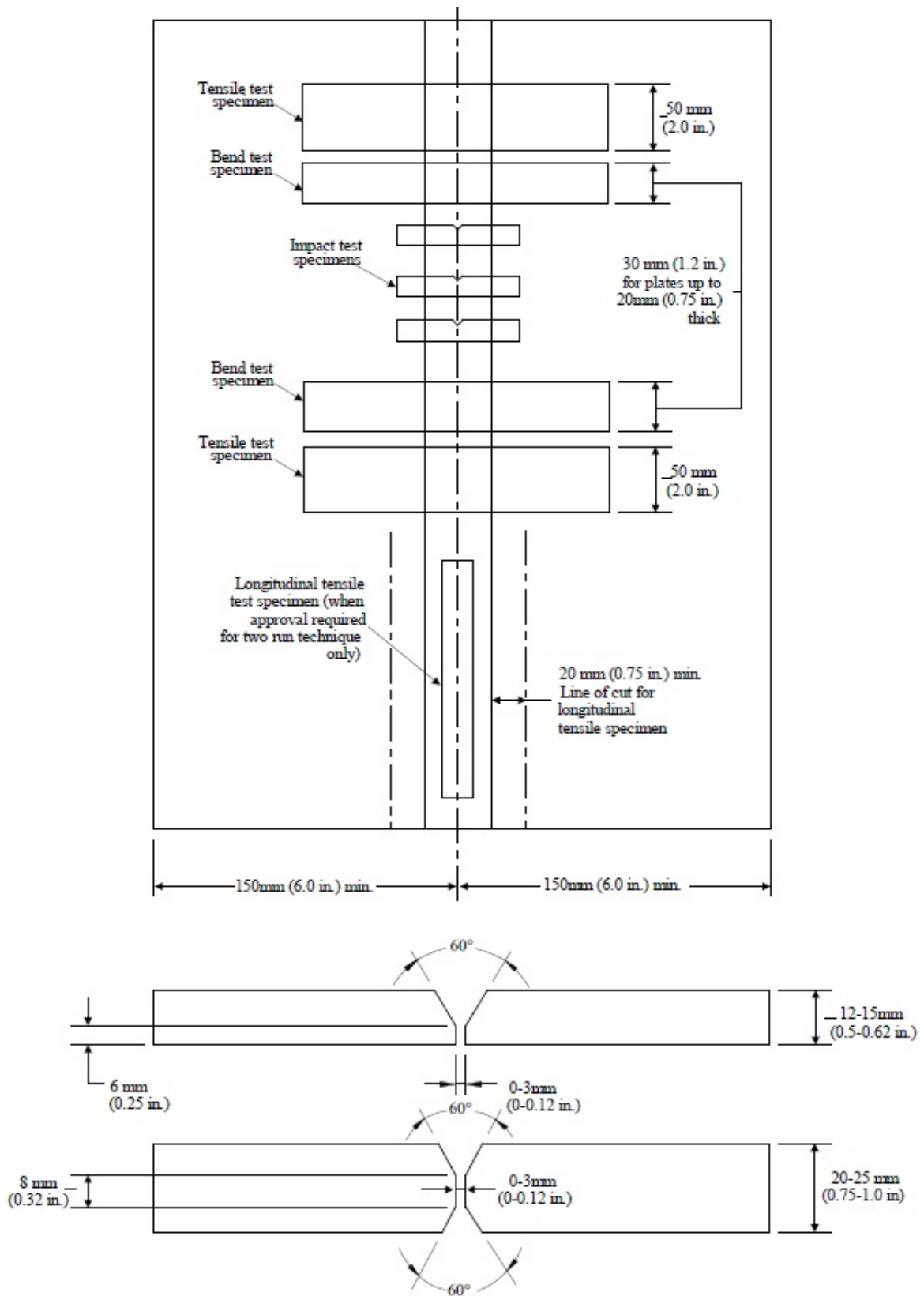
The test results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

### 17.5 Upgrading and Uprating (1996)

Upgrading and uprating will be considered at the manufacturer's request. Full tests as indicated in 2-A2-4/17.1 will be required.

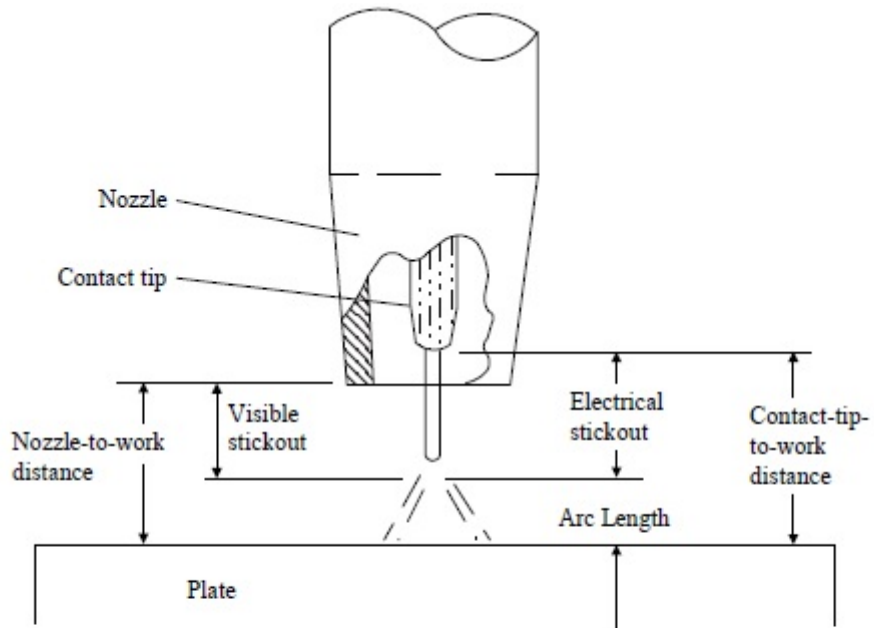
The test results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

**FIGURE 1**  
**Butt-Weld Test Assembly for Gas-Metal Arc Welding -Two-run Technique**





**FIGURE 2**  
**Contact Tip to Work Distance (2005)**



# PART 2

## APPENDIX 2

### Requirements for the Approval of Filler Metals

#### SECTION 5

### Requirements for the Approval of Aluminum Filler Metals (2018)

## 1 General

### 1.1 Scope

These requirements give the conditions of approval and inspection for welding consumables to be used in hull construction and marine structures using aluminum alloys according to Part 2, Chapter 5. Where no special requirements are given herein (e.g., for the approval procedure or for welding of test assemblies and testing), those of Sections 1 through 4 of Appendix 2 apply in analogous manner.

The welding consumables preferably to be used for aluminum alloys concerned are divided into two categories as follows:

- W = Wire electrode, and wire-gas combinations for GMAW, GTAW, or PAW
- R = Rod-gas combinations for GTAW

### 1.3 Grading, Designation

#### 1.3.1

Consumables are graded as indicated in 2-A2-5/1.3.1 TABLE 1, in accordance with the alloy type and strength level of base materials used for approval tests.

**TABLE 1**  
**Consumable Grades and Base Materials for the Approval Test (2009)**

<i>Consumable Quality Grade (Symbol)</i>	<i>Base Materials for Tests</i>	
	<i>Alloy Designation</i>	
	<i>Numerical</i>	<i>Chemical Symbol</i>
RA/WA	5754	AlMg3
RB/WB	5086	AlMg4

Consumable Quality Grade (Symbol)	Base Materials for Tests	
	Alloy Designation	
	Numerical	Chemical Symbol
RC/WC	5083	AlMg4.5Mn0.7
	5383	AlMg4.5Mn0.9
	5456	AlMg5
	5059	-----
RD/WD	6005A	AlSiMg(A)
	6061	AlMg1SiCu
	6082	AlSi1MgMn

**Note:** Approval on higher strength AlMg base materials covers also the lower strength AlMg grades and their combination with AlSi grades.

**1.3.2**

Approval of a wire or a rod will be granted in conjunction with a specific shielding gas according to 2-A2-5/1.3.2 TABLE 2 or defined in terms of composition and purity of “special” gas to be designated with group sign “S”. The composition of the shielding gas is to be reported. The approval of a wire or rod with any particular gas can be applied or transferred to any combination of the same wire or rod and any gas in the same numbered group as defined in 2-A2-5/1.3.2 TABLE 2, subject to the agreement of ABS.

**TABLE 2**  
**Compositional Limits of Shielding Gases and Mixtures to be Used**

Group	Gas composition (Vol.%)	
	Argon	Helium
I-1	100	---
I-2	---	100
I-3	Rest	> 0 to 33
I-4	Rest	> 33 to 66
I-5	Rest	> 66 to 95
S <sup>(1)</sup>	Special gas, composition to be specified; see 2-A2-5/1.3.2	

**Note:**

- Gases of other chemical composition (mixed gases) may be considered as “special gases” and covered by a separate test.

**1.5 Manufacture, Testing and Approval Procedure**

Manufacturer’s plant, production methods, and quality control measures shall be such as to ensure reasonable uniformity in manufacture; see also Part 2, Appendix 2.

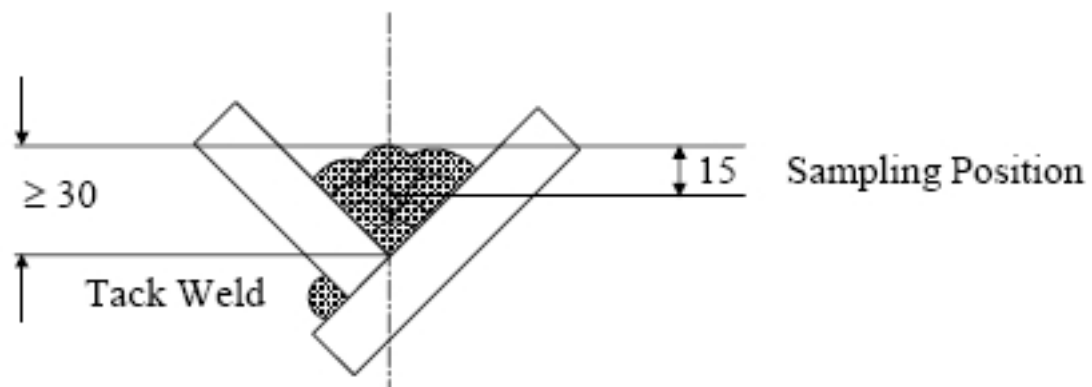
Testing and approval procedure shall be in accordance with Section 2-A2-1 for the individual categories (types) or welding consumables, shielding gases, and gas mixtures mentioned in 2-A2-5/1.1 above.

### 3 Testing and Required Properties

#### 3.1 Testing of the Deposited Weld Metal

For testing the deposited weld metal chemical composition, a test piece according to 2-A2-5/3.1 FIGURE 1 shall be prepared. The size depends on the type of the welding consumable (and on the welding process) and shall give a sufficient amount of pure weld metal for chemical analysis. The base metal used shall be compatible with the weld metal with respect to chemical composition.

**FIGURE 1**  
**Deposited Weld Metal Test Assembly**



The chemical composition of the deposited weld metal shall be determined and certified in a manner analogous to that prescribed in 2-A2-1/13. The results of the analysis shall not exceed the limit values specified by the manufacturer.

#### 3.3 Testing of Butt Weld Assemblies

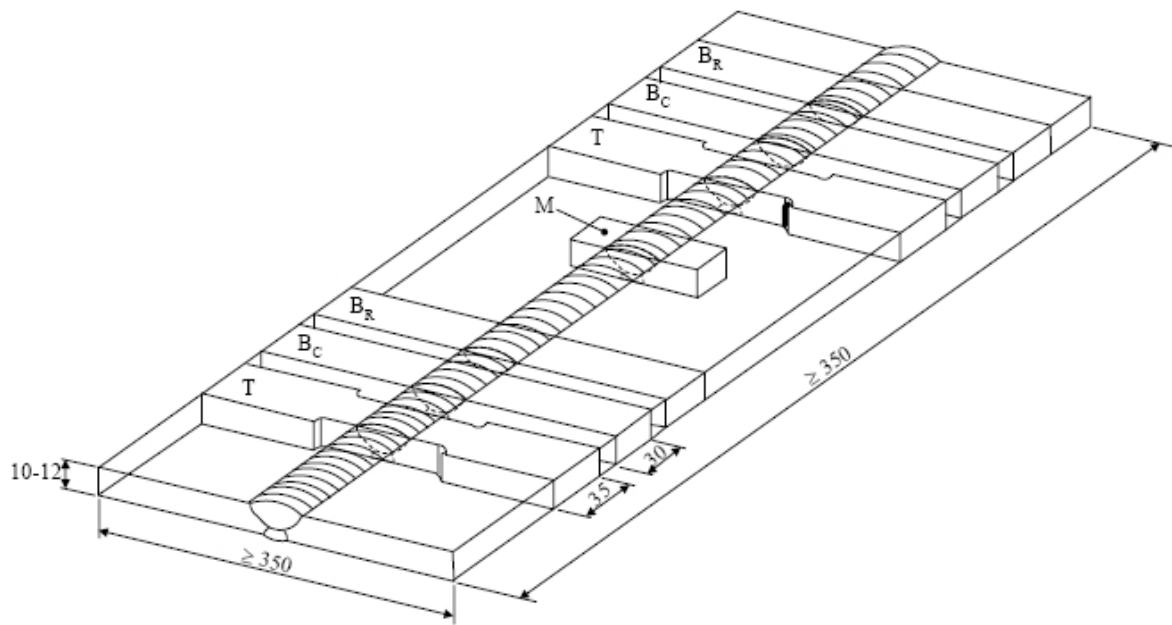
Testing of the welded joints shall be performed on butt-weld test assemblies according to 2-A2-5/Figures 2 and 3, made from materials as given in 2-A2-5/1.3.1 TABLE 1, in an analogous manner to 2-A2-1/17 and 2-A2-4/7.

Butt weld test assemblies according to 2-A2-5/3.3 FIGURE 2 with a thickness of 10 to 12 mm ( $3/8$  to  $1/2$  in.) are to be prepared for each welding position (flat, horizontal, vertical-up, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for flat and vertical-up positions will be considered as also complying with the requirements for horizontal position.

Additionally, one test assembly according to 2-A2-5/3.3 FIGURE 3 with thickness of 20 to 25 mm ( $3/4$  to 1 in.) is to be welded in the flat position only.

**FIGURE 2**  
**Butt Weld Test Assembly for Out-of-position Welding**

- T = Flat tensile test specimen
- B<sub>C</sub> = Face bend test specimen
- B<sub>R</sub> = Root bend test specimen
- M = Macrographic section

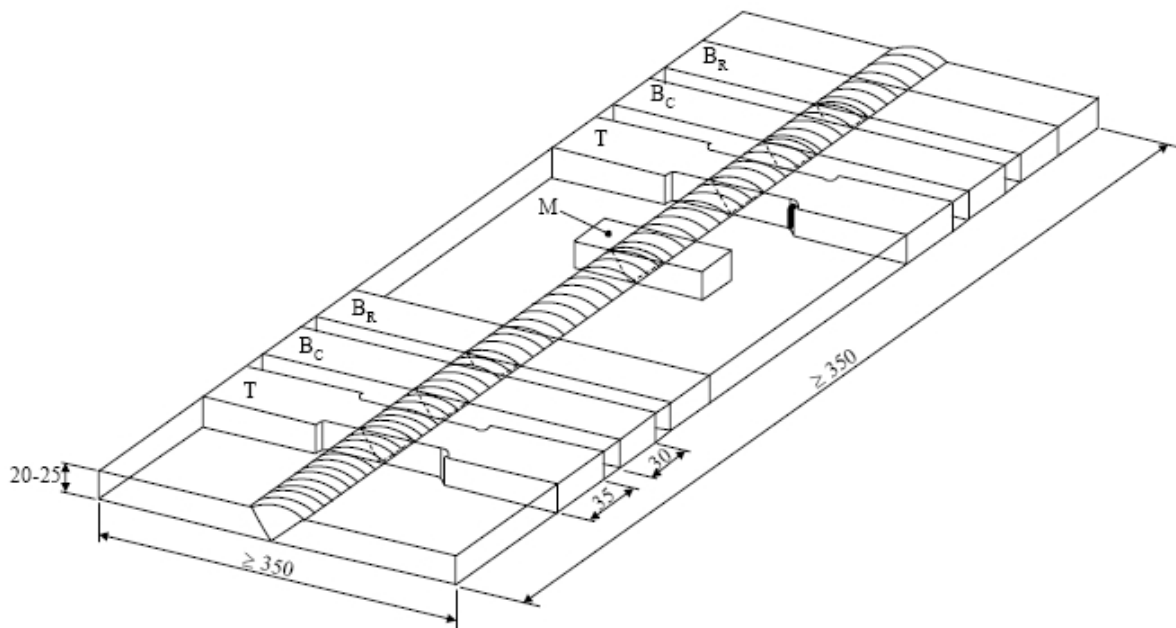


*Notes:*

- 1 Edge preparation is to be single V or double V with 70° angle.
- 2 Back sealing runs are allowed in single V weld assemblies.
- 3 In case of double V assembly, both sides shall be welded in the same welding position.

**FIGURE 3**  
**Butt Weld Test Assembly in Flat Position**

- T = Flat tensile test specimen  
B<sub>C</sub> = Face bend test specimen  
B<sub>R</sub> = Root bend test specimen  
M = Macrographic section



*Notes:*

- 1 Edge preparation is to be single V with 70° angle.
- 2 Back sealing runs are allowed.

On completion of welding, assemblies must be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens must not be subjected to any heat treatment. Grade D assemblies should be allowed to naturally age for a minimum of 72 hours after completion of welding before testing is carried out.

Test specimens shown in 2-A2-5/Figures 2 and 3 and described in Section 2-A2-4 shall be taken from the butt weld test assemblies.

The mechanical properties must meet the requirements stated in 2-A2-5/3.3 TABLE 3. The provisions of Section 2-A2-1 apply in analogous manner to the performance of the tests, including requirements for annual check tests and retesting. The position of the fractures is to be stated in the report. The macrographic specimen shall be examined for imperfections such as lack of fusion, cavities, inclusions, pores, and cracks.

**TABLE 3**  
**Requirements for the Transverse Tensile and Bend Tests (2009)**

<i>Grade</i>	<i>Base Material Used for the Test</i>	<i>Tensile strength <math>R_m</math>, N/mm<sup>2</sup> (ksi) min.</i>	<i>Former Diameter</i>	<i>Bending angle <sup>(1)</sup> [degrees] min.</i>
RA/WA	5754	190 (27.5)	3t	180
RB/WB	5086	240 (35)	6t	
RC/WC	5083	275 (40)	6t	
	5383 or 5456	290 (42)	6t	
	5059	330 (47)	6t	
RD/WD	6005A, 6021, 6082	170 (24.5)	6t	

*Note:*

- (2009) During testing, the test specimen shall not reveal any one single flaw greater than 3 mm in any direction. Flaws appearing at the corners of a test specimen shall be ignored in the evaluation unless there is evidence that they result from lack of fusion.

## 5 Annual Check Tests

Annual check tests shall entail the preparation and testing of the deposited weld metal test assembly as prescribed in 2-A2-5/3.1 FIGURE 1 and of the flat position butt weld test assembly according to 2-A2-5/3.3 FIGURE 2.



# PART 2

## APPENDIX 3

### Application of Filler Metals to ABS Steels

#### CONTENTS

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SECTION	1	Application of Filler Metals to ABS Steels (2014).....	562
---------	---	--	-----



# PART 2

## APPENDIX 3

### Application of Filler Metals to ABS Steels

#### SECTION 1

#### Application of Filler Metals to ABS Steels (2014)

A chart indicating acceptable ABS filler metal grades for welding various ABS grades of hull steel is given below.

(2021)

<i>ABS Hull Structural Steel</i>	<i>Acceptable ABS Filler Metal Grade</i>
<b>Ordinary Strength</b>	
A to 12.5 mm ( $\frac{1}{2}$ in.) inclusive	1, 2, 3, 1Y**, 2Y, 3Y, 4Y
A over 12.5 mm ( $\frac{1}{2}$ in.), B, D	2, 3, 2Y, 3Y, 4Y
E	3, 3Y, 4Y
<b>Higher Strength (2009)*</b>	
AH 32/36 to 12.5 mm ( $\frac{1}{2}$ in.) inclusive	1Y, 2Y**, 2Y400, 3Y, 3Y400, 4Y, 4Y400, 5Y400
AH 32/36 over 12.5 mm ( $\frac{1}{2}$ in.), DH32/36	2Y, 2Y400, 3Y, 3Y400, 4Y, 4Y400, 5Y400
EH32/36	3Y, 3Y400, 4Y, 4Y400, 5Y400
FH32/36	4Y, 4Y400, 5Y400
AH40, DH40	2Y400, 3Y400, 4Y400, 5Y400
EH40	3Y400, 4Y400, 5Y400
FH40	4Y400, 5Y400
<b>Extra High Strength</b>	
XQ43	ZYQ420, ZYQ460***, ZYQ500***
XQ47	ZYQ460, ZYQ500***
XQ51	ZYQ500, ZYQ550***
XQ56	ZYQ550, ZYQ620***
XQ63	ZYQ620, ZYQ690***
XQ70	ZYQ690

<i>ABS Hull Structural Steel</i>		<i>Acceptable ABS Filler Metal Grade</i>
	XQ91	ZYQ890****
	XQ98	ZYQ960****

*Note:*

For X = A or D, Z = 3, 4 and 5

For X = E, Z = 4 and 5

For X = F, Z = 5

The tensile strength range of ABS ordinary strength hull structural steel is 400-520 N/mm<sup>2</sup>, (41-53 kgf/mm<sup>2</sup>, 58-75 ksi). The tensile strength range for ABS H32/H36 higher strength hull structural steel is 440-620 N/mm<sup>2</sup> (45-63 kgf/mm<sup>2</sup>, 64-90 ksi). For ABS H40 higher strength hull structural steel, the tensile strength range is 510-650 N/mm<sup>2</sup> (52-66 kgf/mm<sup>2</sup>, 74-94 ksi). The ABS filler metal grades for welding ordinary and higher strength hull structural steels are assigned according to Charpy V-notch impact requirements, aimed at providing comparable levels of notch toughness of the various grades of steel. Because of inherent differences in the quality of machine automatic versus manual and manual semi-automatic produced welds, the impact strength requirements for both ordinary and higher strength filler metal grades are divided into two levels according to whether the process used is automatic or manual. The specific value requirements may be found in 2-A2-1/33 TABLE 1.

- \* (2008) Non-low hydrogen type electrode and wire approvals for welding higher strength steels (denoted by \* in the list) are subject to satisfactory procedure tests at the user's plant. Use of non-low hydrogen electrodes and wires on higher strength steels is limited to steels with carbon equivalent of 0.41% or less (see 2-1-3/7.1). Furthermore, these procedure tests should include fabrication of a double fillet weld assembly(ies) representative of material(s) and thickness(es) to be used in production. Weld on the first side is to be allowed to cool to ambient temperature before the second side weld is made. Three macrosections (a section from the center, and a section at one inch from each end), taken 72 hours (minimum) after welding are to be free of weld and heat affected zone cracks when etched and examined at 10X magnification.
- \*\* Grade 1Y not applicable to manual welding electrodes and semi-automatic wire-gas combinations.
- \*\*\* See 2-4-1/5.7.2 concerning overmatching of electrodes for quenched and tempered steels.
- \*\*\*\* For grades YQ890 and YQ960, where the design requirements permit an undermatching weld joint, then welding consumables within the scope of these Rules with lower tensile properties can be considered subject to ABS agreement and Manufacturer's recommendations. If undermatching is applied, then a note is to be made on the drawing or document. If there are locations where undermatching can not be applied, then these locations should be indicated. In cases where the design requires the tensile properties to meet the base metal, YQ890 and YQ960 consumables may still be applied based on actual test results meeting the minimum requirements.

# PART 2

## APPENDIX 4

### Procedure for the Approval of Manufacturers of Hull Structural Steel (2003)

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Procedure for the Approval of Manufacturers of Semi-Finished Products for Hull Structural Steel (2010).....</b>	<b>566</b>
	1	Scope .....	566
	3	Approval Application.....	566
	3.1	Documents to be Submitted.....	566
	5	Approval Tests.....	568
	5.1	Extent of the approval tests.....	568
	5.3	Approval Test Program.....	568
	5.5	Approval Survey.....	568
	5.7	Selection of the Test Product.....	568
	5.9	Position of the Test Samples.....	569
	5.11	Tests on Base Material (2012).....	569
	7	Results.....	569
	9	Certification.....	570
	9.1	Approval.....	570
	9.3	List of Approved Manufacturers.....	570
	11	Renewal of Approval.....	570
	13	Withdrawal of the Approval.....	570
<b>SECTION</b>	<b>2</b>	<b>Procedure for the Approval of Manufacturers of Rolled Hull Structural Steel (2010).....</b>	<b>572</b>
	1	Scope .....	572
	3	Approval Application.....	572
	3.1	Documents to be Submitted.....	572
	5	Approval Tests.....	575
	5.1	Extent of the Approval Tests.....	575
	5.3	Approval Test Program.....	575
	5.5	Approval Survey.....	575
	5.7	Selection of the Test Product.....	575
	5.9	Position of the Test Samples.....	576
	5.11	Tests on Base Material.....	576

	5.13	Weldability Tests.....	578
7		Results.....	579
9		Certification.....	579
	9.1	Approval.....	579
	9.3	List of Approved Manufacturers.....	579
11		Renewal of Approval (2007).....	580
13		Withdrawal of the Approval.....	580

TABLE 1	Tests for Rolled Products Manufacturer Approval.....	576
---------	--	-----

<b>SECTION</b>	<b>3</b>	<b>Procedure for the Approval of Manufacturers of Extra High Strength Steels (2018).....</b>	<b>581</b>
	1	Scope.....	581
	3	Approval Application.....	581
	3.1	Documents to be Submitted.....	581
	5	Approval Tests.....	584
	5.1	Extent of the Approval Tests.....	584
	5.3	Approval Test Program.....	584
	5.5	Approval Survey.....	584
	5.7	Selection of the Test Product.....	585
	5.9	Position of the Test Samples and Specimens.....	585
	5.11	Tests on Base Material.....	585
	7	Results.....	591
	9	Certification.....	591
	9.1	Approval.....	591
	9.3	List of Approved Manufacturers.....	591
	11	Maintenance and Renewal of Approval.....	592
	13	Withdrawal of the Approval.....	592

TABLE 1	Tests on Base Material(2018).....	585
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FIGURE 1A	Plate Thickness $t \leq 50$ mm (2018).....	590
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FIGURE 1B	Plate Thickness $t > 50$ mm (2018).....	591
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**Procedure for the Approval of Manufacturers of Hull Structural Steel  
(2003)****SECTION 1****Procedure for the Approval of Manufacturers of Semi-Finished Products  
for Hull Structural Steel (2010)****1 Scope**

In accordance with 2-1-1/1.2, this Section provides specific requirements for the approval of manufacturers of semi-finished products such as ingots, slabs, blooms and billets for hull structural steels. Slabs, blooms, and billets can also be supplied in the partially-rolled condition.

The manufacturer approval procedure is intended to verify the manufacturer's capability of furnishing satisfactory products in a consistent manner under effective process and production controls in operation, as required in 2-1-1/1.2.2.

**3 Approval Application****3.1 Documents to be Submitted****3.1.1 Initial Approval**

The manufacturer is to submit to ABS request of approval together with proposed approval test program (see 2-A4-1/5.1) and general information relative to:

*3.1.1(a)* Name and address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of semi-finished products for shipbuilding and for other applications, as deemed useful.

*3.1.1(b) Organization and Quality*

- Organizational chart
- Staff employed
- Organization of the quality control department and its staff employed
- Qualification of the personnel involved in activities related to the quality of the products
- Certification of compliance of the quality system with ISO 9001 or 9002, if any.
- Approval certificates already granted by other Classification Societies, if any.

3.1.1(c) *Manufacturing facilities*

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of semi-finished products
- Equipment for systematic control during fabrication

3.1.1(d) *Details of inspections and quality control facilities*

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for nondestructive examinations
- List of quality control procedures

3.1.1(e) *Type of Products (ingots, slabs, blooms, billets), Types of Steel (normal or higher strength), Range of Thickness and Target Material Properties as Follows:*

- Range of chemical composition and target analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
- Target maximum carbon equivalent according to IIW formula
- Target maximum  $P_{cm}$  content for higher strength grades with low carbon content  $C < 0.13\%$
- Production statistics of the chemical composition and, if available at rolling mills, mechanical properties (ReH, Rm, A% and KV). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

3.1.1(f) *Steelmaking*

- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- Deoxidation and alloying practice
- Desulphurization and vacuum degassing installations, if any
- Casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided, as appropriate.
- Ingot or slab size and weight
- Ingot or slab treatment: scarfing and discarding procedures

3.1.1(g) Approval already granted by the other Classification Societies and documentation of approval tests performed.

3.1.1(h) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by ABS is to be included.

### 3.1.2 Changes to the Approval Conditions

Where any one or more of the following cases 2-A4-1/3.1.2(a) through 2-A4-1/3.1.2(c) are applicable, the manufacturer is to submit to ABS the documents required in 2-A4-1/3.1.1 together with the request of changing the approval conditions,

#### 3.1.2(a)

Change of the manufacturing process (steel making, casting, steel making plant, caster)

#### 3.1.2(b)

Change of the maximum thickness (dimension)

#### 3.1.2(c)

Change of the chemical composition, added element, etc.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted, except the approval test program (see 2-A4-1/5.1).

## 5 Approval Tests

### 5.1 Extent of the approval tests

The extent of the test program is specified in 2-A4-1/5.11. The test program may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular, a reduction of the indicated number of casts, product thicknesses and types to be tested or complete omission of the approval tests may be considered, taking into account:

- i)* Approval already granted by other Classification Societies and documentation of approval tests performed
- ii)* Types of steel to be approved and availability of long-term historical statistic results of chemical properties and of mechanical properties tested on rolled products
- iii)* Change of the approval conditions

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

### 5.3 Approval Test Program

Where the number of tests differs from those shown in 2-A4-1/5.11, the program is to be confirmed by ABS before the commencement of the tests.

### 5.5 Approval Survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant. An inspection by the Surveyor of the plant in operation will be required.

If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

### 5.7 Selection of the Test Product

For each type of steel and for each manufacturing process (e.g., steel making, casting), one test product with the maximum thickness (dimension) and one test product with the minimum thickness to be approved are, in general, to be selected for each kind of product (ingots, slabs, blooms/billets).

In addition, for initial approval, ABS will require selection of one test product of average thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified  $C_{eq}$  or  $P_{cm}$  values and grain refining micro-alloying additions.

## 5.9 Position of the Test Samples

The test samples are to be taken, unless otherwise agreed, from the product (slabs, blooms, billets) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.

## 5.11 Tests on Base Material (2012)

### 5.11.1 Type of Tests (2022)

The tests to be carried out for the approval of the manufacturing process of semi-finished products are:

- i) Chemical analysis. The analysis is to be complete including micro alloying elements.
- ii) Sulphur prints and photomacrograph (acid etched) pictures. **Alternatively, non-metallic inclusion content may be proposed in lieu of Sulphur prints.**

In addition, for initial approval and for any upgrade of the approval, ABS will require full tests indicated in 2-A4-2/5 to be performed at rolling mill on the minimum thickness semi-finished product.

In case of a multi-caster work, full tests on finished products shall be carried out for one caster and reduced tests (chemical analysis, sulphur print, and photomacrograph picture) for the others. The selection of the caster shall be based on the technical characteristics of the casters to be evaluated on case by case basis to be performed at rolling mill on products manufactured from the minimum thickness semi-finished product.

### 5.11.2 Test Specimens and Testing Procedure

The test specimens and testing procedures are to be, as a rule, in accordance with Section 2-1-1 with particular attention to the following:

#### 5.11.2(a) Chemical analyses.

Both the ladle and product analyses are to be reported. In general, the content of the following elements is to be checked: C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Cu, As, Sn, Ti, Ca, and, for steel manufactured from electric or open-hearth furnace, Sb and B.

#### 5.11.2(b) Sulphur Prints and Photomacrograph (Acid Etched) Pictures.

Sulphur prints and photomacrograph pictures are to be taken from product edges which are perpendicular to the axis of the ingot or slab (full transverse cross-section). These sulphur prints and photomacrograph pictures are to be approximately 600 mm long, taken from the center of the edge selected (i.e., on the ingot centerline) and are to include the full product thickness.

#### 5.11.2(c) Non-Metallic Inclusion Content. (2022)

**The level of non-metallic inclusions and impurities in term of amount, size, shape and distribution shall be controlled by the manufacturer. The standards of the micrographic examination methods ISO 4967 or ASTM E45 or equivalent standards are applicable. Alternative methods for demonstrating the non-metallic inclusions and impurities may be used by the manufacturer.**

## 7 Results

Before the approval, all test results are evaluated for compliance with the Rules. Depending upon the finding, limitations or testing conditions, as deemed appropriate, may be specified in the approval document.



All information required under 2-A4-2/3, applicable to the products submitted to the tests, is to be collected by the manufacturer and incorporated into a single document including all test results and operation records relevant to steel making, casting, and when applicable, rolling and heat treatment of the tested products.

## **9 Certification**

### **9.1 Approval**

Upon satisfactory completion of the survey, approval will be granted by ABS.

The following information is to be stated on the approval certificate:

- i)* Type of products (ingots, slabs, blooms, billets)
- ii)* Steelmaking and casting processes
- iii)* Thickness range of the semi-finished products
- iv)* Types of steel (normal or higher strength)

It is also to be indicated that the individual users of the semi-finished products are to be approved for the manufacturing process of the specific grade of rolled steel products they are going to manufacture with those semi-finished products.

### **9.3 List of Approved Manufacturers**

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

## **11 Renewal of Approval**

The validity of the approval is to be to the maximum of five years, renewable subject to an audit and assessment of the result of satisfactory survey during the preceding period. The Surveyor's report confirming no process changes, along with mechanical property statistical data for various approved types, is to be made available to the ABS Engineering/Materials department for review and issuance of renewal letter/certificate. \*

Where for operational reasons, the renewal audit cannot be carried out within the validity of approval, the manufacturer will still be considered as being approved if agreement to such extension of audit date is provided for in the original approval. In such instance, the extension of approval will be backdated to the original renewal date.

Manufacturers who have not produced the approved types and products during the period preceding the renewal may be required to carry out approval tests, unless the results of production of similar types of products during the period are evaluated by ABS and found acceptable for renewal.

#### *Note:*

\* The provisions for renewal of approval are also applicable to all grades and products which were approved by ABS prior to an implementation of 2-1-1/1.2 and this Appendix, regardless of any validity of prior approval. Such renewal is to be completed before 1 January 2008, that is, within five years after the 1 January 2003 effective date of this Rule change.

## **13 Withdrawal of the Approval**

The approval may be withdrawn before the expiry of the validity period in the following cases:

- i)* In-service failures traceable to product quality
- ii)* Nonconformity of the product revealed during fabrication and construction

- iii)* Discovery of failure of the manufacturer's quality system
- iv)* Changes made by the manufacturer, without prior agreement of ABS, to the extent of the approval defined at the time of the approval
- v)* Evidence of major nonconformities during testing of the products.

**Procedure for the Approval of Manufacturers of Hull Structural Steel  
(2003)****Procedure for the Approval of Manufacturers of Rolled Hull Structural  
Steel (2010)****1 Scope**

In accordance with 2-1-1/1.2, this Appendix provides specific requirements for the approval of manufacturers of rolled hull structural steel.

The manufacturer approval procedure is intended to verify the manufacturer's capability of furnishing satisfactory products in a consistent manner under effective process and production controls in operation including programmed rolling.

**3 Approval Application****3.1 Documents to be Submitted****3.1.1 Initial Approval**

The manufacturer is to submit to ABS request of approval together with proposed approval test program (see 2-A4-2/5.1) and general information relative to:

*3.1.1(a)* Name and address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products for shipbuilding and for other applications, as deemed useful.

*3.1.1(b) Organization and Quality*

- Organizational chart
- Staff employed
- Organization of the quality control department and its staff employed
- Qualification of the personnel involved in activities related to the quality of the products
- Certification of compliance of the quality system with ISO 9001 or 9002, if any.
- Approval certificates already granted by other Classification Societies, if any.

