



GUIDE FOR THE CERTIFICATION OF OFFSHORE MOORING CHAIN

MAY 2017

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

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Foreword

This is the **fourth** edition of the *Guide for the Certification of Offshore Mooring Chain*, following from the **1986, 1999 and 2009** versions.

Based on IACS UR W22, this new version adds **requirements for thimbles, introduces qualification of higher grades to cover lower grades, and includes more detail on CTOD tests, furnace calibration, guidance on failed proof load tests, and more detail on NDE.**

This Guide supersedes previous versions and ABS encourages its immediate application. Compliance with this edition is required for offshore **units and single point moorings contracted for construction on or after 1 July 2017 and when the application for certification of chains and accessories is dated on or after 1 July 2017.**

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.



GUIDE FOR THE CERTIFICATION OF OFFSHORE MOORING CHAIN

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SECTION 1 General Requirements

1 Scope

1.1 Application (1 May 2017)

This Guide supersedes previous versions and ABS encourages its immediate application. Compliance with this edition is required for offshore **units and single point moorings contracted for construction on or after 1 July 2017 and when the application for certification of chains and accessories is dated on or after 1 July 2017.**

These requirements apply to the materials, design, manufacture, and testing of offshore mooring chain and accessories intended to be used for temporary and permanent applications such as: mooring of mobile offshore units, mooring of floating production units, mooring of offshore loading systems, and mooring of gravity based structures during fabrication.

1.3 Mooring Equipment (1 May 2017)

Mooring equipment covered is common stud and studless links, connecting common links (splice links), enlarged links, end links, detachable connecting links (shackles), end shackles, double pinned H-type links, tri-plates and shackles, **subsea mooring hooks**, and H-links specifically designed for chain to wire/polyester rope connections **and thimbles**.

Mooring foundation shackles and anchor shackles for mooring are also to comply with the requirements of this Guide.

In addition, accessories specifically designed for temporary applications, such as pear links, Kenter shackles, swivels and swivel shackles, and similar designs are covered.

1.5 Studless Chain

Studless link chain is normally deployed only once, being intended for long-term permanent mooring systems with pre-determined design life.

1.7 Chafing Chain (1 May 2017)

Requirements for chafing chain for **Emergency Towing Arrangement (ETA)** are given in 3-5-1/17 of the *ABS Rules for Building and Classing Steel Vessels*. In addition, recognized industry standards such as OCIMF may be applied. **Also refer to Appendix 1 for the requirements applying to chafing chain for single point mooring arrangements (short lengths approximately 8 m).**

Materials requirements are to comply with applicable parts of this Guide.

1.9 Special Subsea Mooring Connectors

In the case of specially designed subsea connectors, these requirements are in general applicable. However, consideration will be given to unique designs, validated by first principles engineering, with mechanical and material properties different from those herein.

3 Chain and Accessory Grades

3.1 R3, R3S, R4, R4S, and R5

Depending on the nominal tensile strength of the steels used for manufacture, chains are to be subdivided into five grades (i.e., R3, R3S, R4, R4S, and R5). Refer to Section 1, Table 1 below for mechanical properties.

3.3 R4S and R5 (1 May 2017)

Manufacturer's proprietary specifications for R4S and R5 may vary subject to design conditions and material physical properties, therefore more detailed information regarding design, manufacture, testing, and specifications are to be submitted to ABS.

3.5 Approval (1 May 2017)

Each grade of chain or accessory is to be individually approved. Approval for a higher grade does not constitute approval of a lower grade. If it is demonstrated to the satisfaction of ABS Materials engineering that the higher and lower grades are produced to the same manufacturing procedure using the same chemistry and heat treatment, consideration will be given to qualification of a lower grade by a higher grade. The parameters applied during qualification are not to be modified during production. Approved manufacturers will be included in the list of ABS Approved Manufacturers on the ABS website. The approval will indicate the Company, grade, product, maximum size, and any limitations.

