DNV·GL

OFFSHORE STANDARD

DNVGL-OS-E304 Edition July 2015

Offshore mooring steel wire ropes

DNV GL AS

FOREWORD

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

Any comments may be sent by e-mail to *rules@dnvgl.com*

CHANGES – CURRENT

General

This document supersedes DNV-OS-E304, October 2013.

Text affected by the main changes in this edition is highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

On 12 September 2013, DNV and GL merged to form DNV GL Group. On 25 November 2013 Det Norske Veritas AS became the 100% shareholder of Germanischer Lloyd SE, the parent company of the GL Group, and on 27 November 2013 Det Norske Veritas AS, company registration number 945 748 931, changed its name to DNV GL AS. For further information, see www.dnvgl.com. Any reference in this document to "Det Norske Veritas AS", "Det Norske Veritas", "DNV", "GL", "Germanischer Lloyd SE", "GL Group" or any other legal entity name or trading name presently owned by the DNV GL Group shall therefore also be considered a reference to "DNV GL AS".

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.

Editorial corrections

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

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Contents

CHAPTER 1 INTRODUCTION

SECTION 1 GENERAL

1 General

1.1 Introduction

1.1.1 This Offshore Standard contains criteria, technical requirements and guidance on materials, design, manufacture and testing of offshore mooring steel wire ropes, sockets and pins.

1.1.2 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.

1.1.3 The objectives of this standard are to:

- provide an internationally acceptable standard of safety by defining minimum requirements for offshore mooring steel wire ropes, sockets and pins
- 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 steel wire ropes, sockets and pins subject to DNV GL certification and classification.

1.1.4 This standard is divided into three main chapters:

- Ch.1: with general information, scope, definitions and references
- Ch.2*:* with technical provisions
- Ch.3: giving specific procedures and requirements applicable for certification and classification in accordance with this standard. Also, requirements to design verification are given.

1.2 Scope and application

1.2.1 The mooring steel wire ropes, sockets and pins 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.

1.2.2 This standard covers:

- stranded ropes and spiral ropes
- sockets and pins including socketing performance criteria and socketing procedures.

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 RP 2SK	Recommended Practice for Design and Analysis of Station-keeping Systems for Floating Structures
API Spec 9A / ISO 10425	Steel wire ropes for the petroleum and natural gas industries – Minimum requirements and terms for acceptance
ASTM A275	Standard practice for Magnetic Particle Examination of Steel Forgings
ASTM A388	Standard Practice for Ultrasonic Examination of Heavy Steel Forgings
ASTM A487M	Specification for Steel Castings suitable for Pressure service
ASTM A586	Zinc Coated Parallel and Helical Structural Strand and Zinc Coated Wire for Spun-in-Place Structural Strand
ASTM A603	Standard Specification for Zinc-Coated Steel Structural Wire Rope
ASTM A609	Standard Practise for Castings, Carbon, Low-Alloy and Martensitic Stainless Steel, Ultrasonic Examination Thereof
ASTM A703	Steel Castings, General Requirements for Pressure – Containing Parts
ASTM A856	Standard Specification for Zinc-5% Aluminium-Mischmetal Alloy-Coated Carbon Steel Wire
ASTM D1248	Standard Specification for Polyethylene Plastics Moulding and Extrusion Materials
ASTM E112	Test methods for determining average grain size
ASTM E709	Standard Guide for Magnetic Particle Examination
DNVGL-OS-B101	Metallic Materials
DNVGL-OS-C401	Fabrication and Testing of Offshore Structures
DNVGL-OS-E301	Position Mooring
DNVGL-OS-E302	Offshore Mooring Chain
DNV-OS-F101	Submarine Pipeline Systems
EN 59	Method of testing plastics
EN 1179	Zinc and zinc alloys – Primary zinc
EN 10016-4	Non-Alloy Steel Rod for Drawing and/or Cold Rolling. Part 4: "Specific Requirements for Rod for Special Applications"
EN 10083-1	Steels for quenching and tempering – Part 1: General delivery conditions
EN 10088-2	Stainless Steels – Part 2: "Technical Delivery Conditions for Sheet/Plate and Strip of corrosion resistant steels for general purposes".
EN 10204	Metallic Products – Types of Inspection Documents
EN 10218	Steel Wire and Wire products – General: Part 1 "Test Methods"
EN 10228-1/3	Non-destructive testing of steel forgings
EN 10264-2	Steel wire and wire products – Steel wire for ropes – Part 2: Cold drawn non alloyed steel wire for ropes for general applications
EN 10264-3	Steel wire and wire products – Steel wire for ropes – Part 3: "Round and shaped non alloyed wire for high duty applications".
EN 12385-10	Steel wire ropes – Safety – Part 10: "Spiral ropes for general structural applications"
ISO 604	Plastics – Determination of compressive properties
ISO 2232	Round drawn wire for general purpose non-alloy steel wire ropes and for large diameter steel wire ropes - Specifications
ISO 3108	Steel wire rope for general purposes – determination of actual breaking load
ISO 4346	Steel wire ropes for general purposes – Lubricants – basic requirements
ISO 9712	Non-destructive testing – Qualification and certification of personnel
ISO 16120-4	Non alloyed steel wire rod for conversion to wire: Part 4 "Specific requirements for wire rod for special applications"
ISO 17558	Socketing procedures for wire ropes – resin socketing
ISO 17893	Steel wire ropes – Vocabulary, designation and classification
SNT-TC-1A (ASNT)	Personnel Qualification and Certification in Non-destructive Testing