*3.1.1(c) Manufacturing Facilities*

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of finished products
- Equipment for systematic control during fabrication

#### 3.1.1(d) Details of Inspections and Quality Control Facilities

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for non destructive examinations
- List of quality control procedures

#### 3.1.1(e) Type of Products (plates, sections, coils), Grades of Steel, Range of Thickness and Target Material Properties as Follows:

- Range of chemical composition and aim analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
- Target maximum carbon equivalent according to IIW formula
- Target maximum  $P_{cm}$  content for higher strength grades with low carbon content  $C < 0.13\%$
- Production statistics of the chemical composition and mechanical properties (ReH, Rm, A% and KV). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

#### 3.1.1(f) Steelmaking

- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- Deoxidation and alloying practice
- Desulphurisation and vacuum degassing installations, if any
- Casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided, as appropriate.
- Ingot or slab size and weight
- Ingot or slab treatment: scarfing and discarding procedures

#### 3.1.1(g) Reheating and Rolling

- Type of furnace and treatment parameters
- Rolling: reduction ratio of slab/bloom/billet to finished product thickness, rolling and finishing temperatures
- Descaling treatment during rolling
- Capacity of the rolling stands

#### 3.1.1(h) Heat Treatment

- Type of furnaces, heat treatment parameters and their relevant records
- Accuracy and calibration of temperature control devices

*3.1.1(i) Programmed Rolling.*

For products delivered in the controlled rolling (CR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:

- Description of the rolling process
- Normalizing temperature, re-crystallization temperature and Ar3 temperature and the methods used to determine them
- Control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- Calibration of the control equipment

*3.1.1(j) Recommendations for working and welding, in particular, for products delivered in the CR or TM condition*

- Cold and hot working recommendations, if needed, in addition to the normal practice used in the shipyards and workshops
- Minimum and maximum heat input, if different from the ones usually used in the shipyards and workshops (15 – 50 kJ/cm)

*3.1.1(k) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by ABS is to be included.*

*3.1.1(l) (2010) Approval already granted by other IACS Member Societies and documentation of approval tests performed.*

**3.1.2 Changes to the Approval Conditions**

Where any one or more of the following cases 2-A4-2/3.1.2(a) through 2-A4-2/3.1.2(e) are applicable, the manufacturer is to submit to ABS the documents required in 2-A4-2/3.1.1 together with the request of changing the approval conditions,

*3.1.2(a) Change of the manufacturing process (steel making, casting, rolling and heat treatment)*

*3.1.2(b) Change of the maximum thickness (dimension)*

*3.1.2(c) Change of the chemical composition, added element, etc.*

*3.1.2(d) Subcontracting the rolling, heat treatment, etc.*

*3.1.2(e) (2010) Use of the slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.*

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted, except the approval test program (see 2-A4-2/5.1).

## 5 Approval Tests

### 5.1 Extent of the Approval Tests (2022)

The extent of the test program is specified in 2-A4-2/5.11 and 2-A4-2/5.13. The test program may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular, a reduction of the indicated number of casts, steel plate or tubular thicknesses and grades to be tested or complete omission of the approval tests may be considered, taking into account:

- i) Approval already granted by other Classification Societies and documentation of approval tests performed
- ii) Grades of steel to be approved and availability of long term historical statistic results of chemical and mechanical properties
- iii) Approval for any grade of steel also covers approval for any lower grade in the same strength level, provided that the target analyses, method of manufacture and condition of supply are similar.
- iv) For higher tensile steels, approval of one strength level covers the approval of the strength level immediately below, provided the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.
- v) Change of the approval conditions

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 2-A4-2/5.11 and 2-A4-2/5.13. A reduction or complete omission of the approval tests may be considered, taking into account previous approval as follows:

- The rolled steel manufacturer has already been approved for the manufacturing process using other semi-finished products characterized by the same thickness, steel grade, grain refining and micro-alloying elements, steel making and casting process;
- The semi-finished products manufacturer has been approved for the complete manufacturing process with the same conditions (steelmaking, casting, rolling and heat treatment) for the same steel types.

### 5.3 Approval Test Program

Where the number of tests differs from those shown in 2-A4-2/5.11 and 2-A4-2/5.13, the program is to be confirmed by ABS before the commencement of the tests.

### 5.5 Approval Survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant. An inspection by the Surveyor of the plant in operation will be required.

If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

### 5.7 Selection of the Test Product

For each grade of steel and for each manufacturing process (e.g., steel making, casting, rolling and condition of supply), one test product with the maximum thickness (dimension) to be approved is, in general, to be selected for each kind of product.

In addition, for initial approval, ABS will require selection of one test product of average thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified  $C_{eq}$  or  $P_{cm}$  values and grain refining micro-alloying additions.

## 5.9 Position of the Test Samples (2022)

The test samples are to be taken, unless otherwise agreed, from the product (plate, tubular, flat, section, bar) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.

The position of the samples to be taken in the length of the rolled product, “piece”, defined in 5C-8-6/1 (ABS) of the *Marine Vessel Rules*, (top and/or bottom of the piece) and the direction of the test specimens with respect to the final direction of rolling of the material are indicated in 2-A4-2/5.11.1 TABLE 1.

The position of the samples in the width of the product is to be in compliance with 5C-8-6/3.5.1 (ABS) of the *Marine Vessel Rules*.

## 5.11 Tests on Base Material

### 5.11.1 Type of Tests

The tests as indicated in 2-A4-2/5.11.1 TABLE 1 are to be carried out.

**TABLE 1**  
**Tests for Rolled Products Manufacturer Approval (2022)**

<i>Type of Test</i>	<i>Position of the Samples and Direction of the Test Specimen <sup>(1)</sup></i>	<i>Remarks</i>			
Tensile test	Top and bottom transverse <sup>(2)</sup>	ReH, Rm, A <sub>5</sub> (%), RA(%) are to be reported			
Tensile test (stress relieved) For TM steel only	Top and bottom transverse <sup>(2)</sup>	Stress relieving at 600°C (2 min/mm) with minimum 1 hour)			
Impact tests <sup>(3)</sup> on non aged specimens for grades:	Top and bottom – longitudinal	Testing temperature (0°C)			
A, B, AH32, AH36, AH40		+20	0	-20	
D, DH32, DH36, DH40		0	-20	-40	
E, EH32, EH36, EH40		0	-20	-40	-60
FH32, FH36, FH40		-20	-40	-60	-80
A, B, AH32, AH36, AH40	Top – transverse <sup>(4)</sup>	+20	0	-20	
D, DH32, DH36, DH40		0	-20	-40	
E, EH32, EH36, EH40		-20	-40	-60	
FH32, FH36, FH40		-40	-60	-80	
Impact tests <sup>(3)</sup> on strain aged specimens <sup>(5)</sup> for grades:	Top - longitudinal	Testing temperature (0°C)			
AH32, AH36, AH40		+20	0	-20	
D, DH32, DH36, DH40		0	-20	-40	
E, EH32, EH36, EH40		-20	-40	-60	
FH32, FH36, FH40		-40	-60	-80	
Chemical analysis (%) <sup>(6)</sup>	Top	Complete analysis including micro alloying elements			

<i>Type of Test</i>	<i>Position of the Samples and Direction of the Test Specimen <sup>(1)</sup></i>	<i>Remarks</i>
Sulfur prints and photomicrographs	Top	Non-metallic inclusion count per ISO 4967 or ASTM E45 or equivalent standards may be proposed in lieu of Sulfur prints.
Micro examination	Top	
Grain size determination	Top	For fine grain steel only
Drop weight test <sup>(4)</sup>	Top	For grades E, EH32, EH36, EH40, EQ43-70, FH32, FH36, FH40, FQ43-70 only
Through thickness tensile tests	Top and bottom	For grades with improved through thickness properties only

**Notes:**

- 1 For hot rolled strips see 2-A4-2/5.11.2
- 2 Longitudinal direction for sections and plates having width less than 600 mm
- 3 One set of 3 Charpy V-notch impact specimens is required for each impact test
- 4 Not required for sections and plates having width less than 600 mm
- 5 (2012) Deformation 5% + 1 hour at 250°C. The impact energy value is reported for information only. However, if impact values obtained during qualification testing do not meet the requirements of 2-1-2/11 and 2-1-2/15.9 TABLE 4, 2-1-3/7.3 TABLE 4, and 2-1-8/5.11 TABLE 5A of these Rules, as applicable, additional testing may be requested.
- 6 Besides product analysis, ladle analysis is also required

### 5.11.2 Test Specimens and Testing Procedure

The test specimens and testing procedures are to be, as a rule, in accordance with Section 2-1-1 with particular attention to the following:

#### 5.11.2(a) Tensile Test (2022)

- For plates made from hot rolled strip, one additional tensile specimen is to be taken from the middle of the strip constituting the coil.
- For plates and tubulars having thickness higher than 40 mm, when the capacity of the available testing machine is insufficient to allow the use of test specimens of full thickness, multiple flat specimens, representing collectively the full thickness, can be used. Alternatively two round specimens with the axis located at one quarter and at mid-thickness can be taken.

#### 5.11.2(b) Impact Test (2022)

- For plates made from hot rolled strip, one additional set of impact specimens is to be taken from the middle of the strip constituting the coil.
- For plates and tubulars having thickness higher than 40 mm (1.575 in.), one additional set of impact specimens is to be taken with the axis located at mid-thickness.
- For plates and tubulars having thickness higher than 100 mm (3.937 in.), impact specimens are to be taken with the axis located at quarter depth and mid-thickness
- In addition to the determination of the energy value, also the lateral expansion and the percentage crystallinity are to be reported.

#### 5.11.2(c) Chemical Analyses.



Both the ladle and product analyses are to be reported. The material for the product analyses should be taken from the tensile test specimen. In general, the content of the following elements is to be checked: C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Cu, As, Sn, Ti and, for steel manufactured from electric or open-hearth furnace, Sb and B.

*5.11.2(d) Sulphur Prints and Photomicrograph (Acid Etched) Pictures (2012).*

Sulphur prints and photomicrograph pictures are to be taken from plate edges which are perpendicular to the axis of the ingot or slab. These sulphur prints and photomicrograph pictures are to be approximately 600 mm long, taken from the center of the edge selected (i.e., on the ingot centerline) and are to include the full plate thickness.

*5.11.2(e) Micrographic Examination.*

The micrographs are to be representative of the full thickness. For thick products in general, at least three examinations are to be made at surface, one quarter and mid-thickness of the product.

All photomicrographs are to be taken at  $\times 100$  magnification and where ferrite grain size exceeds ASTM 10, additionally at  $\times 500$  magnification. Ferrite grain size should be determined for each photomicrograph

*5.11.2(f) Drop Weight Test.*

The test is to be performed in accordance with ASTM E208. The NDTT is to be determined and photographs of the tested specimens are to be taken and enclosed with the test report.

*5.11.2(g) Through Thickness Tensile Test.*

The test is to be performed in accordance with 2-1-1/17.

The test results are to be in accordance, where applicable, with the requirements specified for the different steel grades in Part 2, Chapter 1.

### 5.11.3 Other Tests

Additional tests such as CTOD test, large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.) or other tests may be required in the case of newly developed type of steel, outside the scope of Part 2, Chapter 1, or when deemed necessary by ABS.

## 5.13 Weldability Tests

### 5.13.1 General (2022)

Weldability tests are required for plates and tubulars and are to be carried out on samples of the thickest product. Tests are required for normal strength grade E and for higher strength steels.

### 5.13.2 Preparation and Welding of the Test Assemblies

In general the following tests are to be carried out:

- i)* One (1) butt weld test assembly welded with a heat input approximately 15 kJ/cm
- ii)* One (1) butt weld test assembly welded with a heat input approximately 50 kJ/cm.

The butt weld test assemblies are to be prepared with the weld seam transverse to the plate rolling direction, so that impact specimens will result in the longitudinal direction.

The edge preparation is preferably to be 1/2 V or K.

As far as possible, the welding procedure is to be in accordance with the normal welding practice used at the yards for the type of steel in question.

The welding parameters including consumables designation and diameter, pre-heating temperatures, interpass temperatures, heat input, number of passes, etc. are to be reported.

### 5.13.3 Type of Tests

From the test assemblies, the following test specimens are to be taken:

#### 5.13.3(a)

One (1) cross weld tensile test

#### 5.13.3(b)

A set of three (3) Charpy V-notch impact specimens transverse to the weld with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade in question.

#### 5.13.3(c) (2022)

Hardness tests HV 10 across the weldment. The indentations are to be made along a 1 mm transverse line beneath the surface on both the face side and the root side of the weld as follows:

- Fusion line
- HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

The maximum hardness value is to be not higher than 350 HV10.

A sketch of the weld joint depicting groove dimensions, number of passes, hardness indentations is to be attached to the test report, together with photomicrographs of the weld cross section.

### 5.13.4 Other Tests

Additional tests such as cold cracking tests (CTS, Cruciform, Implant, Tekken, Bead-on plate), CTOD, or other tests may be required in the case of newly developed type of steel, outside the scope of Part 2, Chapter 1, or when deemed necessary by ABS.

## 7 Results

Before the approval, all test results are evaluated for compliance with the Rules. Depending upon the finding, limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All information required under 2-A4-2/3, applicable to the products submitted to the tests, is to be collected by the manufacturer and incorporated into a single document including all test results and operation records relevant to steel making, casting, rolling and heat treatment of the tested products.

## 9 Certification

### 9.1 Approval

Upon satisfactory completion of the survey, approval will be granted by ABS.

### 9.3 List of Approved Manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

## 11 Renewal of Approval (2007)

The validity of the approval is to be to the maximum of five years, renewable subject to an audit and assessment of the result of satisfactory survey during the preceding period. The Surveyor's report confirming no process changes, along with mechanical property statistical data for various approved grades, is to be made available to the ABS Engineering/Materials department for review and issuance of renewal letter/ certificate. \*

Where for operational reasons, the renewal audit cannot be carried out within the validity of approval, the manufacturer will still be considered as being approved if agreement to such extension of audit date is provided for in the original approval. In such instance, the extension of approval will be backdated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period preceding the renewal may be required to carry out approval tests, unless the results of production of similar grades of products during the period are evaluated by ABS and found acceptable for renewal.

### *Note:*

\* The provisions for renewal of approval are also applicable to all grades and products which were approved by ABS prior to an implementation of 2-1-1/1.2 and this Appendix, regardless of any validity of prior approval. Such renewal is to be completed before 1 January 2008, that is, within five years after the 1 January 2003 effective date of this Rule change.

## 13 Withdrawal of the Approval

The approval may be withdrawn before the expiry of the validity period in the following cases:

- i)* In-service failures traceable to product quality
- ii)* Non conformity of the product revealed during fabrication and construction
- iii)* Discovery of failure of the manufacturer's quality system
- iv)* Changes made by the manufacturer, without prior agreement of ABS, to the extent of the approval defined at the time of the approval
- v)* Evidence of major non conformities during testing of the products.

**Procedure for the Approval of Manufacturers of Hull Structural Steel  
(2003)****Procedure for the Approval of Manufacturers of Extra High Strength  
Steels (2018)****1 Scope**

In accordance with 2-1-1/1.2, this section provides specific requirements for the approval of manufacturers of rolled extra high strength steels.

All materials are to be manufactured at works which have been approved by ABS for the type, delivery condition, grade and thickness of steel which is being supplied. The suitability of each grade of steel for forming and welding is to be demonstrated during the initial approval tests at the steelworks.

The manufacturer approval procedure is intended to verify the manufacturer's capability of furnishing satisfactory products in a consistent manner under effective process and production controls in operation including programmed rolling.

**3 Approval Application****3.1 Documents to be Submitted****3.1.1 Initial Approval**

The manufacturer is to submit to ABS a request for approval together with a proposed approval test program (see 2-A4-3/5.1) and general information relative to:

*3.1.1(a)* Name and site address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products for shipbuilding and for other applications, as deemed useful.

*3.1.1(b) Organization and Quality*

- Organizational chart
- Number of staff employed
- Organization of the quality control department and its staff employed
- Qualification of the personnel involved in activities related to the quality of the products
- Certification of compliance of the quality system with ISO 9001 or 9002, if any.
- Approval certificates already granted by other Classification Societies, if any.

### 3.1.1(c) Manufacturing Facilities

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of finished products
- Equipment for systematic control during fabrication

### 3.1.1(d) Details of Inspections and Quality Control Facilities

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for nondestructive examinations (NDE)
- List of quality control procedures

## 3.1.2 Manufacturing Specification

### 3.1.2(a) Material to be approved, including type of products (plates, sections, bars and tubular), delivery condition, grades of steel, range of thickness and aim materials properties as follows:

- Range of chemical composition, aim analyses and associated control limits, including grain refining, nitrogen binding, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and delivery condition, the different ranges are to be specified, as appropriate.
- In addition, where zirconium, calcium and rare earth metals have been used during steel making for grain refinement and, or inclusion shape control and modification, the contents of these elements shall be specified in the manufacturing specification.
- Target maximum carbon equivalent according to IIW formula or CET formula and/or target  $P_{cm}$  content and associated control limits.
- Target maximum  $P_{cm}$  content for higher strength grades with low carbon content  $C < 0.13\%$
- Production statistics of the chemical composition and mechanical properties (ReH, Rm, A% and CVN). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

### 3.1.2(b) Steelmaking (if applicable)

- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- The steel mill is to have a documented process for quality of scrap control. The quality of scrap is to be established at the time of qualification.
- Deoxidation, grain refining, nitrogen binding and alloying practice
- Desulphurisation, dehydrogenation, dephosphorization, sulphide treatment, ladle refining and vacuum degassing installations, if any
- Casting methods: ingot (bottom or top poured, ingot shape) or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided, as appropriate.
- Casting/solidification cooling rate control
- Ingot or slab size and weight
- Ingot or slab treatment: scarfing and discarding procedures

### 3.1.2(c) Reheating and Rolling

- Type of furnace and treatment parameters

- Rolling: reduction ratio of ingot/slab/bloom/billet to finished product thickness, rolling and finishing temperatures for each grade/thickness combination.
- Descaling treatment during rolling
- Capacity of the rolling stands

*3.1.2(d) Heat Treatment*

- Type of furnaces, heat treatment parameters for products to be approved and their relevant records
- Accuracy and calibration of temperature control devices
- The methods used to determine austenitizing temperature, re-crystallization temperature and Ar<sub>3</sub> temperature.
- Description of quenching and tempering process, if applicable.

*3.1.2(e) Programmed Rolling.*

For products delivered in the controlled rolling (CR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:

- Description of the rolling process
- The methods used to determine austenitizing temperature, re-crystallization temperature and Ar<sub>3</sub> temperature.
- Control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- Calibration of the control equipment

*3.1.2(f) (2022)*

Recommendations for fabrication and welding, in particular, for products delivered in the NR/CR, TM or QT condition

- Cold and hot working recommendations, if needed, in addition to the normal practice used in the shipyards and workshops
- Minimum and maximum heat input and proposed pre-heat/interpass temperature

*3.1.2(g)*

Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by ABS is to be included.

*3.1.2(h)*

Approval already granted by other IACS Member Societies and documentation of approval tests performed.

**3.1.3 Changes to the Approval Conditions**

The manufacturer has to submit to ABS the documents required in 2-A4-3/3.1.1 together with the request of changing the approval conditions, in the case of the following 2-A4-3/3.1.3(a) through 2-A4-3/3.1.3(e), as applicable

*3.1.3(a)* Change of the manufacturing process (steel making, casting, rolling and heat treatment)

*3.1.3(b)* Change of the maximum thickness (dimension)

*3.1.3(c)* Change of the chemical composition, added element, etc.

3.1.3(d) Subcontracting the rolling, heat treatment, etc.

3.1.3(e) Use of the ingots, slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted, except the approval test program (see 2-A4-3/5.1).

## **5 Approval Tests**

### **5.1 Extent of the Approval Tests**

The extent of the test program is specified in 2-A4-3/5.11 . The test program may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular, a reduction of the indicated number of casts, steel plate thicknesses and grades to be tested or complete omission of the approval tests may be considered, taking into account:

- i)* Approval already granted by other Classification Societies and documentation of approval tests performed
- ii)* Grades of steel to be approved and where available the long term statistical results of chemical and mechanical properties
- iii)* Approval for any grade of steel also covers approval for any lower grade in the same strength level, provided that the target analyses, the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.
- iv)* For extra high tensile steels, approval of one strength level covers the approval of the strength level immediately below, provided that the target analyses, the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.

An increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 2-A4-3/5.11 . A reduction or complete omission of the approval tests may be considered, taking into account previous approval as follows:

- The rolled steel manufacturer has already been approved for the rolling process and heat treatment using other approved semi-finished products characterized by the same thickness, steel grade, grain refining and micro-alloying elements, steel making (deoxidation) and casting process;
- The semi-finished products have been approved for the complete manufacturing process with the same conditions (steelmaking, casting, rolling and heat treatment) for the same steel types.

### **5.3 Approval Test Program**

Where the number of tests differs from those shown in 2-A4-3/5.11, the program is to be confirmed by ABS before the commencement of the tests.

### **5.5 Approval Survey**

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant. An inspection by the Surveyor of the plant in operation will be required during his/her visit for approval.

If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

## 5.7 Selection of the Test Product

For each grade of steel and for each manufacturing process (e.g., steel making, casting, rolling and condition of supply), one test product with the maximum thickness (dimension) to be approved is, in general, to be selected for each kind of product.

In addition, for initial approval, ABS will require selection of one test product of representative thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified  $C_{eq}$ ,  $CET$  or  $P_{cm}$  values and grain refining micro-alloying additions.

In cases where chemistry changes with increase in thickness, qualification tests are to be carried out on the different chemistries.

## 5.9 Position of the Test Samples and Specimens

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar and tubular) corresponding to the top and bottom of the ingot, or, in the case of continuous casting, one at each end of the product.

The position of the samples to be taken in the length of the rolled product, “piece”, defined in 5C-8-6/1(ABS) of the *Marine Vessel Rules*, (top and bottom of the piece) and the direction of the test specimens with respect to the final direction of rolling of the material are indicated in 2-A4-3/5.11.1 TABLE 1.

The position of the samples in the width of the product is to be in compliance with 5C-8-6/3.5.1 (ABS) of the *Marine Vessel Rules*.

## 5.11 Tests on Base Material

### 5.11.1 Type of Tests

The tests as indicated in 2-A4-3/5.11.1 TABLE 1 are to be carried out.

**TABLE 1**  
**Tests on Base Material(2018)**

<i>Type of Test</i>	<i>Position and direction of test specimens</i>	<i>Remarks</i>
1 Chemical analysis(ladle and product <sup>(1)</sup> )	Top	a) Contents of C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Ti, B, Zr, Cu, As, Sn, Bi, Pb, Ca, Sb, O, H are to be reported. b) Carbon equivalent calculation, and/or c) $P_{cm}$ calculation, as applicable.
2 Segregation examination and Photomicrographs	Top	a) Segregation examination and assessment is to be detailed and acceptance standards submitted b) Photomicrographs are to be taken from plate edges which are perpendicular to the axis of the ingot or slab. c) Sulphur prints may be required by ABS



<i>Type of Test</i>	<i>Position and direction of test specimens</i>	<i>Remarks</i>
3 Micrographic examination <sup>(2)</sup>	Top	a) Grain size determination. Ferrite and/or prior austenite grain size should be determined. b) All photomicrographs are to be taken at x 100 and 500 magnification. c) Non-metallic inclusion contents/Cleanliness The level of non-metallic inclusions and impurities in term of amount, size, shape and distribution shall be controlled by the manufacturer. The standards of the micrographic examination methods ISO 4967 or equivalent standards are applicable. Alternative methods for demonstrating the non-metallic inclusions and impurities may be used by the manufacturer.
4 Tensile test	One sample at each end of the product-longitudinal and transverse direction	Yield strength (ReH), Tensile strength (Rm), Elongation (A5), Reduction in Area (RA) and Y/T ratio are to be reported.
5a Charpy Impact tests on unstrained specimens for grades <sup>(4)</sup>	One set <sup>(3)</sup> of samples at each end of the product	Testing temperature (°C)
AQ	Longitudinal and transverse direction	+20                      0                      -20
DQ		0                      -20                      -40
EQ		0                      -20                      -40                      -60
FQ		-20                      -40                      -60                      -80
5b Charpy Impact tests on strain aged specimens for grades <sup>(4, 5)</sup>	Top	Deformation of 5% + 1 hour at 250°C
AQ	Longitudinal and transverse direction	+20                      0                      -20
DQ		0                      -20                      -40
EQ		0                      -20                      -40                      -60
FQ		-20                      -40                      -60                      -80
6 Drop weight test	Top	The test is to be performed only on plates in accordance with ASTM E208. The NDTT is to be determined and photographs of the tested specimens are to be taken and enclosed with the test report.
7 Through thickness tensile tests	One sample at each end of the product	Testing in accordance with 2-1-1/17, <ul style="list-style-type: none"> <li>• In case of thickness up to 75 mm, improved through thickness property is optional</li> <li>• In case of thickness greater than 75 mm, through thickness testing is to be carried out</li> </ul>
8 CTOD testing	Top	The test is to be performed at -10C on plate and seamless tubulars in accordance with ISO 12135 or equivalent.
9 Ultrasonic Examination		EN 10160 – Acceptance Level S1/E1 (Z grade) or ASTM A578 level C; S2/E3 for Leg, rack and chord plates; Other products to be agreed with manufacturer. (Materials intended for leg, racks and chords are to have a designation “R” after the Grade i.e., EQ70-R)
10 Weld ability test <sup>(6)</sup>	Ref 2-A4-3/5.11.3	

<i>Type of Test</i>	<i>Position and direction of test specimens</i>	<i>Remarks</i>
a) Butt Weld Assembly as-welded	Top	Cross weld tensile, Charpy impact test on FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.
b) Butt Weld Assembly (PWHT), if applicable	Top	Cross weld tensile, Charpy impact test on FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.
c) Cold cracking tests as such CTS-Test, Y-groove test U-groove test or Implant test or Alternative tests	Top	National and International recognized standards such as ISO 17642-2, ISO17642-3, GB/T4675.1 and JIS Z 3158.

**Notes:**

- 1) The product analysis should be taken from the tensile specimen. The deviation of the product analysis from the ladle analysis shall be permissible in accordance with the limits given in the manufacturing specification.
- 2) The Micrographs are to be representative of the full thickness. For thick products in general at least three examinations are to be made at surface,  $1/4t$  and  $1/2t$  of the product.
- 3) One set of three Charpy V-Notch per sample
- 4) In addition to the determination of the absorbed energy value, also the lateral expansion and the percentage crystallinity are to be reported.
- 5) Strain ageing test is to be carried out on the thickest plate. (Deformation 5% + 1 hour at 250°C. The impact energy value is reported for information only. However, if impact values obtained during qualification testing do not meet the requirements of 2-1-8/5.11 TABLE 5A as applicable, additional testing may be requested.)
- 6) Weldability is to be carried out in the thickest plate.

**5.11.2 Test Specimens and Testing Procedure**

The test specimens and testing procedures are to be, as a rule, in accordance with Section 2-1-1 with particular attention to the following:

**5.11.2(a) Tensile Test (2022)**

- For plates made from hot rolled strip, one additional tensile specimen is to be taken from the middle of the strip constituting the coil.
- For plates having thickness higher than 40 mm (1.575 in.), when the capacity of the available testing machine is insufficient to allow the use of test specimens of full thickness, multiple flat specimens, representing collectively the full thickness, can be used. Alternatively two round specimens with the axis located at one quarter and at mid-thickness can be taken.
- For tubulars, supplied in QT condition, test samples are to be taken from either end of the product.

**5.11.2(b) Impact Test (2022)**

- For plates made from hot rolled strip, one additional set of impact specimens is to be taken from the middle of the strip constituting the coil.
- For plates having thickness higher than 40 mm (1.575 in.), one additional set of impact specimens is to be taken with the axis located at mid-thickness.
- For plates having thickness higher than 100 mm (3.937 in.), impact specimens are to be taken with the axis located at quarter depth and mid-thickness

- For tubulars, supplied in QT condition, test samples are to be taken from either end of the product.
- In addition to the determination of the energy value, also the lateral expansion and the percentage crystallinity are to be reported.

5.11.2(c) CTOD Tests.

CTOD test specimens are to be taken from full thickness of the plate or seamless tubulars, with the notch in the through thickness direction. Three tests shall be performed at  $-10^{\circ}\text{C}$ . CTOD test is to be carried out in accordance with ISO 12135 or equivalent.

Alternative CTOD specimen dimensions can be agreed with ABS.

5.11.2(d) Other Tests.

Additional tests on parent plate such as large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.) or other tests may be required in the case of newly developed type of steel, outside the scope of Part 2 or when deemed necessary by ABS.

### 5.11.3 Weldability Test - Butt Weld Test

5.11.3(a) For 43 to 51 Grade Steels. (2022)

Weldability tests are to be carried out on samples of the thickest plate. Testing on higher grades can cover the lower strength and toughness grades.

- i) 1x butt weld test assembly welded with a heat input  $15 \pm 2$  kJ/cm is to be tested aswelded.
- ii) 1x butt weld test assembly welded with a heat input  $50 \pm 5$  kJ/cm for N/NR/CR and TM and  $35 \pm 3.5$  kJ/cm for QT steels is to be tested as welded.
- iii) 1x butt weld test assembly welded with the same heat input as given in ii) is to be post-weld heat treated (PWHT) prior to testing.

Alternative heat inputs can be agreed with ABS.

*Option:* Steels intended to be designated as steels for high heat input welding are to be tested with 1x butt weld test assembly in the as-welded condition and 1x test assembly in the PWHT condition, both welded with the maximum heat input being approved.

5.11.3(b) For 56 to 98 Grade Steels.

In general, the thickest plate with the highest toughness grade for each strength grade is to be tested. Provided the chemical composition of the higher grade is similar to the lower grade, testing requirements on the lower grades may be reduced at the discretion of ABS.

- i) 1x butt weld test assembly welded with a heat input  $10 \pm 2$  kJ/cm is to be tested as-welded.
- ii) 1x butt weld test assembly welded with a maximum heat input as proposed by the manufacturer is to be tested as-welded. The approved maximum heat input shall be stated on the manufacturer approval letter.

Alternative heat inputs can be agreed with ABS.

*Option:* If the manufacturer requests to include the approval for Post Weld Heat Treated (PWHT) condition, 1x additional butt weld test assembly welded with a maximum heat input proposed by the manufacturer for the approval same as test assembly ii) is to be post-weld heat treated (PWHT) prior to testing. See 2-A4-3/5.11.3(e).

5.11.3(c) Butt Weld Test Assembly.

The butt weld test assemblies of plates are to be prepared with the weld seam parallel to the final plate rolling direction.

The butt weld test assemblies of long products, sections and seamless tubular in any delivery condition are to be prepared with the weld seam transverse to the rolling direction.

*5.11.3(d) Bevel Preparation.*

The bevel preparation should be preferably 1/2V or K related to thickness.

The welding procedure should be as far as possible in accordance with the normal welding practice used for the type of steel in question.

The welding procedure and welding record are to be submitted to ABS for review.

*5.11.3(e) Post-weld Heat Treatment Procedure. (2022)*

- i)* Steels delivered in N/NR/CR or TM/TM+AcC/TM+DQ condition shall be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes), where the minimum and maximum temperatures are to be established.
- ii)* Steels delivered in QT condition shall be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes) where the minimum and maximum temperatures are to be established and should generally be at least 14°C (25°F) below the tempering temperature, unless otherwise agreed at the time of approval.
- iii)* Heating and cooling above 300°C shall be carried out in a controlled manner in order to heat/cool the material uniformly. The cooling rate from the maximum holding temperature to 300°C shall not be slower than 55°C/hr.

*5.11.3(f) Type of Tests.*

From the test assemblies, the following test specimens are to be taken:

- i)* 1 cross weld tensile test - 1 full thickness test sample or sub-sized samples cut from the full thickness cross section.
- ii)* 1 set of 3 Charpy V-notch impact specimens transverse to the weld seam and 1-2 mm below the surface with the notch located at the fusion line and at a distance 2, 5 and 20 mm from the straight fusion line. An additional set of 3 Charpy test specimens at root is required for each aforementioned position for plate thickness  $t \geq 50$  mm. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade.
- iii)* Hardness tests HV10 across the weldment. The indentations are to be made along a 1- 2 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:
  - Fusion line
  - HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

The maximum hardness value should not be higher than 350HV10 for grade steels 43 to 47; not be higher than 420HV10 for 51 to 70; and not be higher than 450HV10 for 91 and 98.

A sketch of the weld joint depicting groove dimensions, number of passes, hardness indentations should be attached to the test report together with photomicrographs of the weld cross section.

iv) *CTOD test.* CTOD test specimens are to be taken from butt weld test assembly specified in 2-A4-3/5.11.3(a).ii) or 2-A4-3/5.11.3(b).ii). CTOD test is to be carried out in accordance with EN ISO 15653 or equivalent.

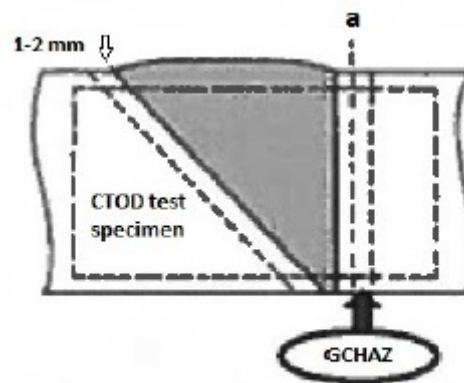
- The specimen geometry ( $B = W$ ) is permitted for plate thickness up to 50 mm. For plate thicker than 50 mm, subsidiary specimen geometry ( $50 \times 50$  mm) is permitted, which is to be taken 50 mm in depth through thickness from the subsurface and 50 mm in width. See 2-A4-3/Figure 1A and 1B for more details.
- The specimens shall be notched in through thickness direction.
- Grain-coarsened HAZ (GCHAZ) shall be targeted for the sampling position of the crack tip.
- The test specimens shall be in as-welded and post-weld heat treated, if applicable.
- Three tests shall be performed at  $-10^{\circ}\text{C}$  on each butt weld test assembly.

For grades 70 and above, dehydrogenation of as-welded test pieces may be carried out by a low temperature heat treatment, prior to CTOD testing. Heat treatment conditions of  $200^{\circ}\text{C}$  for 4 hours are recommended, and the exact parameters shall be notified with the CTOD test results.

Alternative CTOD test methodology and acceptance can be agreed with ABS at the time of qualification.

**FIGURE 1A**  
**Plate Thickness  $t \leq 50$  mm (2018)**

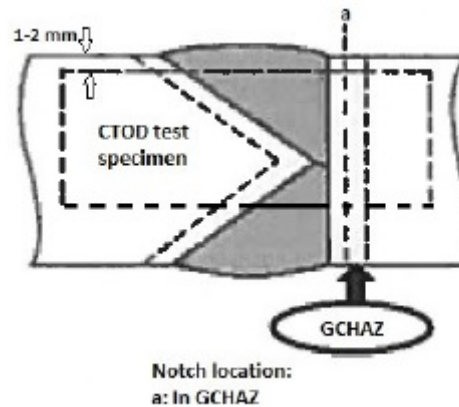
For plate thickness  $t \leq 50$  mm, CTOD test specimen is to be sampled in full thickness.



Notch location:  
a: in GCHAZ

**FIGURE 1B**  
**Plate Thickness  $t > 50$  mm (2018)**

For plate thickness  $t > 50$  mm, subsidiary CTOD test specimen with a thickness of maximum 50 mm in subsurface area is to be sampled.



#### 5.11.3(g) Cold Cracking Test.

Testing in accordance with national and international recognized standards such as ISO 17642, GB/T4675.1 and JIS Z 3158 for Y-groove weld crack test. Minimum preheat temperature is to be determined and the relationship of minimum preheat temperature with thickness is to be derived.

#### 5.11.3(h) Other Tests.

Additional tests may be required in the case of newly developed types of steel, outside the scope of Section 2-A4-3, or when deemed necessary by ABS.

## 7 Results

All the results are to comply with the requirements of the scheme of initial approval. Before the approval, all test results are evaluated for compliance with the Rules. Depending upon the finding, limitations or testing conditions may be specified in the approval document.

The subject manufacturer shall submit all the test results together with the manufacturing specification containing all the information required under 2-A4-2/3, and manufacturing records relevant to steel making, casting, rolling and heat treatment applicable to the product submitted to the tests.

## 9 Certification

### 9.1 Approval

Upon satisfactory completion of the survey, approval will be granted by ABS.

### 9.3 List of Approved Manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

## 11 Maintenance and Renewal of Approval

The validity of the approval is to be to the maximum of five years, renewable subject to an audit and assessment of the result of satisfactory survey during the preceding period. The Surveyor's report confirming no process changes, along with mechanical property statistical data for various approved grades, is to be made available to the ABS Engineering/Materials department for review and issuance of renewal letter/ certificate.\*

Where for operational reasons, the renewal audit cannot be carried out within the validity of approval, the manufacturer will still be considered as being approved if agreement to such extension of audit date is provided for in the original approval. In such instance, the extension of approval will be backdated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period preceding the renewal may be required to carry out approval tests, unless the results of production of similar grades of products during the period are evaluated by ABS and found acceptable for renewal.

*Note:*

\* The provision for renewal of approval is also to be applied to all grades and products which were approved by ABS prior to an implementation of 2-1-1/1.2 and this Appendix regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the 1 January 2018 effective date of this rule change.

## 13 Withdrawal of the Approval

The approval may be withdrawn before the expiry of the validity period in the following cases:

- i) In-service failures traceable to product quality
- ii) Non conformity of the product revealed during fabrication and construction
- iii) Discovery of failure of the manufacturer's quality system
- iv) Changes made by the manufacturer, without prior agreement of ABS, to the extent of invalidating the approval
- v) Evidence of major non conformities during testing of the products.