TABLE 1
Mechanical Properties of Offshore Mooring Chain and Accessories

Grade	Yield Strength ⁽¹⁾ minimum N/mm ² (kg/mm ² , ksi)	Tensile Strength ⁽¹⁾ minimum N/mm ² (kg/mm ² , ksi)	Elongation in 5D minimum in percent	Reduction of Area minimum in percent ⁽³⁾	Charpy V-Notch impact Tests Energy in Joules Minimum Average		
					Temp. °C ⁽²⁾	Average for Base Metal	Average at Flash Weld
R3	410 (42, 59)	690 (70, 100)	17	50	0 -20	60 40	50 30
R3S	490 (50, 71)	770 (78, 112)	15 ⁽⁵⁾	50 ⁽⁵⁾	0 -20	65 45	53 33
R4	580 (59, 84)	860 (87, 125)	12 ⁽⁵⁾	50 ⁽⁵⁾	-20	50	36
R4S ⁽⁴⁾	700 (71, 101)	960 (98, 139)	12 ⁽⁵⁾	50 ⁽⁵⁾	-20	56	40
R5 ⁽⁴⁾	760 (77, 110)	1000 (102, 145)	12 ⁽⁵⁾	50 ⁽⁵⁾	-20	58	42

Notes

- 1 Aim value of yield to tensile ratio: 0.92 maximum.
- 2 At the option of ABS, the impact test of Grade R3 and R3S may be carried out at either 0°C or minus 20°C to meet the indicated values. It is not required to Charpy test at both temperatures.
- 3 Reduction of area of cast steel accessories is to be for Grades R3 and R3S: minimum 40%; for Grades R4, R4S, and R5: minimum 35%.
- 4 Surface hardness tests are required for R4S and R5 chain and accessories. The target maximum hardness for R4S is HB330 and for R5 is HB340. Two hardness tests at each end 180° apart of chain links or accessories are to be taken.
- 5 For chain cross-weld tensile tests, these properties are to be reported for information only; the stated requirements do not apply.

5 Chain Manufacturer Approval

5.1 Approval of Chain Manufacturers (1 May 2017)

Offshore mooring chains are to be manufactured only by works approved by ABS. For this purpose, approval tests are to be carried out, the scope of which is to include proof and breaking load tests, measurements, and mechanical tests, including fracture mechanics tests. Approval will be given only after successful testing of the completed chain. The approval for each grade will normally be limited up to the maximum chain diameter tested.

Chain manufacturers are to have a documented and effective quality system approved by ABS. The provision of such a quality system is required in addition to, and not in lieu of, the witnessing of tests by a Surveyor as specified in Sections 2 to 5 of these requirements.

Welding repair of the chain links is not permitted.

5.3 Manufacturing Process Approval (1 May 2017)

Manufacturers are to submit for review and approval the sequence of operations from receiving inspection to shipment, including details of the following manufacturing processes:

- i) Bar heating and bending, including method, temperatures, temperature control, recording, and in-process bar identification
- ii) Flash welding, including current, force, time, and dimensional variables, as well as control and recording of parameters, **maintenance procedures and monitoring program for welding machine**
- iii) Flash removal, including method and inspection
- iv) Stud insertion (for stud link chain) method, imprint, and degree of plastic deformation after heat treatment. Stud welding (if applicable)
- v) Heat treatment, including furnace types, means of specifying, controlling and recording of temperature, chain speed and allowable limits, quenching bath and agitation, and cooling method after exit. **To include** procedures, practices, temperatures and **associated** limits, heating and cooling rates.
- vi) Proof and break loading, including method, machine, means of horizontal support (if applicable), method of measurement, and recording
- vii) Nondestructive examination procedures
- viii) The manufacturer's surface quality requirement of mooring components
- ix) Connecting common link (splice link) procedures **for removing and replacing defective links without heat treatment of the entire chain**

5.5 CTOD Tests (Crack Tip Opening Displacement Tests) (1 May 2017)

For initial approval, CTOD tests are to be carried out on the particular ABS mooring grade of material. CTOD tests are to be carried out in accordance with a recognized standard such as BS 7448 Part 1 & **BS EN ISO 15653:2010**. The CTOD test piece is to be a standard 2×1 single edge notched bend piece, test location as shown in **Section 1, Figure 1** below. **The notch of the CTOD specimen is to be located as close to the surface as practicable.** The minimum cross section of the test piece size is to be 50×25 mm for chain diameters less than 120 mm, and 80×40 mm for diameters 120 mm and above. CTOD specimens are to be taken from both the side of the link containing the weld and from the opposite side. Three links are to be selected for testing, giving a total of six CTOD specimens. The tests are to be taken at minus 20°C and **the lowest CTOD of each set of three specimens is to** meet the minimum values indicated below in **Section 1, Table 2:**