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

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
non-destructive testing (NDT)	visual inspection, radiographic testing, ultrasonic testing, magnetic particle testing, penetrant testing and other non-destructive methods for revealing defects and irregularities
mobile mooring	anchoring at a specific location for a period less than 5 years
long term mooring	mooring of a unit at the same location for more than 5 years
unit	is a general term for an offshore installation such as ship-shaped, column-stabilised, self-elevating, tension leg or deep draught floater
stranded rope	assembly of several strands laid helically in one (single-layer rope) or more (rotation-resistant or parallel-closed rope) layers around a core or centre e.g. 6×19, 6×36, 6×61
spiral rope	assembly of at least two layers of wires laid helically over a centre round wire, built-up strand or parallel-lay strand, with at least one layer of wires being laid in the opposite direction, i.e. contra-lay, to that of the outer layer(s) e.g. spiral strand, half locked coil, full locked coil
wire tensile strength grade	level of requirement of tensile strength of a wire and its corresponding range, designated by the value according to the lower limit of tensile strength and used when specifying wire and when determining the calculated minimum breaking load or calculated minimum aggregate breaking load of a rope

CHAPTER 2 TECHNICAL PROVISIONS

SECTION 1 GENERAL

1 Introduction

1.1 Steel wire rope constructions

1.1.1 Steel wire rope segments of mooring lines could be of various constructions as shown in Figure 1. Other type of constructions may also be used if relevant experience can be documented.

1.1.2 The stranded rope constructions include a number of strands wound in the same rotational direction around a centre core to form the wire rope. The number of strands and wires in each strand (e.g. 6×19, 6×36, 6×61) are governed by required strength and bending fatigue considerations for the wire rope. This construction generates torque as tension increases.

1.1.3 The torque balanced spiral rope constructions (spiral strand, half locked and full locked coils) do not generate significant torque with tension changes. These constructions use layers of wires (or bundles of wires) wound in opposing directions to obtain the torque balanced characteristics. The half locked and full locked coil constructions consist of one or more layers of shaped wires over the basic spiral rope construction resulting in a design more resistant to the ingress of corrosion media. The shaped layer(s) of wires will also prevent any outer wire fracture from unwinding. These constructions will normally give higher load capacity related to nominal diameter due to the increased metallic area, compared to other constructions.