**Hull Structural Steels Intended for Welding with High Heat Input****CONTENTS**

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<b>SECTION</b>	<b>1</b>	<b>Procedure for the Approval of Manufacturers of Hull Structural Steels Intended for Welding with High Heat Input (2006)</b>	<b>594</b>
	1	Scope	594
	3	Application for Certification	594
	5	Confirmation tests	595
	5.1	Range of Certification	595
	5.3	Weldability Test Program	595
	5.5	Test Plate	595
	5.7	Test Assembly	595
	5.9	Examinations and Tests for the Test Assembly	596
	7	Results	597
	9	Certification	597
	11	Grade Designation	597



**Hull Structural Steels Intended for Welding with High Heat Input****SECTION 1****Procedure for the Approval of Manufacturers of Hull Structural Steels Intended for Welding with High Heat Input (2006)****1 Scope**

This Appendix specifies the weldability confirmation procedures of normal and higher strength hull structural steels stipulated in Sections 2-1-2 and 2-1-3 intended for welding with high heat input over 50 kJ/cm (127 kJ/in.).

The weldability confirmation procedure is to be generally applied at manufacturer's option and valid for certifying that the steel has satisfactory weldability for high heat input welding concerned under testing conditions.

Demonstration of conformance to the requirements of this Appendix approves a particular steel mill to manufacture grades of steel to the specific chemical composition range, melting practice, and processing practice for which conformance was established. The approval scheme does not apply to qualification of welding procedures to be undertaken by shipyards.

**3 Application for Certification**

The manufacturer is to submit to ABS a request for certification of the proposed weldability test program (see 2-A5-1/5.3 below) and technical documents relevant to:

- i)* Outline of steel plate to be certified
  - Grade
  - Thickness range
  - Deoxidation practice
  - Fine grain practice
  - Aim range of chemical composition
  - Aim maximum  $C_{eq}$  and  $P_{cm}$
  - Production statistics of mechanical properties (tensile and Charpy V-notch impact tests), if any
- ii)* Manufacturing control points to prevent toughness deterioration in heat affected zones of high heat input welds, relevant to chemical elements, steel making, casting, rolling, heat treatment etc.

- iii) Welding control points to improve joint properties on strength and toughness.

## 5 Confirmation tests

### 5.1 Range of Certification

Range of certification for steel grades is to be in accordance with the following, unless otherwise agreed by ABS:

- i) Approval tests on the lowest and highest toughness levels cover the intermediate toughness level.
- ii) Approval tests on normal strength level cover that strength level only.
- iii) For high tensile steels, approval tests on one strength level cover strength level immediately below.
- iv) Tests may be carried out separately provided the same manufacturing process is applied.
- v) Certification and documentation of confirmation tests performed by another Classification Society may be accepted at the discretion of ABS.

### 5.3 Weldability Test Program

The extent of the test program is specified in 2-A5-1/5.9, but it may be modified according to the contents of certification. In particular, additional test assemblies and/or test items may be required in the case of newly developed types of steel, welding consumable and welding method, or when deemed necessary by ABS. Where the content of tests differs from those specified in 2-A5-1/5.9, the program is to be confirmed by ABS before the tests are carried out.

### 5.5 Test Plate

The test plate is to be manufactured by a process approved by ABS in accordance with the requirements of Part 2, Appendix 4. For each manufacturing process route, two test plates with different thickness are to be selected. The thicker plate ( $t$ ) and thinner plate (less than or equal to  $t/2$ ) are to be proposed by the manufacturer.

Minor changes in manufacturing processing (e.g. within the TMCP process) may be considered for acceptance without testing, at the discretion of ABS.

### 5.7 Test Assembly

One butt weld assembly welded with heat input over 50 kJ/cm is generally to be prepared with the weld axis transverse to the plate rolling direction.

Dimensions of the test assembly are to be amply sufficient to take all the required test specimens specified in 2-A5-1/5.5.

The welding procedures should be as far as possible in accordance with the normal practices applied at shipyards for the test plate concerned, and including the following:

- Welding process
- Welding position
- Welding consumable (manufacturer, brand, grade, diameter and shield gas)
- Welding parameters including bevel preparation, heat input, preheating temperatures, interpass temperatures, number of passes, etc.

## 5.9 Examinations and Tests for the Test Assembly

The test assembly is to be examined and tested in accordance with the following, unless otherwise agreed by ABS.

- i) *Visual examination.* Overall welded surface is to be uniform and free from injurious defects such as cracks, undercuts, overlaps, etc.
- ii) *Macroscopic test.* One macroscopic photograph is to be representative of transverse section of the welded joint and is to show absence of cracks, lack of penetration, lack of fusion and other injurious defects.
- iii) *Microscopic test.* Along mid-thickness line across transverse section of the weld, one micrograph with  $\times 100$  magnification is to be taken at each position of the weld metal centerline, fusion line and at a distance 2, 5, 10 and a minimum 20 mm (0.8 in.) from the fusion line. The test result is provided for information purpose only.
- iv) *Hardness test.* Along two lines across transverse weld section 1 mm beneath plate surface on both face and root side of the weld, indentations by HV5 are to be made at weld metal centerline, fusion line and each 0.7 mm (0.28 in.) position from fusion line to unaffected base metal (minimum 6 to 7 measurements for each heat affected zone). The maximum hardness value should not be higher than 350 HV.
- v) *Transverse tensile test.* Two transverse (cross weld) tensile specimens are to be taken from the test assembly. Test specimens and testing procedures are to comply with the requirements of Section 2-4-3.

The tensile strength is to be not less than the minimum required value for the grade of base metal.

- vi) *Bend test.* Two transverse (cross weld) test specimens are to be taken from the test assembly and bent on a mandrel with diameter of quadruple specimen thickness. Bending angle is to be at least 120 degrees. Test specimens are to comply with the requirements of 2-4-3.

For plate thickness up to 20 mm (0.8 in.), one face-bend and one root-bend specimens or two side-bend specimens are to be taken. For plate thickness over 20 mm (0.8 in.), two side-bend specimens are to be taken. After testing, the test specimens shall not reveal any crack nor other open defect in any direction greater than 3 mm (0.12 in.).

- vii) *Impact test.* Charpy V-notch impact specimens (three specimens for one set) are to be taken within 2 mm (0.08 in.) below plate surface on face side of the weld with the notch perpendicular to the plate surface.

One set of the specimens transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2, 5 and a minimum 20 mm (0.8 in.) from the fusion line. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade in question.

For steel plate with thickness greater than 50 mm (2.0 in.) or one side welding for plate thickness greater than 20 mm (0.8 in.), one additional set of the specimens is to be taken from the root side of the weld with the notch located at each of the same positions as for the face side.

The average impact energy at the specified test temperature is to comply with the requirements of 2-1-2/15.9 TABLE 4 or 2-1-3/7.3 TABLE 4, depending on the steel grade and thickness. Only one individual value may be below the specified average value provided it is not less than 70% of that value. Additional tests at the different testing temperatures may be required for evaluating the transition temperature curve of absorbed energy and percentage crystallinity at the discretion of ABS.

- viii) *Other tests.* Additional tests, such as wide-width tensile test, HAZ tensile test, cold cracking tests (CTS, Cruciform, Implant, Tekken, and Bead-on plate), CTOD or other tests may be required at the discretion of ABS (see 2-A5-1/5.3).

## 7 Results

The manufacturer is to submit to ABS the complete test report including all the results and required information relevant to the confirmation tests specified in 2-A5-1/5.

The contents of the test report are to be reviewed and evaluated by ABS in accordance with this weldability confirmation scheme.

## 9 Certification

ABS will issue a certificate where the test report is found to be satisfactory. The following information is to be included on the certificate:

- i)* Manufacturer
- ii)* Grade designation with notation of heat input (refer to 2-A5-1/11)
- iii)* Deoxidation practice
- iv)* Fine grain practice
- v)* Condition of supply
- vi)* Plate thickness tested
- vii)* Welding process
- viii)* Welding consumable (manufacturer, brand, grade).
- ix)* Actual heat input applied.

## 11 Grade Designation

Upon issuance of the certificate, the notation indicating the value of heat input applied in the confirmation test may be added to the grade designation of the test plate, e.g. “E36-W300” [in the case of heat input 300 kJ/cm (762 kJ/in.) applied]. The value of this notation is to be not less than 50 and every 10 added.

## **Nondestructive Examination of Marine Steel Castings (2014)**

### **CONTENTS**

<b>SECTION</b>	<b>1</b>	<b>General .....</b>	<b>600</b>
	1	Scope.....	600
		1.1 .....	600
		1.3 .....	600
		1.5 .....	600
		1.7 .....	600
		1.9 .....	600
<b>SECTION</b>	<b>2</b>	<b>Surface Inspection .....</b>	<b>601</b>
	1	General.....	601
		1.1 .....	601
		1.3 .....	601
		1.5 .....	601
	3	Products.....	601
		3.1 .....	601
		3.3 .....	601
	5	Location for Surface Inspections.....	601
		5.1 .....	601
		5.3 .....	602
	7	Surface Condition .....	602
	9	Surface Inspection .....	602
		9.1 .....	602
		9.3 .....	602
		9.5 .....	602
		9.7 .....	602
		9.9 .....	602
	11	Acceptance Criteria and Rectification of Defects .....	602
		11.1 Acceptance Criteria –Visual Inspection.....	602
		11.3 Acceptance Criteria –Magnetic Particle Testing and Liquid Penetrant Testing.....	603
		11.5 Rectification of Defects.....	603
	13	Record.....	604

13.1	.....	604
------	-------	-----

TABLE 1	Allowable Number and Size of Indications in a Reference Band Length/Area.....	605
---------	---	-----

<b>SECTION</b>	<b>3 Volumetric Inspection.....</b>	<b>606</b>
1	General .....	606
	1.1 .....	606
	1.3 .....	606
	1.5 .....	606
	1.7 .....	606
3	Products .....	606
	3.1 .....	606
5	Location for Volumetric Inspection .....	606
	5.1 .....	606
	5.3 .....	607
	5.5 .....	607
7	Surface Condition.....	607
	7.1 .....	607
	7.3 .....	607
9	Acceptance Criteria .....	607
11	Record .....	607

TABLE 1	Acceptance Criteria for Steel Castings.....	608
---------	---	-----

<b>ANNEX</b>	<b>1 General Location for the Type of Nondestructive Examinations of Typical Hull Steel Castings.....</b>	<b>609</b>
FIGURE 1	Stern Frame.....	609
FIGURE 2	Rudder stock.....	610
FIGURE 3	Stern Boss (2011).....	610
FIGURE 4	Rudder Hangings (2011).....	611
FIGURE 5	Rudder (Upper Part) (2011).....	612
FIGURE 6	Rudder (Lower Part) (2011).....	613

*Note:*

The requirements in this Appendix are adopted from the IACS Recommendation No. 69. "Guidelines for Non-destructive Examination of Marine Steel Castings" with some modifications in order to be consistent with existing ABS publications. It becomes effective as of 1 January 2014.

**1 Scope****1.1**

This Appendix contains general guidance for the nondestructive examination methods, the extent of examination and the minimum recommended quality levels to be complied with for marine steel castings, unless otherwise approved or specified.

**1.3**

This document contains guidelines on "Surface Inspections" (2-A6-2) by visual examination, magnetic particle testing and liquid penetrant testing and "Volumetric Inspection" (2-A6-3) by ultrasonic testing and radiographic testing.

**1.5**

Although no detailed guidelines are given for machinery components, the requirements in this Appendix may apply correspondingly considering their materials, kinds, shapes and stress conditions being subjected.

**1.7**

Castings should be examined in the final delivery condition. For specific requirements, see 2-A6-2/9.3 and 2-A6-3/7.3.

**1.9**

Where intermediate inspections have been performed the manufacturer is to furnish the documentation of the results upon request of the Surveyor.

**1 General****1.1**

Surface inspections in this Appendix are to be carried out by visual examination and magnetic particle testing or liquid penetrant testing.

**1.3**

The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing are to comply with a recognized national or international standard.

**1.5**

Personnel engaged in visual examination are to have sufficient knowledge and experience. Personnel engaged in magnetic particle testing or liquid penetrant testing are to be qualified in accordance with the *ABS Guide for Nondestructive Inspection*. The qualification is to be verified by the certificates.

**3 Products****3.1**

Steel castings are to be subjected to a 100% visual examination of all accessible surfaces by the Surveyor.

**3.3**

Surface inspections by magnetic particle and/or liquid penetrant methods apply to the hull steel castings indicated in 2-A6-A1 of this Appendix.

**5 Location for Surface Inspections****5.1**

Surface inspections are to be carried out in the following locations:

- At all accessible fillets and changes of section
- At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging
- In way of fabrication weld preparation, for a band width of 30 mm (1.2 in.)



- In way of weld repairs

### 5.3

The following quality levels are considered for magnetic particle testing (MT) and/or liquid penetrant testing (PT):

- Level MT1/PT1 –fabrication weld preparation and weld repairs.
- Level MT2/PT2 –other locations shown in 2-A6-2/5.1.

The required quality level is to be shown on the manufacturer’s drawings.

## 7 Surface Condition

The surfaces of castings to be examined are to be free from scale, dirt, grease or paint and are to be shot blasted or ground.

## 9 Surface Inspection

### 9.1

Magnetic particle inspection is to be carried out with the following exceptions, when liquid penetrant testing is to be permitted:

- Austenitic stainless steels
- Interpretation of open visual or magnetic particle indications
- At the instruction of the Surveyor

### 9.3

Unless otherwise specified in the order, the magnetic particle test is to be performed on a casting in the final delivery condition and final thermally treated condition or within 0.3 mm (0.012 in.) of the final machined surface condition for AC techniques [0.8 mm (0.03 in.) for DC techniques].

### 9.5

Unless otherwise agreed, the surface inspection is to be carried out in the presence of the Surveyor.

### 9.7

For magnetic particle testing, attention is to be paid to the contact between the casting and the clamping devices of stationary magnetization benches in order to avoid local overheating or burning damage in its surface. Prods are not permitted on finished machined items.

### 9.9

When indications are detected as a result of the surface inspection, the acceptance or rejection is to be decided in accordance with 2-A6-2/11.

## 11 Acceptance Criteria and Rectification of Defects

### 11.1 Acceptance Criteria –Visual Inspection

All castings are to be free of cracks, crack-like indications, hot tears, laps, seams, folds or other injurious indications. Thickness of the remains of sprues, heads or burrs is to be within the casting dimensional tolerance. Additional magnetic particle, liquid penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor.

## 11.3 Acceptance Criteria –Magnetic Particle Testing and Liquid Penetrant Testing

### 11.3.1

The following definitions relevant to indications apply:

- *Linear indication.* An indication in which the length is at least three times the width.
- *Nonlinear indication.* An indication of circular or elliptical shape with a length less than three times the width.
- *Aligned indication.* Three or more indications in a line, separated by 2 mm (0.08 in.) or less edge-to-edge.
- *Open indication.* An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
- *Non-open indication.* An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
- *Relevant indication.* An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5 mm (0.06 in.) are to be considered relevant.

### 11.3.2

For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm (6 in.) for level MT1/PT1 and into reference areas of 225 cm<sup>2</sup> (35 in<sup>2</sup>) for level MT2/PT2. The band length and/or area is to be taken in the most unfavorable location relative to the indication being evaluated.

### 11.3.3

The allowable number and size of indications in the reference band length and/or area is given in 2-A6-2/13.1 TABLE 1. Cracks and hot tears are not acceptable.

## 11.5 Rectification of Defects

Defects and unacceptable indications are to be repaired as indicated below and detailed in 2-A6-2/11.5.2.

### 11.5.1

Defective parts of material may be removed by grinding, or by chipping and grinding, or by arc air-gouging and grinding. All grooves are to have a bottom radius of approximately three times the groove depth and be smoothly blended to the surface area with a finish equal to the adjacent surface.

### 11.5.2

Repairs by welding are defined as follows:

*Major repairs:*

- Where the depth is greater than 25% of the wall thickness or 25 mm (1 in.) whichever is the less, or
- Where the weld area (length x width) exceeds 1250 cm<sup>2</sup> (194 in<sup>2</sup>) (*Note:*where a distance between two welds is less than their average width, they are considered as one weld), or
- Where the total weld area on a casting exceeds 2% of the casting surface.

*Minor repairs:*

- Where the total weld area (length x width) exceeds 5 cm<sup>2</sup> (0.8 in<sup>2</sup>).

*Cosmetic repairs:*

- All other welds.

*11.5.2(a)* Major repairs are to be approved before the repair is carried out. The repair should be carried out before final furnace heat treatment.

*11.5.2(b)* Minor repairs do not require approval before the repair is carried out but should be recorded on a weld repair sketch as a part of the manufacturing procedure documents. These repairs should be carried out before final furnace heat treatment.

*11.5.2(c)* Cosmetic repairs do not require approval before the repair is carried out but should be recorded on a weld repair sketch. These repairs may be carried out after final furnace heat treatment but are subject to a local stress relief heat treatment. Thermal methods of metal removal should only be allowed before the final heat treatment. After final heat treatment only grinding or chipping and grinding should be allowed. Weld repairs should be suitably classified.

Parts which are repaired should be examined by the same method as at initial inspection as well as by additional methods as required by the Surveyor.

## 13 Record

### 13.1

Test results of surface inspections are to be recorded at least with the following items:

- i)* Date of testing
- ii)* Names and qualification level of inspection personnel
- iii)* Kind of testing method
  - For liquid penetrant testing: test media combination
  - For magnetic particle testing: method of magnetizing, test media and magnetic field strength
- iv)* Kind of product
- v)* Product number for identification
- vi)* Grade of steel
- vii)* Heat treatment
- viii)* Stage of testing
- ix)* Locations for testing
- x)* Surface condition
- xi)* Test standards used
- xii)* Testing condition
- xiii)* Results
- xiv)* Statement of acceptance/non acceptance
- xv)* Details of weld repair including sketch

**TABLE 1**  
**Allowable Number and Size of Indications in a Reference Band Length/Area**

<i>Quality Level</i>	<i>Max. Number of Indications</i>	<i>Type of Indication</i>	<i>Max. Number for Each Type</i>	<i>Max. Dimension mm (in.)<sup>(2)</sup></i>
MT1/PT1	4 in a 15 cm (6 in.) length	Linear	4 <sup>(1)</sup>	3 (0.12)
		Nonlinear	4 <sup>(1)</sup>	5 (0.2)
		Aligned	4 <sup>(1)</sup>	3 (0.12)
MT2/PT2	20 in a 225 cm <sup>2</sup> (35 in <sup>2</sup> ) area	Linear	6	5 (0.2)
		Nonlinear	10	7 (0.28)
		Aligned	6	5 (0.2)

*Notes:*

- 1 30 mm (1.2 in.) min. between relevant indications.
- 2 In weld repairs, max. dimension < 2 mm (0.08 in.).

**1 General****1.1**

Volumetric inspection in this Appendix is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique.

**1.3**

The testing procedures, apparatus and conditions of ultrasonic testing are to comply with the recognized national or international standards. Generally, the DGS (distance-gain size) procedure is to be applied using straight beam probes and/or angle beam probes with 1 to 4 MHz and an inspection should be carried out using a twin crystal 0° probe for near surface scans [25 mm (1 in.)] plus a 0° probe for the remaining volume. Fillet radii should be examined using 45°, 60° or 70° probes.

**1.5**

Radiographic testing is to be carried out in accordance with an approved plan.

**1.7**

Personnel engaged in ultrasonic or radiographic testing is to be qualified in accordance with the ABS *Guide for Nondestructive Inspection*. The qualification is to be verified by certificates.

**3 Products****3.1**

Volumetric inspection by ultrasonic or radiographic testing applies to the hull steel castings indicated in 2-A6-A1 of this Appendix.

**5 Location for Volumetric Inspection****5.1**

Volumetric inspection is to be carried out according to the inspection plan. The inspection plan should specify the extent of the examination, the examination procedure, the quality level or, if necessary, levels for different locations of the castings. The inspection plan is to be approved.

### 5.3

Ultrasonic testing is to be carried out in the following locations:

- In way of all accessible fillets and changes of section
- In way of fabrication weld preparation for a distance of 50 mm (2 in.) from the edge
- At all locations to be subject to subsequent machining (including bolt holes)
- In way of weld repairs where original defect was detected by ultrasonic testing

### 5.5

The following quality levels are considered for ultrasonic testing (UT):

*Level UT1:*

- Fabrication weld preparation for a distance of 50 mm (2 in.)
- 50 mm (2 in.) depth from the final machined surface including bolt holes
- Fillet radii for a depth of 50 mm (2 in.) and within distance of 50 mm (2 in.) from the radius end

*Level UT2:*

- Other locations.

The required quality levels are to be shown on the manufacturer's drawings.

## 7 Surface Condition

### 7.1

The surfaces of castings to be examined are to be such that adequate coupling can be established between the probe and the casting and that excessive wear of the probe can be avoided. The surfaces are to be free from scale, dirt, grease or paint.

### 7.3

The ultrasonic testing is to be carried out after the steel castings have been machined to a condition suitable for this type of testing and after the final heat treatment. Black castings are to be inspected after removal of the oxide scale by either flame descaling or shot blasting methods.

## 9 Acceptance Criteria

Acceptance criteria of volumetric inspection by ultrasonic testing are shown in 2-A6-3/11 TABLE 1.

## 11 Record

Test results of volumetric inspection are to be recorded at least with the following items:

- i) Date of testing
- ii) Names and qualification level of inspection personnel
- iii) Kind of testing method
- iv) Kind of product
- v) Product number for identification
- vi) Grade of steel
- vii) Heat treatment

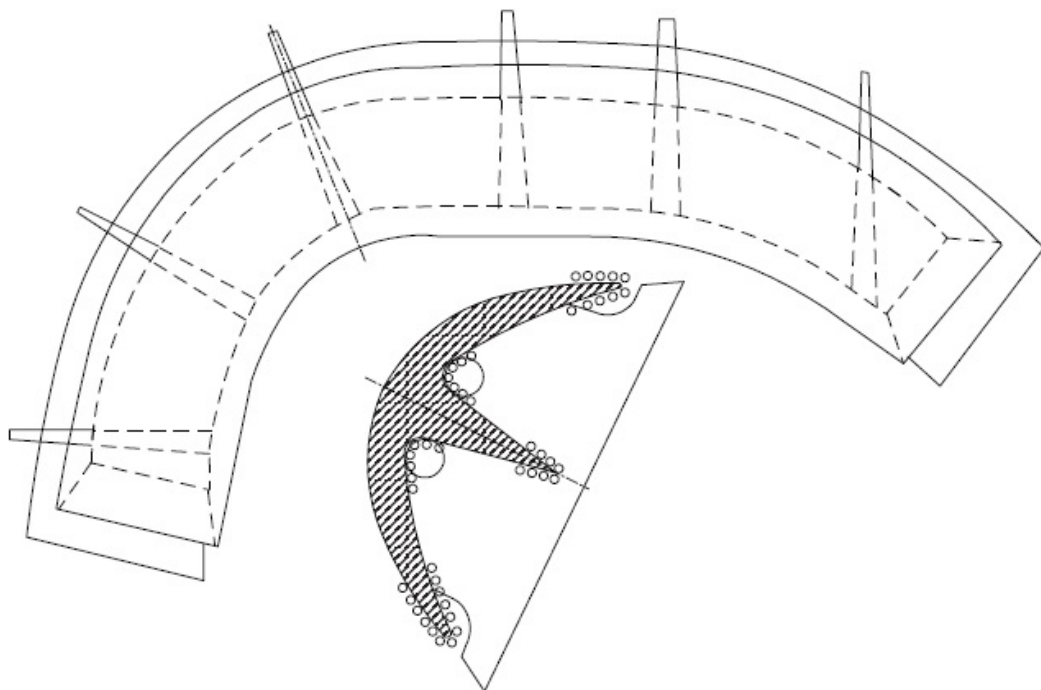
- viii) Stage of testing
- ix) Locations for testing
- x) Surface condition
- xi) Test standards used
- xii) Testing condition
- xiii) Results
- xiv) Statement of acceptance/non acceptance

**TABLE 1**  
**Acceptance Criteria for Steel Castings**

<i>Quality Level <sup>(1)</sup></i>	<i>Allowable Disk Shape According to DGS <sup>(2)</sup></i>	<i>Max. Number of Indications to be Registered</i>	<i>Allowable Length of Linear Indications mm (in.)</i>
UT1	6	3	10 (0.4)
UT2	12	5	50 (2.0)

*Notes:*

- 1 For the castings subject to cyclic bending stresses, e.g., rudder horn, rudder castings and rudder stocks, the outer one third of thickness is to comply with the acceptance criteria for level UT 1.
- 2 DGS: distance – gain size.

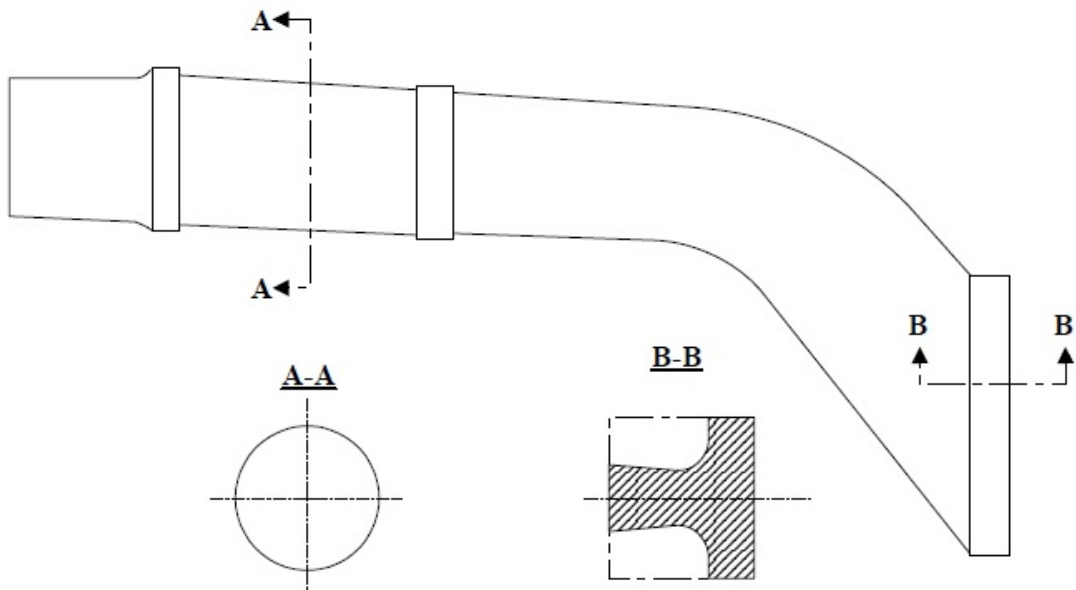
**General Location for the Type of Nondestructive Examinations of Typical Hull Steel Castings****FIGURE 1  
Stern Frame***Notes:*

Location of nondestructive examination:

- |   |   |  |
|---|---|--|
| 1 | All surfaces:   | Visual examination                               |
| 2 | Location indicated with (OOO):  | Magnetic particle testing and ultrasonic testing |
| 3 | The detailed extents of examinations and quality levels are given in 2-A6-2 and 2-A6-3. |  |



**FIGURE 2**  
**Rudder stock**

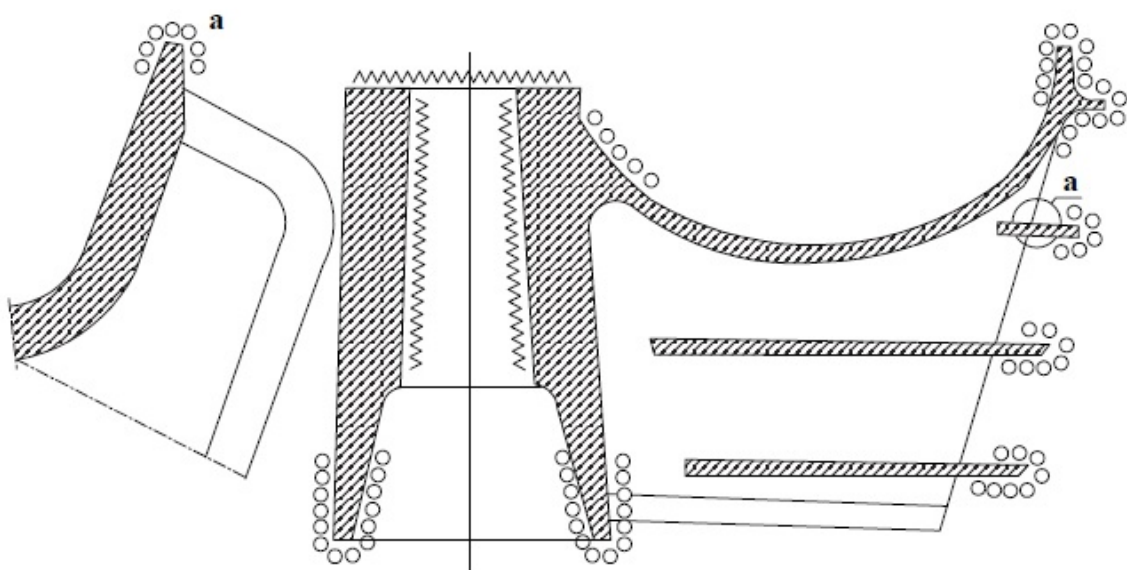


*Notes:*

Location of nondestructive examination:

- 1 All surfaces: Visual examination.  
 Magnetic particle testing and Ultrasonic testing.
- 2 The detailed extents of examinations and quality levels are given in 2-A6-2 and 2-A6-3.

**FIGURE 3**  
**Stern Boss (2011)**

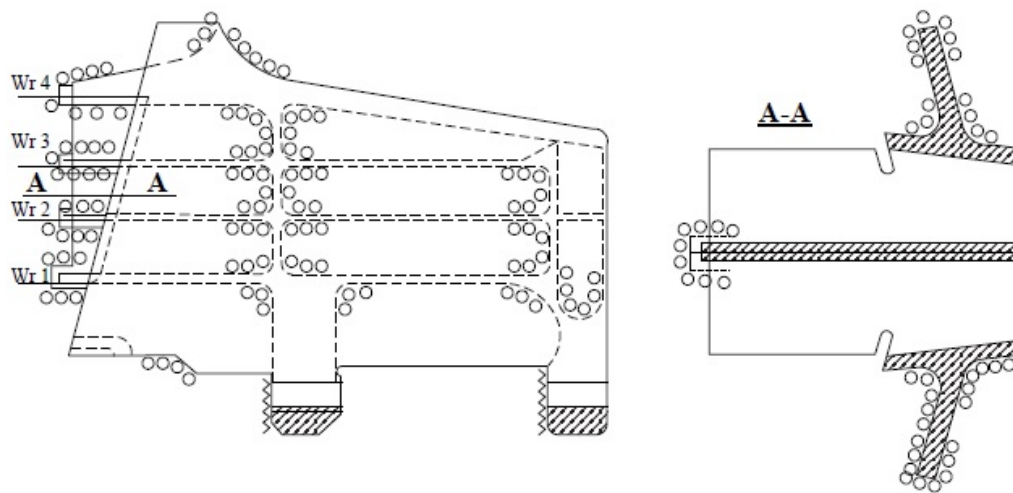


Notes:

Location of nondestructive examination:

- 1 All surfaces: Visual examination
- 2 Location indicated with (OOO): Magnetic particle testing and Ultrasonic testing
- 3 Location indicated with (^^^): Ultrasonic testing
- 4 The detailed extents of examinations and quality levels are given in 2-A6-2 and 2-A6-3.
- 5 (2011) Radiography testing is permitted in lieu of Ultrasonic testing.

**FIGURE 4  
 Rudder Hangings (2011)**

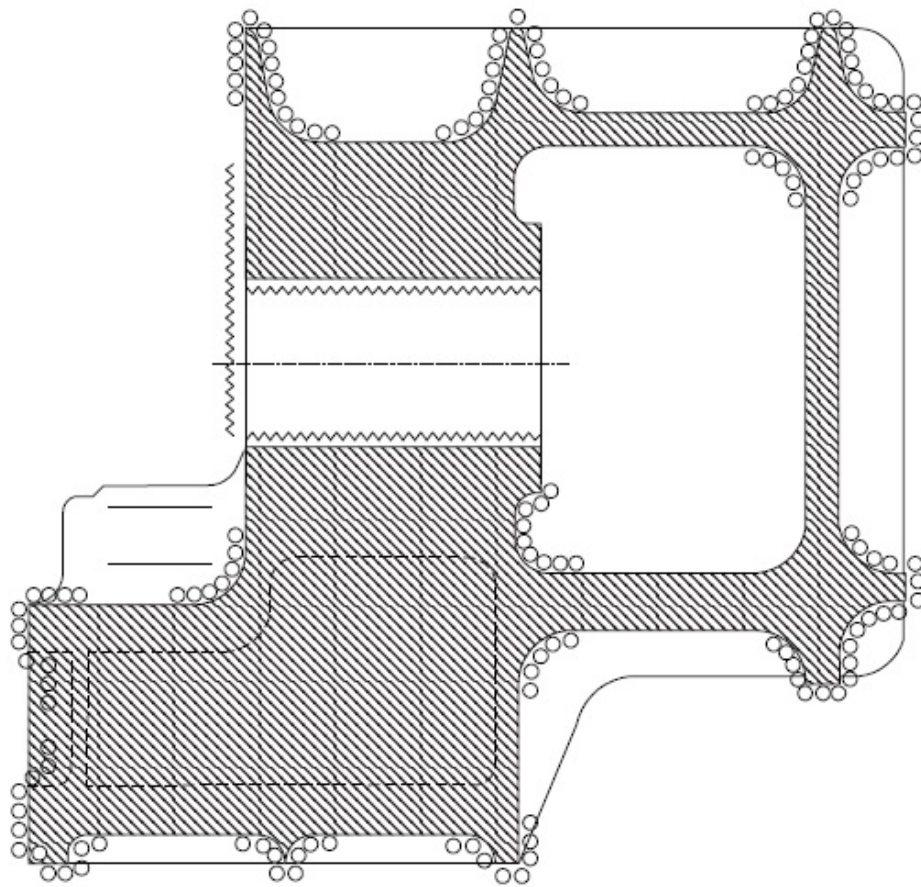


Notes:

Location of nondestructive examination:

- 1 All surfaces: Visual examination
- 2 Location indicated with (OOO): Magnetic particle testing and Ultrasonic testing
- 3 Location indicated with (^^^): Ultrasonic testing
- 4 The detailed extents of examinations and quality levels are given in 2-A6-2 and 2-A6-3.
- 5 (2011) Radiography testing is permitted in lieu of Ultrasonic testing.