FIGURE 1
CTOD Test Specimen Location in Chain (1 May 2017)

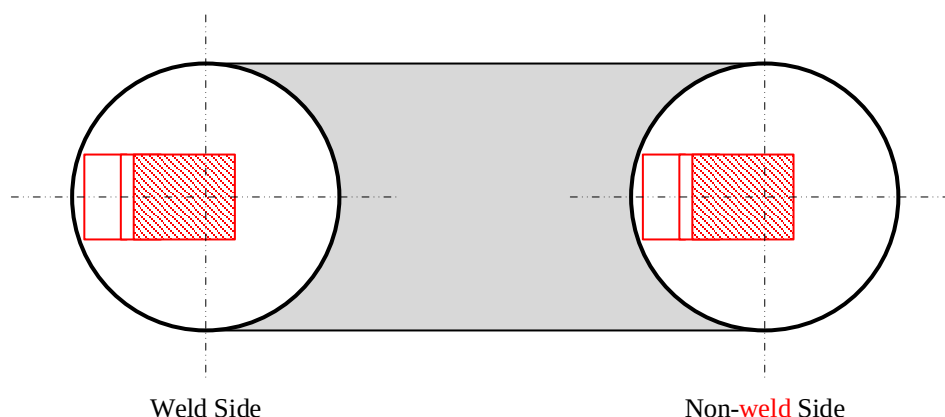


TABLE 2
Minimum CTOD Values for Chain Type

Chain Type	R3 in mm		R3S in mm		R4 in mm		R4S & R5 in mm	
	BM	FBW	BM	FBW	BM	FBW	BM	FBW
Stud link	0.20	0.10	0.22	0.11	0.24	0.12	0.26	0.13
Studless	0.20	0.14	0.22	0.15	0.24	0.16	0.26	0.17

BM = Base Metal

FBW = Flash Butt Weld

5.7 Furnace Calibration (1 May 2017)

Calibration of furnaces **are to** be verified by measurement and recording of a calibration test piece with dimensions equivalent to the maximum size of link manufactured. **The manufacturer is to submit a procedure for furnace temperature surveys which is to include the following requirements:**

- The temperature uniformity of furnaces is to be surveyed whenever approval of manufacturer is requested and at least annually during normal operating conditions.
- Furnaces are to be checked by conveying a monitoring link instrumented with two thermocouples through the furnaces at representative travel speed.
- One thermocouple is to be attached to the surface of the straight part and one thermocouple is to be imbedded in a drilled hole located at the mid thickness position of the straight part of the calibration block.
- The time-temperature curves is to show that the temperatures throughout the cross section and the soaking times are within specified limits as given in the heat treatment procedure.

Evidence of furnace surveys and calibration is to be provided.

5.9 R4S and R5 Additional Requirements (1 May 2017)

For R4S and R5 chain, prior to approval, the manufacturer is to have undertaken experimental tests or have relevant supporting data to develop the chain material. The tests and data are to include:

- Fatigue tests,
- Hot** ductility tests (no internal flaws are to develop whilst bending in the link forming temperature range)
- Flash butt welding** parameter research

- iv) Heat treatment study
- v) Strain age resistance
- vi) Temper embrittlement study
- vii) Stress corrosion cracking (SCC) data
- viii) Hydrogen embrittlement (HE) study, using slow strain test pieces in hydrated environments

Reports indicating the results of experimental tests are to be submitted.

5.11 Qualification Testing

Qualification testing is to include, as a minimum, the tests and examinations on the largest diameter product for each grade for which approval is requested. All proof tests, break tests, and mechanical tests (tension and impact) are to be witnessed by the Surveyor. In addition, hardness distribution and CTOD tests (1/5.5) are to be done but need not be witnessed by the Surveyor. All tests are to be performed on a product that has been subjected to the final heat treatment. Mechanical tests are to be taken from a proof loaded product. Where plastic straining of heat treated chain is used to set studs or stretch chain, appropriate tensile and impact data are to be provided to demonstrate that chain properties are not significantly degraded by the extent of plastic deformation used. Other tests such as hot ductility (creasing), corrosion tests, fatigue tests, and stress corrosion cracking, provide useful information about the characteristics of the chain and such supporting data is to be submitted.

