DNV·GL

OFFSHORE STANDARDS

DNVGL-OS-E302 Edition July 2018

Offshore mooring chain

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DNV GL AS

FOREWORD

DNV GL offshore standards contain technical requirements, principles and acceptance criteria related to classification of offshore units.

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CHANGES – CURRENT

This document supersedes the July 2015 edition of DNVGL-OS-E302.

Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or subsection, normally only the title will be in red colour.

Changes July 2018

Topic	*Reference*	*Description*
Alignment to revised IACS W22 on Offshore Mooring Chain (rev 6 June 2016)	Ch.2 Sec.1 [1.2.2]	Updated clause, clarification on samples location.
	Ch.2 Sec.1 [1.5.3]	Updated clause, clarification on charpy samples.
	Ch.2 Sec.1 [1.6.2]	Updated clause, included ISO 9934 as acceptable NDT standard.
	Ch.2 Sec.1 [2.8.1]	Updated clause, possibility for magnetic flux leakage.
	Ch.2 Sec.1 [2.9.2]	New clause, clarification on welding repair.
	Ch.2 Sec.2 [2.3.2]	Updated clause, clarification on control parameters.
	Ch.2 Sec.2 [2.5.3]	Updated clause, doc req change.
	Ch.2 Sec.2 [2.6.2]	Updated clause, new approach.
	Ch.2 Sec.2 [2.7.5]	
	Ch.2 Sec.2 [2.9.4]	Updated clause, small change to the tolerances.
	Ch.2 Sec.2 [3.5.2]	Updated clause, clarification.
	Ch.2 Sec.2 [3.5.3]	Updated clause, new requirement.
Introduction of R6 material grade	Ch.2 Sec.2 Table 1 and 3	New R6 mechanical properties and proof load/break load test values.
	Ch.2 Sec.1 Table 1	New R6 mechanical properties.

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.

CONTENTS

CHAPTER 1 INTRODUCTION

SECTION 1 INTRODUCTION

1 General

1.1 Introduction

This offshore standard contains criteria, technical requirements and guidance on materials, design, manufacture and testing of offshore mooring chain and accessories.

1.2 Objective

The objectives of this standard are to:

- provide an internationally acceptable standard of safety by defining minimum requirements for offshore mooring chain and accessories
- serve as a contractual reference document between manufacturers and purchasers
- serve as a guideline for designers, suppliers, purchasers and regulators
- specify procedures and requirements for offshore mooring chain and accessories subject to DNV GL certification and classification.

1.3 Scope and application

1.3.1 The standard has been written for general world-wide application. Governmental regulations may include requirements in excess of the provisions by this standard depending on the size, type, location and intended service of the offshore unit or installation.

1.3.2 The mooring chain and accessories specified herein are intended for position mooring applications such as: mooring of mobile offshore units, mooring of floating production units, mooring of offshore loading systems, and mooring of gravity base structures during fabrication.

1.3.3 Mooring chain links covered are common stud links and common stud less links, connecting common links (splice links), enlarged links and end links.

1.3.4 Mooring chain accessories covered are detachable connecting links (shackles), connecting plates (triplates etc), end (anchor) shackles, swivels and swivel shackles.

1.4 Structure

This standard is divided into three main chapters:

- *Chapter 1:* Sec.1 with general information, scope, definitions and references
- *Chapter 2:* Sec.1 and Sec.2 with technical provisions for materials and chain cables
- *Chapter 3:* Sec.1 specific procedures and requirements applicable for certification and classification of materials and chain cables in accordance with this standard. Also, requirements to design verification are given.
- App.A and App.B list the scope of survey for the mooring chain respectively mooring chain accessories.

2 Normative references

2.1 General

2.1.1 The standards in Table 1 include provisions which, through reference in this text, constitute provisions of this offshore standard. Latest issue of the standards shall be used unless otherwise agreed.

2.1.2 Other recognised standards may be used provided it can be demonstrated that these meet or exceed the requirements of the standards in Table 1.

2.1.3 Any deviations, exceptions and modifications to the design codes and standards shall be documented and agreed between the supplier, purchaser and verifier, as applicable.

2.2 Reference documents

Applicable reference documents are given in Table 1.

Table 1 Normative references

No.	*Title*
API Spec 2F	Specification for mooring chain
API Spec 6A	Specification for Wellhead and Christmas Tree Equipment, Twentieth Edition (ISO 10423:2009 Modification)
ASME BPVC IX	Boiler and Pressure Vessel Code - Section IX: Welding and Brazing Qualifications
ASNT	SNT-TC-1A American Society for Non-destructive Testing – Recommended Practice
ASTM A255	Standard Test Methods for Determining Hardenability of Steel
ASTM A275	Standard Practice for Magnetic Particle Examination of Steel Forgings
ASTM A388	Standard Practice for Ultrasonic Examination of Steel Forgings
ASTM A488	Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
ASTM A609	Standard Practice for Castings, Carbon, Low-Alloy and Martensitic Stainless Steel, Ultrasonic Examination Thereof
ASTM A991	Standard Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
ASTM E112	Standard Test Methods for Determining Average Grain Size
ASTM E381	Standard Method of Macro-etch Testing Steel Bars, Billets, Blooms and Forgings
ASTM E587	Practice for Ultrasonic Angle-Beam Examination by the Contact Testing
ASTM E709	Standard Guide for Magnetic Particle Testing
ASTM E1417	Standard Practice for Liquid Penetrant Testing
ASTM E1444	Standard Practice for Magnetic Particle Testing
DNVGL-OS-B101	Metallic materials
DNVGL-CP-0237	Offshore mooring chain and accessories

No.	Title
EN 287-6	Qualification test of welders - Fusion welding - Part 6: Cast iron
EN 10204	Metallic products - Types of inspection documents
EN 10228-1/3	Non-destructive testing of steel forgings
ISO 4967	Steel – Determination of content of non-metallic inclusions – Micrographic method using standard diagrams
ISO 1704	Ships and marine technology – Stud-link anchor chains
ISO 8501-1	Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
ISO 9606 series	Qualification testing of welders - Fusion welding
ISO 9712	Non-destructive testing - Qualification and certification of NDT personnel
ISO 10423	Petroleum and natural gas industries - Drilling and production equipment - Wellhead and christmas tree equipment
ISO 13588	Non-destructive testing of welds - Ultrasonic testing - Use of automated phased array technology
ISO 15549	Non-destructive testing – Eddy current testing – General principles
ISO 15614 series	Specification and qualification of welding procedures for metallic materials - Welding procedure test

3 Definitions

3.1 Verbal forms

Table 2 Verbal forms

Term	Definition
shall	verbal form used to indicate requirements strictly to be followed in order to conform to the document
should	verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.
may	verbal form used to indicate a course of action permissible within the limits of the document.
Agreement, agreed or by agreement	unless otherwise indicated, agreed in writing between manufacturer and purchaser or DNV GL where DNV GL is certifying the product

3.2 Terms

Table 3 Terms

Term	*Definition*
purchaser	the owner or another party acting on his behalf, who is responsible for procuring materials, components or services intended for the design, fabrication or modification of a unit or installation
manufacturer	the party who is contracted to be responsible for planning, execution and documentation of manufacturing

CHAPTER 2 TECHNICAL PROVISIONS

SECTION 1 MATERIALS

1 General requirements

1.1 Scope

1.1.1 Sub-section A specifies the general requirements for rolled steel bars, steel forgings and steel castings to be used in the manufacture of offshore mooring chain and accessories. Specific requirements are given in [2] to [4]. If the specific requirements differ from these general requirements, the specific requirements shall prevail. Separate requirements for materials for studs are given in [5].

1.1.2 The steels concerned are classified by specified minimum ultimate tensile strength into five grades: R3, R3S, R4, R4S, R5 and R6.

1.2 Manufacture

1.2.1 The steels shall be manufactured by an electric or one of the basic oxygen processes or any other approved process involving secondary refining. Steel grades R4S, R5 and R6 shall be vacuum degassed.

1.2.2 The steels shall be killed and fine grain treated. The austenite grain size shall be 6 or finer in accordance with ISO 643 or ASTM E112. Measurements shall be taken at one third of the radius below surface for circular sections and one quarter of the thickness below surface for non-circular sections. The fine grain size requirement shall be deemed to be fulfilled if the steels contain Al, Nb, V or Ti, either singly or in any combination, as follows:

— When Al is used singly, the minimum total content shall be 0.020% or, alternatively, the Al to N ratio shall be minimum 2:1.
— When Al and Nb are used in combination, the minimum total Al content shall be 0.015% and the minimum Nb content shall be 0.010%.
— When Al and V are used in combination, the minimum total Al content shall be 0.015% and the minimum V content shall be 0.030%.