**FIGURE 5**  
**Rudder (Upper Part) (2011)**

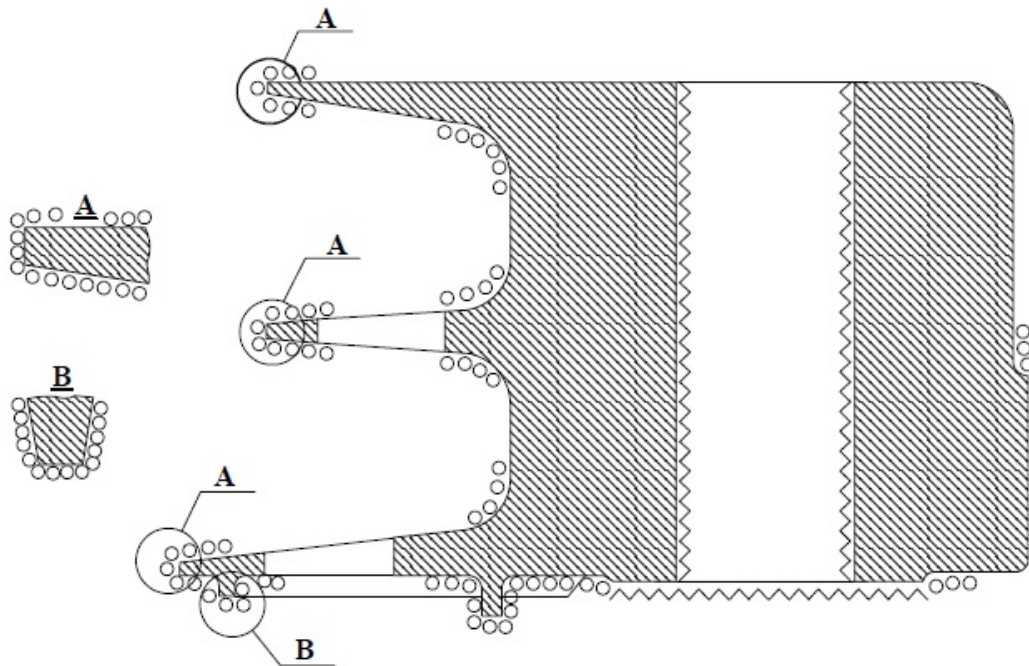


*Notes:*

Location of nondestructive examination:

- |   |   |  |
|---|---|--|
| 1 | All surfaces:   | Visual examination                               |
| 2 | Location indicated with (OOO):  | Magnetic particle testing and Ultrasonic testing |
| 3 | Location indicated with (^^^):  | Ultrasonic testing                               |
| 4 | The detailed extents of examinations and quality levels are given in 2-A6-2 and 2-A6-3. |  |
| 5 | (2011) Radiography testing is permitted in lieu of Ultrasonic testing.                  |  |

**FIGURE 6**  
**Rudder (Lower Part) (2011)**



*Notes:*

Location of nondestructive examination:

- |   |   |  |
|---|---|--|
| 1 | All surfaces:   | Visual examination                               |
| 2 | Location indicated with (OOO):  | Magnetic particle testing and Ultrasonic testing |
| 3 | Location indicated with (^^^):  | Ultrasonic testing                               |
| 4 | The detailed extents of examinations and quality levels are given in 2-A6-2 and 2-A6-3. |  |
| 5 | (2011) Radiography testing is permitted in lieu of Ultrasonic testing.                  |  |

## Nondestructive Examination of Hull and Machinery Steel Forgings (2014)

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General .....</b>	<b>616</b>
	1	Scope.....	616
		1.1 .....	616
		1.3 .....	616
		1.5 .....	616
		1.7 .....	616
		1.9 .....	616
		1.11 .....	616
<b>SECTION</b>	<b>2</b>	<b>Surface Inspection .....</b>	<b>617</b>
	1	General.....	617
		1.1 .....	617
		1.3 .....	617
		1.5 .....	617
	3	Products.....	617
		3.1 .....	617
		3.3 .....	617
	5	Zones for Surface Inspections.....	618
	7	Surface Condition.....	618
	9	Surface Inspection.....	618
		9.1 .....	618
		9.3 .....	618
		9.5 .....	618
		9.7 .....	618
		9.9 .....	618
	11	Acceptance Criteria and Rectification of Defects.....	618
		11.1 Acceptance Criteria Visual Inspection.....	618
		11.3 Acceptance Criteria Magnetic Particle Testing and Liquid Penetrant Testing.....	619
		11.5 Rectification of Defects.....	620
	13	Record.....	621
		13.1 .....	621

TABLE 1	Crankshaft Forgings - Allowable Number and Size of Indications in a Reference Area of 225 cm <sup>2</sup> (35 in <sup>2</sup> ) (2010).....	619
TABLE 2	Steel Forgings Excluding Crankshaft Forgings - Allowable Number and Size of Indications in a Reference Area of 225 cm <sup>2</sup> (35 in <sup>2</sup> ) (2010).....	620
FIGURE 1	Zones for Magnetic Particle/Liquid Penetrant Testing on Crankshafts.....	622
FIGURE 2	Zones for Magnetic Particle/Liquid Penetrant Testing on Shafts.....	624
FIGURE 3	Zones for Magnetic Particle/Liquid Penetrant Testing on Machinery Components.....	625
FIGURE 4	Zones for Magnetic Particle/Liquid Penetrant Testing on Rudder Stocks.....	627
<b>SECTION 3</b>	<b>Volumetric Inspection.....</b>	<b>628</b>
1	General.....	628
1.1	.....	628
1.3	.....	628
1.5	.....	628
3	Products.....	628
3.1	(2012).....	628
5	Zones for Volumetric Inspection.....	629
7	Surface Condition.....	629
7.1	.....	629
7.3	.....	629
9	Acceptance Criteria.....	629
11	Record.....	629
TABLE 1	Acceptance Criteria for Crankshafts.....	630
TABLE 2	Acceptance Criteria for Shafts and Machinery Components (2012).....	630
FIGURE 1	Zones for Ultrasonic Testing on Crankshafts.....	631
FIGURE 2	Zones for Ultrasonic Testing on Shafts.....	632
FIGURE 3	Zones for Ultrasonic Testing on Machinery Components.....	634
FIGURE 4	Zones for Ultrasonic Testing on Rudder Stocks.....	635

**Nondestructive Examination of Hull and Machinery Steel Forgings (2014)**

## SECTION 1

**General***Note:*

Requirements in the Appendix are based on IACS Recommendation No. 68. "Guidelines for Non-destructive Examination of Hull and Machinery Steel Forgings" with modifications in order to be consistent with existing ABS publications.

**1 Scope****1.1**

This Appendix complements the ABS requirements for "Hull and machinery steel forgings" and "Parts of internal combustion engines for which non-destructive tests are required", and contains general guidance for the nondestructive examination methods, the extent of examination and the minimum recommended quality levels to be complied with unless otherwise approved or specified.

**1.3**

This document contains guidelines on "Surface Inspections" (2-A7-2) by visual examination, magnetic particle testing and liquid penetrant testing and "Volumetric Inspection" (2-A7-3) by ultrasonic testing.

**1.5**

For steel forgings (e.g., components for couplings, gears, boilers and pressure vessels) other than those specified in this Appendix, the requirements in this Appendix may apply correspondingly considering their materials, kinds, shapes and stress conditions being subjected.

**1.7**

Forgings should be examined in the final delivery condition. For specific requirements, see 2-A7-2/9.3 and 2-A7-3/7.3.

**1.9**

Where intermediate inspections have been performed, the manufacturer is to furnish a documentation of the results upon the request of the Surveyor.

**1.11**

Where a forging is supplied in semi-finished condition, the manufacturer is to take into consideration the quality level of final finished machined components.

**Nondestructive Examination of Hull and Machinery Steel Forgings (2014)****SECTION 2  
Surface Inspection****1 General****1.1**

Surface inspections in this Appendix are to be carried out by visual examination and magnetic particle testing or liquid penetrant testing.

**1.3**

The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing are to comply with a recognized national or international standard.

**1.5**

Personnel engaged in visual examination are to have sufficient knowledge and experience. Personnel engaged in magnetic particle testing or liquid penetrant testing are to be qualified in accordance with the *ABS Guide for Nondestructive Inspection*. The qualification is to be verified by certificates.

**3 Products****3.1**

The steel forgings intended for hull and machinery applications such as rudder stocks, pintles, propeller shafts, crankshafts, connecting rods, piston rods, gearing, etc. are to be subjected to a 100% visual examination by the Surveyor. For mass produced forgings the extent of examination is to be established at the discretion of the attending Surveyor.

**3.3**

Surface inspections by magnetic particle and/or liquid penetrant methods generally apply to the following steel forgings:

- i)* Crankshafts with minimum crankpin diameter not less than 100 mm (4 in.)
- ii)* Propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 100 mm (4 in.)
- iii)* Connecting rods, piston rods and crosshead with minimum diameter not less than 75 mm (3 in.) or equivalent cross section



- iv) Bolts with minimum diameter not less than 50 mm (2 in.), which are subjected to dynamic stresses such as cylinder cover bolts, tie rods, crankpin bolts, main bearing bolts, propeller blade fastening bolts

## 5 Zones for Surface Inspections

Magnetic particle, or where permitted, liquid penetrant testing, is to be carried out in the zones I and II as indicated in 2-A7-2/Figures 1 to 4.

## 7 Surface Condition

The surfaces of forgings to be examined are to be free from scale, dirt, grease or paint.

## 9 Surface Inspection

### 9.1

Where indicated by Section 2, Figures 1 to 4, magnetic particle inspections are to be carried out with the following exceptions, when liquid penetrant testing is permitted:

- Austenitic stainless steels
- Interpretation of open visual or magnetic particle indications
- At the instruction of the Surveyor

### 9.3

Unless otherwise specified in the order, the magnetic particle test is to be performed on a forging in the final machined surface condition and final thermally treated condition or within 0.3 mm (0.012 in.) of the final machined surface condition for AC techniques [0.8 mm (0.0315 in.) for DC techniques].

### 9.5

Unless otherwise agreed, the surface inspection is to be carried out in the presence of the Surveyor. The surface inspection is to be carried out before the shrink fitting, where applicable.

### 9.7

For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetization benches in order to avoid local overheating or burning damage in its surface. Prods are not permitted on finished machined items.

### 9.9

When indications are detected as a result of the surface inspection, the acceptance or rejection is to be decided in accordance with 2-A7-2/11.

## 11 Acceptance Criteria and Rectification of Defects

### 11.1 Acceptance Criteria Visual Inspection

All forgings are to be free of cracks, crack-like indications, laps, seams, folds or other injurious indications. At the request of the Surveyor, additional magnetic particle, liquid penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

The bores of hollow propeller shafts are to be visually examined for imperfections uncovered by the machining operation. Machining marks are to be ground to a smooth profile.

### 11.3 Acceptance Criteria Magnetic Particle Testing and Liquid Penetrant Testing

#### 11.3.1

The following definitions relevant to indications apply:

- *Linear indication.* An indication in which the length is at least three times the width.
- *Nonlinear indication.* An indication of circular or elliptical shape with a length less than three times the width.
- *Aligned indication.* Three or more indications in a line, separated by 2 mm (0.08 in.) or less edge-to-edge.
- *Open indication.* An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
- *Non-open indication.* An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
- *Relevant indication.* An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5 mm (0.06 in.) are to be considered relevant.

#### 11.3.2

For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm<sup>2</sup> (35 in<sup>2</sup>). The area is to be taken in the most unfavorable location relative to the indication being evaluated.

#### 11.3.3

The allowable number and size of indications in the reference area is given in 2-A7-2/11.3.3 TABLE 1 for crankshaft forgings and in 2-A7-2/11.3.3 TABLE 2 for other forgings, respectively. Cracks are not acceptable. Irrespective of the results of nondestructive examination, the Surveyor may reject the forging if the total number of indications is excessive.

**TABLE 1**  
**Crankshaft Forgings - Allowable Number and Size of Indications in a Reference Area of 225 cm<sup>2</sup>(35 in<sup>2</sup>) (2010)**

<i>Inspection Zone</i>	<i>Max. Number of Indications</i>	<i>Type of Indication</i>	<i>Max. Number for Each Type</i>	<i>Max. Dimension mm (in.)</i>
I (Critical Fillet Area)	0	Linear	0	---
		Nonlinear	0	---
		Aligned	0	---
II (Important Fillet Area)	3	Linear	0	---
		Nonlinear	3	3.2 (0.125)
		Aligned	0	---
III (Journal Surfaces)	3	Linear	0	---
		Nonlinear	3	5.0 (0.2)
		Aligned	0	---

**TABLE 2**  
**Steel Forgings Excluding Crankshaft Forgings - Allowable Number and Size of Indications in a Reference Area of 225 cm<sup>2</sup>(35 in<sup>2</sup>) (2010)**

<i>Inspection Zone</i>	<i>Max. Number of Indications</i>	<i>Type of Indication</i>	<i>Max. Number for Each Type</i>	<i>Max. Dimension mm (in.)</i>
I	3	Linear	0 <sup>(1)</sup>	---
		Nonlinear	3	3.2 (0.125)
		Aligned	0 <sup>(1)</sup>	---
II	10	Linear	3 <sup>(1)</sup>	3.2 (0.125)
		Nonlinear	7	5.0 (0.2)
		Aligned	3 <sup>(1)</sup>	3.2 (0.125)

*Note:*

- 1 Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g. main bearing bolts, connecting rod bolts, crosshead bearing bolts, cylinder cover bolts.

## 11.5 Rectification of Defects

### 11.5.1

Defects and unacceptable indications are to be rectified as indicated below and detailed in 2-A7-2/11.5.2 through 2-A7-2/11.5.6.

*11.5.1(a)* Defective parts of material may be removed by grinding, or by chipping and grinding. All grooves are to have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to the adjacent surface.

*11.5.1(b)* To depress is to flatten or relieve the edges of a non-open indication with a fine pointed abrasive stone with the restriction that the depth beneath the original surface is to be 0.08 mm (0.003 in.) minimum to 0.25 mm (0.01 in.) maximum and that the depressions be blended into the bearing surface. A depressed area is not considered a groove and is made only to prevent galling of bearings.

*11.5.1(c)* Non-open indications evaluated as segregation need not be rectified.

*11.5.1(d)* Complete removal of the defect is to be proved by magnetic particle testing or penetrant testing, as appropriate.

*11.5.1(e)* Repair welding is not permitted for crankshafts. Repair welding of other forgings is subjected to prior approval on a case-by-case basis.

### 11.5.2 Zone I in Crankshaft Forgings

Neither indications nor repair are permitted in this zone.

### 11.5.3 Zone II in Crankshaft Forgings

Indications are to be removed by grinding to a depth no greater than 1.5 mm (0.06 in.). Indications detected in the journal bearing surfaces are to be removed by grinding to a depth no greater than 3.0 mm (0.12 in.). The total ground area is to be less than 1% of the total bearing surface area concerned. Non-open indications, except those evaluated as segregation, are to be depressed but need not be removed.

#### 11.5.4 Zone I in Other Forgings

Indications are to be removed by grinding to a depth no greater than 1.5 mm (0.06 in.). However, grinding is not permitted in way of finished machined threads.

#### 11.5.5 Zone II in Other Forgings

Indications are to be removed by grinding to a depth no greater than 2% of the diameter or 4.0 mm (0.16 in.), whichever is smaller.

#### 11.5.6 Zones Other than I and II in All Forgings

Defects detected by visual inspection are to be removed by grinding to a depth no greater than 5% of the diameter or 10 mm (0.4 in.), whichever is smaller. The total ground area is to be less than 2% of the forging surface area.

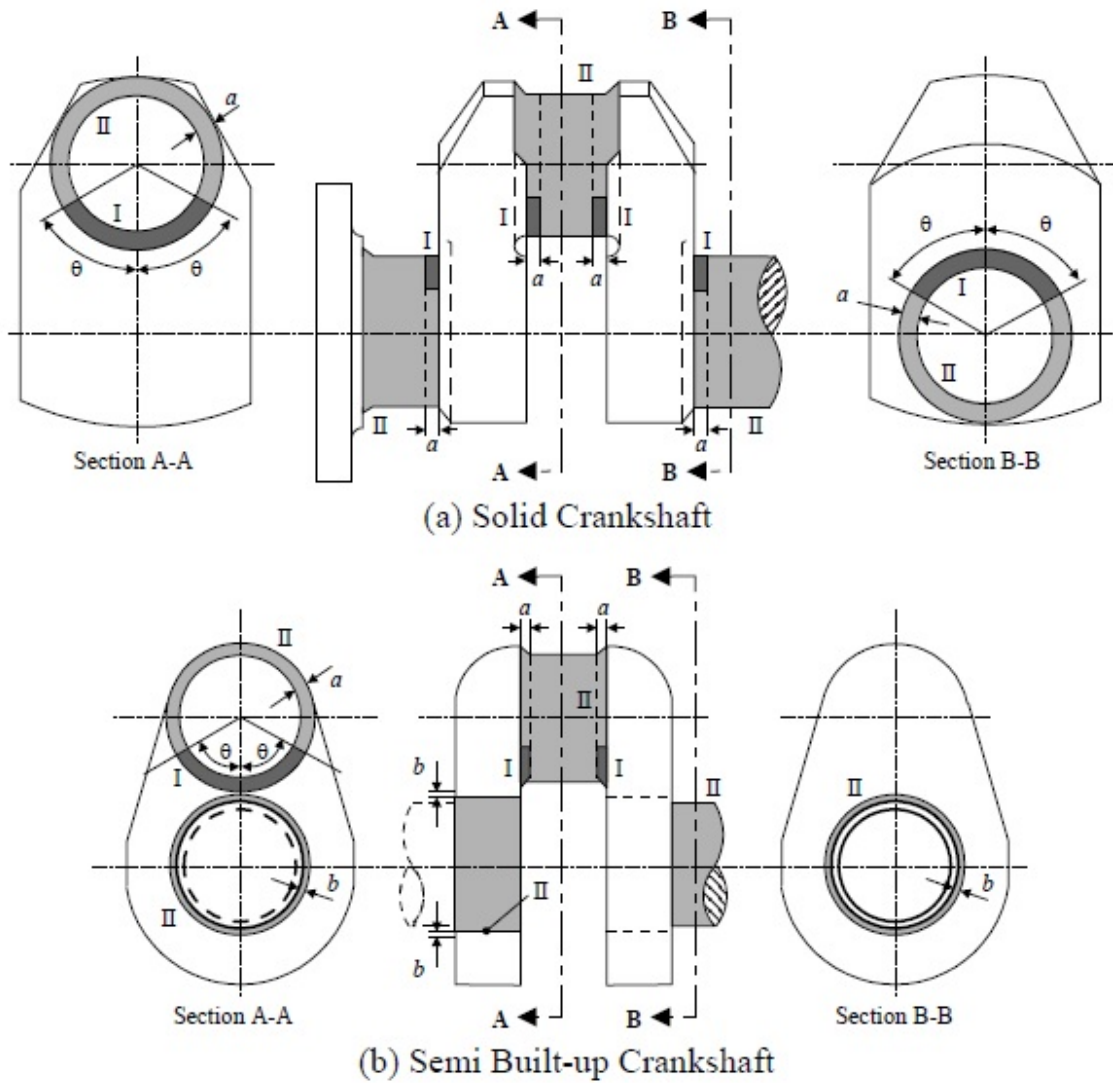
## 13 Record

### 13.1

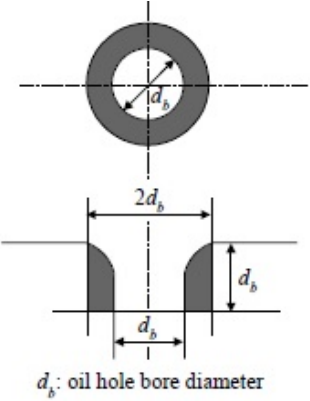
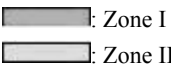


Test results of surface inspections are to be recorded at least with the following items:

- i)* Date of testing
- ii)* Names and qualification level of inspection personnel
- iii)* Kind of testing method
  - For liquid penetrant testing: test media combination
  - For magnetic particle testing: method of magnetizing, test media and magnetic field strength
- iv)* Kind of product
- v)* Product number for identification
- vi)* Grade of steel
- vii)* Heat treatment
- viii)* Stage of testing
- ix)* Position (zone) of testing
- x)* Surface condition
- xi)* Test standards used
- xii)* Testing condition
- xiii)* Results
- xiv)* Statement of acceptance/non acceptance
- xv)* Details of weld repair including sketch

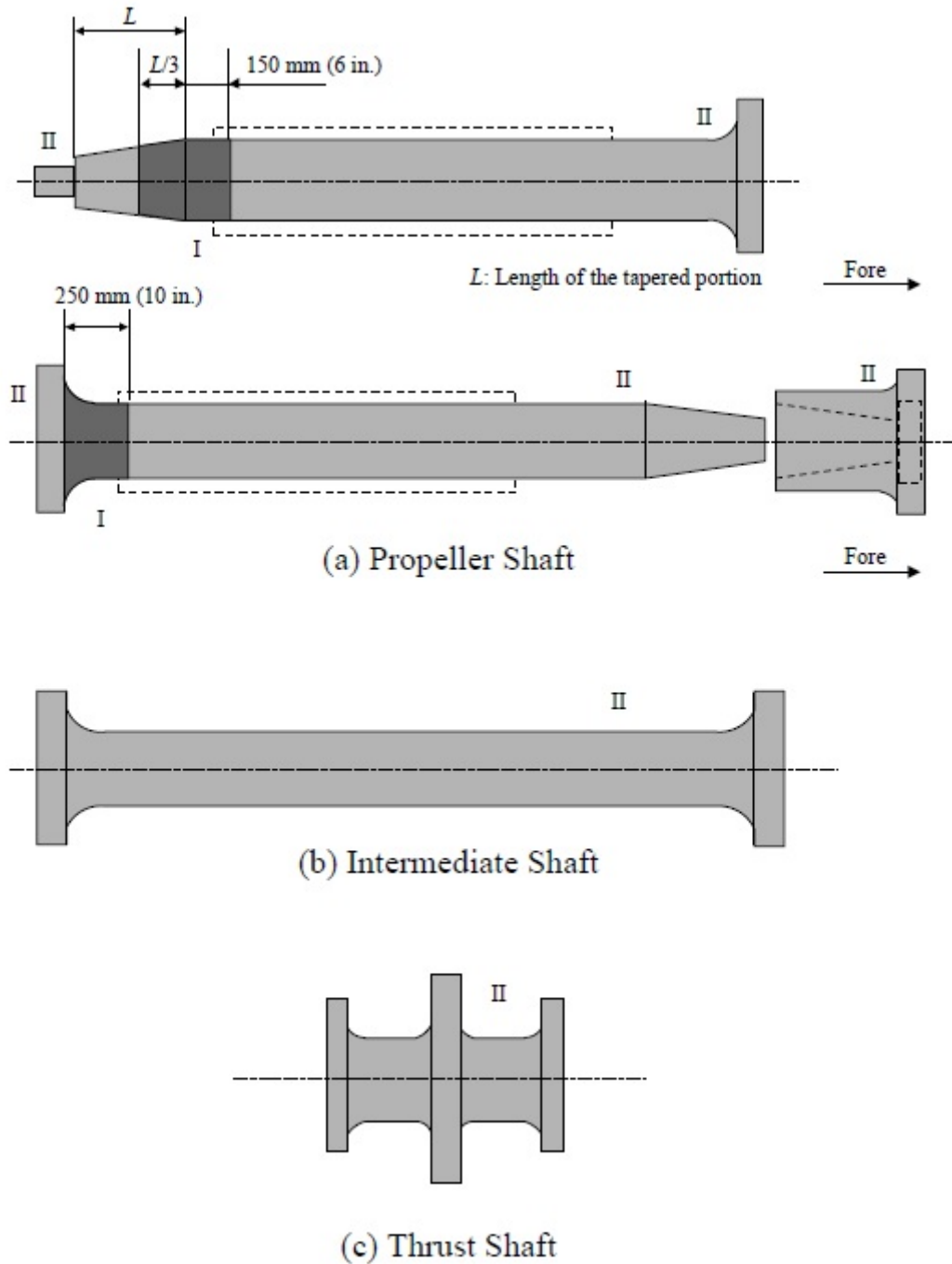
**FIGURE 1**  
**Zones for Magnetic Particle/Liquid Penetrant Testing**  
**on Crankshafts**



Notes

1	Where the crankpin or journal has oil holes, the circumferential surfaces of the oil holes are to be treated as Zone I. (See the figure in the right.)	 <p><math>d_b</math>: oil hole bore diameter</p>
2	In the above figures, “ $\theta$ ”, “ $a$ ” and “ $b$ ” mean: $\theta = 60^\circ$ $a = 1.5 r$ $b = 0.05 d$ (: circumferential surfaces of shrinkage fit) where $r$ = fillet radius $d$ = journal diameter	
3	Identification of the Zones (Similar in 2-A7-2/Figures 1 through 4):  <p>: Zone I  : Zone II</p>	

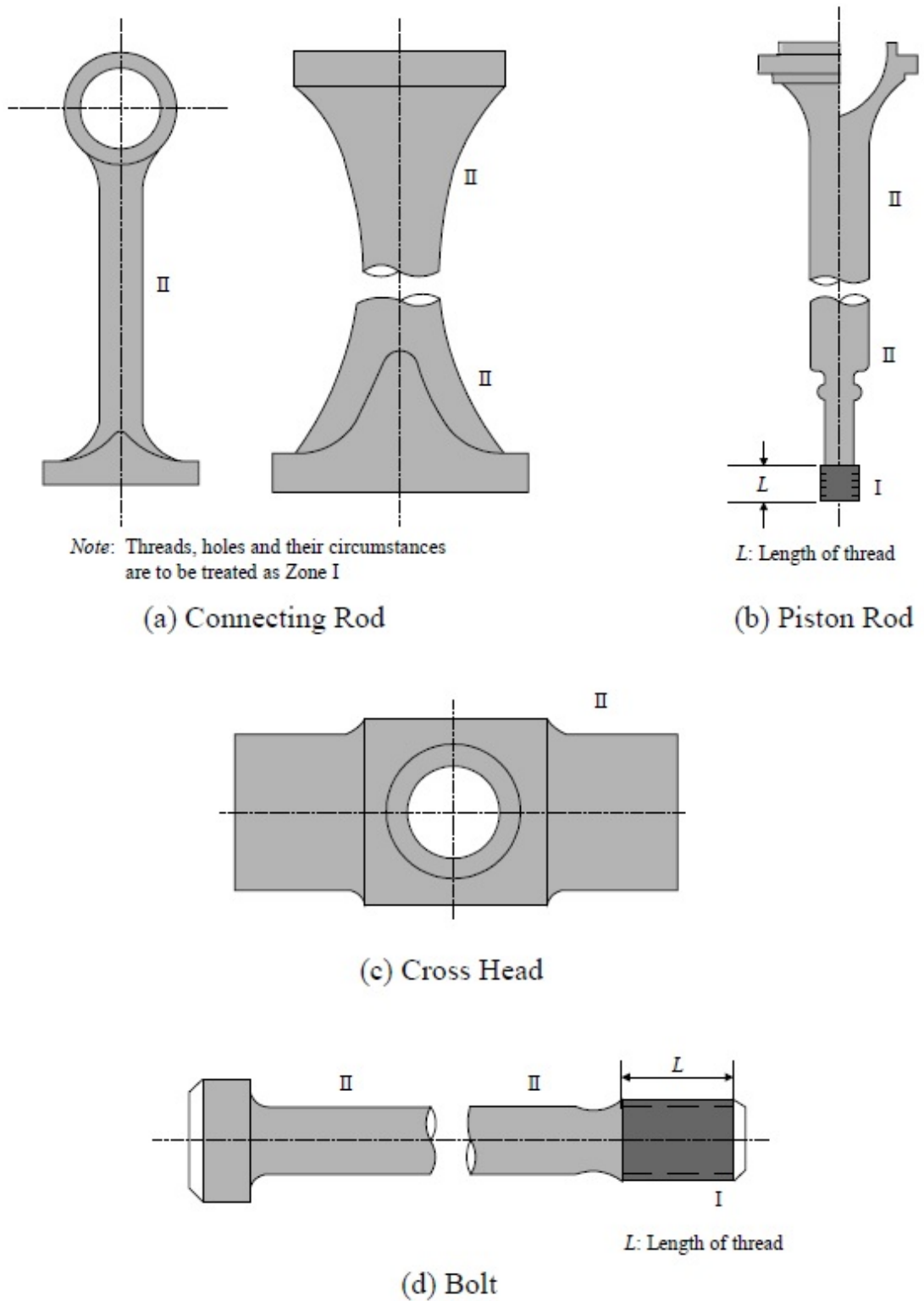
**FIGURE 2**  
**Zones for Magnetic Particle/Liquid Penetrant Testing on Shafts**



**Note:**

For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

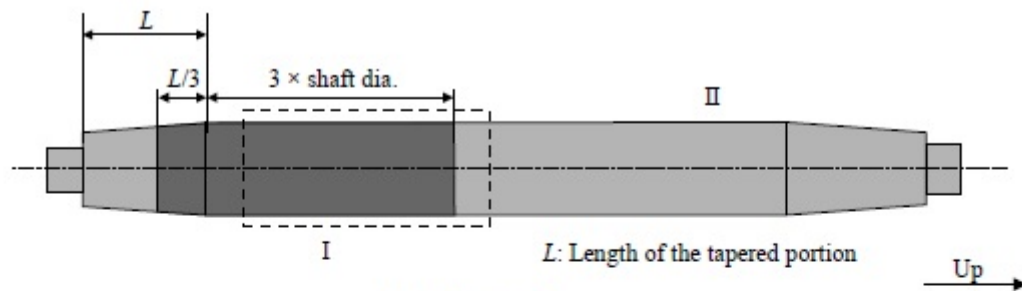
**FIGURE 3**  
**Zones for Magnetic Particle/Liquid Penetrant Testing on Machinery Components**



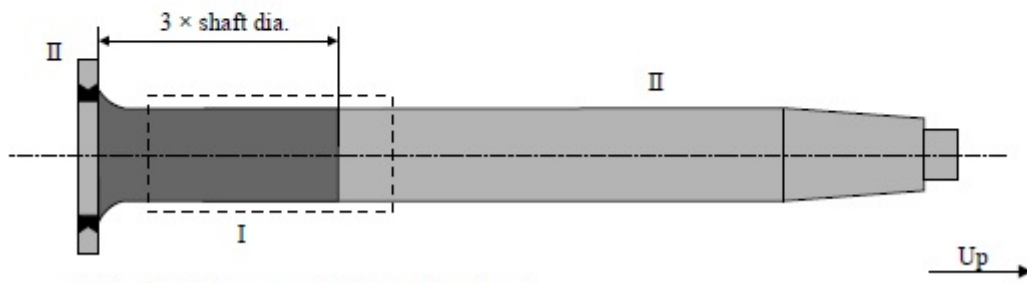




**FIGURE 4**  
**Zones for Magnetic Particle/Liquid Penetrant Testing on Rudder Stocks**

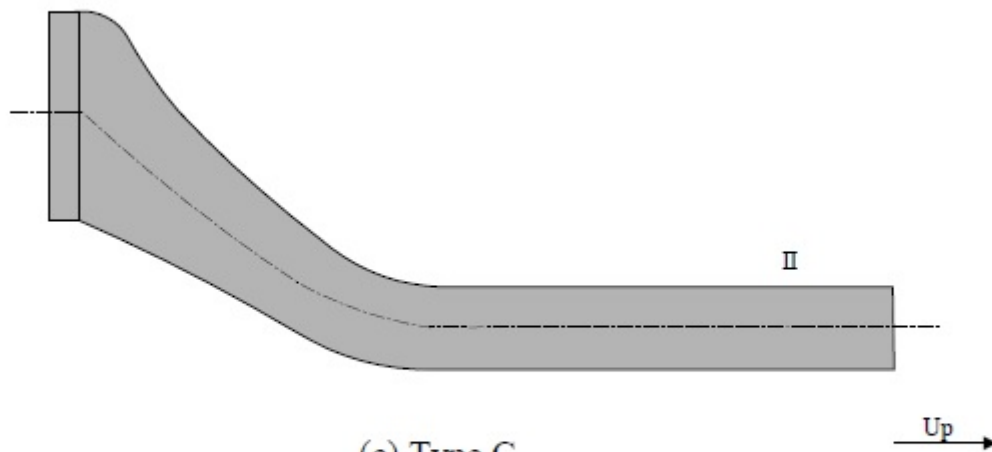


(a) Type A



Note: Welded areas are to be treated as Zone I

(b) Type B



(c) Type C

**Nondestructive Examination of Hull and Machinery Steel Forgings (2014)****SECTION 3  
Volumetric Inspection****1 General****1.1**

Volumetric inspection in this Appendix is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique.

**1.3**

The testing procedures, apparatus and conditions of ultrasonic testing are to comply with the recognized national or international standards. Generally the DGS (distance-gain size) procedure is to be applied using straight beam probes and/or angle beam probes with 2 to 4 MHz and inspection should be carried out using a twin crystal 0° probe for near surface scans [25 mm (1 in.)] plus a 0° probe for the remaining volume. Fillet radii should be examined using 45°, 60° or 70° probes.

**1.5**

Personnel engaged in ultrasonic testing is to be qualified in accordance with the *ABS Guide for Nondestructive Inspection*. The qualification is to be verified by certificates.

**3 Products****3.1 (2012)**

Volumetric inspections by ultrasonic testing generally apply to the following steel forgings:

- i)* Crankshaft with minimum crankpin diameter not less than 150 mm (6 in.)
- ii)* Tail shafts with minimum diameter not less than 200 mm (8 in.) and up to 455 mm (18 in.). UT of propeller shafts 455 mm (18 in.) in diameter and over is to be carried out in accordance with Section 7-A1-12.
- iii)* Intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 200 mm (8 in.)
- iv)* Connecting rods, piston rods and crossheads are to be examined in accordance with 4-2-1/15.11 TABLE 1.

## 5 Zones for Volumetric Inspection

Ultrasonic testing is to be carried out in the zones I to III as indicated in 2-A7-3/Figures 1 to 4. Areas may be upgraded to a higher zone at the discretion of the Surveyors.

## 7 Surface Condition

### 7.1

The surfaces of forgings to be examined are to be such that adequate coupling can be established between the probe and the forging and that excessive wear of the probe can be avoided. The surfaces are to be free from scale, dirt, grease or paint.

### 7.3

The ultrasonic testing is to be carried out after the steel forgings have been machined to a condition suitable for this type of testing and after the final heat treatment, but prior to the drilling of the oil bores and prior to surface hardening. Black forgings are to be inspected after removal of the oxide scale by either flame descaling or shot blasting methods.

## 9 Acceptance Criteria

Acceptance criteria of volumetric inspection by ultrasonic testing are shown in 2-A7-3/Tables 1 and 2.

## 11 Record

Test results of volumetric inspection are to be recorded at least with the following items:

- i)* Date of testing
- ii)* Names and qualification level of inspection personnel
- iii)* Kind of testing method
- iv)* Kind of product
- v)* Product number for identification
- vi)* Grade of steel
- vii)* Heat treatment
- viii)* Stage of testing
- ix)* Position (zone) of testing
- x)* Surface condition
- xi)* Test standards used
- xii)* Testing condition
- xiii)* Results
- xiv)* Statement of acceptance/non acceptance

**TABLE 1**  
**Acceptance Criteria for Crankshafts**

<i>Type of Forging</i>	<i>Zone</i>	<i>Allowable Disk Shape According to DGS <sup>(1)</sup></i>	<i>Allowable Length of Indication</i>	<i>Allowable Distance Between Two Indications <sup>(2)</sup></i>
Crankshaft	I	$d \leq 0.5 \text{ mm (0.02 in.)}$	---	---
	II	$d \leq 2.0 \text{ mm (0.08 in.)}$	$\leq 10 \text{ mm (0.4 in.)}$	$\geq 20 \text{ mm (0.8 in.)}$
	II	$d \leq 4.0 \text{ mm (0.16 in.)}$	$\leq 15 \text{ mm (0.6 in.)}$	$\geq 20 \text{ mm (0.8 in.)}$

**Notes:**

- 1 DGS: distance-gain size
- 2 In case of accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighboring indications is to be at least the length of the bigger indication. This applies as well to the distance in axial direction as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.