5.11.1 Chemical Analyses

Both ladle and product analyses are to be provided, and are to include carbon, manganese, silicon, phosphorous, sulfur, and all other intentionally added elements. Restrictions on residual elements are also to be submitted.

5.11.2 Proof Load and Break Load Test

Chains are to withstand the proof loads given in Section 3, Table 1, in accordance with 4/3.1 and 4/3.3.

5.11.3 Mechanical Tests

Tension and Charpy tests are to be carried out in accordance with 2/3.5.3 to meet the requirements of Section 1, Table 1.

- i) *Tension Test (Two links are to be tested).* Two tension tests from each link are to be conducted, one clear of the flash weld and the other at the center of the flash weld.
- ii) *Charpy V-Notch (CVN) Impact Test.* Three sets of CVN specimens are to be tested from four links. One set is to be taken clear of the weld in the un-deformed region of the link, one set is to be taken from the crown, and one set is to be taken with the root of the notches in the center of the flash weld.

5.11.4 Hardness Tests

Hardness distribution is to be determined across a diameter using Vickers or Rockwell indentors. A diagram showing the hardness distribution is to be submitted.

5.11.5 Stud Welding Qualification

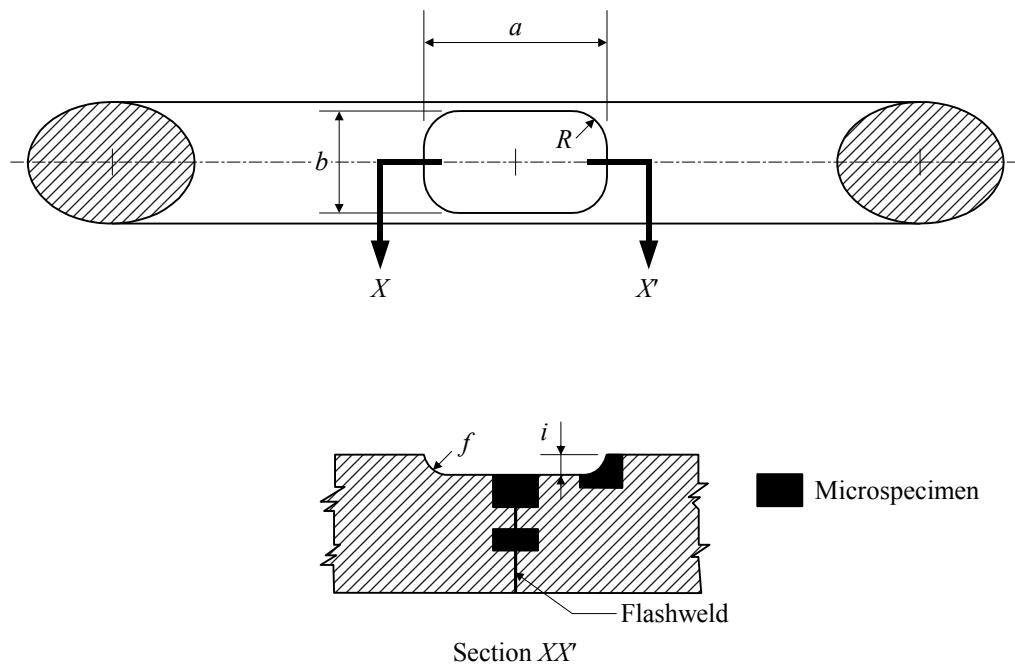
The procedure for fillet welding the stud (if used) is to be qualified in accordance with Chapter 4 of the *ABS Rules for Materials and Welding (Part 2)*, or with another recognized code. All welder qualifications are to be reviewed by the Surveyor.