1.2.3 For steel grades R4S, R5 and R6, the following information shall be supplied by the manufacturer to the mooring chain or accessory manufacturer and the results included in the chain documentation:

a) Each heat shall be examined for non-metallic inclusions according to ISO 4967 or equivalent. The level of inclusions shall be quantified and assessed to be sure inclusion levels are acceptable for the final product.
b) A sample from each heat shall be macro etched according to ASTM E381 or equivalent to be sure there is no injurious segregation or porosity.
c) Jominy hardenability data according to ASTM A255 or equivalent shall be supplied with each heat.

1.2.4 The manufacturer shall ensure that effective manufacture and process controls are implemented in production. Where deviation from the controls occurs and this could produce products of inferior quality, the manufacturer shall investigate to determine the cause and establish countermeasures to prevent its recurrence. Investigation reports to this effect shall be made available on request.

1.3 Chemical composition

1.3.1 The chemical composition shall be according to an approved specification. Steel grades R4, R4S, R5 and R6 shall contain a minimum of 0.20% molybdenum.

1.3.2 The chemical composition of each heat shall be determined on a sample taken preferably during the pouring of the heat and shall comply with the specified limits. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

1.3.3 The composition shall be determined after all alloying additions have been made and sufficient time allowed for such an addition to homogenize.

1.3.4 Elements designated as residual and impurity elements in the individual specifications shall not be intentionally added to the steels. The content of such elements shall be reported.

1.3.5 Adequate controls shall be in place to prevent accumulation of harmful elements such as tin, antimony and arsenic in the final product.

1.4 Heat treatment

1.4.1 Materials shall be heat treated for mechanical properties as specified in [2] to [4]. Heat treatment shall be carried out in a properly constructed furnace which is efficiently maintained and has adequate means for temperature control and is fitted with recording-type pyrometers. The furnace dimensions shall be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. Temperature uniformity surveys of heat treatment furnaces for forged and cast components shall be carried out according to API Spec 6A/ISO 10423 Annex M or ASTM A991. The initial survey shall be carried out with maximum charge (load) in the furnace. Subsequent surveys shall be carried out annually and may be carried out with empty furnace.

1.4.2 Sufficient thermocouples shall be connected to the furnace charge where it is composed of forged or cast components. Thermocouples should be connected by capacitor discharge welding.

1.4.3 Records shall identify the furnace used, furnace charge, date, temperature and time at temperature.

1.4.4 The manufacturer shall ensure that the specified heat treatment is adhered to. Where deviation from the specified heat treatment occurs, the manufacturer shall ensure that affected products are tested or submitted to reheat treatment and that an investigation is carried out according to [1.2.4].

1.5 Mechanical testing

1.5.1 Products shall be grouped in test units and sampled for mechanical testing as detailed in [2] to [4]. Test material from which test pieces are prepared shall be of equivalent cross section and be fully representative of the sample product and, where appropriate, shall not be cut, or partially cut from the sample product leaving a ligament, until heat treatment has been completed. Test material and test pieces shall not be separately heat treated in any way.

1.5.2 Test material and test pieces shall be marked to identify them with the products represented.

1.5.3 For each test unit, one tensile and three Charpy V-notch test pieces shall be taken. Rolled steel bars and steel forgings shall be tested in the longitudinal direction. The longitudinal axis of test pieces shall be located one-third of the radius below the surface or, in the case of non-cylindrical sections, one-quarter of the thickness below the surface. Test pieces shall be positioned such that the tensile test piece middle gauge length and the Charpy V-notch piece root is minimum one diameter or thickness from any second surface unless otherwise agreed.

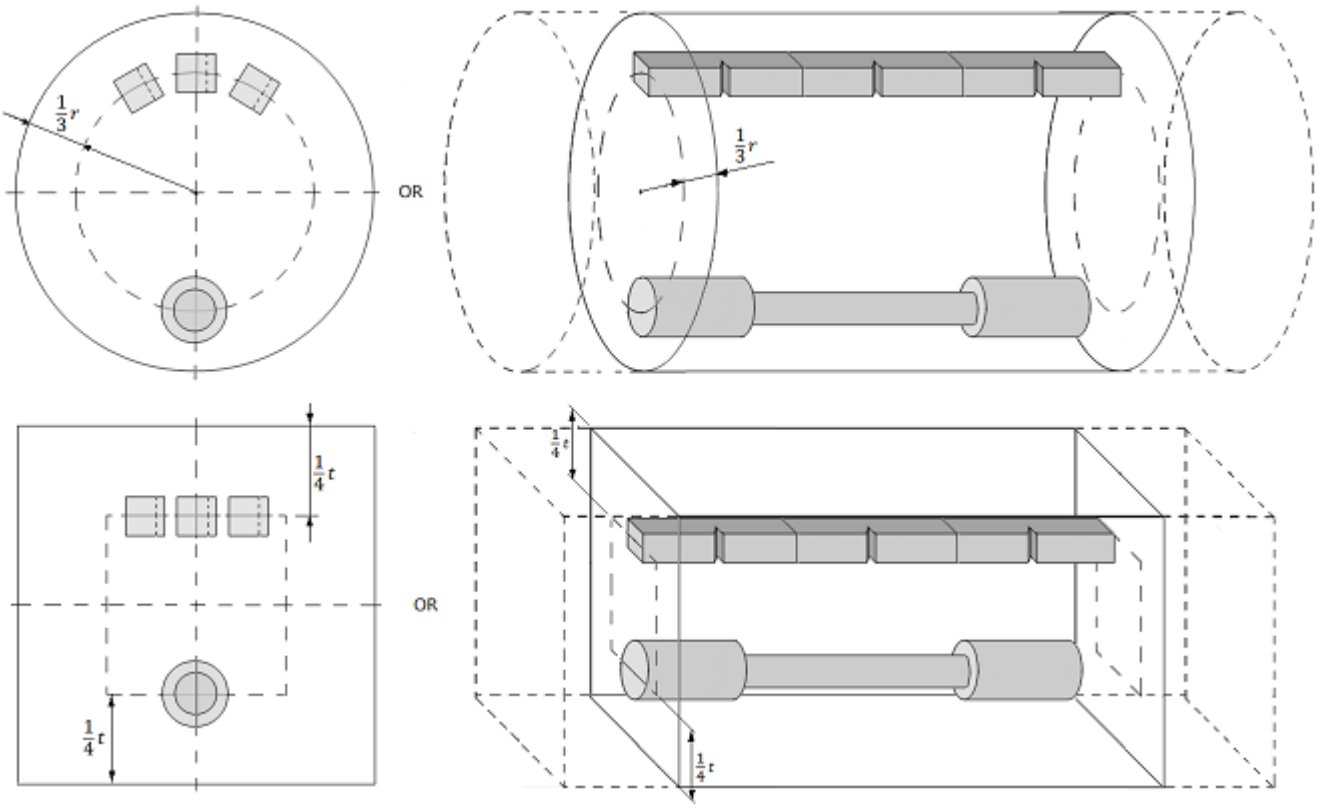

Figure 1 Position of test pieces in round and square/rectangular sections. Alternatively, the three Charpy V-notch test pieces may be taken in series.

1.5.4 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of DNVGL-OS-B101.

1.5.5 The materials shall comply with the mechanical properties specified in Table 1.

1.5.6 If the results from tensile testing do not meet the specified requirements, two further tensile tests may be made from the same sample. If both of these additional tests are satisfactory, the test unit may be accepted.

1.5.7 If the results from a set of three impact test pieces do not meet the specified requirements, three additional test pieces from the same sample may be tested and the results added to those previously obtained to form a new average. If this new average complies with the requirements and if not more than

two individual results are lower than the required average and, of these, not more than one result is below 70% of the specified average value, the test unit may be accepted.

1.5.8 Where forgings or castings and the associated test material are submitted to re-heat treatment, they may not be re-austenitised more than twice. All the tests previously performed shall be repeated after re-heat treatment and the results must meet the specified requirements.

1.6 Inspection

1.6.1 Materials are subject to visual inspection, non-destructive testing (NDT) and measurements of dimensions as detailed in [2] to [4]. The manufacturers shall prepare written procedures for NDT. NDT personnel shall be qualified and certified according to ISO 9712, ACCP or equivalent. Personnel qualification to an employer based qualification scheme as SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level 3 is ASNT Level III or ACCP Professional Level III and certified in the applicable method. NDT operators shall be qualified to at least level II.

1.6.2 NDT shall be performed in accordance with the general practice of recognised standards, e.g.:

Magnetic particle testing (MT) of bars:

— ISO 9934, ASTM E1444

Eddy current testing (ET) of bars:

— ISO 15549

Magnetic particle testing (MT) of forgings:

— EN 10228-1, ASTM A275, using wet continuous magnetisation technique

Ultrasonic testing (UT) of forgings:

— EN 10228-3, ASTM A388, ISO 13588

Magnetic particle testing (MT) of castings:

— ASTM E709, using wet continuous magnetisation technique

Ultrasonic testing (UT) of castings:

— ASTM A609, ISO 13588.