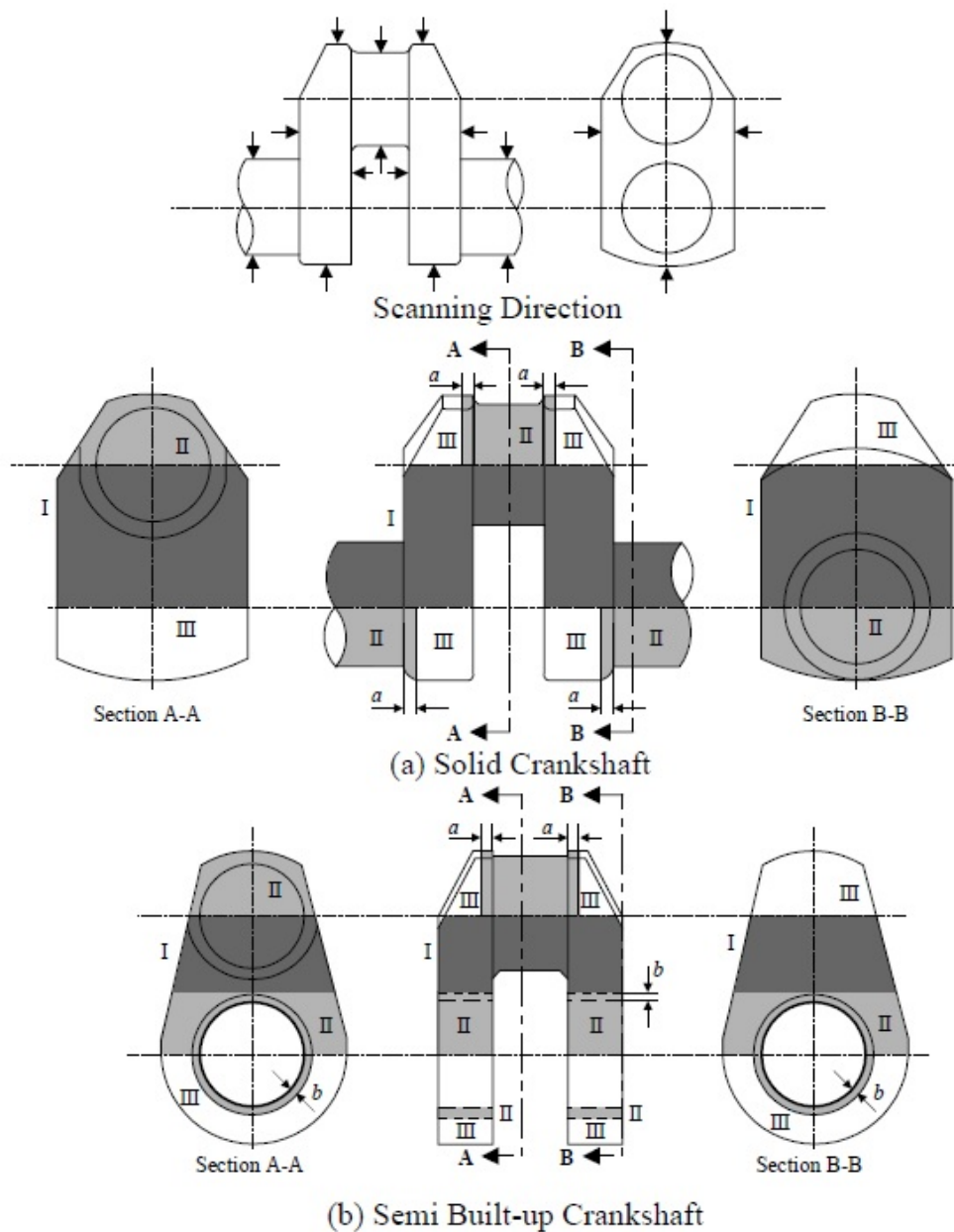
**TABLE 2**  
**Acceptance Criteria for Shafts and Machinery Components (2012)**

<i>Type of Forging</i>	<i>Zone</i>	<i>Allowable Disk Shape According to DGS <sup>(1,2)</sup></i>	<i>Allowable Length of Indication</i>	<i>Allowable Distance Between Two Indications <sup>(3)</sup></i>
Tail Shaft, Intermediate Shaft, Thrust Shaft, Rudder Stock	II	outer: $d \leq 2 \text{ mm (0.08 in.)}$	$\leq 10 \text{ mm (0.4 in.)}$	$\geq 20 \text{ mm (0.8 in.)}$
		inner: $d \leq 4 \text{ mm (0.16 in.)}$	$\leq 15 \text{ mm (0.6 in.)}$	$\geq 20 \text{ mm (0.8 in.)}$
	III	outer: $d \leq 3 \text{ mm (0.12 in.)}$	$\leq 10 \text{ mm (0.4 in.)}$	$\geq 20 \text{ mm (0.8 in.)}$
		inner: $d \leq 6 \text{ mm (0.24 in.)}$	$\leq 15 \text{ mm (0.6 in.)}$	$\geq 20 \text{ mm (0.8 in.)}$
Connecting Rod, Piston Rod, Crosshead	II	$d \leq 2 \text{ mm (0.08 in.)}$	$\leq 10 \text{ mm (0.4 in.)}$	$\geq 20 \text{ mm (0.8 in.)}$
	III	$d \leq 4 \text{ mm (0.16 in.)}$	$\leq 10 \text{ mm (0.4 in.)}$	$\geq 20 \text{ mm (0.8 in.)}$

**Notes:**

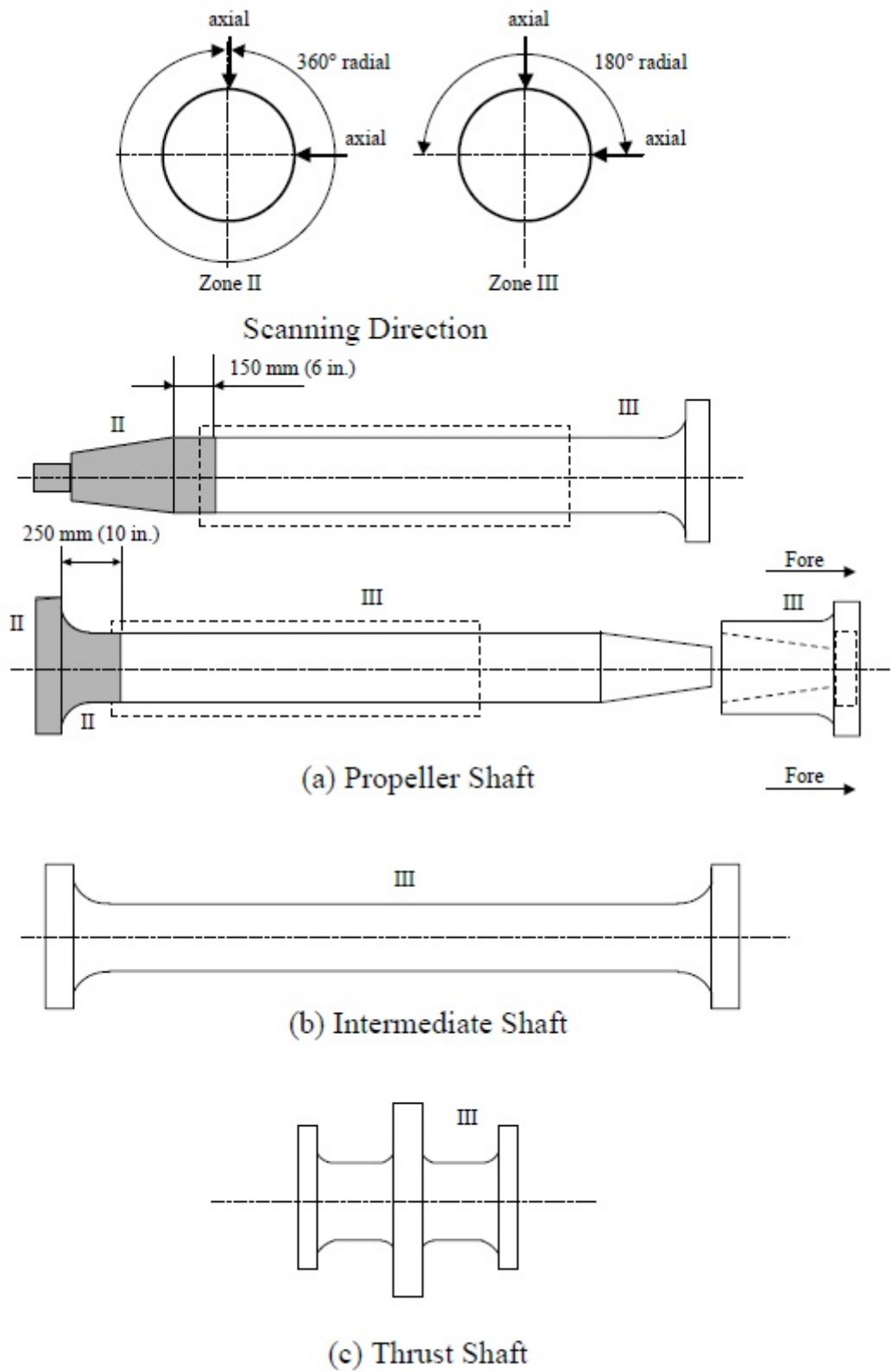
- 1 DGS: distance-gain size
- 2 The “outer part” means the part beyond one third of the shaft radius from the center; the “inner part” means the remaining core area.
- 3 In case of accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighboring indications is to be at least the length of the bigger indication.

**FIGURE 1**  
**Zones for Ultrasonic Testing on Crankshafts**



- Notes
- In the above figures, " $a$ " and " $b$ " mean:  
 $a = 0.1d$  or 25 mm (1 in.), whichever greater  
 $b = 0.05d$  or 25 mm (1 in.), whichever greater (: circumstances of shrinkage fit)  
 where  $d$  = pin or journal diameter.
  - Core areas of crank pins and/or journals within a radius of  $0.25d$  between the webs may generally be coordinated to Zone II.
  - Identification of the Zones (Similar in 2-A7-3/Figures 1 through 4):  
 Zone I  
 Zone II  
 Zone III

**FIGURE 2**  
**Zones for Ultrasonic Testing on Shafts**

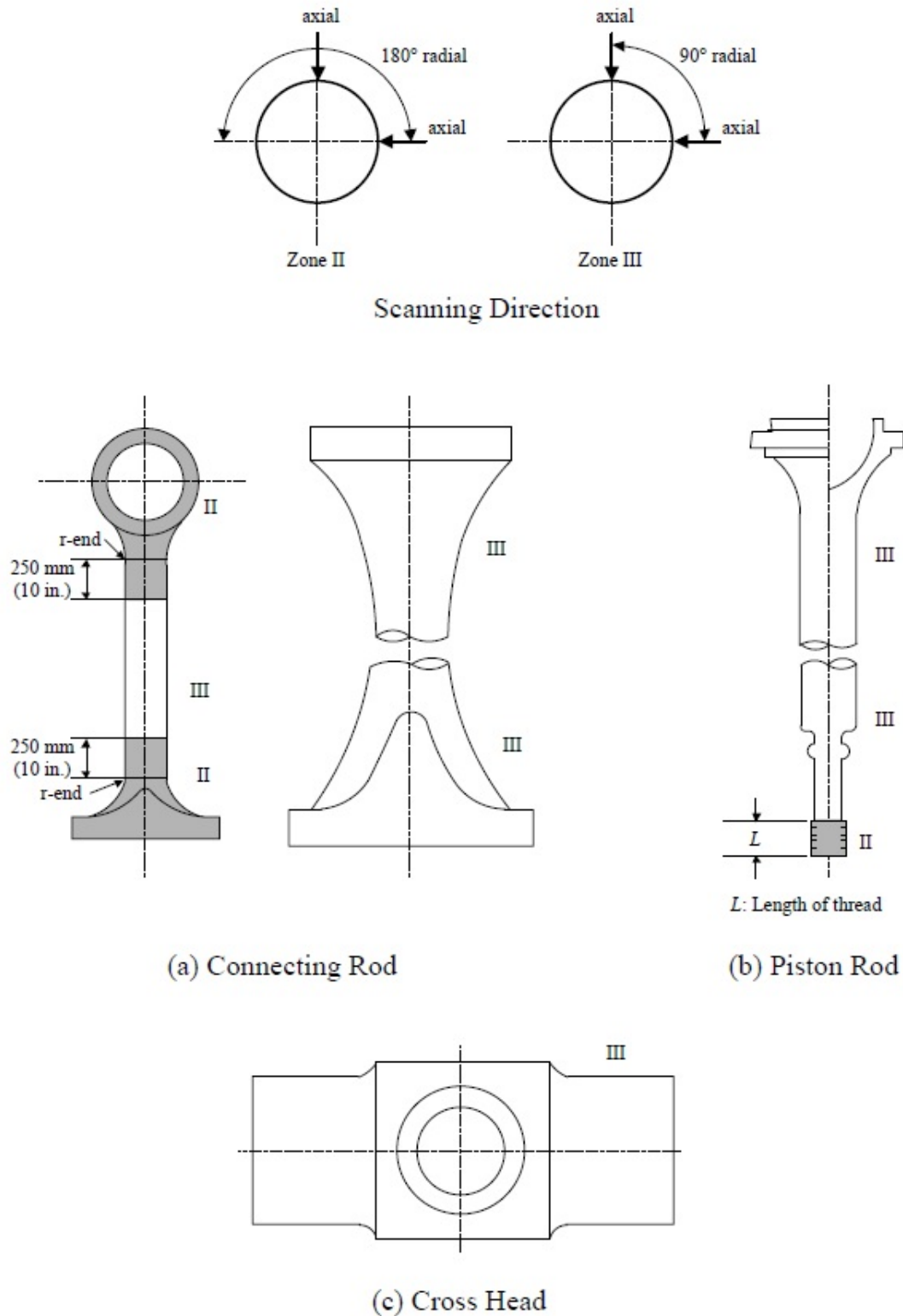


*Notes:*

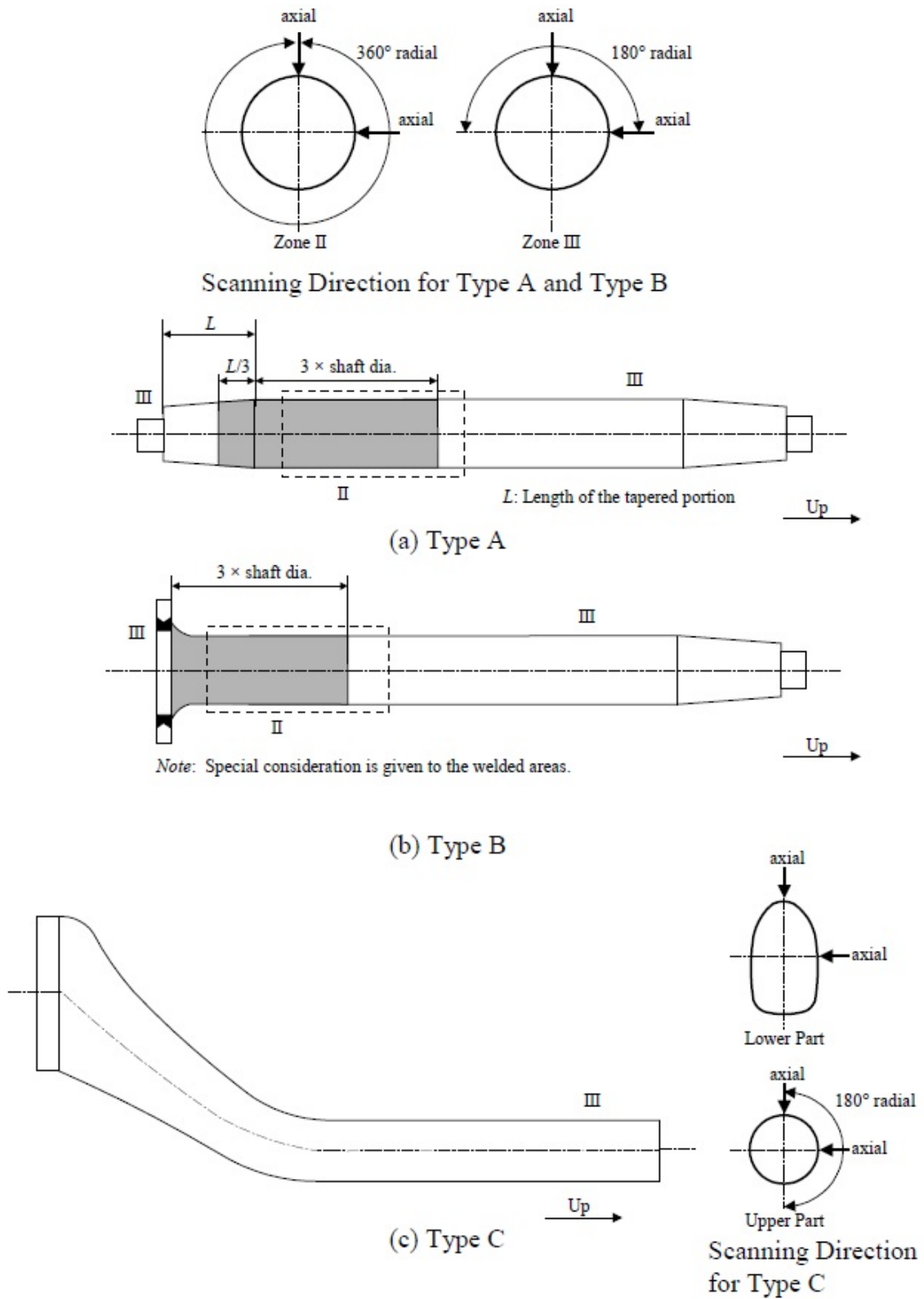
- 1** For hollow shafts, 360° radial scanning applies to Zone III.
- 2** Circumferences of the bolt holes in the flanges are to be treated as Zone II.



**FIGURE 3**  
**Zones for Ultrasonic Testing on Machinery Components**



**FIGURE 4**  
**Zones for Ultrasonic Testing on Rudder Stocks**



### Steel with Enhanced Corrosion Resistance Properties

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Additional Approval Procedure for Steel with Enhanced Corrosion Resistance Properties (2014)</b> .....	<b>637</b>
	1	Scope.....	637
		1.1 .....	637
		1.3 .....	637
	3	Application for Approval.....	637
		3.1 .....	637
	5	Approval of Test Plan.....	638
		5.1 .....	638
		5.3 .....	638
		5.5 .....	638
	7	Carrying out the Approval Test.....	639
		7.1 .....	639
	9	Attendance of the ABS Surveyor for Test.....	639
		9.1 .....	639
	11	Test Results.....	639
		11.1 .....	639
		11.3 .....	639
		11.5 .....	639
	13	Assessment Criteria for Results of Corrosion Resistance Tests of Welded Joint.....	639
		13.1 .....	639
	TABLE 1	Designations for Steels with Enhanced Corrosion Resistance Properties (2014).....	638

**Additional Approval Procedure for Steel with Enhanced Corrosion Resistance Properties (2014)****1 Scope****1.1**

Approval is to be carried out in accordance with the requirements of the Appendices in the *ABS Rules for Materials and Welding (Part 2)* together with the additional requirements for corrosion testing specified in this Appendix.

**1.3**

The corrosion tests and assessment criteria are to be in accordance with the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers (MSC.289 (87)).

**3 Application for Approval****3.1**

The manufacturer has to submit to ABS a request for approval, which is to include the following:

- i)* Corrosion test plan and details of equipment and test environments.
- ii)* Technical data related to product assessment criteria for confirming corrosion resistance
- iii)* The technical background explaining how the variation in added and controlled elements improves corrosion resistance.
- iv)* The grades, the brand name and maximum thickness of steel with enhanced corrosion resistance properties to be approved. Designations for steels with enhanced corrosion resistance properties are given in 2-A8-1/5.3.3 TABLE 1.
- v)* The welding processes and the brand name of the welding consumables to be used for approval.

## 5 Approval of Test Plan

### 5.1

The test program submitted by the manufacturer is to be reviewed by ABS, if found satisfactory, it will be approved and returned to the manufacturer for acceptance prior to tests being carried out. Tests that need to be witnessed by the ABS Surveyor will be identified.

### 5.3

Method for selection of test samples is to satisfy the following:

#### 5.3.1

The numbers of test samples is to be in accordance with the requirements of the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers (MSC.289 (87)).

#### 5.3.2

The number of casts and test samples selected are to be sufficient to make it possible to confirm the validity of interaction effects and/or the control range (upper limit, lower limit) of the elements which are added or intentionally controlled, for improving the corrosion resistance. Where agreed, this may be supported with data submitted by the manufacturer.

#### 5.3.3

Additional tests may be required by ABS when reviewing the test program against 2-A8-1/5.3.2.

**TABLE 1**  
**Designations for Steels with Enhanced Corrosion Resistance Properties (2014)**

<i>Type of Steel</i>	<i>Location where Steel is Effective</i>	<i>Enhanced Corrosion Resistance Properties Designation</i>
Rolled steel for hull	For strength deck, ullage space.	RCU
	For inner bottom	RCB
	For both strength deck and inner bottom plating	RCW

### 5.5

In addition to 2-A8-1/5.3 above, ABS may require additional tests in the following cases:

- i)* When ABS determines that the control range is set by the theoretical analysis of each element based on existing data, the number of corrosion resistance tests conducted in accordance with the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks (MSC.289 (87)) is too few to adequately confirm the validity of the control range of chemical composition;
- ii)* When ABS determines that the data of the corrosion resistance test result obtained for setting the control range of chemical composition varies too widely;
- iii)* When ABS determines that the validity of the corrosion resistance test result for setting the control range of chemical composition is insufficient, or has some flaws;
- iv)* When the ABS surveyor has not attended the corrosion resistance tests for setting the control range of chemical composition, and ABS determines that additional testing is necessary in order to confirm the validity of the test result data; and

- v) When ABS determines that it is necessary, for reasons other than cases i) to iv) above.

*Note:*

The chemical composition of the steel with enhanced corrosion resistance properties is to be within the range specified for rolled steel for hull. Elements to be added for improving the corrosion resistance and for which content is not specified are to be generally within 1% in total.

## **7 Carrying out the Approval Test**

### **7.1**

The manufacturer is to carry out the approval test in accordance with the approved test plan.

## **9 Attendance of the ABS Surveyor for Test**

### **9.1**

The ABS Surveyor is to be present, as a rule, when the test samples for the approval test are being identified and for approval tests, see also 2-A8-1/5.1.

## **11 Test Results**

### **11.1**

After completion of the approval test, the manufacturer is to produce the report of the approval test and submit it to ABS.

### **11.3**

ABS will give approval for steel with enhanced corrosion resistance properties where approval tests are considered by the society to have given satisfactory results based on the data submitted in accordance with the provisions of this Appendix.

### **11.5**

The certificate is to contain the manufacturer's name, the period of validity of the certificate, the grades and thickness of the steel approved, welding methods and welding consumables approved.

## **13 Assessment Criteria for Results of Corrosion Resistance Tests of Welded Joint**

### **13.1**

The results will be assessed by ABS in accordance with the acceptance criteria specified in the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks (MSC.289 (87)).

### Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General Requirements.....</b>	<b>642</b>
	1	Scope.....	642
		1.1 .....	642
		1.3 .....	642
	3	General.....	642
		3.1 .....	642
		3.3 .....	642
		3.5 .....	642
		3.7 .....	642
		3.9 .....	643
		3.11 .....	643
		3.13 .....	643
		3.15 .....	643
		3.17 .....	643
	5	Welding Procedure Specification – pWPS and WPS.....	643
		5.1 Preliminary Welding Procedure Specification (pWPS) and Welding Procedure Specification (WPS).....	643
	7	Welding Procedure Qualification Test –WPQT.....	644
		7.1 General.....	644
		7.3 Butt Welds.....	644
		7.5 Fillet Welds.....	649
		7.7 Re-testing.....	651
		7.9 Test Record.....	652
	9	Range of Approval.....	652
		9.1 General.....	652
		9.3 Base Metal.....	652
		9.5 Thickness.....	653
		9.7 Welding Position.....	654
		9.9 Welding Process.....	654
		9.11 Welding Consumable.....	654
		9.13 Heat Input.....	655

	9.15	Preheating and Interpass Temperature.....	655
	9.17	Post-weld Heat Treatment.....	655
	9.19	Type of Joint.....	655
	9.21	Other Variables.....	656
TABLE 1		Impact Test Requirements for Butt Joints ( $t \leq 50$ mm) <sup>(1)</sup> , <sup>(2)</sup> (1 July 2014).....	648
TABLE 2		Approval Range of Thickness for Butt and T-Joint Welds and Fillet Welds (1 July 2014).....	653
TABLE 3		Range of Approval for Type of Welded Joint (1 July 2014).....	655
FIGURE 1		Test Assembly for Butt Weld (1 July 2014).....	645
FIGURE 2		Test Sampling (1 July 2014).....	646
FIGURE 3		Test Assembly for Fillet Weld (1 July 2014).....	650
<b>ANNEX</b>	<b>1</b>	<b>Location of Charpy V-Notch Impact Test.....</b>	<b>657</b>
	FIGURE 1	Locations of V-notch for Butt Weld of Normal Heat Input (Heat Input $\leq 50$ kJ/cm) (1 July 2014).....	657
	FIGURE 2	Locations of V-Notch for Butt Weld of High Heat Input (Heat Input $> 50$ kJ/cm) (1 July 2014).....	658
<b>ANNEX</b>	<b>2</b>	<b>Hardness Test (Typical examples of hardness test).....</b>	<b>659</b>
	TABLE 1	Recommended Distances $\ell$ Between Indentations for Hardness Test in the Heat Affected Zone (1 July 2014).....	660
	FIGURE 1	Examples of Hardness Test with Rows of Indentations (R) in Butt Welds (1 July 2014).....	659
	FIGURE 2	Example Showing the Position of the Indentations for Hardness Test in the Weld Metal, the Heat Affected Zone and the Base Metal of a Butt Weld (dimensions in mm) (1 July 2014).....	660
	FIGURE 3	Examples of Hardness Test with Row Indentation (R) in Fillet Welds and in T-Joint Welds (1 July 2014).....	661
	FIGURE 4A	Example Showing the Position of the Indentations for Hardness Test in the Weld Metal, the Heat Affected Zone and the Base Metal of a Fillet Weld (dimensions in mm) (1 July 2014).....	662
	FIGURE 4B	Example Showing the Position of the Indentations for Hardness Test on the Weld Metal, the Heat Affected Zone and the Base Metal of a T-Joint Weld (dimensions in mm) (1 July 2014).....	663
<b>ANNEX</b>	<b>3</b>	<b>Welding Positions.....</b>	<b>664</b>
	1	Welding Positions According to ISO Standard.....	664
	3	Welding Positions According to AWS-Code.....	665



# PART 2

## APPENDIX 9

### Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

#### SECTION 1 General Requirements

#### 1 Scope

##### 1.1 (2022)

Refer to 2-4-1/1.7 "Welding Procedures". This appendix covers weld procedure qualification of steels used in marine and offshore hull structures.

##### 1.3 (2022)

For weld procedure qualification of stainless steels, refer to the *ABS Guide for Materials and Welding of Stainless Steels*.

#### 3 General

##### 3.1

Welding procedure qualification tests are intended to verify that a manufacturer is adequately qualified to perform welding operations using a particular procedure.

##### 3.3

In general, welding procedure tests are to reflect fabrication conditions with respect to welding equipment, inside or outside fabrication, weld preparation, preheating and any post-weld heat treatment. It is the manufacturer's responsibility to establish and document whether a procedure is suitable for the particular application.

##### 3.5

For welding procedure approval, welding procedure qualification tests are to be carried out with satisfactory results. Welding procedure specifications are to reference the weld qualification test results achieved during welding procedure qualification testing.

##### 3.7

The approved WPS shall be restricted to the contractor or subcontractor performing the qualification. If the approved WPS's are to be applied at workshops or yards belonging to the contractor or subcontractor, they

are to be under the same technical management and working to the same quality assurance procedures and program.

**3.9** (2022)

For slot welding, a procedure qualification test is to be carried out in accordance with AWS D1.1 Figure 6.26 or other recognized standards as agreed with ABS. Alternatively, a butt weld qualification may also qualify slot welds.

**3.11** (2022)

Stud welding procedure qualification is to be carried out in accordance with AWS D1.1 Chapter 5 or other recognized standards, as agreed with ABS.

**3.13** (2022)

This qualification scheme does not cover welding of process piping, structural tubulars or TKY joints. Weld procedures for process piping are to be qualified in accordance with ASME IX or other welding codes or standards agreed with ABS. For qualification of weld procedures intended for structural tubulars or TKY joints, refer to AWS D1.1 or other welding codes as agreed with ABS.

**3.15** (2022)

A butt weld procedure qualification is required for welding full penetration T-butt joint.

**3.17** (2022)

Butt weld qualification will permit welding of partial penetration welds. Alternatives for weld procedure qualification for partial penetration welds can be specifically agreed with ABS.

## **5 Welding Procedure Specification – pWPS and WPS**

### **5.1 Preliminary Welding Procedure Specification (pWPS) and Welding Procedure Specification (WPS)**

#### **5.1.1 pWPS**

The shipyard or manufacturer is to submit a pWPS for review prior to the Weld Procedure Qualification Tests (WPQT). The pWPS can be modified and amended during the WPQT as deemed necessary. The pWPS is to define all the variables (refer to AWS D.1.1, ISO 15614 or other recognized standards) that will be included in the WPS. In case the test pieces welded according to the pWPS show unacceptable results the pWPS is to be adjusted by the shipyard or manufacturer. The new pWPS is to be prepared and the test pieces welded in accordance with the new pWPS.

#### **5.1.2 WPS**

Upon completion of the WPQT and satisfactory review, the pWPS is given approval and becomes the WPS. The WPS is to be used as a basis for production welds. The approval range of the WPS is to be in compliance with 2-A9-1/9.

*Note:*

The generic term WPS is sometimes applied to a document before and after qualification tests, this can be accepted. The use of pWPS helps identify that the document has not yet been qualified by satisfactory tests.

## 7 Welding Procedure Qualification Test –WPQT

### 7.1 General

#### 7.1.1

Preparation and welding of test pieces are to be carried out in accordance with the pWPS and under the general condition of production welding which it represents.

#### 7.1.2

Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.

#### 7.1.3

If tack welds and/or start and stop points are a condition of the weld process they are to be fused into the joint and are to be included in the test assemblies.

### 7.3 Butt Welds

#### 7.3.1 Assembly of Test Pieces

The test assembly is to be in accordance with 2-A9-1/7.3.1 FIGURE 1 with the following minimum dimensions:

- *Manual or Semi-automatic Welding:*

Thickness =  $t$

Width =  $2a$ , where  $a = 3 \times t$ . Minimum width to be no less than 150 mm

Length  $b = 6 \times t$ . Minimum length to be no less than 350 mm

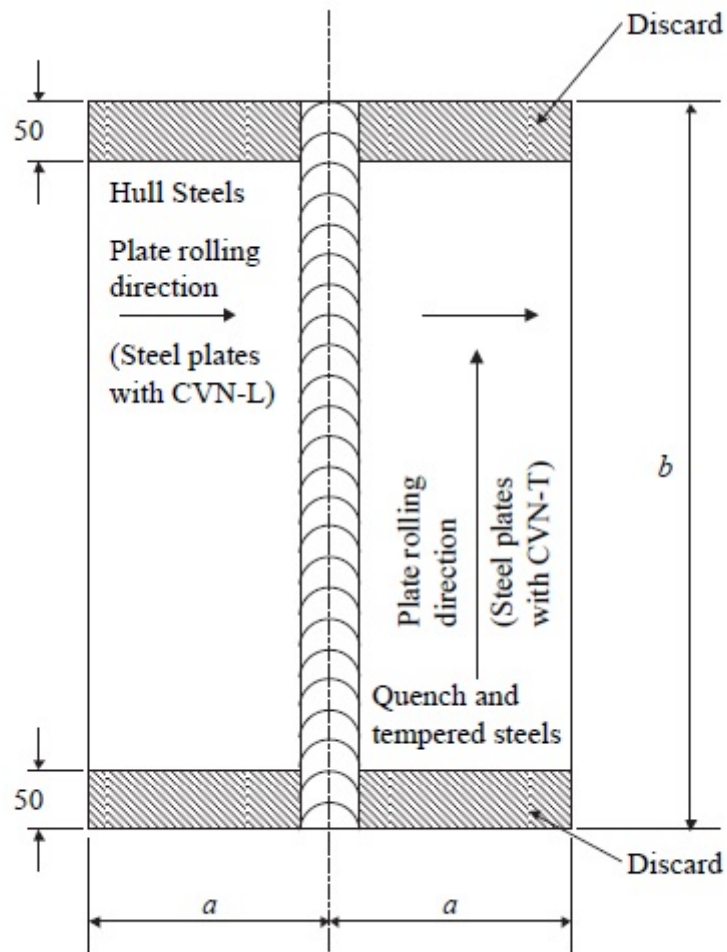
- *Automatic Welding:*

Thickness =  $t$

Width =  $2a$ , where  $a = 4 \times t$ . Minimum width to be no less than 200 mm

Length  $b$ . Minimum length to be no less than 1000 mm

**FIGURE 1**  
**Test Assembly for Butt Weld (1 July 2014)**

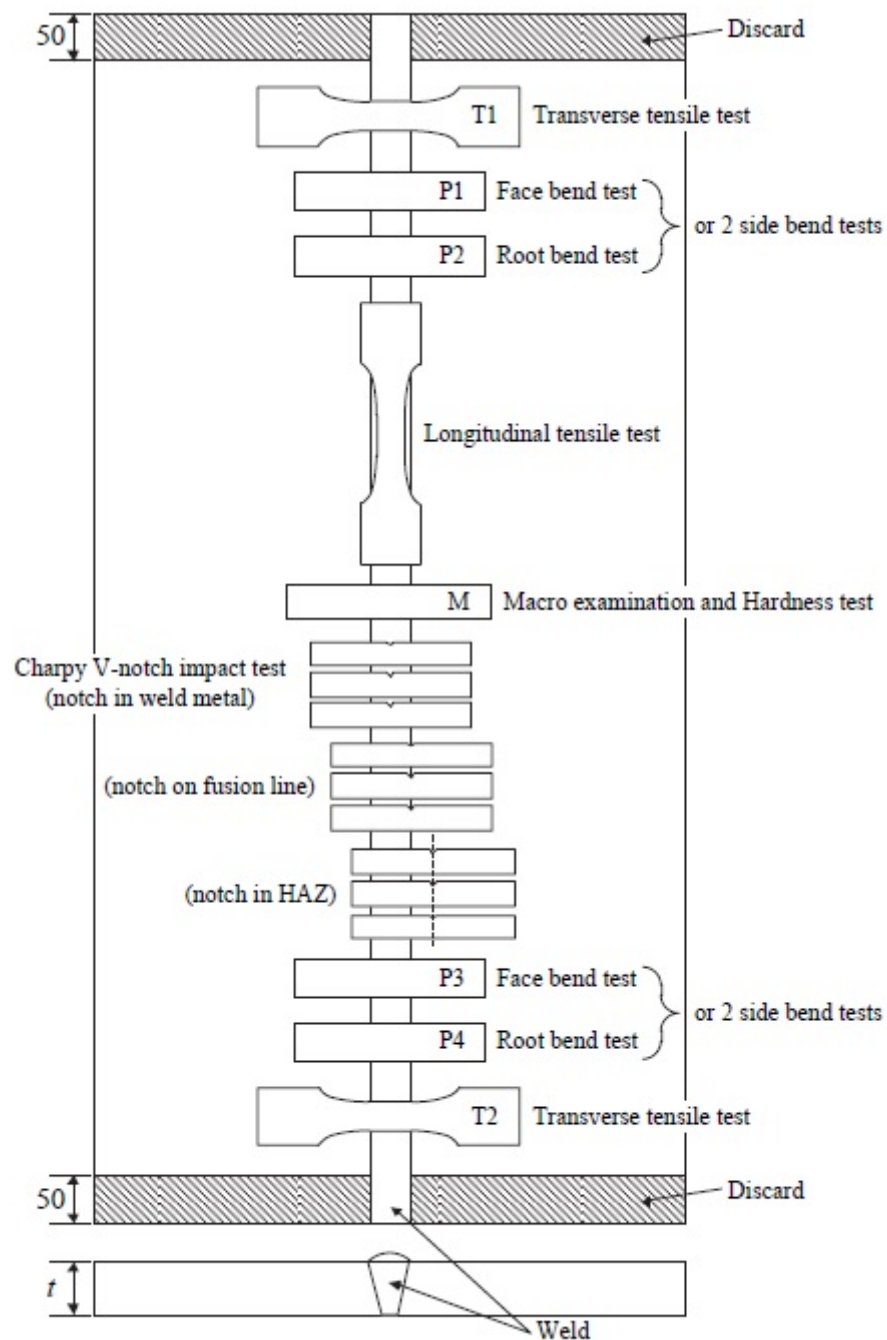


### 7.3.2 Examinations and Tests

Test assemblies are to be examined nondestructively and destructively in accordance with the following requirements and 2-A9-1/7.3.2 FIGURE 2:

- Visual testing 100%
- Surface crack detection 100%  
(dye penetrant testing or magnetic particle testing)
- Radiographic or Ultrasonic testing 100%
- Transverse tensile test two specimens as per 2-A9-1/7.3.2(b)
- Longitudinal tensile test as per 2-A9-1/7.3.2(c)
- Transverse bend test four specimens as per 2-A9-1/7.3.2(d)
- Charpy V-notch impact test as per 2-A9-1/7.3.2(e)
- Macro examination one specimen as per 2-A9-1/7.3.2(f)
- Hardness test required as per 2-A9-1/7.3.2(g)

**FIGURE 2**  
**Test Sampling (1 July 2014)**



7.3.2(a) *Nondestructive Testing.*

Test assemblies are to be examined by visual and by nondestructive testing prior to the cutting of test specimens. In case any post-weld heat treatment is required or specified, nondestructive testing is to be performed after heat treatment. For steels with specified minimum yield strength of 420 N/mm<sup>2</sup> and above the nondestructive testing is to be delayed for a minimum of 48 hrs, unless

post weld heat treatment has been carried out. NDT procedures are to be to the satisfaction of the Surveyor.

Imperfections detected by visual or nondestructive testing are to be assessed in accordance with ISO 5817, class B, except for excess weld metal and excess penetration for which the level C applies.

*7.3.2(b) Transverse Tensile Test.*

The testing is to be carried out in accordance with 2-4-3/11.5 FIGURE 3. The tensile strength recorded for each specimen is not to be less than the minimum required for the base metal. When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength. If a lower strength consumable is proposed the details are to be submitted to ABS for consideration.

*7.3.2(c) Longitudinal Tensile Test.*

Longitudinal tensile test of deposited weld metal taken lengthways from the weld is required for cases where the welding consumable is not ABS approved.

Testing is to be carried out in accordance with 2-A2-1/33 FIGURE 1. The tensile properties recorded for each specimen are not to be less than the minimum required for the approval of the appropriate grade of consumable.

Where more than one welding process or type of consumable has been used to make the test weld, test specimens are to be taken from the area of the weld where each was used with the exception of those processes or consumables used to make the first weld run or root deposit.

*7.3.2(d) Bend Test.*

Transverse bend tests for butt joints are to be in accordance with 2-4-3/11.5 FIGURE 5 and 2-4-3/11.5 FIGURE 6. The mandrel diameter to thickness ratio (i.e.,  $D/t$ ) is to be in accordance with 2-4-3/11.5 FIGURE 7.

The bending angle is to be 180°. After testing, the test specimens are not to reveal any open defects in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing are to be investigated case by case.

Two root and two face bend specimens are to be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested.

For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

*7.3.2(e) Impact Test*

*i) Normal and higher strength hull structural steels.* The positions of specimens are to be in accordance with these requirements. Dimensions and testing are to be in accordance with the requirements of 2-1-1/11.11.

Test specimens with Charpy-V-notch are to be used and sampled from 1 to 2 mm below the surface of the base metal, transverse to the weld and on the side containing the last weld run. V-notch specimens are located in the butt-welded joint as indicated in 2-A9-A1/ FIGURE 1 and 2-A9-A1/ FIGURE 2, and the V-notch is to be cut perpendicular to the surface of the weld.