5.11.6 Microexamination

Microspecimens are to be taken showing the:

- i) Flash weld, at the surface, at the two-thirds radius and at the mid-thickness
- ii) Base metal, at the surface, at the two-thirds radius and at the mid-thickness
- iii) Stud indentation radius (for stud link only)

FIGURE 2
Microspecimens



$i = \text{typically } 0.02d \text{ to } 0.06d$, where d is the nominal diameter

The microspecimens are to be etched with a suitable etchant and photographed at 100X and 500X magnifications. Austenitic and ferritic grain sizes are to be determined and reported. Austenitic grain size is to be number 6 or finer, in accordance with ASTM E112.

Stud imprint and depth are to be measured and recorded

5.11.7 Macroexamination

Two macrospecimens are to be taken at:

- i)* A link longitudinal section at the flash welded side showing the stud indentation area (for stud link only)
- ii)* The cross section at both crowns
- iii)* The centerline section showing the flash weld, stud indentation depth and radius (if applicable), and stud weld (if applicable)

Macrosections are to be etched. A 10X examination of the entire stud indentation area is to be conducted and reported to verify freedom from cracks, laps or surface imperfections. The macrospecimens are to be photographed at 1X.

7 Approval of Quality Systems at Chain Manufacturers and Bar Producers

7.1 Quality Provision

(1 May 2017) Chain manufacturers and producers of bar intended for chain are to have a documented and effective quality system that meets ABS requirements for approval. The provision of such a quality system is required in addition to, and not in lieu of, the witnessing of tests by a Surveyor as specified in Sections 2 to 5 of this Guide.

7.1.1 Quality System – General

The manufacturer is to have a documented, effective quality system to ISO 9001 that addresses the following:

- i) Management structure
- ii) Corporate policies regarding quality
- iii) Internal auditing practices
- iv) Calibration practices for tools, gauges, thermocouples, etc.
- v) Receiving, in process and pre-delivery, inspection practice
- vi) Testing practices
- vii) Procedures for handling discrepant material
- viii) Marking
- ix) Storage
- x) Record retention

7.1.2 Manual of Quality System

The manufacturer is to submit details of the quality system employed at the plant in the form of a manual. The effectiveness of the system is to be verified by the Surveyor.

7.1.3 Scope of Acceptance

A Quality System accepted by ABS will only apply to the particular plant that has been qualified, and does not extend to other plants under the control of the manufacturer; neither does it apply to licensees, subcontractors, nor suppliers. However, the manufacturer's system for controlling the quality of important purchased materials, components, and services will be evaluated.

7.1.4 Maintenance of Approval

The quality system of an approved manufacturer will be reviewed periodically. To this end, the manufacturer's facilities and records are to be open to the Surveyor at all reasonable times.

7.1.5 Notification Responsibility

A manufacturer is responsible for notifying ABS of changes in the quality system.

7.1.6 Withdrawal of Approval

ABS approval of the manufacturer's Quality System may be withdrawn at any time by the ABS Materials Department if such action is warranted.

7.3 Procedures for Obtaining Approval

7.3.1 Prior to Approval

Before approval of the quality system can be granted, qualification of the Manufacturer (see Subsection 1/5) **is to** be obtained for all products, as required by the Guide.

7.3.2 Manufacturer Application

The manufacturer is to apply to the local ABS Office, or to ABS Materials Department, for approval of the quality system.

7.3.3 Details on Application

The application for certification is to include a detailed description of quality policies, procedures, and organization, and is to be forwarded to the ABS Materials Department, through the local ABS Office.

7.3.4 On-Site Audit

After review of the quality manual, ABS will carry out an on-site audit of the plant to verify the effectiveness of the quality system. On-site surveillance audits will be carried out annually or as specified by ABS.

7.5 Quality Assurance Certificate

A certificate will be issued to the qualified manufacturer. Certificates will be valid for five years.

7.5.1 Certification of Other Products

To obtain certification of products other than those originally approved or qualified, the manufacturer **is to** obtain an extension of certification from ABS.

7.5.2 Suspension of Certification

If the Quality System or product is found to be deficient, certification of the manufacturer's Quality System may be suspended and the manufacturer so notified in writing.

7.5.3 Withdrawal of Certification

If the manufacturer fails to correct, within a reasonable time, conditions that led to a suspension, certification will be withdrawn.

7.5.4 Renewal

The validity of the approval is to be a 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.

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.

7.7 Test Data and Documentation

The required documentation in Subsection 4/15 is to be retained by the manufacturer for submission to ABS as required.