1.6.3 MT of forged or cast accessories shall be carried out after proof load testing. Where a forging or casting is delivered in an intermediate condition for subsequent processing and final MT, the manufacturer should perform suitable intermediate inspections taking into consideration the quality level required in finished condition. In such cases the extent of testing and acceptance criteria shall be agreed. See also [3.6], [4.6], and Sec.2 [3].

1.6.4 UT of forgings or castings shall be carried out at an appropriate stage after the final heat treatment for mechanical properties, e.g. after proof load testing of finished accessories.

1.7 Repair

1.7.1 Surface defects may be removed by grinding as detailed in [2] to [4]. The resulting grooves shall have a bottom radius of approximately three times the depth and shall be blended into the surrounding surface to avoid any sharp contours. Complete elimination of the defective material shall be verified by suitable NDT.

1.7.2 Except as provided for steel castings, repair by welding is not permitted.

1.8 Identification

Each bar, forging, or casting shall be suitably identified with at least the following:

a) identification number, heat number or other marking that will enable the history of the item to be traced
b) steel grade designation.

1.9 Records

The manufacturer shall maintain traceable records of the following and present them on request:

a) steelmaking process and chemical composition
b) heat treatment
c) mechanical testing
d) inspection
e) repair.

2 Rolled steel bars

2.1 Scope

These requirements are supplementary to [1] and apply to hot rolled steel bars to be used in the manufacture of offshore mooring chain and accessories.

2.2 Manufacture

2.2.1 Bars shall be made from ingots or continuous cast blooms or billets. Ingots shall be cast in chill moulds with the larger cross-section up, and with efficient feeder heads. Sufficient discard shall be made to ensure soundness in the finished bar. Surface and skin defects, which may be detrimental during the subsequent working and forming operations, shall be removed.

2.2.2 The rolling reduction ratio shall be at least 5:1. The rolling reduction ratio shall be calculated as the ratio average cross-sectional area of the cast material to cross-sectional area of the finished bar.

2.3 Chemical composition

The chemical composition shall comply with the agreed specification.

2.4 Condition of supply and heat treatment

2.4.1 Unless otherwise agreed, the bars shall be delivered in the as rolled condition.

2.4.2 For mechanical testing and hydrogen embrittlement testing, bar material shall be tested in the condition of heat treatment used for the chain as advised by the chain manufacturer.

2.5 Mechanical testing

2.5.1 A test unit shall consist of bars of the same nominal diameter, made from the same heat of steel, and with a total mass not exceeding 50 tonnes.

2.5.2 Test material shall consist of a suitable length cut from one bar in each test unit. The test material shall be heat treated in full cross-section, see [2.4.2].

2.5.3 For each test unit, one tensile and three Charpy V-notch test pieces shall be taken. For Charpy V-notch impact testing, the notch shall be cut in a face of the test piece which was originally approximately perpendicular to the rolled surface.

2.5.4 The mechanical properties shall comply with the values given in Table 1.

2.6 Hydrogen embrittlement testing

2.6.1 For grade R3S, R4, R4S, R5 and R6, each heat of steel shall be tested for hydrogen embrittlement by slow strain rate tensile testing. Samples shall be taken from two bars representing the front end and tail end of the billet string in case of continuous casting, or two ingots in case of ingot casting.

2.6.2 Two tensile test pieces shall be taken from the central region of each bar. The test pieces shall have a diameter of 20 mm, or alternatively 14 mm. One test piece shall be tested within three hours after machining for a 20 mm diameter test piece, or 1.5 hours for a 14 mm diameter test piece. The other test piece shall be tested after baking at 250°C for four hours for a 20 mm diameter test piece, or two hours for a 14 mm diameter test piece. The test pieces shall be loaded at a strain rate not exceeding 0.0003 per second until fracture occurs.

2.6.3 As an alternative to testing within the time limits given in [2.6.2] the test pieces may be cooled to –60°C immediately after machining and kept at that temperature for a maximum period of five days before testing.

2.6.4 The reduction of area values shall be determined. The ratio Z_1 to Z_2, where Z_1 is the value without baking and Z_2 is the value after baking, shall not be less than 0.85. Alternatively, the ratio shall not be less than 0.80 provided Z_1 is at least 50%.

2.6.5 If the results do not meet the specified requirements, the bar material may be subjected to a hydrogen degassing treatment. The embrittlement tests shall be repeated after degassing and the results must meet the specified requirements.

2.7 Dimensions and tolerances

The tolerances on diameter and roundness shall be in accordance with Table 2. Measurements shall be made on at least 1% of the bars.

2.8 Inspection

2.8.1 All bars supplied in a machined (peeled) condition shall be visually inspected. All bars supplied without machining shall be subjected to magnetic particle testing (MT), eddy current testing (ET) or flux leakage testing for longitudinal imperfections, see [1.6]. Other methods may be accepted subject to agreement.

2.8.2 All bar material shall be subjected to ultrasonic testing at an appropriate stage of manufacture.

2.8.3 All bars shall be free from injurious pipe, cracks, seams, laps or other imperfections which, due to their nature, degree or extent, will interfere with the use of the bars.

2.9 Repair

2.9.1 Defects may be removed by grinding to a depth of 1% of the nominal bar diameter.

2.9.2 Repair of bar by welding is not permitted.

3 Steel forgings

3.1 Scope

These requirements are supplementary to [1] and apply to steel forgings to be used in the manufacture of chain accessories. Additional requirements for the finished accessories are given in Sec.2 [3].

3.2 Manufacture

3.2.1 Forgings shall be made from ingots or continuous cast blooms or billets. Ingots for forgings shall be cast in chill moulds with the larger cross-section up, and with efficient feeder heads. Adequate top and bottom discards shall be made to ensure freedom from piping and harmful segregations in the finished forgings. Surface and skin defects, which may be detrimental during the subsequent working and forming operations, shall be removed.

3.2.2 The material shall be progressively hot worked by hammer or press, and shall be forged as close as practical to the finished shape and size.

3.2.3 The reduction ratio shall be calculated with reference to the average cross-sectional area of the cast material. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation. The total reduction ratio shall be at least 3:1. 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.

3.2.4 Welding to forgings is not permitted. This includes the welding of brackets, bosses, or attachments.

3.3 Chemical composition

The chemical composition shall comply with the agreed specification.

3.4 Heat treatment

3.4.1 Forged accessories in grade R3 and R3S shall be supplied in the normalised, normalised and tempered, or quenched and tempered condition. Grade R4, R4S, R5 and R6 shall be supplied in the quenched and tempered condition. Quenched and tempered accessories with diameter over 120 mm shall receive an annealing or normalising heat treatment prior to quenching and tempering.

3.4.2 For grade R4, R4S, R5 and R6, tempering temperatures shall not be less than 590°C and cooling after tempering shall be in water or oil.

3.4.3 Where forgings are to be quenched and tempered and cannot be hot worked close to shape, they shall be rough machined prior to being subjected to this treatment.

3.4.4 All hot forming operations shall be conducted prior to the final heat treatment. If a forging is subsequently heated for further hot forming, the forging shall be re-heat treated.

3.5 Mechanical testing

Forged accessories shall be mechanically tested as given in Sec.2 [3].

3.6 Inspection

3.6.1 All forgings shall be visually inspected on accessible surfaces. Where applicable, this is to include the inspection of internal surfaces and bores. The surfaces shall be adequately prepared for inspection. Black forgings shall be suitably de-scaled.

3.6.2 Forgings shall be free from injurious pipe, cracks, seams, laps or other imperfections which, due to their nature, degree or extent, will interfere with the use of the forgings.

3.6.3 All finished accessories are subject to magnetic particle testing, see [1.6] and Sec.2 [3].

3.6.4 Ultrasonic testing shall be carried out on all forgings after the final heat treatment when the surfaces have been brought to a condition suitable for UT. Both radial and axial scanning shall be used when appropriate for the shape and dimensions of the forging being tested. Unless otherwise agreed the entire volume of the forgings shall be tested.

3.6.5 For calibration, reference blocks shall be made from steel that is similar in chemistry and processing history to the production forgings. The distance amplitude curve (DAC) shall be based on 3 mm flat bottom hole. No indications equal to or larger than the reference DAC are acceptable.

3.7 Repair

Defects on non-machined surfaces may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0.8 mm in order to investigate spurious indications. Welding and weld repairs are not permitted.

4 Steel castings

4.1 Scope

These requirements are supplementary to [1] and apply to steel castings to be used in the manufacture of chain accessories. Additional requirements for the finished accessories are given in Sec.2 [3].