Test temperature and absorbed energy are to be in accordance with 2-A9-1/7.3.2(e).i TABLE 1.

When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.

Where more than one welding process or consumable has been used to make the test weld, impact test specimens are to be taken from the respective areas where each was employed. This is not to apply to the process or consumables used solely to make the first weld run or root deposit.

The testing of sub-size specimens is to be in accordance with Section 2-1-2 and 2-1-1/16 FIGURE 3.

**TABLE 1**  
**Impact Test Requirements for Butt Joints ( $t \leq 50$  mm)<sup>(1,2)</sup> (1 July 2014)**

Grade of Steel	Testing Temperature (C°)	Value of Minimum Average Absorbed Energy (J)		
		For Manually or Semi-automatically Welded Joints		For Automatically Welded Joints
		Downhand, Horizontal, Overhead	Vertical Upward, Vertical Downward	
A <sup>(3)</sup>	20	47	34	34
B <sup>(3)</sup> , D	0			
E	-20			
AH32, AH36	20			
DH32, DH36	0			
EH32, EH36	-20			
FH32, FH36	-40			
AH40	20	39	39	
DH40	0			
EH40	-20			
FH40	-40			

**Notes:**

- 1 For thickness above 50 mm impact test requirements reference is to be made to ABS Rules 2-4-3/11.5 TABLE 2
- 2 These requirements apply to test pieces with butt weld perpendicular to the plate rolling direction.
- 3 For Grade A and B steels average absorbed energy on the fusion line and in the heat affected zone is to be minimum 27 J.

ii) *High Strength Quenched and Tempered Steels.* Impact tests are to be performed as described in i) above.

V-notch specimens are located in the butt welded joint as indicated in 2-A9-A1/ FIGURE 1 and 2-A9-A1/ FIGURE 2. The V-notch is to be cut perpendicular to the surface of the weld.

Test temperature and absorbed energy are to be in accordance with the requirements of the base metal.

- iii) *Weldable C and C-Mn Hull Steel Castings and Forgings*. For base metal with specified impact values, test temperature and absorbed energy are to be in accordance with the requirements of the base metal to be welded.

7.3.2(f) *Macro Examination.*

Test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, and heat affected zone.

Macro examination is to include approximately 10 mm of unaffected base metal.

The examination is to reveal a regular weld profile, fusion between adjacent layers of weld and base metal and the absence of defects such as cracks, lack of fusion, etc.

7.3.2(g) *Hardness Tests. (2020)*

Hardness tests are required for steels with specified minimum yield strength of  $R_{eH} \geq 355 \text{ N/mm}^2$ . The Vickers method HV 10 is normally used. The indentations are to be made in the weld metal, the heat affected zone and the base metal. The hardness values are to be measured and recorded. At least two rows of indentations are to be carried out in accordance with 2-A9-A2/ FIGURE 1 and 2-A9-A2/ FIGURE 2.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). A typical example is shown in Annex 2.

The results from the hardness test are not to exceed the following:

- Steel with a specified minimum yield strength  $R_{eH} \leq 420 \text{ N/mm}^2$ : 350 HV10
- Steel with a specified minimum yield strength  $420 \text{ N/mm}^2 < R_{eH} \leq 690 \text{ N/mm}^2$ : 420 HV10
- Steel with a specified minimum yield strength  $690 \text{ N/mm}^2 < R_{eH} \leq 960 \text{ N/mm}^2$ : 450 HV10

## 7.5 Fillet Welds

### 7.5.1 Assembly of Test Pieces

The test assembly is to be in accordance with 2-A9-1/7.5.1 FIGURE 3 with the minimum dimensions:

- *Manual and Semi-automatic Welding:*

Thickness =  $t$

Width  $a = 3 \times t$ . Minimum width is to be no less than 150 mm

Length  $b = 6 \times t$ , Minimum length is to be no less than 350 mm

- *Automatic Welding:*

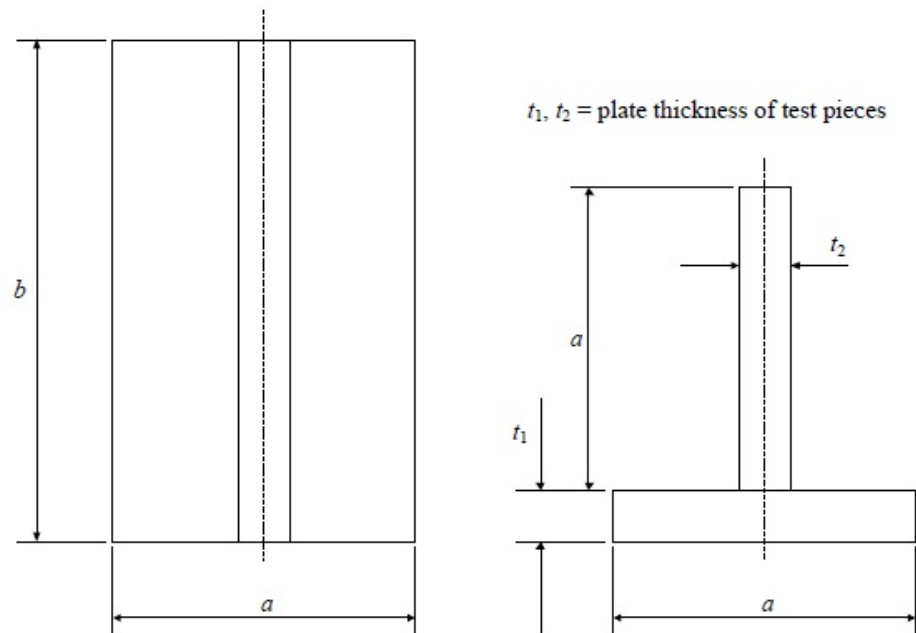
Thickness =  $t$

Width  $a = 3 \times t$ , Minimum width is to be no less than 150 mm

Length  $b =$  Minimum length is to be no less than 1000 mm



**FIGURE 3**  
**Test Assembly for Fillet Weld (1 July 2014)**



### 7.5.2 Welding of Test Pieces

The test assembly is welded on one side only. For single run manual and semi-automatic welding, a stop/restart is to be included in the test length and its position is to be clearly marked for subsequent examination.

### 7.5.3 Examinations and Tests

Test assemblies are to be examined nondestructively and destructively in accordance with the following:

- Visual testing 100%
- Surface crack detection 100% (dye penetrant testing or magnetic particle testing)
- Macro examination two specimen as per 2-A9-1/7.5.3(b)
- Hardness test required as per 2-A9-1/7.5.3(c)
- Fracture test required as per 2-A9-1/7.5.3(d)

#### 7.5.3(a) Nondestructive Testing.

Test assemblies are to be examined by visual and by nondestructive testing prior to the cutting of test specimens. In case any post-weld heat treatment is required or specified nondestructive testing is to be performed after heat treatment. For steels with specified minimum yield strength of 420 N/mm<sup>2</sup> and above, nondestructive testing is to be delayed for a minimum of 48 hrs, unless post weld heat treatment has been carried out. NDT procedures are to be to the satisfaction of the Surveyor.

Imperfections detected by visual or nondestructive testing are to be assessed in accordance with ISO 5817, class B except for excess convexity and excess throat thickness for which the level C applies.

*7.5.3(b) Macro Examination.*

Test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, root penetration and the heat affected zone.

Macro examination is to include approximately 10 mm unaffected base metal.

The examination is to reveal a regular weld profile, fusion between adjacent layers of weld and base metal, sufficient root penetration and the absence of defects such as cracks, lack of fusion, etc.

*7.5.3(c) Hardness Test. (2020)*

Hardness test is required for steels with specified minimum yield strength of  $R_{eH} \geq 355 \text{ N/mm}^2$ . The Vickers method HV10 is normally used. The indentations are to be made in the weld metal, heat affected zone, and base metal. The hardness values are to be measured and recorded. At least two rows of indentations are to be carried out in accordance with 2-A9-A2/ FIGURE 3, 2-A9-A2/ FIGURE 4A and 2-A9-A2/FIGURE 4B.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, heat affected zone (both sides), and base metal (both sides). A typical example is shown in 2-A9-A2.

Results from the hardness test are not to exceed the following:

- Steel with a specified minimum yield strength  $R_{eH} \leq 420 \text{ N/mm}^2$  : 350 HV10
- Steel with a specified minimum yield strength  $420 \text{ N/mm}^2 < R_{eH} \leq 690 \text{ N/mm}^2$  : 420 HV10
- Steel with a specified minimum yield strength  $690 \text{ N/mm}^2 < R_{eH} \leq 960 \text{ N/mm}^2$ : 450 HV10

*7.5.3(d) Fracture Test.*

The fracture test is to be carried out by folding the upright plate onto the through plate.

Evaluation is to concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration. Imperfections that are detected are to be assessed in accordance with ISO 5817, class B.

## 7.7 Re-testing

### 7.7.1

If the test piece fails to comply with any of the requirements for visual or nondestructive testing one further test piece is to be welded and subjected to the same examination. If this additional test piece does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

### 7.7.2

If any test specimens fail to comply with the relevant requirements for mechanical testing due to weld imperfections only, two further test specimens are to be obtained for each one that failed. These specimens can be taken from the same test piece if there is sufficient material available or from a new test piece, and are to be subjected to the same test. If either of these additional test specimens does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

### 7.7.3

If a tensile test specimen fails to meet the requirements, re-testing is to be in accordance with 2-1-2/9.11.

#### 7.7.4

If there is a single hardness value above the maximum values allowed, additional hardness tests are to be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface). None of the additional hardness values is to exceed the maximum hardness values required.

#### 7.7.5

Re-testing of Charpy impact specimens is to be carried out in accordance with the requirements of 2-1-2/11.7.

#### 7.7.6

Where there is insufficient welded assembly remaining to provide additional test specimens, a further assembly is to be welded using the same procedure to provide the additional specimens.

### 7.9 Test Record

#### 7.9.1

Welding conditions for test assemblies and test results are to be recorded in the welding procedure test record, sometimes referred to as the PQR or WPQR.

#### 7.9.2

A statement of the results of assessing each test piece, including repeat tests, is to be made for each welding procedure test. The relevant items listed for the WPS of these requirements are to be included.

#### 7.9.3

A statement that the test piece was made according to the particular welding procedure is to be signed by the Surveyor witnessing the test and is to include the ABS stamp.

## 9 Range of Approval

### 9.1 General

All the conditions governing the range of approval stated below are to be met independently of each other.

Changes outside of the ranges specified are to require a new welding procedure test.

Shop primer may have an influence on the quality of fillet welds and is to be considered.

Welding procedure qualification with shop primer will qualify those without but not vice versa.

### 9.3 Base Metal

#### 9.3.1 Ordinary Strength Hull Structural Steel

For each grade tested, welding procedures are considered applicable to that grade and the lower toughness designations (grades).

#### 9.3.2 Higher Strength Hull Structural Steel

9.3.2(a) For each strength level tested, welding procedures are considered applicable to that strength level, and any of the lower toughness designations (grades) in that strength level.

9.3.2(b) For each toughness designation (grade) tested, welding procedures are considered applicable to that toughness designation (grade) and two lower strength levels in that toughness designation (grade), including the lower toughness designations (grades) of the lower strength levels.

9.3.2(c) For applying the above 2-A9-1/9.3.2(a) and 2-A9-1/9.3.2(b) to high heat input processes above 50 kJ/cm, e.g., the two-run technique with either submerged arc or gas shielded metal arc welding, electroslag and electrogas welding, the welding procedure is applicable to that toughness grade tested and one strength level below.

9.3.2(d) Where steels used for construction are supplied with different delivery conditions from those tested ABS may require additional tests.

### 9.3.3 High Strength Quenched and Tempered Steels

9.3.3(a) For each strength level tested, welding procedures are considered applicable to that strength level and the lower toughness designations (grades) in that strength level.

9.3.3(b) For each toughness designation (grade) tested, welding procedures are considered applicable to that toughness designation (grade) and two lower strength levels in that toughness designation (grade).

9.3.3(c) The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

### 9.3.4 Weldable C and C-Mn Hull Steel Forgings

9.3.4(a) Welding procedures are considered applicable to that strength level and strength levels lower than that tested.

9.3.4(b) The approval of quenched and tempered hull steel forgings does not qualify other delivery conditions and vice versa.

### 9.3.5 Weldable C and C-Mn Hull Steel Castings

9.3.5(a) Welding procedures are considered applicable to that strength level and strength levels lower than that tested.

9.3.5(b) (2020)

The approval of quenched and tempered hull steel castings does not qualify other delivery conditions and vice versa.

## 9.5 Thickness

### 9.5.1

The thickness  $t$  used in a WPQT is valid for the thickness range given in 2-A9-1/9.5.1 TABLE 2.

**TABLE 2**  
**Approval Range of Thickness for Butt and T-Joint Welds and Fillet Welds (1 July 2014)**

Thickness of Test Piece $t^{(1)}$ (mm)	Range of Approval	
	Butt and T-joint Welds with Single Run or Single Run from Both Sides	Butt and T-Joint Welds with Multi-run and Fillet Welds <sup>(2)</sup>
$3 < t \leq 12$	$0.7 \times t$ to $1.1 \times t$	3 to $2 \times t$
$12 < t \leq 100$	$0.7 \times t$ to $1.1 \times t^{(3)}$	$0.5 \times t$ to $2 \times t$ ( $> 150$ mm) <sup>(4)</sup>

*Notes:*

- 1 For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval for the individual welding process.
- 2 For fillet welds, the range of approval is to be applied to both base metals.
- 3 For high heat input processes over 50 kJ/cm, the upper limit of range of approval is to be  $1.0 \times t$ .
- 4 Thicknesses above 150 mm are subject to special consideration.

### 9.5.2

In addition to the requirements of 2-A9-1/9.5.1 TABLE 2, the range of approval of throat thickness “ $a$ ” for fillet welds is to be as follows:

- Single run ; “ $0.75 \times a$ ” to “ $1.5 \times a$ ”
- Multi-run ; as for butt welds with multi-run (i.e.,  $a = t$ )

### 9.5.3

For vertical-down welding, the test piece thickness “ $t$ ” is always taken as the upper limit of the range of application.

### 9.5.4

For unequal plate thickness of butt welds the lesser thickness is the ruling dimension.

### 9.5.5

Notwithstanding the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of test assembly if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated in 2-A9-1/7.3.2(g) and 2-A9-1/7.5.3(c).

## 9.7 Welding Position

Approval for a test made in any position is restricted to that position (see 2-A9-A3). To qualify a range of positions, test assemblies are to be welded using the highest heat input position and the lowest heat input position, and all applicable tests are to be made on those assemblies.

## 9.9 Welding Process

### 9.9.1

The approval is only valid for the welding process(es) used in the welding procedure test. It is not permitted to change from a multi-run process to a single run process.

### 9.9.2

For multi-process procedures the welding procedure approval may be carried out with separate welding procedure tests for each welding process. It is also possible to make the welding procedure test as a multi-process procedure test. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test.

## 9.11 Welding Consumable (2022)

Except high heat input processes over 50 kJ/cm, welding consumables cover other approved welding consumables having the same grade mark including all suffixes specified in Section 2-A2-1 with the welding consumable tested.

A re-qualification test is to be carried out if any one or more of below conditions are met.

- Any change in consumable classifications: mechanical properties, type of covering core or flux (e.g., basic, rutile), nominal chemical composition and increase in hydrogen content

- ABS is to be notified if there is a change of filler consumable brand name. In such cases ABS may require additional qualification tests such as CVN tests or confirmation that a satisfactory weld can be produced without defects using the essential variables from the existing weld procedure
- This section does not cover allowable limits for changes of mixture or composition, flow rate, filling time and filling volume for shielding and purging gases. Refer to applicable recognized standards for structural welding for range of approval and requalification requirements.

### 9.13 Heat Input

#### 9.13.1

The upper limit of heat input approved is 25% greater than that used in welding the test piece or 55 kJ/cm whichever is smaller, except that the upper limit is 10% greater than that for high heat input processes over 50 kJ/cm.

#### 9.13.2

The lower limit of heat input approved is 25% lower than that used in welding the test piece. New materials will be subject to special approval.

### 9.15 Preheating and Interpass Temperature

#### 9.15.1 (2022)

The minimum preheating temperature is not to be less than that used in the qualification test. Alternatively, the range of preheat and interpass temperature can be based on AWS D1.1, ASME BPVC.IX or other recognized standards, as agreed with the ABS Materials Department.

#### 9.15.2

The maximum interpass temperature is not to be higher than that used in the qualification test.

### 9.17 Post-weld Heat Treatment

The heat treatment used in the qualification test is to be maintained during manufacture. Holding time may be adjusted as a function of thickness.

### 9.19 Type of Joint

#### 9.19.1

Range of approval depending on type of welded joints for test assembly is to be as specified in 2-A9-1/9.19.2 TABLE 3.

#### 9.19.2

A qualification test performed on a butt weld will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in 2-A9-1/9.5 above.

**TABLE 3**  
**Range of Approval for Type of Welded Joint (1 July 2014)**

<i>Type of Welded Joint for Test Assembly</i>			<i>Range of Approval</i>	
Butt welding	One side	With backing	A	A, C
		Without backing	B	A, B, C, D
	Both side	With gouging	C	C
		Without gouging	D	C, D

### 9.21 Other Variables (2022)

- i)* A change in the current (AC or DC) or polarity (electrode positive or negative for DC current) would require weld procedure requalification.
- ii)* A change from semi-automatic to automatic welding processes, or vice versa would require weld procedure requalification.

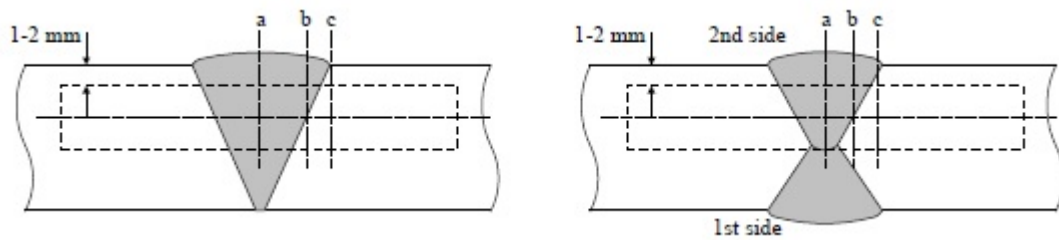
Other variables may also be considered in determining the range of approval.

## Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

### Location of Charpy V-Notch Impact Test

**FIGURE 1**  
**Locations of V-notch for Butt Weld of Normal Heat Input**  
**(Heat Input  $\leq 50$  kJ/cm) (1 July 2014)**

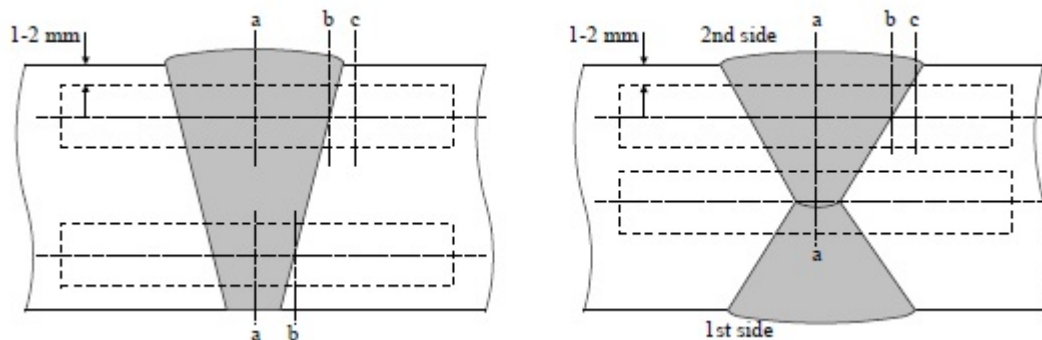
a)  $t < 50$  mm <sup>(1)</sup>



*Note:*

1 For one side single run welding over 20 mm notch location "a" is to be added on root side.

b)  $t > 50$  mm



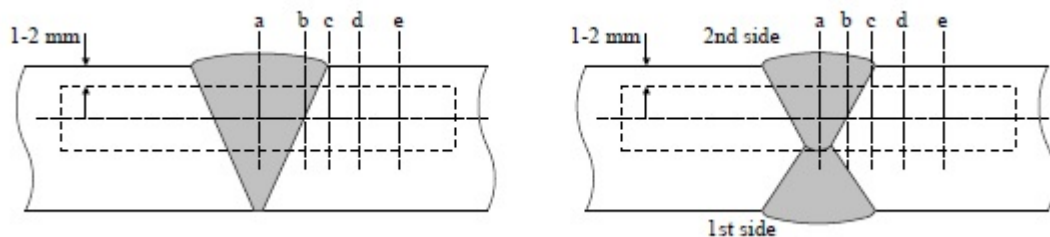


Notch locations:

- a: center of weld “WM”
- b: on fusion line “FL”
- c: in HAZ, 2 mm from fusion line

**FIGURE 2**  
**Locations of V-Notch for Butt Weld of High Heat Input**  
**(Heat Input > 50 kJ/cm) (1 July 2014)**

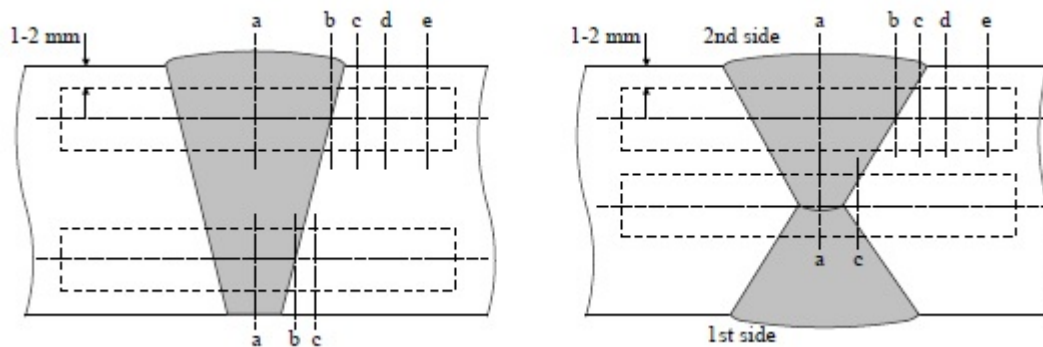
a)  $t \leq 50 \text{ mm}$  <sup>(1)</sup>



Note:

- 1 For one side welding with thickness over 20 mm notch locations “a”, “b” and “c” are to be added on root side.

b)  $t > 50 \text{ mm}$

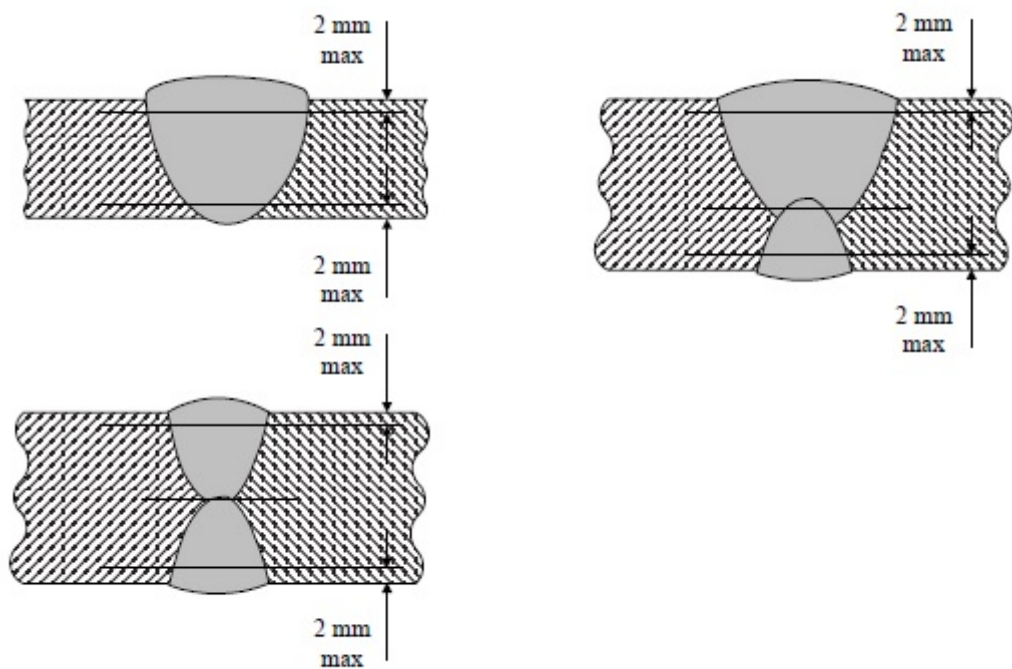


Notch locations:

- a: center of weld “WM”
- b: on fusion line “FL”
- c: in HAZ, 2 mm from fusion line
- d: in HAZ, 5 mm from fusion line
- e: in HAZ, 10 mm from fusion line

**Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)****Hardness Test (*Typical examples of hardness test*)**

**FIGURE 1**  
**Examples of Hardness Test with Rows of Indentations (R) in Butt Welds (1 July 2014)**

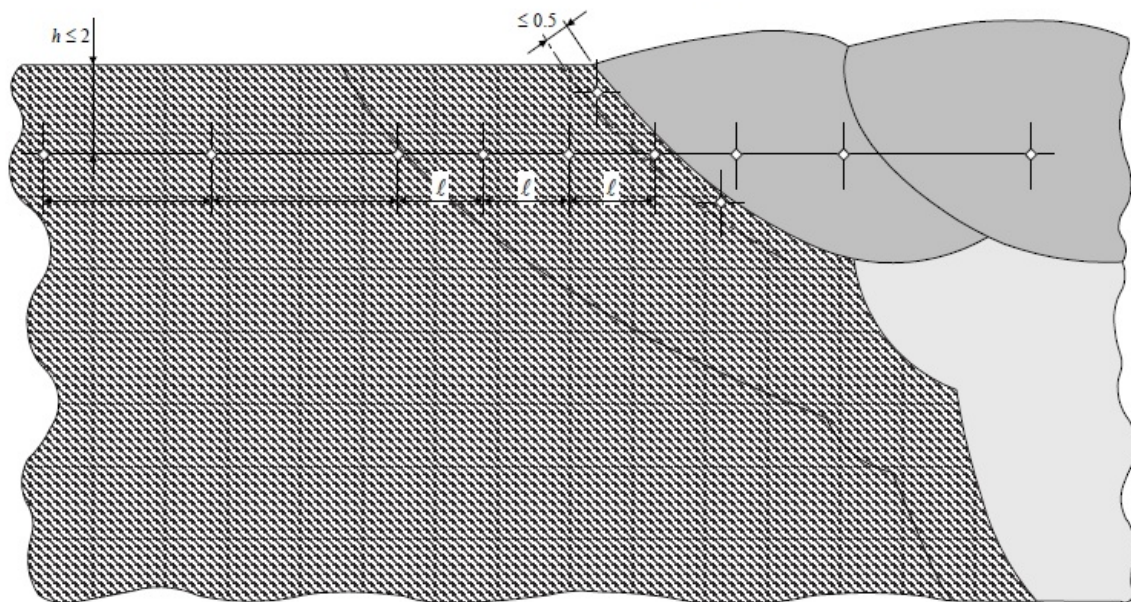


**TABLE 1**  
**Recommended Distances  $\ell$  Between Indentations**  
**for Hardness Test in the Heat Affected Zone (1 July 2014)**

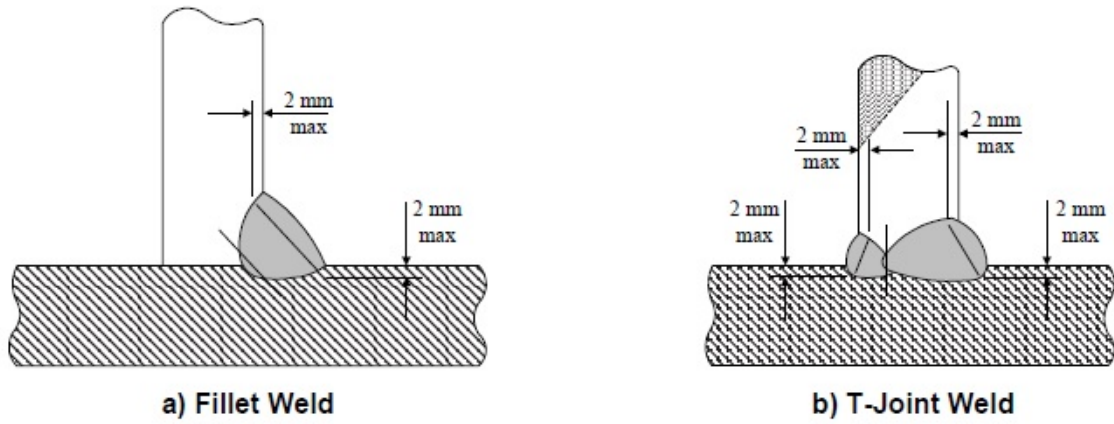
<i>Vickers Hardness Symbol</i>	<i>Distance Between Indentations <math>\ell</math> (mm)</i>
HV 10	1

The distance of any indentation from the previous indentation is not to be less than the value allowed for the previous indentation by ISO 6507/1.

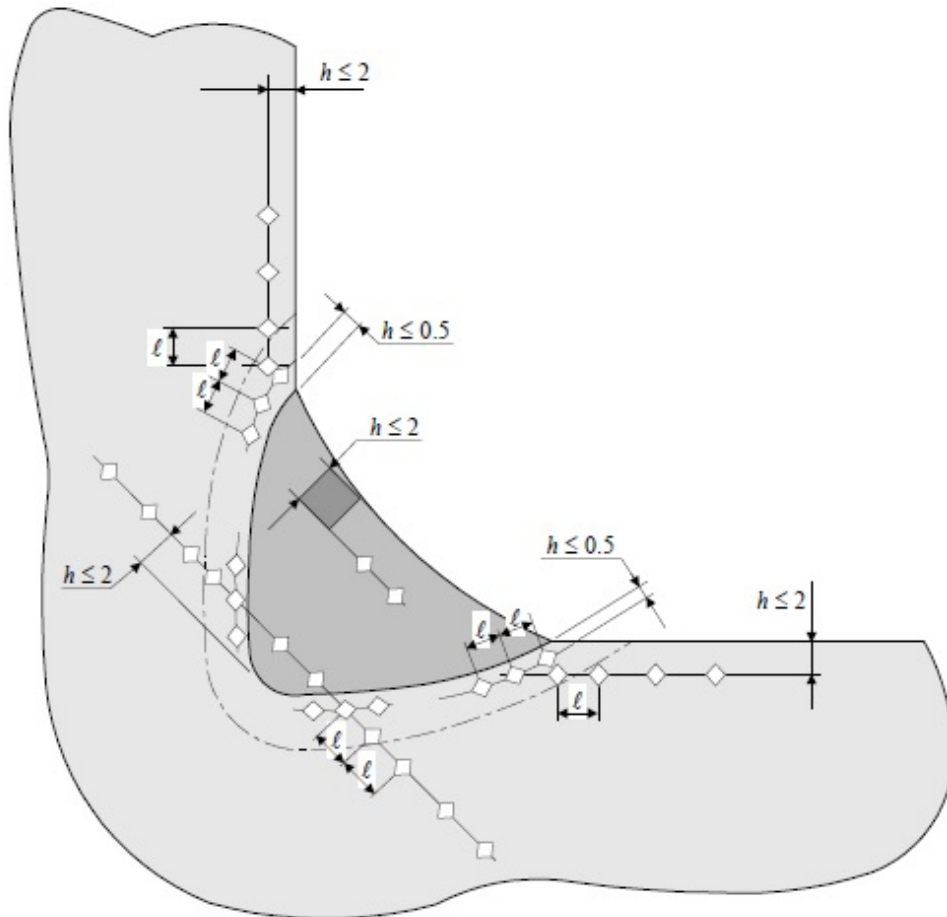
**FIGURE 2**  
**Example Showing the Position of the Indentations for Hardness Test**  
**in the Weld Metal, the Heat Affected Zone and the Base Metal**  
**of a Butt Weld (dimensions in mm) (1 July 2014)**



**FIGURE 3**  
**Examples of Hardness Test with Row Indentation (R)**  
**in Fillet Welds and in T-Joint Welds (1 July 2014)**

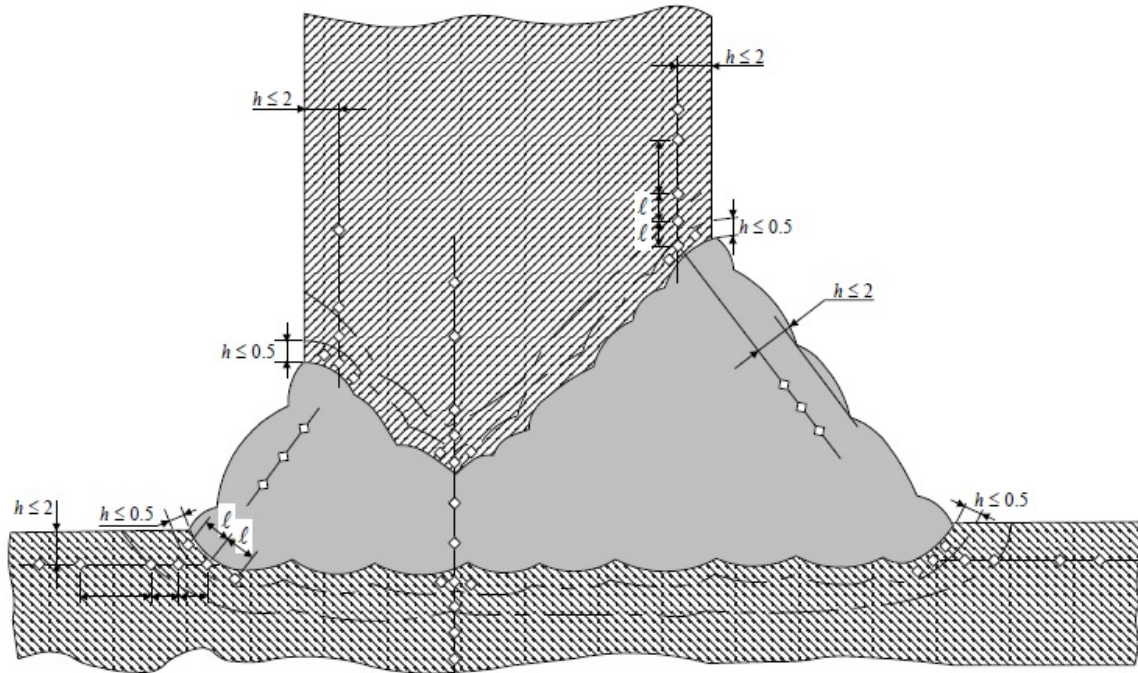


**FIGURE 4A**  
**Example Showing the Position of the Indentations for Hardness Test**  
**in the Weld Metal, the Heat Affected Zone and the Base Metal**  
**of a Fillet Weld (dimensions in mm) (1 July 2014)**



**Note:** Where the measurement at less than 0.5 mm of heat affected zone from fusion is impractical, the greater distance than 0.5 mm may be accepted.

**FIGURE 4B**  
**Example Showing the Position of the Indentations for Hardness Test on the Weld Metal, the Heat Affected Zone and the Base Metal of a T-Joint Weld (dimensions in mm) (1 July 2014)**



**Note:** Where the measurement at less than 0.5mm of heat affected zone from fusion is impractical, the greater distance than 0.5mm may be accepted.