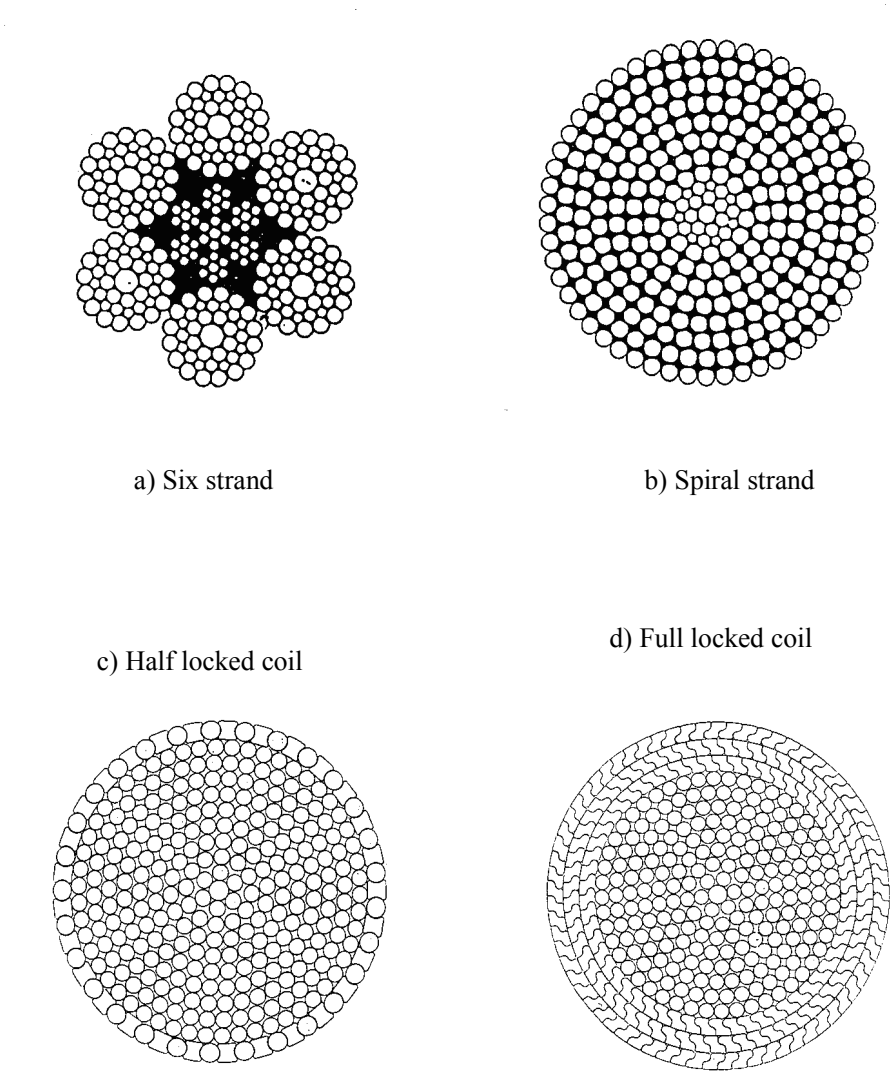

Figure 1 Steel wire rope constructions

1.2 Corrosion protection measures

1.2.1 A common design requirement is that wire rope segments in mooring lines shall be protected against corrosion attacks throughout the design life. The wire rope is therefore assumed to be fully protected such that its fatigue life approaches that in air. This normally is ensured by the following measures or combinations thereof:

- Sacrificial coating of wires.
- Application of a blocking compound on each layer of the strand during stranding. The compound should fill all crevices in the wire rope, strongly adhere to wire surfaces and have good lubricating properties.
- Surface sheathing of the wire rope by an extruded plastic jacket in order to prevent ingress of sea water and flushing out of blocking compound.

1.2.2 The ends of each wire rope segment are normally to be terminated with sockets. Resin shall be used for pouring the sockets. For long term mooring the sockets should be provided with bend stiffeners (bend limiting devices). This is to protect the wire ropes from bending during installation operations when the bending radiuses are close to the minimum allowed value. To prevent water ingress in the socket a sealing system may be incorporated in the device.

1.3 Guidance for choice of wire rope construction

1.3.1 For long term mooring spiral ropes are normally used. These ropes maximise the available steel area and provide high strength to size ratio, high axial stiffness and limited rotation under load (i.e. torque balanced as mentioned above). Further, these constructions are considered to have high corrosion resistance since a lower proportion of steel wire area is exposed and the ingress of water to the centre of the rope is more difficult than with stranded ropes. Also, the closed and compact design of these ropes are very suitable to jacketing for added corrosion protection. Within this type of ropes half locked and full locked coil constructions have a higher wear resistance than spiral strands because of the compact, near cylindrical surface. However, these are stiffer constructions and may, depending on the number of shaped wire layers, require more care during handling and installation. Locked coil ropes also require a larger bending radius than other constructions.

1.3.2 For mobile mooring stranded ropes are most commonly used. However, due to their flexibility, they may also be used in long term mooring systems as for example the upper short segment which is subject to winching damage, fairlead bending fatigue and splash zone corrosion. In these mooring systems stranded ropes may be considered as a "consumable" item which can be replaced every few years, whereas the lower segments are not intended to be replaced

1.3.3 Type of rope construction and extent of corrosion protection must be a case to case evaluation depending on factors like design life, level of bending stresses, environmental conditions, position of the wire rope segment in the mooring system and possibilities for replacement of the wire rope segment.

1.3.4 In DNVGL-OS-E301 Ch.2 Sec.4 Table 4-1 guidelines for choice of wire rope construction as a function of field design life and possibilities for replacement have been given. However, it should be emphasized that this table is a rough guidance and that there are no distinct limits of use for each construction.