4.2 Manufacture

4.2.1 Castings shall be manufactured according to drawings showing the positions of gates, risers and chills (if used).

4.2.2 Where flame cutting, scarfing or arc-air gouging to remove surplus metal is undertaken, the affected areas shall be either machined or ground smooth.

4.3 Chemical composition

The chemical composition shall comply with the agreed specification.

4.4 Heat treatment

4.4.1 Cast accessories in grade R3 and R3S shall be supplied in the normalised, normalised and tempered, or quenched and tempered condition. Grade R4, R4S, R5 and R6 shall be supplied in the quenched and

tempered condition. Quenched and tempered accessories with diameter over 120 mm shall receive an annealing or normalising heat treatment prior to quenching and tempering.

4.4.2 For grade R4, R4S, R5 and R6, tempering temperatures shall not be less than 590°C and cooling after tempering shall be in water or oil.

4.5 Mechanical testing

Cast accessories shall be mechanically tested as given in Sec.2 [3].

4.6 Inspection

4.6.1 All castings shall be visually inspected on accessible surfaces. Where applicable, this is to include the inspection of internal surfaces and bores. The surfaces shall be adequately prepared for inspection.

4.6.2 Castings shall be free from adhering sand, scale, cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings.

4.6.3 All finished accessories are subject to MT, see [1.6] and Sec.2 [3].

4.6.4 Ultrasonic testing shall be carried out on all castings after the final heat treatment when the surfaces have been brought to a condition suitable for UT. Both radial and axial scanning shall be used when appropriate for the shape and dimensions of the casting being tested. The entire volume of the castings shall be tested.

4.6.5 For calibration, reference blocks shall be made from steel that is similar in chemistry and processing history to the production castings. The distance amplitude curve (DAC) shall be based on 3 mm flat bottom hole for testing to a depth of 25 mm below the surface and 6 mm flat bottom hole for testing the remaining volume. No indications equal to or larger than the reference DAC are accepted.

4.7 Repair

4.7.1 Defects on non-machined surfaces may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0.8 mm in order to investigate spurious indications.

4.7.2 Where the repair entails removal of more than 5% of the diameter or thickness, the defective area shall be repaired by welding. The excavations shall be suitably shaped to allow good access for welding. The resulting grooves shall be subsequently ground smooth and complete elimination of the defective material shall be verified by NDT.

4.7.3 Weld repairs are classified as major or minor. A weld repair is considered major when the depth of the groove prepared for welding exceeds 25% of the diameter or 25 mm, whichever is smaller. All other weld repairs are considered minor.

4.7.4 Major weld repairs require approval before the repair is commenced. Proposals for major repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs. A grain refining heat treatment shall be given to the whole casting prior to major repairs.

4.7.5 Minor weld repairs must be recorded on sketches or photographs showing the extent and positions of the repairs.

4.7.6 All weld repairs shall be done by qualified welders using qualified procedures. Welders shall be qualified according to EN 287, ISO 9606, ASME IX, ASTM A488 or equivalent. Procedures shall be qualified according to ISO 15614, ASME IX, ASTM A488 or equivalent with the following additional requirements: Charpy V-notch impact tests with notch locations in weld metal, fusion line and heat affected zone + 2 mm and + 5 mm from fusion line, respectively. Test results shall meet the requirements specified for the parent metal.

4.7.7 The welding consumables used shall be of a suitable composition giving a weld deposit with mechanical properties similar to those of the parent castings. Low hydrogen consumables shall be used. Welding consumables shall be stored and handled so as to maintain the hydrogen classification and in accordance with the consumable manufacturer's recommendations.

4.7.8 When repair welding is done after the casting has been heat treated for mechanical properties, the repaired casting shall be given a furnace stress relieving or tempering heat treatment as detailed in the qualified procedure.

4.7.9 On completion of heat treatment the weld repairs and adjacent material shall be ground smooth. All weld repairs are subject to NDT as required by [4.6].

5 Materials for studs

5.1 Scope

These requirements apply to forged or cast steel materials to be used in the manufacture of studs.

5.2 Chemical composition

5.2.1 The chemical composition shall be similar to that of the chain link or in compliance with a specification that provides for similar response to heat treatment.

5.2.2 The carbon content should not exceed 0.25% or the carbon equivalent (IIW) should not exceed 0.58% if the studs are to be welded in place.

Table 1 Minimum mechanical properties for chain cable materials

Steel grade	*Yield stress*	*Tensile strength*	*Elongation*	*Reduction of area*	*Charpy V-notch*		
	R_e	R_m	A_5	*Z*	*Temperature* [1]	*Average energy*	*Single energy*
	N/mm²	*N/mm²*	*%*	*%*	*°C*	*J*	*J*
R3	410	690	17	50 [2]	0	60	45
					-20	40	30
R3S	490	770	15	50 [2]	0	65	49
					-20	45	34
R4	580	860	12	50 [3]	-20	50	38
R4S	700	960	12	50 [3]	-20	56	42

Steel grade	Yield stress	Tensile strength	Elongation	Reduction of area	Charpy V-notch		
	R_e	R_m	A_5	Z	Temperature [1]	Average energy	Single energy
	N/mm^2	N/mm^2	%	%	°C	J	J
R5	760	1000	12	50 [3]	-20	58	44
R6	900	1100	12	50 [3]	-20	60	46

[1] For grade R3 and R3S, testing may be carried out at either 0°C or -20°C.

[2] For cast accessories, the minimum value shall be 40%.

[3] For cast accessories, the minimum value shall be 35%.

Table 2 Dimensional tolerances for rolled bars

Nominal bar diameter	Tolerance on diameter	Tolerance on roundness
mm	mm	$(d_{max} - d_{min})$ mm
51 – 80	-0 +2.0	1.50
81 – 100	-0 +2.6	1.95
101 – 120	-0 +3.0	2.25
121 – 160	-0 +4.0	3.00
161 – 200	-0 +5.0	4.00
201 – 220	-0 +6.0	4.50
221 – 250	-0 +8.0	6.00

SECTION 2 MOORING CHAIN CABLES AND ACCESSORIES

1 General requirements

1.1 Scope

Sub-section [1] specifies the general requirements for mooring chain and accessories in grade R3, R3S, R4, R4S, R5 and R6. The materials used shall comply with the requirements in Sec.1.

1.2 Inspection

Chain and accessories are subject to visual inspection, non-destructive testing (NDT) and measurements of dimensions as detailed in [2] and [3]. The manufacturer shall prepare written procedures for NDT. NDT personnel shall be qualified and certified according to ISO 9712, ACCP or equivalent. NDT operators shall be qualified and certified to at least level II. Personnel qualification to an employer based qualification scheme such as SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level 3 is ASNT Level III or ACCP Professional Level III and certified in the applicable method.

1.3 Repair

Defects may be removed by grinding as specified in [2] and [3]. The resulting grooves shall have a bottom radius of approximately three times the depth and shall be blended into the surrounding surface to avoid any sharp contours. Complete elimination of the defective material shall be verified by suitable NDT.

1.4 Identification

Identification marks shall be legible and, as far as possible, permanent throughout the expected service life of the chains and accessories.

1.5 Records

1.5.1 The manufacturer shall maintain traceable records of the following:

a) materials, as detailed in Sec.1
b) manufacture and heat treatment of chain and accessories
c) proof load testing
d) breaking load testing
e) mechanical testing
f) measurement of dimensions
g) inspection
h) repair.

1.5.2 The manufacturer is responsible for storing, in a safe and retrievable manner, all records for at least ten years.

2 Mooring chain

2.1 Scope

These requirements are supplementary to [1] and apply to stud link and stud less mooring chain.

2.2 Design

2.2.1 For stud link mooring chain, the form and proportion of links shall be in accordance with ISO 1704. The stud shall be designed to give an impression radius not less than 4 mm and a depth of impression between 2 and 6% of the nominal chain diameter.

2.2.2 For stud less mooring chain, the nominal outside length shall be six times nominal diameter and the nominal outside width shall be 3.35 times nominal diameter. Special designs may be agreed. Links having different proportions must be able to accommodate adjacent links and connectors.

2.3 Manufacture

2.3.1 Mooring chains shall be manufactured in continuous lengths by flash butt welding.

2.3.2 Blanks for links shall be heated by electric resistance, induction or in a furnace. For electric resistance heating and induction heating, the heating phase shall be controlled by an optical heat sensor. For furnace heating, the temperature shall be controlled and continuously recorded using thermocouples in close proximity to the bars. In both cases, the controls shall be checked at least once every eight hours and records made.

2.3.3 The following welding parameters shall be controlled during welding of each link:

— platen motion
— current as a function of time
— hydraulic upset pressure.