# PART 2

## APPENDIX 9

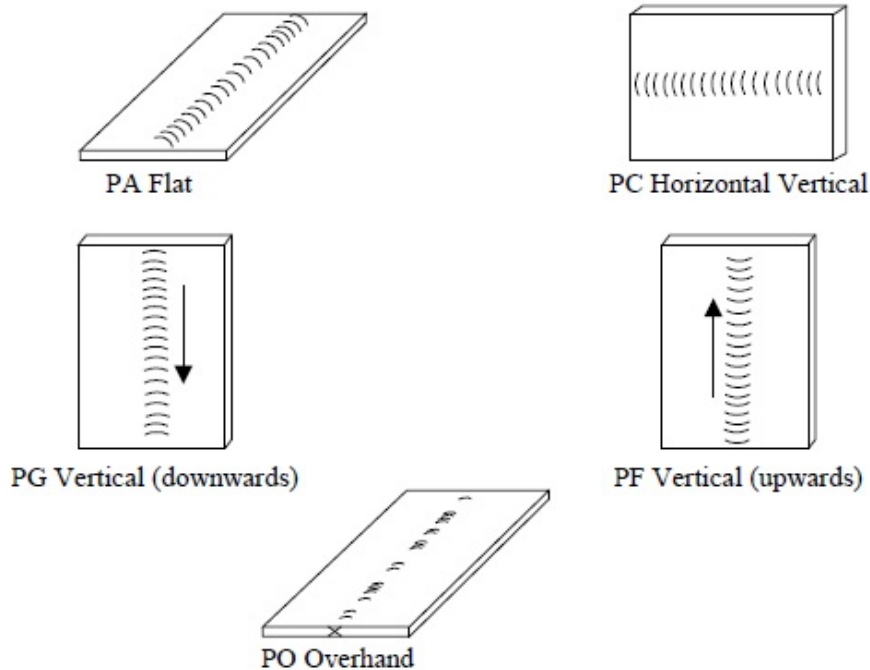
### Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

## ANNEX 3

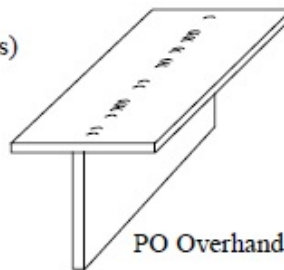
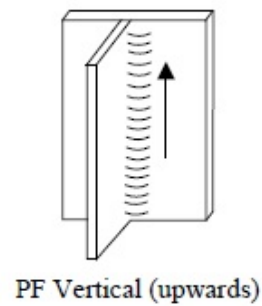
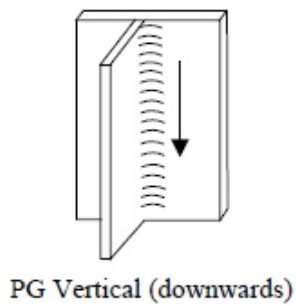
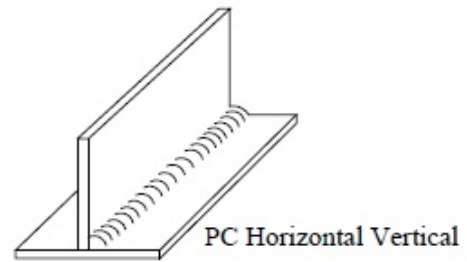
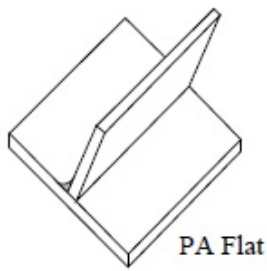
### Welding Positions

#### 1 Welding Positions According to ISO Standard

##### a) Butt Welds for Plates



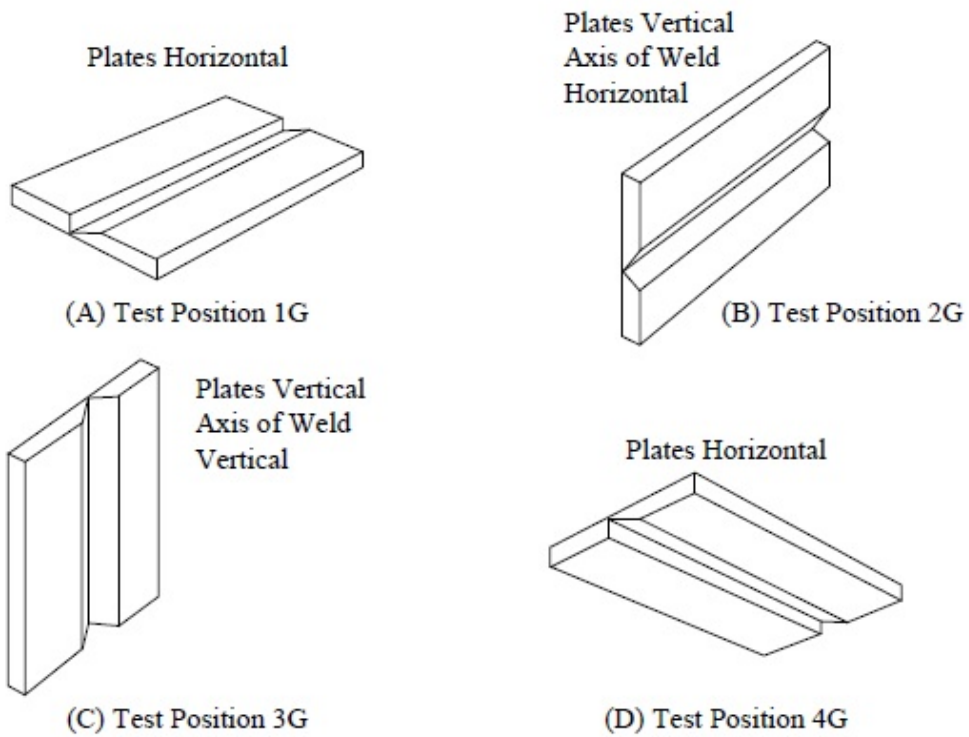
##### b) Fillet Welds for Plates



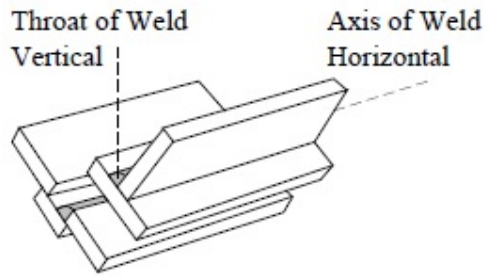
### 3 Welding Positions According to AWS-Code

#### a) Butt Welds for Plates

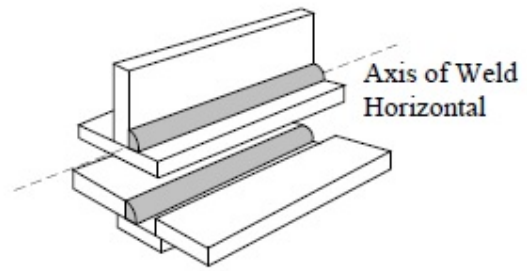




**b) Fillet Welds for Plates**

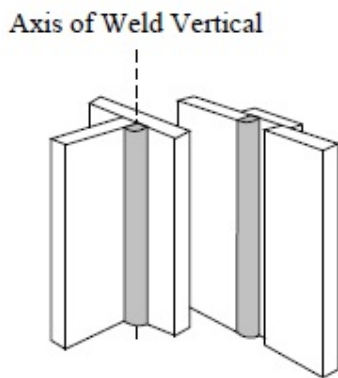


(A) Flat Position 1F

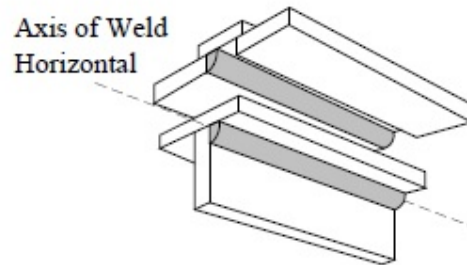


Note: One plate must be horizontal

(B) Horizontal Position 2F



(C) Vertical Position 3F



Note: One plate must be horizontal

(D) Overhead Position 4F



# PART 2

## APPENDIX 10

### Procedure for the Approval of Aluminum Manufacturers

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Scheme for the Approval of Aluminum Manufacturers.....</b>	<b>669</b>
	1	Scope (2013).....	669
	3	Approval Application.....	669
	3.1	Initial Approval.....	669
	3.3	Content of Application.....	669
	3.5	Information and Data Required for Approval.....	669
	3.7	Superior Properties.....	671
	3.9	ABS Activity in the Approval Process.....	671
	5	Renewal of Approval (2011).....	671

**Procedure for the Approval of Aluminum Manufacturers****SECTION 1****Scheme for the Approval of Aluminum Manufacturers****1 Scope (2013)**

In accordance with 2-5-1/1.3, this Appendix provides specific requirements for the approval of manufacturers of aluminum plate, sheet, extrusions, castings, and forgings. The manufacturer approval scheme is intended to certify the manufacturer's capability of furnishing satisfactory products in a consistent manner under effective process and production controls in operation.

**3 Approval Application****3.1 Initial Approval**

For consideration to produce ABS-certified aluminum alloy plate and sheet or extrusions, the manufacturer is to apply for approval of the process of manufacture by submitting information and supporting test data to ABS Houston Materials Department, or alternatively to the local Surveyor who attends the facility who is to include this information with the survey report.

**3.3 Content of Application**

The submittal is to be specific to the Alloy and Temper, product form, maximum thickness, melting practice, casting practice and heat treatment or special rolling or extrusion practice for which approval is sought. At the option of the facility, this submittal may be preceded by a proposed test program to assure that the appropriate testing is scheduled.

**3.5 Information and Data Required for Approval**

The following summarizes the minimum information and test data required for approval as well additional requirements for special alloys, claimed to exhibit superior properties.

**3.5.1 Production and Process Information**

- i)* Plant tonnage capacity
- ii)* Product type and grade
- iii)* Maximum thickness
- iv)* Melting, refining and pouring practices
  - Furnace type
  - Melting practice-including charges of metallics and slag

- Ladle additions
- Refining practice
- Pouring practice
- Reheating furnace equipment and practices
- Special rolling or extrusion practices
- Inspection practices
- Heat treatment equipment and procedure if applicable
- Nondestructive testing procedures

### 3.5.2 Test Data (2013)

- i)* Sketch showing locations of test coupons.
- ii)* Tension Test Specimen
  - At least two tension specimens from two different locations of the sample or from two samples are to be taken for each qualification testing
  - Rectangular full-thickness specimens for thickness of less than 12.5 mm (0.5 inch).
  - Round specimens for thicknesses of 12.5 mm (0.5 inch) and greater. For material thickness of 12.5 mm (0.5 inch) and up to 40 mm (1.5 inch), tensile specimens to be from mid-thickness or of full-section. For thickness over 40 mm (1.5 inch), two specimens are to be taken from  $\frac{1}{2}$  and  $\frac{1}{4}$  thickness.
- iii)* Tension Test Specimen Orientation
  - Nonheat-treatable Sheet/Plate - longitudinal
  - Heat-treatable Sheet/Plate - long-transverse
  - Heat-treatable Extrusion/Section - longitudinal
  - Forging - longitudinal (specimen axis parallel to grain flow direction)
- iv)* Tension Test Data
  - Yield Point (or Strength)
  - Ultimate Tensile Strength
  - Elongation
- v)* Chemical Analysis
  - Ladle and Product  
Fe, Si, Cu, Mn, Mg, Cr, Zn, Ti  
Plus any other intentionally added element
- vi)* Metallographic Examination
  - Photomicrographs – at surface,  $\frac{1}{4}$  thickness and mid-thickness locations
  - Microstructure – longitudinal at 100 $\times$  and 500 $\times$ , unetched and etched
  - Photomacrograph – etched  
Transverse from center width of slabs

Transverse from center width of plates

Full transverse section of shapes and bars

Rolled plate/sheet and extruded sections are to be tested for minimum and maximum approval thickness. The extent of testing for minimum thickness may be reduced to tensile test, photomicrograph examination and micrographic examination at mid-thickness if the test scope is accepted by ABS Materials Department.

Drift expansion test for extruded closed profiles are to be carried out as indicated in 2-5-8/5.3.

Corrosion testing for rolled 5xxx alloys in H116 and H321 tempers are to be carried out in accordance with G66 and G67 or equivalent standards satisfying the acceptance criteria as indicated in 2-5-6/3.

The photomicrographs and photomicrographs are considered acceptable if they are representative of metallurgically sound material.

### 3.7 Superior Properties

In the event that aluminum alloys which are claimed to exhibit superior properties are the subject of the approval, the additional test data for special alloys that are listed below will also be required as part of the test program.

#### Additional Test Data for Special Aluminum Alloys\*

<i>Test Data</i>	<i>Special Alloy</i>
Fracture Test	Specific Fracture Criterion
Weldability Test	Superior Weldability
Corrosion Tests – ASTM G 66 and G 67	Superior Corrosion Resistance
Ultrasonic Inspection	Superior Internal Quality

\* The alloy and temper designations should be denoted when reporting the data

### 3.9 ABS Activity in the Approval Process

<i>Topic</i>	<i>MMPS</i>	<i>Attending Surveyor</i>
Process/Production Information	Technical Review	Verification by Plant Survey
Proposed Test Program*	Technical Review	---
Material Test Data	Technical Review	Witness of Mechanical Testing**

\* Optional

\*\* Not necessary during production testing for manufacturing facilities participating in the ABS Quality Assurance Program

## 5 Renewal of Approval (2011)

The validity of the approval is to be to the maximum of five years, renewable subject to an audit and assessment of the result of satisfactory survey during the preceding period. The Surveyor's report confirming no process changes, along with chemical, mechanical, and corrosion, if applicable, property statistical data for various approved grades, is to be made available to the ABS Engineering/Materials department for review and issuance of renewal letter/certificate.

Manufacturers who have not produced the approved grades and products during the period preceding the renewal may be required to carry out approval tests, unless the results of production of similar grades of products during the period are evaluated by ABS and found acceptable for renewal.



# PART 2

## APPENDIX 11

### Qualification for Welders and Welding Operators

#### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General.....</b>	<b>676</b>
	1	.....	676
	3	.....	676
	5	.....	676
	7	.....	676
	9	.....	676
<b>SECTION</b>	<b>2</b>	<b>Welders Qualification for Hull Structures*.....</b>	<b>677</b>
	1	Scope.....	677
		1.1 .....	677
		1.3 .....	677
		1.5 .....	677
		1.7 .....	677
	3	General.....	678
		3.1 .....	678
		3.3 .....	678
		3.5 .....	678
		3.7 .....	678
	5	Range of Qualification of Welders.....	678
		5.1 .....	678
		5.3 .....	678
		5.5 .....	678
		5.7 .....	679
		5.9 .....	679
		5.11 .....	680
		5.13 .....	680
		5.15 .....	680
		5.17 .....	681
	7	Test Assemblies.....	681
		7.1 .....	681
		7.3 .....	681



	7.5	.....	682
	7.7	.....	682
	7.9	.....	682
9	Examination and Test.....		688
	9.1	Types of Tests.....	688
	9.3	Visual Examination.....	689
	9.5	Bend Test.....	689
	9.7	Radiographic Test.....	689
	9.9	Fracture Test (Butt Welds).....	689
	9.11	Fracture Test (Fillet Welds).....	690
	9.13	Macro Examination (Fillet Welds).....	690
11	Retest.....		690
	11.1	.....	690
	11.3	.....	690
13	Certification.....		690
	13.1	.....	690
	13.3	.....	690
	13.5	.....	691
	13.7	.....	691
15	Period of Validity of Initial Approval.....		691
	15.1	.....	691
	15.3	.....	691
	15.5	.....	691
17	Maintenance of the Approval.....		691
	17.1	.....	691
	17.3	.....	692
TABLE 1	Welding Processes for Welder's Qualification.....		679
TABLE 2	Types of Welded Joint for Welder's Qualification.....		680
TABLE 3	Plate Thicknesses for Welder's Qualification.....		680
TABLE 4	Qualified Welding Positions When Testing with Butt Welding 2-A11-2/7.9 FIGURE 1.....		681
TABLE 5	Qualified Welding Positions when Testing with Fillet Welding 2-A11-2/7.9 FIGURE 1.....		681
FIGURE 1	Welding Positions.....		683
FIGURE 2	Dimensions and Types of Test Assembly for Butt Welds (T < 12 mm (0.5 in.)).....		684
FIGURE 3	Dimensions and Types of Test Assembly for Butt Welds (T ≥ 12 mm (0.5 in.)).....		685
FIGURE 4	Dimensions and Types of Test Assembly for Fillet Welds..		686
FIGURE 5	Dimensions and Types of Test Assembly for Tack Butt Welds.....		687

FIGURE 6	Dimensions and Types of Test Assembly for Tack Fillet Welds.....	688
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<b>SECTION</b>	<b>3</b>	<b>Welding Operators Qualification.....</b>	<b>693</b>
	1	.....	693
	3	.....	693
	5	.....	693
	7	.....	693
<b>SECTION</b>	<b>4</b>	<b>Certification Process.....</b>	<b>694</b>
	1	.....	694
	3	.....	694
<b>ANNEX</b>	<b>1</b>	<b>Example of Welder’s Qualification Certificate.....</b>	<b>695</b>

# PART 2

## APPENDIX 11

### Qualification for Welders and Welding Operators

#### SECTION 1

#### General (1 July 2018)

#### 1

The general guidelines and requirements defined in the *ABS Rules for Materials and Welding (Part 2)* are to be applied. This Appendix covers the qualification for welders and welding operators for structural welding of marine and offshore vessels.

#### 3

These requirements apply to ABS's acceptance of welders and welding operators for welding of steel and non-ferrous metals.

#### 5

This Appendix specifies the requirements for welder and operator qualifications including:

- Ship hull structure and other ship structure
- Offshore hull and other offshore structure

#### 7

The training of welders and welding operators, control of their qualification, and maintenance of their skills are the responsibility of the builders and subcontractors. When requested, these are to be documented and demonstrated to the satisfaction of ABS.

#### 9

The certified welders and welding operators are to be recorded by builders and subcontractors with welders' training, as well as date and documents of qualification tests. The qualification documents are to include the information about the base metal, type of welding consumable, welding process, type of welded joint, material thickness, welding position, and destructive and nondestructive test results. One example is shown in 2-A11-A1.

*Note:* This Appendix specifies an alternative welder qualification process per 2-4-3/11.3.

## 1 Scope

### 1.1

The general requirements for weld tests defined in Section 2-4-3 are to be applied.

### 1.3

This Section gives requirements for a qualification scheme for welders intended to be engaged in the fusion welding of steels for hull structures as specified in the *ABS Rules for Materials and Welding (Part 2)* as follows:

- Section 2-1-2: Ordinary-Strength Hull Structural Steel
- Section 2-1-3: Higher-Strength Hull Structural Steel
- Section 2-1-5: Hull Steel Castings
- Section 2-1-6: Hull Steel Forgings
- Section 2-1-7: Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks
- Section 2-1-8: Extra High Strength Steels

and other steels, at the discretion of ABS, such as:

- H47 and H36/H40/H47 BCA (Brittle Crack Arrest) Steel.

### 1.5

This qualification scheme does not cover welders engaged in oxy-acetylene welding.

### 1.7

This qualification scheme does not cover welding of pipes or structural tubulars.

### 3 General

#### 3.1

Those welders intended to be engaged in welding of hull structures in shipyards, manufacturers, and subcontractor are to be tested and qualified in accordance with this scheme and issued with a qualification certificate endorsed by ABS.

#### 3.3

This Appendix is applicable to welding of hull structures during new construction, conversion, and the repair of vessels or offshore structures.

#### 3.5

Welders or welding operators qualified in accordance with recognized national or international welder qualification standards may also be engaged in welding of hull structures at the discretion of ABS, provided that the qualification testing, range of approval, and revalidation requirements are considered to meet the technical intent of this Section.

#### 3.7

If the production weld has restricted access the ABS Surveyor is to verify the welder has the necessary skill to achieve a satisfactory production weld under the anticipated production conditions.

### 5 Range of Qualification of Welders

#### 5.1

A welder is to be qualified in relation to the following variables:

- i)* Base metal
- ii)* Welding consumables type
- iii)* Welding process
- iv)* Type of welded joint
- v)* Plate thickness
- vi)* Welding position

#### 5.3

In case of steels, base metals for qualification of welders or welding operators are divided into two groups. Steels with a specified minimum yield strength  $ReH \leq 460 \text{ N/mm}^2$  (67 ksi) are considered Group 1. Steels with a specified minimum yield strength  $460 (67) < ReH \leq 690 \text{ N/mm}^2$  (100 ksi) are considered Group 2. Welding of any one metal in a group covers qualification of the welder or welding operator within the group.

Steels with a specified minimum yield strength  $ReH > 690 \text{ N/mm}^2$  (100 ksi) are to be specially considered.

Depending upon the welders experience and level of skill, additional qualification test may be required, at the discretion of the ABS Surveyor, if the welder is only qualified in welding ordinary strength steel and is required to weld higher strength grades.

#### 5.5

For Shielded/Manual metal arc welding, qualification tests are required using basic, acid or rutile covered electrodes. Basic (B) electrode covers basic (B), acid (A) and rutile (R) electrodes. Acid (A) or rutile (R)

electrode covers acid (A) and rutile (R) electrodes. The type of covered electrodes (basic, acid or rutile) included in the range of approval is at the discretion of ABS.

Welding with filler material qualifies for welding without filler material, but not vice versa.

## 5.7

The welding processes for welder’s qualification are classified in 2-A11-2/5.7 TABLE 1 as:

- M –Manual welding
- S – Semi-automatic welding/partly mechanized welding
- T – Gas Tungsten arc welding (GTAW) or Tungsten inert gas (TIG) welding

Each testing normally qualifies only for one welding process. A change of welding process requires a new qualification test.

For automatic welding (e.g., SAW), see Section 2-A11-3 for Welding Operators Qualification.

**TABLE 1**  
**Welding Processes for Welder’s Qualification (1 July 2018)**

<i>Symbol</i>	<i>Welding Process in Actual Welding Works</i>		<i>ISO 4063</i>
<b>M</b>	Manual welding	Shielded/Manual metal arc welding (metal arc welding with covered electrode)	111
<b>S</b>	Partly mechanized welding	Gas metal arc welding (GMAW)	131
		Metal active gas (MAG) welding Flux cored arc welding (FCAW)	135, 138 <sup>(1)</sup> 136 <sup>(2)</sup>
<b>T</b>	TIG welding	Gas Tungsten arc welding (GTAW)	141

**Notes:**

ABS may require separate qualification for solid wires, metal-cored wires and flux-cored wires as follows:

- 1) A change from MAG welding with solid wires (135) to that with metal cored wires (138), or vice versa is permitted.
- 2) A change from a solid or metal cored wire (135/138) to a flux cored wire (136) or vice versa requires a new welder qualification test.

## 5.9

The types of welded joint for welder’s qualification are to be classified as shown in 2-A11-2/5.9 TABLE 2 in accordance with the qualification test. Welders engaged in full/partial penetration T welds are to be qualified for butt welds for the welding process and the position corresponding to the joints to be welded.

**TABLE 2**  
**Types of Welded Joint for Welder’s Qualification (1 July 2018)**

<i>Type of Welded Joint Used in the Test Assembly for the Qualification Test</i>				<i>Type of Welded Joint Qualified</i>
Butt weld	Single sided weld	With backing	A	A, C, F
		Without backing	B	A, B, C, D, F
	Double sided weld	With gouging	C	A, C, F
		Without gouging	D	A, C, D, F
Fillet weld	----	----	F	F

**5.11**

For fillet welding, welders who passed the qualification tests for multi-layer technique welding can be deemed as qualified for single-layer technique, but not vice versa.

**5.13**

The qualified plate thickness range arising from the welder qualification test plate thickness is shown in 2-A11-2/5.13 TABLE 3.

**TABLE 3**  
**Plate Thicknesses for Welder’s Qualification (1 July 2018)**

<i>Thickness of Test Assembly</i> <i>T</i>		<i>Qualified Plate Thickness Range</i> <i>t</i>	
<i>mm</i>	<i>in.</i>	<i>mm</i>	<i>in.</i>
$T < 3$	$T < 0.12$	$T \leq t \leq 2T$	$T \leq t \leq 2T$
$3 \leq T < 12$	$0.12 \leq T < 0.47$	$3 \leq t \leq 2T$	$0.12 \leq t \leq 2T$
$12 \leq T$	$0.47 \leq T$	$3 \leq t$	$0.12 \leq t$

**5.15**

The welding positions qualified as a result of the actual welding position used in a satisfactory welder’s qualification test, are shown in 2-A11-2/5.15 TABLE 4 and 2-A11-2/5.15 TABLE 5. Diagrams showing the definitions of weld position used in 2-A11-2/5.15 TABLE 4 and 2-A11-2/5.15 TABLE 5 are shown in 2-A11-2/7.9 FIGURE 1.

ABS may require a qualification test with fillet welding for welders who are employed to perform fillet welding only.

**TABLE 4**  
**Qualified Welding Positions When Testing with Butt Welding 2-A11-2/7.9**  
**FIGURE 1 (1 July 2018)**

<i>Qualification Test Position with Butt Weld</i>	<i>Qualified Welding Positions in Actual Welding Works</i>	
	<i>Butt Welds</i>	<i>Fillet Welds</i>
PA-Flat (1G)	1G, PA	1F, 2F, PA, PB
PC-Horizontal (2G)	1G, 2G, PA, PC	1F, 2F, PA, PB, PC
PE-Overhead (4G)	1G, 2G, 4G, PA, PC, PE	1F, 2F, 4F, PA, PB, PC, PD, PE
PF-Vertical upwards (3G)	1G, 3G Up, PA, PF	1F, 2F, 3F Up, PA, PB, PF
PG-Vertical downwards (3G)	3G Down, PG	3F Down, PG

**TABLE 5**  
**Qualified Welding Positions when Testing with Fillet Welding 2-A11-2/7.9**  
**FIGURE 1 (1 July 2018)**

<i>Qualification Test Position with Fillet Weld</i>	<i>Qualified Welding Positions in Actual Welding Works</i>
	<i>Fillet Welds</i>
PA-Flat (1F)	1F, PA
PB-Horizontal vertical (2F)	1F, 2F, PA, PB
PC-Horizontal	1F, 2F, PA, PB, PC
PD-Horizontal overhead (4F)	1F, 2F, 4F, PA, PB, PC, PD, PE
PE-Overhead	1F, 2F, 4F, PA, PB, PC, PD, PE
PF-Vertical upwards (3F Up)	1F, 2F, 3F Up, PA, PB, PF
PG-Vertical downwards (3F Down)	3F Down, PG

### 5.17

A welder qualified for butt or fillet welding can be engaged in tack welding for the welding process and position corresponding to those permitted in his certificate.

Alternatively, welders engaged in tack welding only can be qualified on the test assemblies shown in 2-A11-2/7.9 FIGURE 5 or 2-A11-2/7.9 FIGURE 6.

## 7 Test Assemblies

### 7.1

Welding of the test assemblies is to be witnessed by the Surveyor. Test assemblies for butt welds and for fillet welds are to be prepared as shown in 2-A11-2/7.9 FIGURE 2, 2-A11-2/7.9 FIGURE 3 and 2-A11-2/7.9 FIGURE 4 in each qualification test.

### 7.3

Test assemblies for butt tack welds and for fillet tack welds are to be prepared as shown in 2-A11-2/7.9 FIGURE 5 and 2-A11-2/7.9 FIGURE 6.



## 7.5

Testing materials and welding consumables are to conform to one of the following requirements or to be of equivalent grade approved by ABS:

### 7.5.1 Testing Materials

- Section 2-1-2: Ordinary-Strength Hull Structural Steel
- Section 2-1-3: Higher-Strength Hull Structural Steel
- Section 2-1-5: Hull Steel Castings
- Section 2-1-6: Hull Steel Forgings
- Section 2-1-7: Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks
- Section 2-1-8: Extra High Strength Steels

and other steels, at the discretion of ABS, such as:

- H47 and H36/H40/H47 BCA (Brittle Crack Arrest) Steel.

### 7.5.2 Welding Consumables

- Consumables for hull structural steels specified in Part 2, Appendix 2 and Part 2, Appendix 3, or
- Other consumables, such as for BCA steels, at the discretion of ABS.

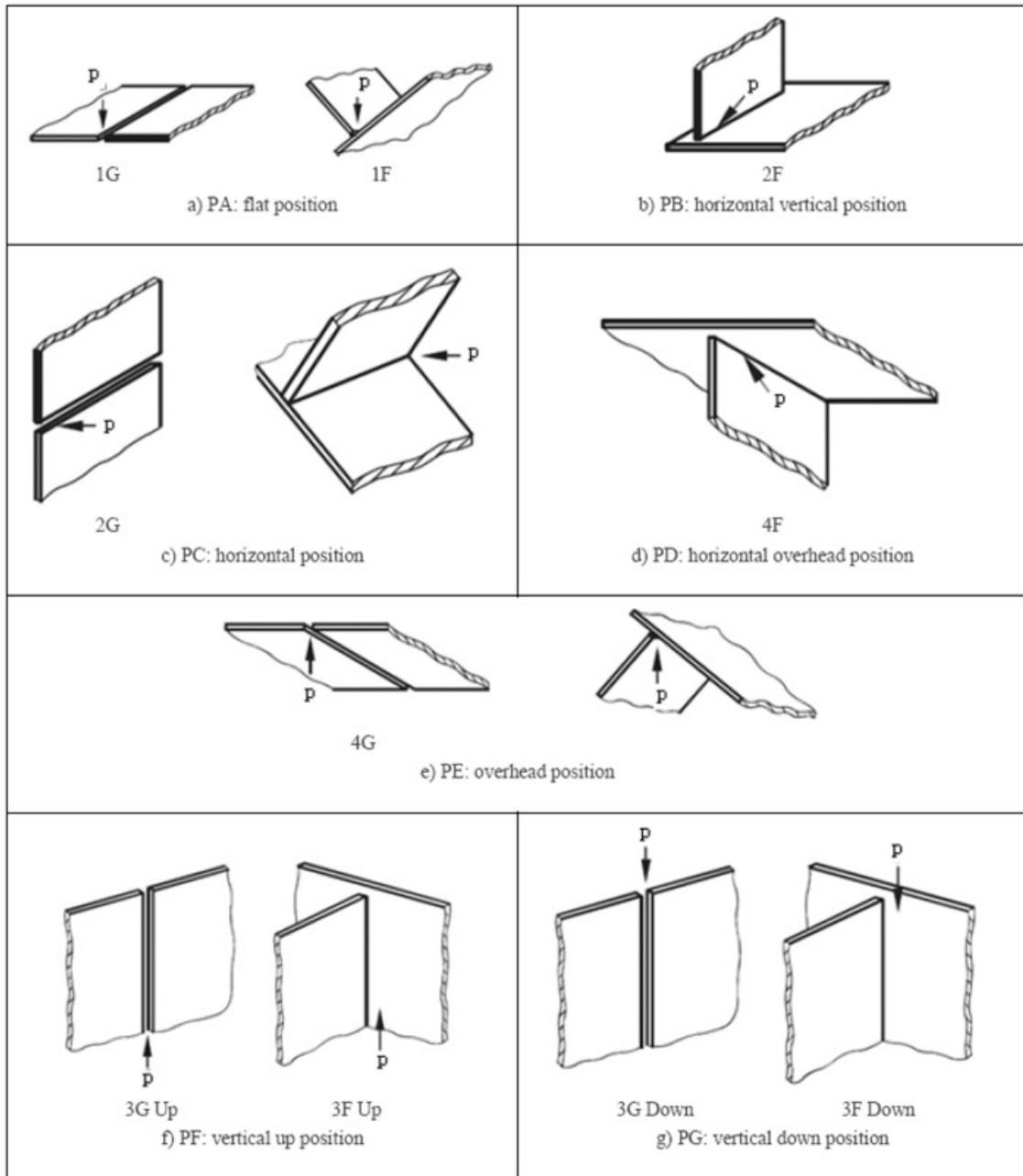
## 7.7

The welder qualification test assembly is to be welded according to a welding procedure specification (WPS or pWPS).

## 7.9

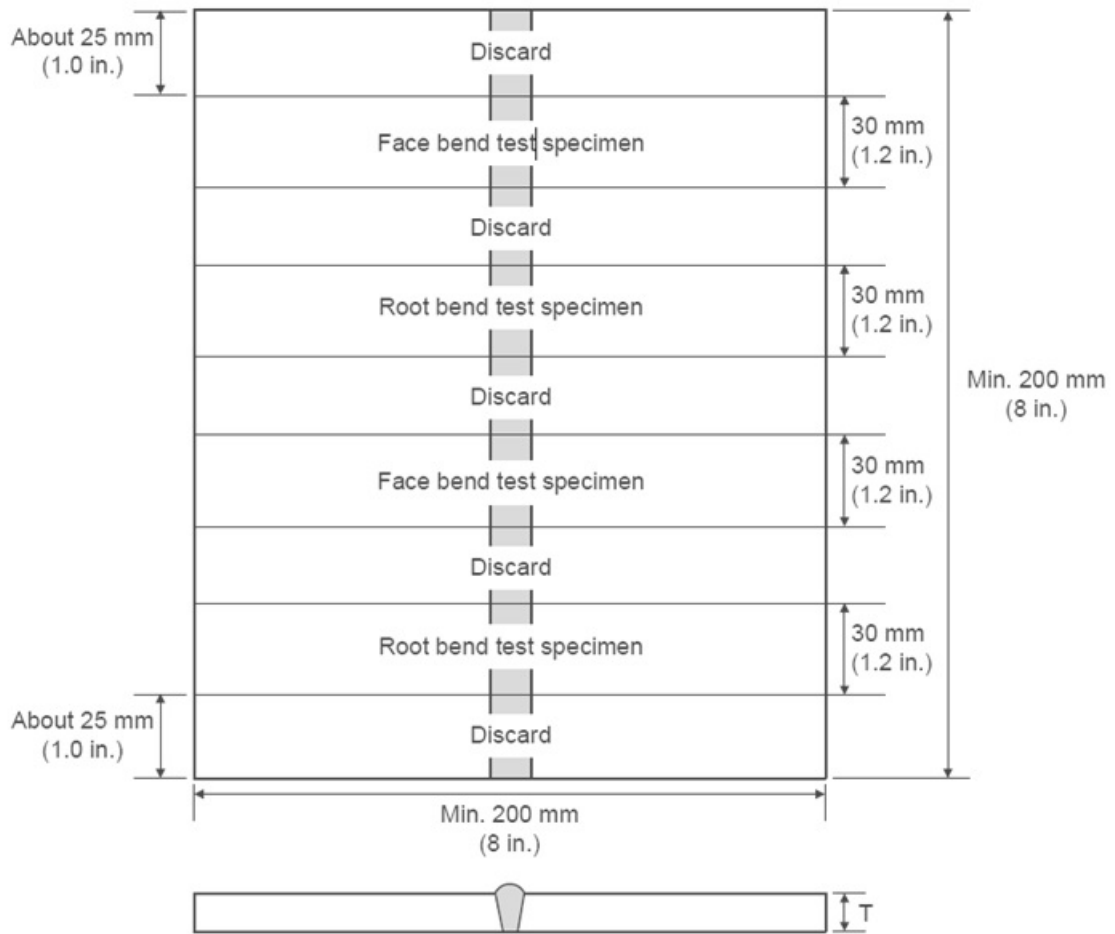
Root run and capping run are each to have a minimum of one stop and restart. The welders are allowed to remove minor imperfections in the stop by grinding before restarting welding.

**FIGURE 1**  
**Welding Positions (1 July 2018)**



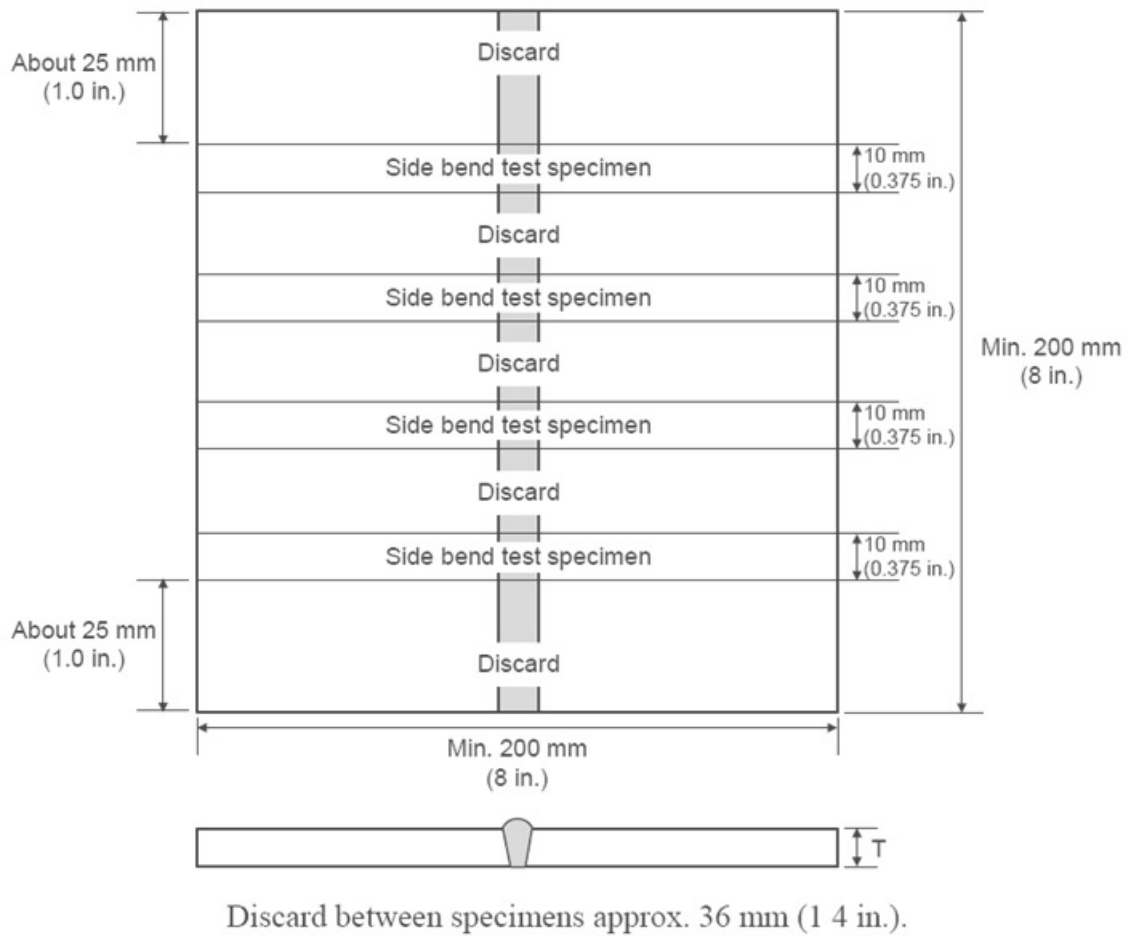
Note: *p* is the welding position.