SECTION 2 MATERIALS

1 General

1.1 Scope

1.1.1 These requirements apply to steel and plastic materials used for the manufacture of offshore mooring steel wire ropes, sockets and pins.

1.1.2 The requirements given in [5], [6], and [7] are relevant for steel wire ropes in long term mooring lines.

2 Wires

2.1 Manufacture

2.1.1 The steels shall be manufactured by an electric or one of the basic oxygen processes or any other agreed process involving secondary refining.

2.1.2 The steels shall be killed and fine grain treated. The austenite grain size of the bar used for drawing of wire shall be 5 or finer in accordance with ASTM E112. 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%.

2.2 Chemical composition

The chemical composition shall in general be in accordance with ISO 16120-4 or equivalent. Deviations from the chemistry may be permitted subject to agreement.

2.3 Quality and strength

The wire shall be of homogenous quality, consistent strength and free from visual defects likely to impair the performance of the rope.

2.4 Wire finish

2.4.1 For spiral ropes the wire shall be hot dip coated or equivalent after final drawing. Wires for stranded ropes may be drawn coated or equivalent. In the case of galvanising, the zinc coating shall be continuous and of reasonably uniform thickness and shall comply with EN 1179:1995 grade Z3. Zn-Al alloys shall comply with ASTM B750, with or without Mischmetal.

2.4.2 For spiral ropes the minimum weight of zinc coating shall be in accordance with ASTM A586 Class A.

2.4.3 Stranded ropes shall at least conform to the standard to which the wire has been manufactured (API 9A/ISO 10425, EN 10264-2, ISO 2232 or equivalent).

3 Sockets and pins

3.1 Manufacture

3.1.1 The steels shall be manufactured as given in [2.1]. The prior austenite grain size of ferrite steel castings and forgings shall be 5 or finer in accordance with ASTM E112.

3.1.2 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 to the purchaser on request

3.2 Chemical composition

3.2.1 Castings shall comply with the requirements of ASTM A487M Grade4 or equivalent. Grade 10 or equivalent may be used for sockets with large sections subject to agreement.

3.2.2 Forgings shall comply with 34CrNiMo6 according to EN 10083-1 or equivalent.

3.2.3 Pins may be cast, forged or rolled (wrought). If duplex material is used, it shall comply with EN 10088-2 Grade 1.4462 or ASTM A276 S31083. Super duplex material shall satisfy the requirements given for EN 10088-2 Grade 1.4501 or ASTM A276 S32760.

3.3 Heat treatment

3.3.1 Materials shall be heat treated for mechanical properties as specified in [3.4]. 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.

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

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

3.3.4 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 [3.1.2].

3.4 Mechanical testing

3.4.1 Sockets and pins shall be sampled for mechanical testing as detailed in Sec.5 [2.1].

3.4.2 Sample material and test pieces shall be marked to identify them with the products represented.

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

3.4.4 The tensile test value shall satisfy the requirement of the actual material. In addition, the socket materials shall satisfy a Charpy V-notch energy of 50J at -20ºC.

3.4.5 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.

3.4.6 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.

3.4.7 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.

3.5 Inspection

3.5.1 Materials are subject to, non-destructive testing (NDT) and measurements of dimensions as detailed in Sec.5. The manufacturers shall prepare written procedures for NDT. NDT personnel shall be qualified and certified according to EN 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. Company appointed Level 3 is not accepted.

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

Magnetic particle testing (MT) of forgings:	EN 10228-1, ASTM A275, using wet continuous magnetization technique
Ultrasonic testing (UT) of forgings:	EN 10228-3, ASTM A388
Magnetic particle testing (MT) of castings:	ASTM E709, using wet continuous magnetization technique
Ultrasonic testing (UT) of castings:	ASTM A609
Liquid penetrant testing (PT) of casting/forgings	ISO 3452, ASTM E165

3.5.3 UT of forgings or castings shall be carried out at an appropriate stage after the final heat treatment for mechanical properties and prior to machining operations that limit effective interpretation of the results of the testing.

3.6 Repair

3.6.1 Surface defects may be removed by grinding as detailed in Sec.5 [2.3]. 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.

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

3.7 Identification

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

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

4 Socketing compound

4.1 General

4.1.1 A resin socketing system shall be used. The following performance criteria shall be met:

Table 1 Performance criteria

Compressive strength:	min.100 N/mm^2
Modulus of elasticity:	min. 6 000 N/mm^2
Barcol hardness:	min. 36
Specific gravity:	1.55 – 1.95

4.1.2 Whenever possible, the pouring of all sockets should be accomplished using one master batch of resin i.e. all the kits shall have the same unique batch number.