The controls shall be checked at least every four hours and records made.

2.3.4 Excess flash weld material shall be removed. A clean fusion zone, including the zone where the stud is pressed into the link, shall be maintained. The trimming knives used for flash removal shall be systematically and periodically controlled in order to monitor the degree of deterioration. The knives shall be changed out at regular intervals as specified in the applicable work procedure.

2.4 Welding of studs

2.4.1 Studs may be welded for grade R3 and R3S chains. Welding shall be completed before the chain is heat treated. Welding of studs in grade R4, R4S, R5 and R6 chain is not permitted.

2.4.2 Stud welds shall be made by qualified operators or welders using qualified procedures and low-hydrogen processes or consumables. The stud ends must be a good fit inside the link and the weld shall be confined to the stud end opposite the flash butt weld. The full periphery of the stud end shall be welded. The size of the stud welds shall be according to API Specification 2F.

2.5 Heat treatment

2.5.1 Mooring chains shall be heat treated in continuous furnaces. Batch heat treatment is not permitted except for short lengths of chain such as adaptor pieces and chafe chains.

2.5.2 Grade R3 and R3S shall be supplied in the normalised, normalised and tempered, or quenched and tempered condition. Grade R4, R4S, R5 and R6 shall be supplied in the quenched and tempered condition. Tempering temperatures shall not be less than 570°C and cooling after tempering shall be in water.

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

Furnace equipment calibration and temperature uniformity surveys shall be performed according to a documented procedure.

2.5.4 Furnaces shall be fully stabilised before the production chain enters. The leading and trailing ends of the production chain shall be provided with sufficient scrap chain to ensure uniform conditions during heat treatment.

2.5.5 Furnace zone temperatures, chain speed and quenching water temperature shall be controlled and continuously recorded. The records shall identify each chain length treated.

2.5.6 To further control heat treatment of grade R4, R4S, R5 and R6 chains exceeding 700 meters length, hardness surveys along the length shall be made every 100 meters provided every heat of steel is represented. Hardness tests shall also be made on each link subjected to mechanical tests. Indentations shall be made at the same place on each link, preferably on the straight portion, after suitable surface preparation. A minimum of five indentations should be made on each link to obtain an average hardness value. Each link not tested for mechanical properties shall have an average value within 15% of the link(s) from the same heat that has been satisfactorily tested for mechanical properties. If the results do not comply, the link with the largest deviation shall be cut out and subjected to mechanical testing. No further action is required if the mechanical properties are met. Hardness surveys shall be recorded.

2.6 Proof load testing

2.6.1 Each length of chain shall be proof load tested in the condition of supply and shall withstand the proof load specified in Table 1 without fracture. The applied load may exceed the specified minimum load by up to 15% in order to fasten studs and or to adjust dimensions.

2.6.2 In the event of a test failure, a thorough investigation shall be made. Two additional breaking load tests shall be made; one from each side of the failed link. The length shall be considered acceptable if both additional tests meet the requirement and if it has been determined by investigation that the probable cause of failure is not present in any of the remaining links.

2.7 Breaking load testing

2.7.1 Samples of the chain shall be subjected to breaking load testing in the condition of supply. The frequency of sampling shall be in accordance with Table 2 provided that every heat of steel is represented. End links and enlarged links heat treated with the chain need not be tested provided that common links from the same heat of steel are tested.

2.7.2 A sample consists of at least three links, except that for chain with nominal diameter 100 mm or above, the sample may consist of one link provided that terminations of similar size and geometry providing a good fit are used.

2.7.3 Sample links for testing shall be made as part of the chain cable. They may be removed prior to heat treatment provided that:

— each sample is properly identified with the chain represented, and
— each sample is securely attached to and heat treated with the chain represented.

Where multiple samples are needed to represent a continuous length, these shall be attached to both ends of the chain. Where sub-lengths of chain are temporarily joined for continuous passage through the furnace, samples shall also be attached in-between if the number permits.

2.7.4 Each sample shall withstand the breaking load specified in Table 1. It shall be considered acceptable if the samples show no sign of fracture after application of the minimum specified load for 30 seconds. If the capacity of the manufacturer's testing machine is insufficient, the testing shall be carried out at another recognised place.

2.7.5 In the event of a test failure, a thorough investigation shall be made. Two further breaking load tests shall be made. The sampling length shall be considered acceptable if both additional tests meet the requirement and if it has been determined by investigation that the probable cause of failure is not present in any of the remaining links.

2.8 Mechanical testing

2.8.1 Samples of the chain shall be subjected to mechanical testing after proof load testing, except as provided in [2.8.2]. The frequency of sampling shall be in accordance with Table 2 provided that every heat of steel is represented. End links and enlarged links heat treated with the chain need not be tested provided that common links from the same heat of steel are tested.

2.8.2 Prior proof load testing of sample links may be omitted provided it is documented that the properties, when determined after proof load testing, generally equal or exceed those of links without prior proof load testing. Test results from at least three heats of a particular grade shall be provided for this purpose and the test procedure approved.

2.8.3 A sample consists of at least one link. Sample links for testing shall be made as part of the chain cable. They may be removed prior to heat treatment provided that:

— each sample is properly identified with the chain represented, and
— each sample is securely attached to and heat treated with the chain represented.

Where multiple samples are needed to represent a continuous length, these shall be attached to both ends of the chain. Where sub-lengths of chain are temporarily joined for continuous passage through the furnace, samples shall also be attached in-between if the number permits.

2.8.4 One tensile and nine Charpy V-notch test pieces shall be taken from each sample, see Figure 1. The tensile test piece and three impact test pieces shall be taken from the side of the link opposite the flash weld. Three impact test pieces shall be taken across the flash weld with the notch centred in the middle. The position of the weld shall be accurately identified by etching with a suitable reagent before cutting the notches. Three impact test pieces shall be taken from the outer bend region, except as provided in [2.8.5]. The longitudinal axis of the test pieces shall be one third radius below the surface.

2.8.5 The frequency of impact testing at the bend may be reduced subject to agreement. In such cases it shall be documented that the requirements are consistently achieved. Test results from at least five heats of a particular grade shall be provided for this purpose.

2.8.6 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of DNVGL OS B101. The results shall comply with the mechanical properties specified in Table 3.

2.8.7 If the tensile test fails, two further test pieces selected from the same sample shall be tested. If either of the re-tests fails, the sampling length represented is rejected.

2.8.8 If the impact test fails, three further test pieces selected from the same sample shall be tested. The values shall be added to those previously obtained to form a new average. This average shall comply with the requirements. No more than two individual results shall be lower than the specified minimum average and no more than one individual result shall be below the specified minimum single value. If the re-test fails, the sampling length represented is rejected.

2.8.9 Rejected lengths may be submitted to re-heat treatment. In such cases the tests previously performed shall be repeated and the results must meet the requirements.

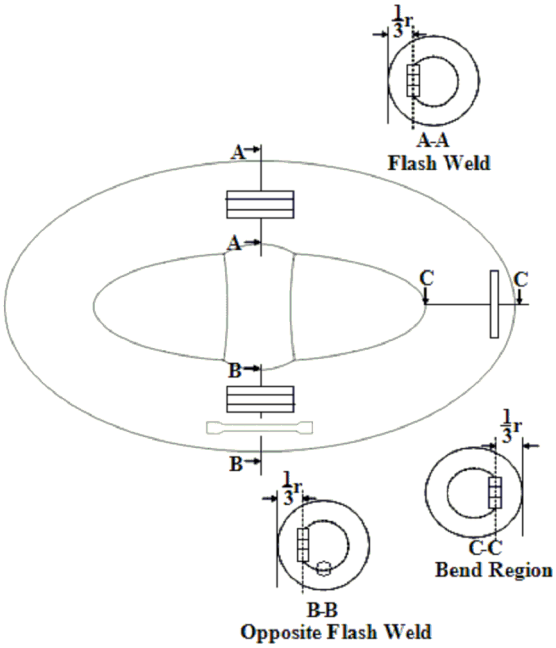

Figure 1 Position of test pieces

2.9 Dimensions and tolerances

2.9.1 After proof load testing, the pitch length in chain intended to work in way of windlass and fairlead shall be measured five links at a time with an overlap of at least one link. The measurements shall be made over the entire length of chain while the chain is either loaded to approximately 10% of the proof load or otherwise suitably arranged to enable correct measurements. The length over five links shall meet the tolerances given in Table 1. The links held in the end blocks may be excluded from these measurements. Accuracy of the 5 link measurement tool is to be within ± 0.1%.

2.9.2 If a five link length is short, the chain may be stretched by loading as detailed in [2.6.1]. If a five link length exceeds the plus tolerance, the affected links are rejected.

2.9.3 Measurements of all other dimensions, as detailed in [2.9.4] to [2.9.7], shall be made on at least 5% of the links distributed over the length.