**FIGURE 2**  
**Dimensions and Types of Test Assembly for Butt Welds (T < 12 mm (0.5 in.))**  
 (1 July 2018)

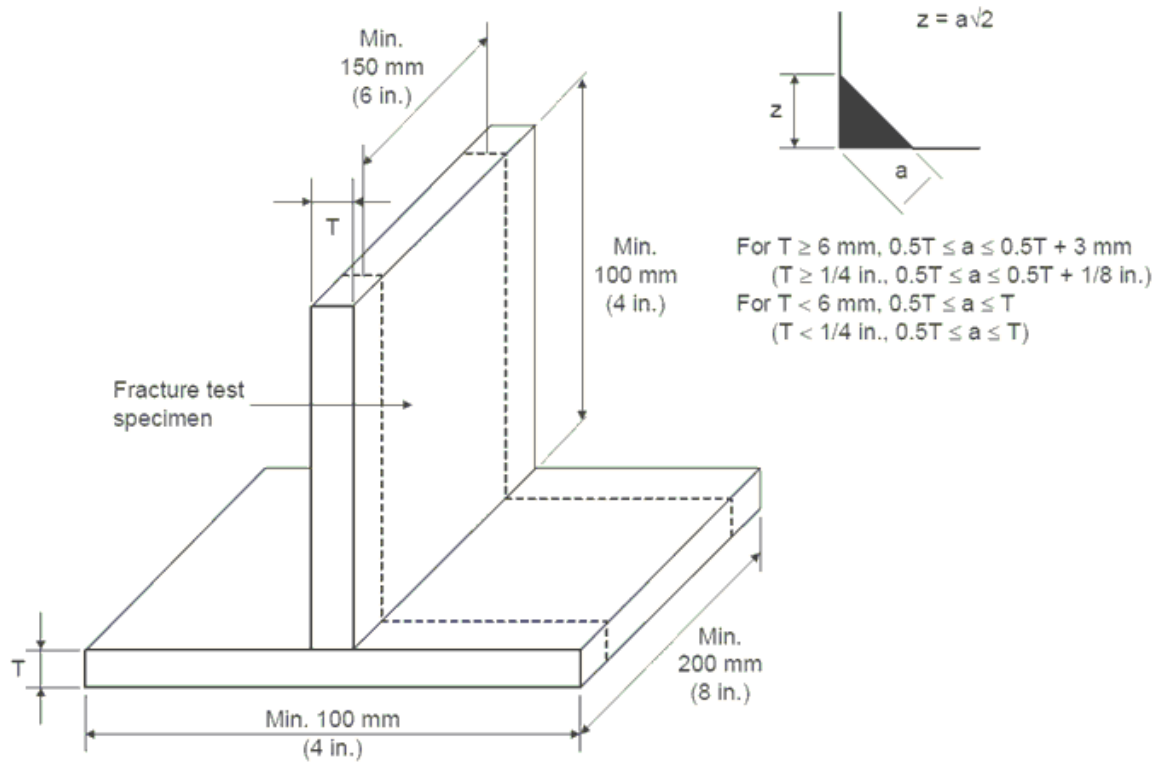


Discard between specimens approx. 10 mm (0.375 in.).

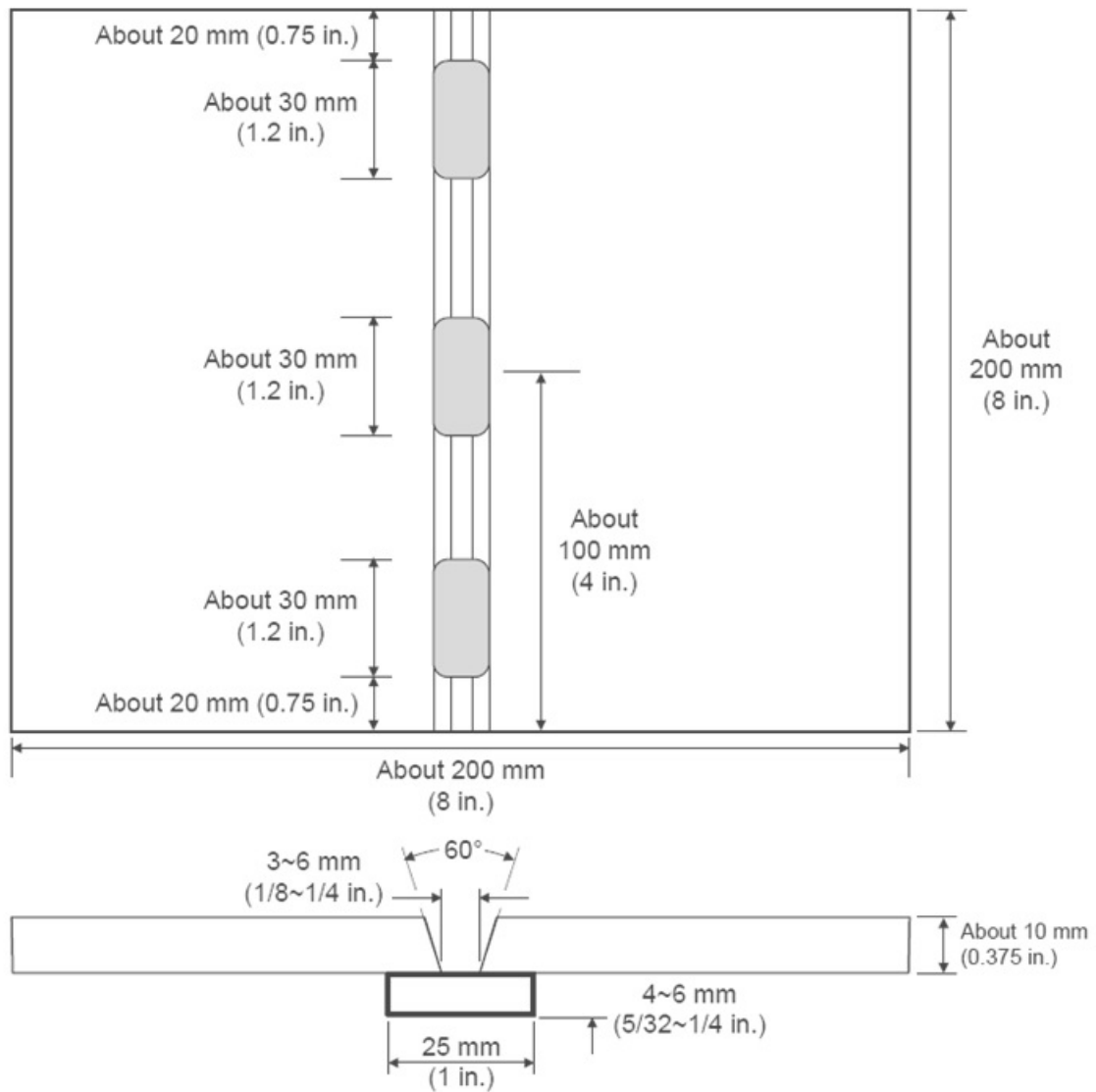
**FIGURE 3**  
**Dimensions and Types of Test Assembly for Butt Welds ( $T \geq 12$  mm (0.5 in.))**  
 (1 July 2018)



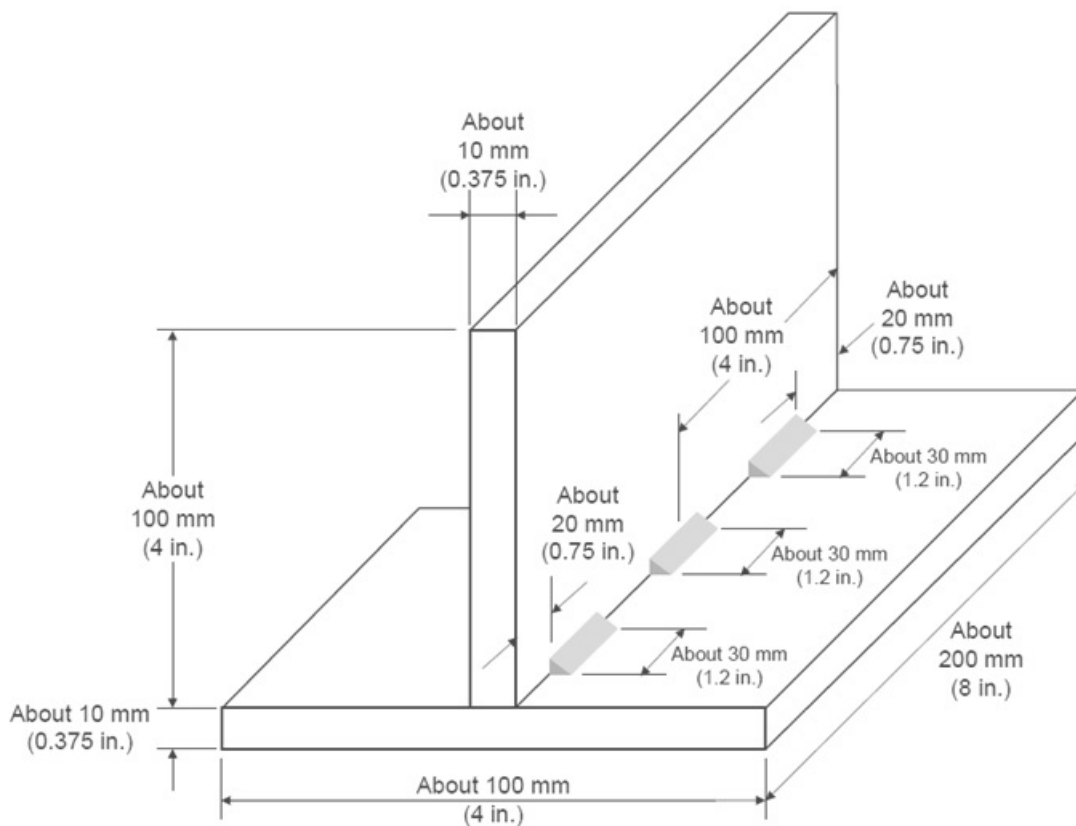
**FIGURE 4**  
**Dimensions and Types of Test Assembly for Fillet Welds (1 July 2018)**



**FIGURE 5**  
**Dimensions and Types of Test Assembly for Tack Butt Welds (1 July 2018)**



**FIGURE 6**  
**Dimensions and Types of Test Assembly for Tack Fillet Welds (1 July 2018)**



## 9 Examination and Test

### 9.1 Types of Tests

Testing of test specimens is to be witnessed by the Surveyor. The test assemblies specified in 2-A11-2/7.3 are to be examined and tested as follows:

*i)* For butt welds:

- Visual examination
- Bend test

*Note:*

Radiography can be used to qualify the welder, except for GMAW with short circuit transfer technique for which bend tests are required.

*ii)* For fillet welds:

- Visual examination
- Fracture test

*Note:*

Two macro sections may be taken in lieu of the fracture test.

*iii)* For tack welds:

- Visual examination
- Fracture test

### 9.3 Visual Examination

The welds are to be visually examined prior to the cutting of the test specimen for the bend test and fracture test. The result of the examination is to show the absence of cracks or other serious imperfections.

Imperfections detected are to be assessed in accordance with quality level B in ISO 5817, except for the following imperfection types for which level C applies:

- Excess weld metal
- Excess penetration
- Excessive convexity
- Excessive throat thickness

### 9.5 Bend Test

Transverse bend test specimens are to be in accordance with 2-4-3/11.5 FIGURE 5.

The mandrel diameter to thickness ratio (i.e.,  $D/T$ ) is to be as follows,

Ordinary Strength	Four times the thickness of the specimen
Y and Y400	Four times the thickness of the specimen
YQ420, YQ460 & YQ500	Five times the thickness of the specimen
YQ550, YQ620 & YQ690	Six times the thickness of the specimen.

For normal and high strength steels, forgings, and castings, the test specimens are to be bent on a mandrel with diameter  $4t$ , where  $t$  is the thickness of the specimen. For extra high strength steels with H47 grade, the mandrel diameter is to be  $5t$ .

Two face bend test and two root bend test specimens are to be tested for initial qualification test, and one face and one root bend test specimens for extension of approval. For thickness 12 mm (0.5 in.) and over, four side specimens (two side specimens for extension of approval) with 10 mm (0.375 in.) in thickness may be tested as an alternative.

At least one bend test specimen is to include one stop and restart in the bending part, for root run or for cap run.

The test specimens are to be bent through 180 degrees shown in 2-4-3/11.5 FIGURE 7. After the test, the test specimens are not to reveal any open defects in any direction greater than 3 mm (0.125 in.). Defects appearing at the corners of a test specimen during testing are to be investigated on a case-by-case basis.

### 9.7 Radiographic Test

When radiographic testing is used for butt welds, imperfections detected are to be assessed in accordance with ISO 5817, level B.

### 9.9 Fracture Test (Butt Welds)

When fracture test is used for butt welds, full test specimen in length is to be tested in accordance with ISO 9017. Imperfections detected are to be assessed in accordance with ISO 5817, level B.



### 9.11 Fracture Test (Fillet Welds)

The fracture test is to be performed by folding the upright plate onto the through plate.

Evaluation is to concentrate on cracks, porosity and pores, inclusions, lack of fusion, and incomplete penetration. Imperfections that are detected are to be assessed in accordance with ISO 5817, level B.

### 9.13 Macro Examination (Fillet Welds)

When macro examination is used for fillet welds, two test specimens are to be prepared from different cutting positions. At least one macro examination specimen is to be cut at the position of one stop and restart in either root run or cap run. These specimens are to be etched on one side to clearly reveal the weld metal, fusion line, root penetration, and the heat affected zone.

Macro sections are to include at least 10 mm (0.375 in.) of unaffected base metal.

The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal, sufficient root penetration, and the absence of defects such as cracks, lack of fusion, etc.

## 11 Retest

### 11.1

When a welder fails a qualification test, the following is to apply.

*i)* In cases where the welder fails to meet the requirements in part of the tests, a retest may be welded immediately, consisting of another test assembly of each type of welded joint and position that the welder failed. In this case, the test is to be done for duplicate test specimens of each failed test.

All retest specimens are to meet all of the specified requirements.

*ii)* In cases where the welder fails to meet the requirements in all parts of the required tests or in the retest, the welder is to undertake further training and practice.

*iii)* When there is specific reason to question the welder's ability or the period of effectiveness has lapsed, the welder is to be requalified.

### 11.3

Where any test specimen does not comply with dimensional specifications due to poor machining, a replacement test assembly is to be welded and tested.

## 13 Certification

### 13.1

Qualification certificates are normally issued when the welder has passed the qualification test by ABS. Each Shipyard, Manufacturer and Subcontractor is to be responsible for the control of the validity of the certificate and the range of the approval.

### 13.3

The following items are to be specified in the certificate:

- i)* Range of qualification for base metal, welding processes, filler metal type, types of welded joint, plate thicknesses, and welding positions
- ii)* Expiry date of the validity of the qualification
- iii)* Name, identification, and the photograph of the welder
- iv)* Name of shipbuilder/manufacturer/subcontractor

### 13.5

When a certificate is issued, the relative documents such as test reports and/or re-validation records are to be archived as annexes to the copy of the certificate according to the ABS Rules.

### 13.7

The status of approvals of each individual qualification is to be demonstrated to ABS when requested.

## 15 Period of Validity of Initial Approval

### 15.1

Normally, the validity of the welder's approval begins from the issue date of qualification certificate when all the required tests are satisfactorily completed.

### 15.3

The validity is to be confirmed at six-month intervals by the shipyards, manufacturers, or subcontractor personnel who are responsible for production weld quality, provided that all the following conditions are fulfilled to the satisfaction of the attending Surveyor:

- i)* The welder has been engaged with reasonable continuity on welding work containing the current range of approval without interruption longer than six months.
- ii)* The welder's work is in general to be in accordance with the technical conditions under which the approval test is carried out.
- iii)* There is to be no specific reason to question the welder's skill and knowledge.

### 15.5

If any of these conditions are not fulfilled, ABS is to be informed and the certificate is to be withdrawn.

The validity of the certificate may be maintained in agreement with ABS as specified in 2-A11-2/17. The maintenance scheme of qualification is in accordance with 2-A11-2/17.1.i, 2-A11-2/17.1.ii or 2-A11-2/17.1.iii.

## 17 Maintenance of the Approval

### 17.1

Revalidation is to be carried out by ABS. The skill of the welder is to be periodically verified by one of the following to the satisfaction of the attending Surveyor:

- i)* The welder is to be tested every three years.
- ii)* Every two years, two welds made during the last six months of the two years' validity period are to be tested by radiographic or ultrasonic testing or destructive testing and are to be recorded. The weld tested is to reproduce the initial test conditions except for the thickness. These tests revalidate the welder's qualifications for an additional two years.
- iii)* The manufacturer is to maintain the qualification and revalidation per the practice of AWS D1.1, or equivalent standards, refer to 2-A11-2/3.5 of this Appendix.
  - The welder has been engaged with reasonable continuity on welding work containing the essential welding variables without interruption longer than six months.

The manufacturer's quality program is to be verified in accordance with ISO 3834-2, 3834-3 or equivalent requirement.

### 17.3

ABS or the builder, manufacturer, or subcontractor is to verify compliance with the above conditions and sign the maintenance of the welder's qualification certificate.

**Qualification for Welders and Welding Operators****SECTION 3****Welding Operators Qualification (1 July 2018)****1**

The welding operator responsible for setting up and/or adjustment of fully mechanized and automatic equipment, such as submerged arc welding, gravity welding, electro-gas welding, and MAG welding with auto-carriage, etc., must be qualified.

**3**

ISO 14732 can be referred as the qualification test and approval range for the welding operator. At the discretion of ABS, the records for welder operator are to give the evidence with adequate regular training to set up, program, and operate welding equipment in accordance with the applicable WPS (welding procedure specification).

**5**

In addition to the above requirements, the welding operator qualification is to include, but not limited to, the following training and skills for:

- i)* Groove dimension
- ii)* Groove cleanliness
- iii)* Weather and wind
- iv)* Storing and handling of welding consumables

**7**

Appropriate records are to be maintained by shipbuilder, manufacturer, or subcontractor and are to be provided at the Surveyor's request.

At the discretion of ABS, the alternative welder operator certificate maybe accepted, per the applicable standards such as ISO 14732, AWS D1.1, ASME IX, or equivalent standards.

# PART 2

## APPENDIX 11

### Qualification for Welders and Welding Operators

#### SECTION 4

#### Certification Process (1 July 2018)

**1**

Test assemblies welding and testing are to be witnessed by the Surveyor. On the client's request, ABS will certify the welder after the welder passes the qualification tests.

**3**

At the discretion of ABS, a welder or operator certified by other classification society or independent organization can be evaluated and accepted on a case-by-case basis. ABS reserves the right to re-validate, which may include testing prior to production, additional NDT and/or welding production tests may be required.

# PART 2

## APPENDIX 11

### Qualification for Welders and Welding Operators

#### ANNEX 1

#### Example of Welder's Qualification Certificate (1 July 2018)

#### WELDER'S QUALIFICATION CERTIFICATE

Welder's name:		Photograph
Cert. No:		
Identification No.		
Employer's name and address		
WPS/pWPS No.		
Date of initial approval		

This is to certify that the welder has passed the qualification test [/and re-validation record audit] according to the rules of ABS, and is qualified to undertake welding operation specified in range of qualification of this certificate.

Items	Test piece	Range of qualification
Welding process		
Base metal		
Filler metal type		
Plate thickness		
Type of welded joint		
Welding position		
Other details		

This certificate is issued at [place], and valid until [DD/MM/YYYY].

Signature/seal of examiner: Issued on [DD/MM/YYYY].

	Report No. to be reviewed	Date of report	Signature of Employee	Date of signature
1				
2				

3				
4				
5				
6				

**TEST RECORD**

<i>Type of test</i>	<i>Performed and accepted</i>	<i>Not required</i>
Visual examination		
Radiographic examination		
Surface examination		
Macro examination		
Fracture test		
Bend test		
Additional tests		

\* At the discretion of ABS, this page can be as the back page of a certificate, and also can be as a separate file.



# PART 2

## APPENDIX 12

### Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules

#### CONTENTS

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SECTION	1	Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules.....	698
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## **PART 2**

### **APPENDIX 12**

#### **Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules**

### **SECTION 1**

#### **Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules**

**Rules for Materials and Welding**

Part	2	Materials and Welding	
Appendix	12	Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules	
Section	1	Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules	2-A12-1

<i>Existing Materials</i>		<i>Title</i>	<i>Materials 2018</i>
Part	2	Rules for Materials and Welding	
Chapter	1	Materials for Hull Construction	
		Chapter 1 is unchanged.	
Part	2	Rules for Materials and Welding	
Chapter	2	Equipment	
		Chapter 2 is unchanged.	
Part	2	Rules for Materials and Welding	
Chapter	3	Materials for Machinery, Boilers, Pressure Vessels, and Piping	
		Chapter 3 is unchanged.	
Part	2	Rules for Materials and Welding	
Chapter	4	Welding and Fabrication	
		Chapter 4, Sections 1 through 4 are unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	1	List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying	
		Appendix 1 is unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	2	Requirements for the Approval of Filler Metals	
		Appendix 2, Sections 1 through 4 are unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	3	Application of Filler Metals to ABS Steels	
		Appendix 3 is unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	4	Procedure for the Approval of Manufacturers of Hull Structural Steel	
		Appendix 4 is unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	5	Procedure for the Approval of Manufacturers of Hull Structural Steels Intended for Welding with High Heat Input	
		Appendix 5 is unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	6	Nondestructive Examination of Marine Steel Castings	
		Appendix 6 is unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	7	Nondestructive Examination of Hull and Machinery Steel Forgings	
		Appendix 7 is unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	8	Additional Approval Procedure for Steel with Enhanced Corrosion Resistance Properties	
		Appendix 8 is unchanged.	
Part	2	Rules for Materials and Welding	
Appendix	9	Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures	
		Appendix 9 is unchanged.	

Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)

<b>Part</b>	<b>2</b>	<b>Materials and Welding</b>	
<b>Appendix</b>	<b>12</b>	<b>Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules</b>	
<b>Section</b>	<b>1</b>	<b>Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules</b>	<b>2-A12-1</b>

<i>AI &amp; FRP 2016</i>	<i>Title</i>	<i>Materials 2017</i>
<b>Part 2</b>	<b>Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)</b>	
<b>Chapter 5</b>	<b>Materials for Hull Construction – Aluminum</b>	
	Chapter 5, Sections 1 through 11 are unchanged.	
<b>Part 2</b>	<b>Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)</b>	
<b>Chapter 5</b>	<b>Materials for Hull Construction – Aluminum</b>	
<b>Appendix 1</b>	<b>Aluminum Welding in Hull Construction</b>	
2-5-A1	Aluminum Welding in Hull Construction	2-4-5
2-5-A1/1	General	2-4-5/1
2-5-A1/1.1	Hull Welding	2-4-5/1.1
2-5-A1/1.3	Plans and Specifications	2-4-5/1.3
2-5-A1/1.5	Workmanship and Supervision	2-4-5/1.5
2-5-A1/1.7	Welding Procedures	2-4-5/1.7
2-5-A1/3	Preparation for Welding	2-4-5/3
2-5-A1/3.1	Edge Preparation and Fitting	2-4-5/3.1
2-5-A1/3.3	Alignment	2-4-5/3.3
2-5-A1/3.3.1	Plate Alignment Tolerances	2-4-5/3.3.1
2-5-A1/3.3.1(a)	Butt Welds	2-4-5/3.3.1(a)
2-5-A1/3.3.1(b)	Fillet Welds	2-4-5/3.3.1(b)
2-5-A1/3.3.1(b)i)	Buttering and Buildup	2-4-5/3.3.1(b)i)
2-5-A1/3.3.1(b)ii)	Make-up Plates	2-4-5/3.3.1(b)ii)
2-5-A1/3.3.1(b)iii)	Access and Closure Plates	2-4-5/3.3.1(b)iii)
2-5-A1/Figure 1A	Inserts and Patches in Plating	2-4-5/Figure 1A
2-5-A1/Figure 1B	Inserts and Patches in Plating	2-4-5/Figure 1B
2-5-A1/3.5	Cleanliness	2-4-5/3.5
2-5-A1/3.7	Tack Welds	2-4-5/3.7
2-5-A1/3.9	Stud Welding	2-4-5/3.9
2-5-A1/3.11	Temporary Back-up Plates and Tapes	2-4-5/3.11
2-5-A1/3.13	Run-on and Run-off Tabs	2-4-5/3.13
2-5-A1/3.15	Forming	2-4-5/3.15
2-5-A1/Table 1	Minimum Cold-forming Radii for Aluminum Alloys	2-4-5/Table 1
2-5-A1/5	Production Welding	2-4-5/5
2-5-A1/5.1	Environment	2-4-5/5.1
2-5-A1/5.3	Preheat	2-4-5/5.3
2-5-A1/5.5	Postheating	2-4-5/5.5
2-5-A1/5.7	Accessibility	2-4-5/5.7
2-5-A1/5.9	Sequence	2-4-5/5.9
2-5-A1/5.11	Back Gouging	2-4-5/5.11
2-5-A1/5.13	Fairing and Flame Shrinking	2-4-5/5.13
2-5-A1/5.15	Inspection of Welds	2-4-5/5.15
2-5-A1/5.15.1	Visual Inspection	2-4-5/5.15.1
2-5-A1/5.15.1(a)	Appearance	2-4-5/5.15.1(a)
2-5-A1/5.15.1(b)	Melt-through	2-4-5/5.15.1(b)
2-5-A1/5.15.1(c)	Suckback	2-4-5/5.15.1(c)
2-5-A1/5.15.1(d)	Undercut	2-4-5/5.15.1(d)
2-5-A1/5.15.1(e)	Welded Joint Offset	2-4-5/5.15.1(e)
2-5-A1/Figure 2	Repairs of Misalignments	2-4-5/Figure 2
2-5-A1/5.15.2	Dye Penetrant	2-4-5/5.15.2
2-5-A1/5.15.2(a)	Type of Dye Penetrant	2-4-5/5.15.2(a)
2-5-A1/5.15.2(b)	Surface Preparation	2-4-5/5.15.2(b)
2-5-A1/5.15.2(c)	Test Procedure Requirements	2-4-5/5.15.2(c)
2-5-A1/5.15.3	Radiographic or Ultrasonic Inspection	2-4-5/5.15.3
2-5-A1/5.15.4	Weld Plugs or Samples	2-4-5/5.15.4
2-5-A1/5.17	Workmanship Requirements	2-4-5/5.17
2-5-A1/5.17.1	Structural Fairness for Plating	2-4-5/5.17.1
2-5-A1/5.17.2	Structural Fairness for Framing and Stiffeners	2-4-5/5.17.2
2-5-A1/5.17.3	Underwater Exterior Surfaces	2-4-5/5.17.3
2-5-A1/5.19	Quality Control	2-4-5/5.19
2-5-A1/5.21	Repair Welding	2-4-5/5.21
2-5-A1/7	Butt Welds	2-4-5/7
2-5-A1/7.1	Joint Design	2-4-5/7.1

**Part 2 Materials and Welding**  
**Appendix 12 Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules**  
**Section 1 Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules**

2-A12-1

<i>AI &amp; FRP 2016</i>	<i>Title</i>	<i>Materials 2017</i>
2-5-A1/9	Fillet Welds	2-4-5/9
2-5-A1/11	Filler Metals	2-4-5/11
2-5-A1/11.1	General	2-4-5/11.1
2-5-A1/11.3	Approval Basis	2-4-5/11.3
2-5-A1/13	Approval of Welding Procedures	2-4-5/13
2-5-A1/13.1	Approved Filler Metals	2-4-5/13.1
2-5-A1/13.3	Surveyor's Acceptance	2-4-5/13.3
2-5-A1/13.5	New Procedures and Methods	2-4-5/13.5
2-5-A1/13.7	Tests	2-4-5/13.7
2-5-A1/13.9	Special Tests	2-4-5/13.9
2-5-A1/15	Welder Qualifications	2-4-5/15
2-5-A1/15.1	General	2-4-5/15.1
2-5-A1/15.3	Qualification Tests	2-4-5/15.3
2-5-A1/17	Alternatives	2-4-5/17
2-5-A1/Table 2	Minimum Mechanical Properties for Butt-Welded Aluminum Alloys	2-4-5/Table 2
2-5-A1/Table 3	Aluminum Alloy Filler Metal Composition	2-4-5/Table 3
2-5-A1/Table 4	Filler Metals for Welding Aluminum Alloy – Sheet, Plate and Extrusions	2-4-5/Table 4
2-5-A1/Table 5	Filler Metals for Welding Aluminum Alloy Castings to Castings and Plate	2-4-5/Table 5
2-5-A1/Table 6	Welder Qualification Tests	2-4-5/Table 6
2-5-A1/Figure 3	Permissible Unfairness in Aluminum Welded Structure	2-4-5/Figure 3
2-5-A1/Figure 4	Permissible Unfairness in Other Aluminum Welded Structure	2-4-5/Figure 4
2-5-A1/Figure 5	Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2	2-4-5/Figure 5
2-5-A1/Figure 6	Typical Arrangement of Test Plates for Workmanship Tests in Group B1	2-4-5/Figure 6
2-5-A1/Figure 7	Test No. 1 – Reduced-section Tension Test for Plate	2-4-5/Figure 7
2-5-A1/Figure 8	Test No. 1 – Reduced-section Tension Test for Pipe	2-4-5/Figure 8
2-5-A1/Figure 9	Test No. 2 – Guided Bend Test for Root Bend and Face Bend (Plate or Pipe)	2-4-5/Figure 9
2-5-A1/Figure 10	Test No. 2 – Guided Bend Test for Side Bend (Plate or Pipe)	2-4-5/Figure 10
2-5-A1/Figure 11	Guided Bend Test Jig	2-4-5/Figure 11
2-5-A1/Figure 12	Alternative Guided Bend Test Jig	2-4-5/Figure 12
2-5-A1/Figure 13	Test No. 3 – Fillet Weld Test	2-4-5/Figure 13
2-5-A1/Figure 14	Welder Qualification Test No. Q1	2-4-5/Figure 14
2-5-A1/Figure 15	Welder Qualification Test No. Q2	2-4-5/Figure 15
2-5-A1/Figure 16	Welder Qualification Test No. Q4	2-4-5/Figure 16
2-5-A1/Figure 17	Welder Qualification Test No. Q5	2-4-5/Figure 17
<b>Part 2</b>	<b>Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)</b>	
<b>Chapter 5</b>	<b>Materials for Hull Construction – Aluminum</b>	
<b>Appendix 2</b>	<b>Requirements for the Approval of Aluminum Filler Metals</b>	
2-5-A2	Requirements for the Approval of Aluminum Filler Metals	2-A2-5
2-5-A2/1	General	2-A2-5/1
2-5-A2/1.1	Scope	2-A2-5/1.1
2-5-A2/1.3	Grading, Designation	2-A2-5/1.3
2-5-A2/1.3.1	---	2-A2-5/1.3.1
2-5-A2/Table 1	Consumable Grades and Base Materials for the Approval Test	2-A2-5/Table 1
2-5-A2/1.3.2	---	2-A2-5/1.3.2
2-5-A2/Table 2	Compositional Limits of Shielding Gases and Mixtures to be Used	2-A2-5/Table 2
2-5-A2/1.5	Manufacture, Testing and Approval Procedure	2-A2-5/1.5
2-5-A2/3	Testing and Required Properties	2-A2-5/3
2-5-A2/3.1	Testing of the Deposited Weld Metal	2-A2-5/3.1
2-5-A2/Figure 1	Deposited Weld Metal Test Assembly	2-A2-5/Figure 1
2-5-A2/3.3	Testing of Butt Weld Assemblies	2-A2-5/3.3
2-5-A2/Figure 2	Butt Weld Test Assembly for Out-of-position Welding	2-A2-5/Figure 2
2-5-A2/Figure 3	Butt Weld Test Assembly in Flat Position	2-A2-5/Figure 3
2-5-A2/Table 3	Requirements for the Transverse Tensile and Bend Tests	2-A2-5/Table 3
2-5-A2/5	Annual Check Tests	2-A2-5/5
<b>Part 2</b>	<b>Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)</b>	
<b>Chapter 5</b>	<b>Materials for Hull Construction – Aluminum</b>	
<b>Appendix 3</b>	<b>Scheme for the Approval of Aluminum Manufacturers</b>	
2-5-A3	Scheme for the Approval of Aluminum Manufacturers	2-A10
2-5-A3/1	Scope	2-A10/1
2-5-A3/3	Approval Application	2-A10/3
2-5-A3/3.1	Initial Approval	2-A10/3.1
2-5-A3/3.3	Content of Application	2-A10/3.3

<b>Part</b>	<b>2</b>	<b>Materials and Welding</b>	
<b>Appendix</b>	<b>12</b>	<b>Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules</b>	
<b>Section</b>	<b>1</b>	<b>Comparison of Existing Materials and Welding Rules vs. 2018 Materials and Welding Rules</b>	<b>2-A12-1</b>

<i>AI &amp; FRP 2016</i>	<i>Title</i>	<i>Materials 2017</i>
2-5-A3/3.5	Information and Data Required for Approval	2-A10/3.5
2-5-A3/3.5.1	Production and Process Information	2-A10/3.5.1
2-5-A3/3.5.2	Test Data	2-A10/3.5.2
2-5-A3/3.7	Superior Properties	2-A10/3.7
2-5-A3/3.9	ABS Activity in the Approval Process	2-A10/3.9
2-5-A3/5	Renewal of Approval	2-A10/5
<b>Part 2</b>	<b>Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)</b>	
<b>Chapter 5</b>	<b>Materials for Hull Construction – Aluminum</b>	
<b>Appendix 4</b>	<b>Aluminum/Steel Bi-material Transition Joints</b>	
2-5-A4	Aluminum/Steel Bi-material Transition Joints	2-5-A1
2-5-A4/1	Scope	2-5-A1/1
2-5-A4/3	Supplementary Requirements	2-5-A1/3
2-5-A4/3.1	Reference Documents	2-5-A1/3.1
2-5-A4/3.3	Process of Manufacture	2-5-A1/3.3
2-5-A4/3.5	Tensile Strength	2-5-A1/3.5
2-5-A4/3.5.1	As-Clad Test	2-5-A1/3.5.1
2-5-A4/3.5.2	Simulated Welded Test	2-5-A1/3.5.2
2-5-A4/3.7	Bend Test	2-5-A1/3.7
2-5-A4/3.9	Shear Test	2-5-A1/3.9
2-5-A4/3.9.1	As-Clad Test	2-5-A1/3.9.1
2-5-A4/3.9.2	Simulated Welded Test	2-5-A1/3.9.2
2-5-A4/3.11	Axial Fatigue Strength Test	2-5-A1/3.11
2-5-A4/Table 1	Fatigue Test Conditions and Requirements	2-5-A1/Table 1
2-5-A4/3.13	Welded Tensile Test	2-5-A1/3.13
2-5-A4/3.15	Nondestructive Examination	2-5-A1/3.15
2-5-A4/3.17	Dimensional Tolerances	2-5-A1/3.17
2-5-A4/3.17.1	Flatness	2-5-A1/3.17.1
2-5-A4/3.17.2	Edge Straightness	2-5-A1/3.17.2
2-5-A4/3.17.3	Edge Chamfer	2-5-A1/3.17.3
2-5-A4/3.19	Sampling Lots	2-5-A1/3.19
2-5-A4/3.19.1	Common Parameters	2-5-A1/3.19.1
2-5-A4/3.19.2	Explosion-Bonding Parameters	2-5-A1/3.19.2
2-5-A4/3.19.3	Roll-Bonding Parameters	2-5-A1/3.19.3
2-5-A4/3.21	Test Sampling	2-5-A1/3.21
2-5-A4/Table 2	Production Lot Testing	2-5-A1/Table 2
2-5-A4/3.23	Retest Sampling	2-5-A1/3.23
2-5-A4/3.25	First Article Inspection	2-5-A1/3.25
2-5-A4/Table 3	First Article Testing	2-5-A1/Table 3
2-5-A4/3.27	Ordering Data	2-5-A1/3.27
2-5-A4/Figure 1	Ram Tensile Test Setup	2-5-A1/Figure 1
2-5-A4/Figure 2	Ram Tensile Specimen	2-5-A1/Figure 2
2-5-A4/Figure 3	Weld Tensile Test Assembly	2-5-A1/Figure 3
<b>Part 2</b>	<b>Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)</b>	
<b>Chapter 5</b>	<b>Materials for Hull Construction – Aluminum</b>	
<b>Appendix 5</b>	<b>Dissimilar Materials</b>	
2-5-A5	Dissimilar Materials	2-5-A2
2-5-A5/1	Material	2-5-A2/1
2-5-A5/1.1	Dissimilar Materials	2-5-A2/1.1
<b>Part 2</b>	<b>Rules for Materials and Welding</b>	
<b>Chapter 6</b>	<b>Materials for Hull Construction – Fiber Reinforced Plastics (FRP)</b>	
	Chapter 6 is unchanged.	