9 Approval of Steel Mills – Rolled Bar and Plate for Chain and Accessories

9.1 Bar and Plate Material for Chain and Accessories, Including Pins (1 May 2017)

Bar and plate materials intended for chain and accessories are to be manufactured only by works approved by ABS **and are to have an approved Quality System**. The approval is limited to a nominated supplier of bar or plate material. If a chain or accessory manufacturer wishes to use material from a number of suppliers, separate approval tests **are to** be carried out for each supplier.

The approval process is to be made in accordance with Appendix 4, "Procedure for the Approval of Rolled Hull Structural Steel Manufacturer", of the *ABS Rules for Materials and Welding (Part 2)*.

9.3 Approval Restrictions (1 May 2017)

Approval will be given only after successful testing of the completed chain or accessory.

Each Grade is to be individually approved. Approval for a higher grade does not constitute approval of a lower grade. If it is demonstrated to the satisfaction of ABS that the higher and lower grades are produced to the same manufacturing procedure using the same chemistry and heat treatment, consideration will be given to qualification of a lower grade by a higher. The parameters applied during qualification are not to be modified during production.

The approval for each grade will normally be limited up to the maximum diameter or thickness equal to that of the chain diameter tested, or accessory diameter/thickness tested.

The rolling reduction ratio for bar is to be recorded and is to be at least 5:1

The rolling reduction ratio for plate is to be recorded and is to be at least 3:1.

The rolling reduction ratio used in production can be higher, but **is not to** be lower than that qualified.

9.5 Chemical Composition (1 May 2017)

The steel **producer** is to submit a specification of the chemical composition of the bar/plate material, which **is to** be approved by ABS and by the chain or accessory manufacturer. **The steel producer is to confirm by analysis and testing that the specification is met.** For Grade R4, R4S, and R5 chain and accessories, the steel **is to** contain a minimum of 0.20% molybdenum.

9.7 Heat Treatment Sensitivity Study for Rolled Bars

A heat treatment sensitivity study simulating chain or accessory production conditions **is to** be applied in order to verify mechanical properties and establish limits for temperature and time combinations.

The effect of variations in heat treatment upon the tensile and Charpy properties is to be carried out on no fewer than 16 test conditions.

All test details and results are to be submitted to ABS.

9.9 Strain Aging, Temper Embrittlement, Hydrogen Embrittlement

The steel manufacturer is to provide evidence in the form of furnace reports and test data, that the manufacturing process produces material that is resistant to strain aging, temper embrittlement, and for R3S, R4, R4S, and R5, hydrogen embrittlement. All test details and results are to be submitted to ABS.

11 Accessory Manufacturer Approval

(Note: The term “Accessory Manufacturer” is the Manufacturer of Record)

11.1 Approval of Forges and Foundries – Accessories (1 May 2017)

Steel producers, forges and foundries intending to supply finished or semi-finished accessories are to be approved by ABS. A description of manufacturing processes and process controls is to be submitted to ABS. The scope of approval is to be agreed with ABS. The approval is to be limited to a nominated supplier of forged or cast material. If an accessory manufacturer wishes to use material from a number of suppliers, a separate approval **is to** be carried out for each supplier.

Accessory manufacturers are to have a documented and effective quality system that meets ABS requirements. The provision of such a quality system is required in addition to, and not in lieu of, the witnessing of tests by a Surveyor as specified in Sections 2 to 5 of this Guide.

11.3 Approval Restrictions (1 May 2017)

Approval will be given only after successful testing of the completed accessory. **Approval for a higher grade does not constitute approval of a lower grade. If it is demonstrated to the satisfaction of ABS that the higher and lower grades are produced to the same manufacturing procedure using the same steel specification, supplier and heat treatment, consideration will be given to qualification of a lower grade by a higher grade.** The approval will normally be limited to the type of accessory, and the ABS designated grade of **mooring material** up to the maximum diameter or thickness equal to that of the completed accessory used for qualification **unless otherwise agreed by ABS.** Qualification of accessory pins to maximum diameters is also required. **Individual accessories of complex geometries will be subject to special approval.**

Welding repair is not permitted on the accessories manufactured from forged or rolled bar.