2.9.4 The diameter shall be measured at the clamp area, and at the crown, unless otherwise approved. The average diameter based on at least two perpendicular measurements shall have no negative tolerance and the plus tolerances shall not exceed 5% of nominal diameter. As a result of being bent around the anvil, however, a particular diameter at the crown may be smaller than the nominal:

- for nominal diameter up to 84 mm: - 2 mm
- for nominal diameter 85 to 122 mm: - 3 mm
- for nominal diameter 123 to 152 mm: - 4 mm
- for nominal diameter 153 to 184 mm: - 6 mm
- for nominal diameter 185 to 222 mm: - 7.5 mm

2.9.5 The largest diameter at the flash weld area shall be checked. The plus tolerance shall not exceed 15% of nominal chain diameter.

2.9.6 The outside length and width shall be measured. Tolerances shall not exceed ±2.5%.

2.9.7 The stud position and alignment shall be measured. The stud shall be located in the link centrally, and at right angles to the sides of the link. The following tolerances are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link:

- maximum off-centre distance shall be 10% of the nominal chain diameter
- maximum angular misalignment shall be four degrees.

2.9.8 If one or two links fail to meet tolerance requirements, measurements of the particular dimension shall be made on 20 more links on each side of the affected links. If a third link fails to meet tolerance requirements, measurements of the particular dimension shall be made on all links. Links that fail to meet the requirements shall be rejected.

2.10 Inspection

2.10.1 After proof load testing, all links shall be visually inspected and non-destructive tested. Prior to inspection the surfaces shall be cleaned by shot or sand blasting to Sa 2.5 minimum according to ISO 8501-1.

2.10.2 All accessible surfaces, including the outer bends, shall be visually inspected. Links shall be free from burrs, rough edges, cracks, dents, cuts, distinct trimming marks, and other injurious imperfections. Studs shall be securely fastened; no axial or lateral movement is permitted.

2.10.3 The flash butt welds and the areas gripped by the clamping dies shall be magnetic particle tested (MT). Additionally, for chain with nominal diameter 132 mm or above, 10% of the links distributed over the length shall be tested on all accessible surfaces. Testing shall be performed in accordance with ASTM E709 or another recognised standard using wet continuous fluorescent magnetisation technique. Non fluorescent techniques can be accepted in special cases where the standard inspection procedures are impractical. Links shall be free from:

- relevant linear indications exceeding 1.6 mm in transverse direction

— relevant linear indications exceeding 3.2 mm in longitudinal direction
— relevant non-linear indications exceeding 4.8 mm.

2.10.4 The flash butt welds shall be ultrasonic tested (UT) in accordance with ASTM E587 or another recognised standard using single probe, angle-beam shear waves in the range from 45 to 70°.

Guidance note:

It should be recognised that the single probe technique has limitations as far as testing of the central region is concerned and that flash weld imperfections such as flat spots may have poor reflectivity. However, the central region would normally not contain the typical imperfections that can occur in flash butt welds. Where it is deemed necessary, detectability of imperfections can be improved by using a tandem technique or Phased Array.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.10.5 UT equipment shall be calibrated using IIW blocks. The search unit shall be checked for beam exit point and angle of reflection at least once per working shift or 8 hours, whichever comes first.

2.10.6 UT reference blocks shall be made from a chain link that is similar in diameter, surface condition, chemistry, and processing history to the production links. The block shall contain two surface notch reflectors in the plane of the weld oriented 180° apart; one located on the inner surface adjacent to the stud, and one located on the outer surface. The notch shall be maximum 3 mm wide and cut to a depth 4% of nominal diameter or 5 mm, whichever is smaller. The notch shall be cut circular with radius 15 mm. With the search unit positioned, the instrument is calibrated to obtain indication amplitude from both reflectors of approximately 75% of full screen height. The procedure shall be repeated from the other side of the weld.

2.10.7 UT of production links shall be performed by scanning along the circumference from both sides of the weld with the amplitude calibration increased by 6 dB. Indications equal to or larger in amplitude to that of the reference notch, when properly corrected for distance, are not accepted.

2.10.8 Stud welds, if used, shall be visually inspected. The toes of the fillets shall have a smooth transition to the link with no undercuts exceeding 1.0 mm. Additionally, at least 10% of the stud welds distributed through the length shall be liquid penetrant tested according to ASTM E1417 or magnetic particle tested according to ASTM E1444. Cracks, lack of fusion or gross porosity are not accepted. If defects are found, testing shall be extended to all stud welds in that length.

2.11 Repair

2.11.1 Defects may be removed by grinding to a depth of 5% of the nominal diameter.

2.11.2 Rejected links shall be cut out and replaced by connecting common links (splice links) or detachable joining shackles.

2.11.3 Splice links to connect lengths of heat treated chain or to replace cut out links without the necessity for re-heat treatment of the whole length shall be made in accordance with an approved procedure. The manufacture and heat treatment of splice links shall not affect the properties of the adjoining links. The temperature reached by adjoining links shall not exceed 250°C.

2.11.4 The use of splice links is restricted to three links, on average, in each 100 m of chain. Each splice link included in a chain shall be proof load tested, measured, inspected, and identified as detailed in [2.6], [2.9], [2.10], and [2.12].

2.11.5 A second identical splice link shall be made for mechanical testing as detailed in [2.8]. Where a number of splice links are included and these are made in series, the link for mechanical testing may represent five splice links from the same heat of steel.

2.11.6 Detachable joining shackles to connect lengths of heat treated chain or to replace cut out links shall be in accordance with [3]. The use of these is subject to approval in terms of the number and type permitted.

2.12 Identification

2.12.1 Each length of chain shall be identified with at least the following:

— identification number or other marking that will enable the history of the length to be traced
— chain grade designation
— connecting common links, if used, shall have unique identification numbers.

2.12.2 The chain shall be marked at the following places:

— at each end
— at intervals not exceeding 100 m
— on connecting common links
— on links next to shackles or connecting common links.

2.12.3 The identification marks shall be placed on the studs or, in the case of stud less links, on the outside of the link opposite the flash weld. Marking by welding is not permitted on stud less links.

3 Chain accessories

3.1 Scope

3.1.1 These requirements are supplementary to [1] and apply to chain accessories.

3.1.2 Where the manufacture of materials and accessories, heat treatments, machining, testing and inspections involve several parties, the purchaser should establish by contract agreement, at the time of ordering, the responsibility of the various parties for meeting the requirements.

3.2 Design

3.2.1 Accessories shall be manufactured in accordance with ISO 1704 or approved drawings showing the finished dimensions and the surfaces that will be subjected to significant loading. Accessories of unconventional design shall have their drawings accompanied by calculations or design reports.

3.2.2 Detailed design of Kenter shackles shall be according to API Spec 2F. Machining of Kenter shackles shall result in fillet radius minimum 3% of nominal diameter. Machined surfaces in high stress areas shall have a surface condition of Ra 3.2 µm or better.

3.3 Proof load testing

3.3.1 All accessories shall be proof load tested in the condition of supply and shall withstand without fracture the proof load prescribed in Table 1 for the stud link chain grade and size for which they are intended.

3.3.2 In the event of a test failure, the accessory shall be rejected. Testing of the remaining accessories shall be considered acceptable if they meet the requirement and if it has been determined by examination that the probable cause of failure is not present in any of the remaining accessories.

3.4 Breaking load testing

3.4.1 At least one accessory out of every test unit shall be breaking load tested in the condition of supply and shall withstand without fracture the breaking load prescribed in Table 1 for the chain grade and size for which they are intended. It shall be considered acceptable if the samples show no sign of fracture after application of the specified minimum load for 30 seconds.

3.4.2 A test unit shall consist of up to 25 accessories of the same type, grade and size, made from the same heat of steel, and heat treated in the same furnace charge.

3.4.3 Where the size of a test unit is less than five produced accessories, alternative testing may be agreed.

3.4.4 Except as provided in [3.4.5], accessories that have been breaking load tested shall be discarded and not used as part of a mooring system.

3.4.5 Accessories that have been breaking load tested may be used as part of a mooring system provided that:

— the accessories are of increased dimensions or alternatively a material with higher strength characteristics is used, and
— it is verified by procedure test that such accessories are so designed that the breaking strength is not less than 1.4 times the breaking load of the chain cable for which they are intended.

3.4.6 In the event of a test failure, two further breaking load tests shall be made. The test unit shall be considered acceptable if both additional tests meet the requirement and if it has been determined by examination that the probable cause of failure is not present in any of the remaining accessories.

3.5 Mechanical testing

3.5.1 At least one accessory out of every test unit, see [3.5.2], shall be tensile and impact tested in the condition of supply. Except as provided in [3.5.3], test material for mechanical testing shall be one of the following:

— a sacrificial accessory that has been proof load tested or breaking load tested
— an integral prolongation or trepanned hole on a production accessory.

3.5.2 A test unit shall consist of up to 25 accessories of the same type, grade and size. Test material shall represent each heat of steel and heat-treat lot.

3.5.3 Where the size of a test unit is less than five produced accessories, alternative testing may be agreed provided that:

— dimensions, manufacture and test sampling of coupons shall be specified in a written procedure
— separately forged coupons shall have the same cross-section, the same or smaller forging reduction ratio and the same thermal history as the thickest section of the accessories represented
— separately cast coupons shall have the same cross-section and the same thermal history as the thickest section of the accessories represented

— test pieces for tensile and Charpy V-notch testing shall be positioned such that the distance to any second (end) surface is at least equal to one coupon diameter or thickness
— procedure shall be qualified by testing of coupon and accessory to verify that the mechanical properties of the coupon represent the largest cross-section of the accessory
— coupon and at least one accessory in each heat-treat lot shall have contact thermocouples attached during heat treatment.

3.5.4 Hardness testing shall be performed on the test material surface and the surface of each production accessory after heat treatment. The test method, locations and acceptance criteria (minimum and maximum hardnesses) shall be as specified by the manufacturer.

3.6 Dimensions and tolerances

3.6.1 After proof load testing, at least one accessory out of every test unit shall be checked for dimensions. Where applicable, the measurements shall include detachable component parts.

3.6.2 The diameter must have no negative tolerance. Unless otherwise specified, the plus tolerance on diameter shall not exceed 5% and tolerances on other dimensions shall not exceed plus or minus 2.5%.

3.6.3 If an accessory fails to meet the tolerance requirements or if Kenter shackles or similar designs are loose upon re-assembly, it shall be rejected and all remaining accessories in the test unit shall be measured.

3.7 Inspection

3.7.1 After proof load testing, all accessories shall be visually inspected and non-destructive tested. Prior to inspection the non-machined surfaces shall be cleaned by shot or sand blasting to Sa 2.5 minimum according to ISO 8501-1. Where applicable, the accessories shall be dismantled for inspection of internal surfaces.

3.7.2 All accessible surfaces shall be visually inspected and be free from burrs, rough edges, cracks, dents, cuts, and other injurious imperfections.

3.7.3 All surfaces shall be magnetic particle tested (MT). Testing shall be performed in accordance with standards referenced in Sec.1 [1.6] using the fluorescent technique. Surfaces shall be free from:

— relevant linear indications exceeding 1.6 mm in transverse direction
— relevant linear indications exceeding 3.2 mm in longitudinal direction
— relevant non-linear indications exceeding 4.8 mm.

3.7.4 Requirements for ultrasonic testing are given in Sec.1 [3.6] (forgings) and Sec.1 [4.6] (castings).

Note:

UT shall be carried out after final heat treatment but need not be performed after proof load testing.

---e-n-d---o-f---n-o-t-e---

3.8 Repair

Defects on non-machined surfaces may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0.8 mm in order to investigate spurious indications.

3.9 Identification

3.9.1 Each accessory shall be identified in a low stress area with at least the following:

— identification number or other marking that will enable the history of the accessory to be traced
— chain grade designation.

3.9.2 Each detachable component part shall be marked with an identifying number to avoid mix-up of parts. In addition, the main component parts shall have incremental numbering referring to the original drawings.

3.9.3 Accessories that have been breaking load tested and are used as part of a mooring system, as permitted in [3.4], shall be marked with the grade of chain for which they are intended.

Table 1 Formulas for proof and breaking test loads, weight, and five link length

	Grade R3	*Grade R3S*	*Grade R4*	*Grade R4S*	*Grade R5*	*Grade R6*
Proof load, stud link (kN)	$0.0156d^2$ (44-0.08d)	$0.0180d^2$ (44-0.08d)	$0.0216d^2$ (44-0.08d)	$0.0240d^2$ (44-0.08d)	$0.0251d^2$ (44-0.08d)	$0.0276d^2$ (44-0.08d)
Proof load, stud less (kN)	$0.0156d^2$ (44-0.08d)	$0.0174d^2$ (44-0.08d)	$0.0192d^2$ (44-0.08d)	$0.0213d^2$ (44-0.08d)	$0.0223d^2$ (44-0.08d)	$0.0246d^2$ (44-0.08d)
Breaking load (kN)	$0.0223d^2$ (44-0.08d)	$0.0249d^2$ (44-0.08d)	$0.0274d^2$ (44-0.08d)	$0.0304d^2$ (44-0.08d)	$0.0320d^2$ (44-0.08d)	$0.0352d^2$ (44-0.08d)
Weight, stud link (kg/m)	$0.0219d^2$					
Five link length (mm)	Minimum 22d and maximum 22.55d					
d is the chain nominal diameter						

Table 2 Frequency of breaking load and mechanical tests

Nominal chain diameter (mm)	*Maximum sampling interval (m)*
74 - 85	152
86 - 98	175
99 - 111	198
112 - 124	222
125 - 137	250
138 - 149	274
150 -162	297
163 - 175	322
176 - 186	346
187 - 199	370

Nominal chain diameter (mm)	Maximum sampling interval (m)
200 - 210	395
211 - 220	420
221 - 230	445

Table 3 Minimum mechanical properties for chain cables

Grade	Yield stress 4)	Tensile strength 4)	Elongation	Reduction of area	Charpy V-notch				
						Base		Weld	
	R_e	R_m	A_5	Z	Temperature 1)	Average energy	Single energy	Average energy	Single energy
	N/mm^2	N/mm^2	%	%	°C	J	J	J	J
R3	410	690	17	50 2)	0	60	45	50	38
					-20	40	30	30	23
R3S	490	770	15	50 2)	0	65	49	53	40
					-20	45	34	33	25
R4	580	860	12	50 3)	-20	50	38	36	27
R4S	700	960	12	50 3)	-20	56	42	40	30
R5	760	1000	12	50 3)	-20	58	44	42	32
R6	900	1100	12	50 3)	-20	60	46	44	34

1) For grade R3 and R3S, testing may be carried out at either 0°C or -20°C.

2) For cast accessories, the minimum value shall be 40%.

3) For cast accessories, the minimum value shall be 35%.

4) For guidance only: Typical yield to tensile strength ration is in the range of 0.85 to 0.95. Tensile strength is normally not to exceed the minimum tensile strength with more than 150 MPa.

CHAPTER 3 CERTIFICATION AND CLASSIFICATION

SECTION 1 CERTIFICATION AND CLASSIFICATION - REQUIREMENTS

1 General

1.1 Introduction

1.1.1 As well as representing DNV GL's recommendations on safe engineering practice for general use by the offshore industry, the offshore standards also provide the technical basis for DNV GL classification, certification and verification services.

1.1.2 A complete description of principles, procedures, applicable class notations and technical basis for offshore classification is given by the DNV GL rules for classification of offshore units, see Table 1.

Table 1 DNV GL Rules for classification - Offshore units

No.	*Title*
DNVGL RU OU-0101	Offshore drilling and support units
DNVGL RU OU-0102	Floating production, storage and loading units
DNVGL RU OU-0103	Floating LNG/LPG production, storage and loading units
DNVGL RU OU-0104	Self elevating units

1.2 Certification and classification principles

Mooring chain and accessories will be certified or classified based on the following main activities:

— design verification
— approval of manufacturers
— survey during manufacture.

1.3 Assumptions

1.3.1 Any deviations, exceptions and modifications to the design codes and standards given as recognised reference codes shall be documented and approved by DNV GL.

1.3.2 Aspects of the design and construction provisions of this standard which are stated to be *specially considered, agreed upon*, or *may be accepted* are subject to DNV GL approval when the standard is used for classification purposes.

1.3.3 DNV GL may accept alternative solutions found to represent an overall safety level equivalent to that stated in the requirements of this standard.

1.4 Documentation requirements

Documentation requirements shall be in accordance with the NPS DocReq (DNV GL Nauticus Production System for documentation requirements) and DNVGL CG 0168.

2 Certification and classification requirements

2.1 General

The following requirements shall be applied in conjunction with the technical requirements in Ch.2 of this standard when used for certification or classification purposes.

2.2 Information to be supplied by the purchaser

The purchaser shall supply the manufacturer with all information necessary to ensure correct material and certification. This applies particularly where optional or additional conditions are specified.

2.3 Design verification

2.3.1 Mooring chain cables and accessories shall be designed according to requirements given in Ch.2 Sec.2 [2.2] and Sec.2 [3.2], respectively. Where designs differ from this, the drawings and calculations shall be submitted to DNV GL for approval.

Guidance note:

Design requirements are given in DNVGL OS E301.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.3.2 Design approval shall be documented by design verification report (DVR), type approval certificate or approval letter.

2.4 Approval of manufacturers

2.4.1 Materials, chain cables and accessories shall be manufactured at works which have been approved by DNV GL. Approved manufacturers are published on www.dnvgl.com.

2.4.2 In order to be approved, the manufacturer shall demonstrate and submit documentation to the effect that the necessary manufacturing, testing and inspection facilities and procedures are available and are supervised by qualified personnel. The manufacturer shall also carry out a test programme and submit the results. The following procedures shall be submitted for approval:

- Procedure for Heat Treatment, Chain.
- Procedure for Splice Links, Chain.
- Procedures for proof load, breaking load and mechanical testing.
- Procedures for measurements, visual inspection and NDT.
- Procedure for Heat Treatment, Accessories.
- Procedure for mechanical testing of full size products. This shall give all relevant details including sketches showing the position of test pieces.
- Procedure for mechanical testing of coupons, i.e. alternative to testing full size products. This shall give all relevant details including sketches showing size of the coupon and the position of test pieces. The procedure shall be accompanied by results from procedure tests.
- For forged accessories: Forging procedure.
- For cast accessories: Procedure for repair by welding.

— Procedures for proof load and breaking load testing of accessories.
— Procedures for measurements, visual inspection and NDT of accessories.

2.4.3 Detailed programmes for approval are given in DNV Approval programme No. 316.

2.5 Survey during manufacture

2.5.1 Survey during manufacture of mooring chain and accessories shall be based on attending tests and inspections, monitoring manufacturing, and review of records. The scopes of survey are defined in App.A and App.B.

2.5.2 The scopes defined in App.A and App.B are typical and adjustments may be permitted or required based on considerations such as:

— complexity and size of a delivery
— previous experience with equipment type
— maturity and effectiveness of manufacturer's quality system
— degree of subcontracting.

2.6 Certification of materials

2.6.1 Rolled steel bars shall be delivered with DNV GL certificates giving the following particulars for each test unit which has been accepted:

— purchaser's name, order number and vessel identification, where known
— manufacturer's name
— number and dimensions of bars and steel grade
— identification marking of bars
— heat number and chemical composition
— results of mechanical tests
— details of heat treatment of test material
— results of hydrogen embrittlement test, where required
— results of visual inspection and NDT
— results of any supplementary and additional test requirements specified.

2.6.2 Steel forgings, steel castings and semi-finished steels such as billets, blooms and forged bars intended for chain cable accessories shall be delivered with the manufacturer's certificates, e.g. EN 10204 type 3.1, giving the following particulars for each test unit which has been accepted:

— purchaser's name, order number and vessel identification, where known
— manufacturer's name
— number and dimensions of semi-finished products and steel grade
— identification marking of products
— heat number and chemical composition
— details of heat treatment
— results of visual inspection and UT, if not carried out on finished product
— results of any supplementary and additional test requirements specified.

2.6.3 Materials for studs shall be delivered with the manufacturer's certificates or test reports, e.g. EN 10204 type 3.1 or 2.2.

2.7 Certification of mooring chain and accessories

Mooring chain and accessories shall be delivered with DNV GL certificates giving the following particulars for each test unit which has been accepted:

— purchaser's name, order number and vessel identification, where known
— manufacturer's name
— description of products and dimensions
— grade of chain, method of manufacture, condition of supply and reference to material certificate
— identification marking
— results of proof load test, breaking load test and mechanical tests
— confirmation of dimensional measurements and inspections.

APPENDIX A SCOPE OF SURVEY FOR MOORING CHAIN

Activity or item	*Ref in OS*	*Survey*	*Description*
Pre-production meeting	NA	H	- Scope of delivery - Schedule - Inspection and test plan - Works approval status - Design approval status - Procedures approval status - Test machines calibration status
Materials	Ch.2 Sec.1	M/R	- Certificates and traceability
Manufacture	Ch.2 Sec.2 [2.3]	M/R	- Procedure compliance - Records
Welding of studs	Ch.2 Sec.2 [2.4]	M/R	- Procedure compliance - Records
Heat treatment	Ch.2 Sec.2 [2.5]	M/R	- Procedure compliance - Records
Proof load testing	Ch.2 Sec.2 [2.6]	W/R	- Witness in beginning, then monitoring - Procedure compliance - Records
Breaking load testing	Ch.2 Sec.2 [2.7]	H/R	- Witness - Procedure compliance - Records
Mechanical testing	Ch.2 Sec.2 [2.8]	H/R	- Witness - Procedure compliance - Records
Dimensional measurements	Ch.2 Sec.2 [2.9]	M/R	- Procedure compliance - Records
Inspection	Ch.2 Sec.2 [2.10]	M/R	- Procedure compliance - Records
Repair	Ch.2 Sec.2 [2.11]	H/M/R	- Witness splice link set-up and testing - Procedure compliance - Records
Identification	Ch.2 Sec.2 [2.12]	M/R	
Records (Data book)	Ch.2 Sec.2 [1.5]	H/R	

Activity or item	Ref in OS	Survey	Description
Definitions			
Hold point (H)			A point where DNV GL shall be present for supervision or survey. Advance notification to DNV GL shall be given in writing or any other agreed system of notification. Work shall not proceed beyond a hold point without DNV GL present or, in exceptional cases where presence is waived, without first obtaining written authorisation from DNV GL.
Witness point (W)			A point where DNV GL may be present for supervision or survey, at their discretion. Advance notification to DNV GL shall be given in writing or any other agreed system of notification. Work may proceed beyond a witness point with or without DNV GL present.
Monitoring (M)			Intermittent monitoring or surveillance of any stage of the work in progress including, but not limited to, checking compliance with procedures/instructions for manufacture, testing and inspection, observing workmanship, traceability, etc.
Review (R)			Examination of records of activities performed or results achieved.

APPENDIX B SCOPE OF SURVEY FOR MOORING CHAIN ACCESSORIES

Activity or item	*Ref in OS*	*Survey*	*Description*
Pre-production meeting	NA	H	- Scope of delivery - Schedule - Inspection and test plan - Works approval status - Design approval status - Procedures approval status - Test machines calibration status
Materials	Ch.2 Sec.1	M/R	- Certificates and traceability
Manufacture	Ch.2 Sec.1	M/R	- Procedure compliance - Records
Heat treatment	Ch.2 Sec.1	M/R	- Procedure compliance - Records
Proof load testing	Ch.2 Sec.2 [3.3]	W/R	- Witness in beginning, then monitoring - Procedure compliance - Records
Breaking load testing	Ch.2 Sec.2 [3.4]	H/R	- Witness - Procedure compliance - Records
Mechanical testing	Ch.2 Sec.2 [3.5]	H/R	- Witness - Procedure compliance - Records
Dimensional measurements	Ch.2 Sec.2 [3.6]	M/R	- Procedure compliance - Records
Inspection	Ch.2 Sec.2 [3.7]	M/R	- Procedure compliance - Records
Repair	Ch.2 Sec.2 [3.8]	M/R	- Procedure compliance - Records
Identification	Ch.2 Sec.2 [3.9]	M/R	
Records (Data book)	Ch.2 Sec.2 [1.5]	H/R	

Activity or item	Ref in OS	Survey	Description
Definitions			
Hold point (H)			A point where DNV GL shall be present for supervision or survey. Advance notification to DNV GL shall be given in writing or any other agreed system of notification. Work shall not proceed beyond a hold point without DNV GL present or, in exceptional cases where presence is waived, without first obtaining written authorisation from DNV GL.
Witness point (W)			A point where DNV GL may be present for supervision or survey, at their discretion. Advance notification to DNV GL shall be given in writing or any other agreed system of notification. Work may proceed beyond a witness point with or without DNV GL present.
Monitoring (M)			Intermittent monitoring or surveillance of any stage of the work in progress including, but not limited to, checking compliance with procedures/instructions for manufacture, testing and inspection, observing workmanship, traceability, etc.
Review (R)			Examination of records of activities performed or results achieved.

CHANGES – HISTORIC

July 2015 edition

Main changes July 2015

• General

The revision of this document is part of the DNV GL merger, updating the previous DNV standard into a DNV GL format including updated nomenclature and document reference numbering, e.g.:

— Main class identification **1A1** becomes **1A**.
— DNV replaced by DNV GL.
— DNV-RP-A201 to DNVGL-CG-0168. A complete listing with updated reference numbers can be found on DNV GL's homepage on internet.

To complete your understanding, observe that the entire DNV GL update process will be implemented sequentially. Hence, for some of the references, still the legacy DNV documents apply and are explicitly indicated as such, e.g.: Rules for Ships has become DNV Rules for Ships.

About DNV GL

DNV GL is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.

SAFER, SMARTER, GREENER