5 Surface sheathing

5.1 General

5.1.1 Where required by the purchaser, a medium or high density plastic material preferably polyethylene in accordance with ASTM D 1248 or equivalent shall be used as surface sheathing. Material data shall be documented by the manufacturer.

5.1.2 The sheathing should have a light colour in order to improve possibilities for video inspection of the wire rope surface in submerged condition. An axial stripe should be provided on the sheathing to control possible twisting of the wire rope.

6 Bend stiffener

Where required by the purchaser, a plastic material (preferably polyurethane), should be used as bend stiffeners. Material data shall be documented by the manufacturer.

7 Lubricating/blocking compound

The lubricating/blocking compound shall be stiff but not solid, and shall have good adhesive properties over the actual operating temperature range. The compound shall be compatible with the sheathing material and shall have long term durability with sea water. Further, the compound shall comply with the basic requirements given in ISO 4346 or equivalent standards.

SECTION 3 DESIGN ASSESSMENT

1 General

1.1 Scope

This section covers requirements to basic documentation and testing procedures in order to perform a design check and issue Design Verification Reports (DVR) for the actual wire rope construction and socket.

1.2 Basic documentation

1.2.1 The design verification aims at confirming that the proposed wire rope construction and socket design satisfy the specified design conditions, codes and standards.

1.2.2 The work consists of review of calculations, drawings and other data supplied by the manufacturer documenting the strength and serviceability of the actual wire rope construction and socket.

1.2.3 The following information is required as a minimum:

- list of design codes and standards including purchaser's specifications
- purchaser supplied design premises including imposed loads and excursions at the end of the line and other relevant design data
- strength and fatigue calculations for the ropes and sockets including dynamic loading
- details of all rope, socket, and plastic materials including mechanical, corrosion resistance and fatigue properties
- details and calculations for corrosion protection methods
- applicable drawings for ropes and sockets including bill of materials
- a summary of service experience where available.

1.2.4 It is assumed that materials and rope/socket test data will be made available to the purchaser as and when required.

2 Design verification criteria of wire rope

2.1 Strength and fatigue analysis

2.1.1 The calculated static strength of the wire rope shall be at least equal to or exceed the minimum certified breaking load.

2.1.2 Fatigue calculations should be carried out according to DNVGL-OS-E301 or equivalent standards subject to agreement.

2.2 Testing procedures

2.2.1 The conditions for acceptance is that testing of the wire rope construction is found to be satisfactory. For acceptance one break load test from the first manufactured length shall be carried out as follows:

- Prior to the break load test an elastic modulus test shall be performed on the test sample. The sample shall be loaded (cycled) until full stabilisation is reached. The load/extension and permanent stretch shall be recorded and reported.
- Load test of the sample to the minimum certified breaking load.

2.2.2 The wire rope construction will be considered to have passed test a) if the permanent elongation of the rope is less than 0.4% for a spiral rope and 0.8% for a stranded rope and test b) if the test sample equals the minimum certified breaking load.

2.2.3 For the above test, the sample does not require actual production sockets to be fitted.

3 Design verification criteria of socket

3.1 Strength and fatigue analysis

The strength of the socket and pin shall be at least that of the minimum certified breaking load of the rope. The fatigue strength should be evaluated against the design life of the mooring system.

3.2 Testing procedures

3.2.1 The conditions for acceptance is that testing of the sockets and pins is found to be satisfactory. For acceptance one socket shall be tested. The same methods, procedures and materials shall be used to connect the rope to the socket as those used to produce the rope/socket connection for in-service use. The following test is required:

3.2.2 Loading of the socket and pin to the minimum certified breaking load of the wire rope for a duration of 30 seconds followed by MT inspection of the pin and defined critical areas of the socket.

3.2.3 The socket will be considered to have passed the test if the following is satisfied:

a) The pin can be removed from the socket and replaced without unreasonable application of force.
b) The MT passes the requirements in Sec.5 [2.2].

SECTION 4 WIRE ROPE MANUFACTURE

1 General

1.1 Scope

This section covers tests to be carried out on wires and general manufacturing requirements of wire ropes.

1.2 Quality plan

Prior to manufacturing a Quality Plan shall be established by the manufacturer and accepted by the purchaser. The Quality Plan shall describe activities to be performed, frequency and type of inspection/tests, criteria to be met as well as give reference to applicable controlling documents.

2 Manufacture

2.1 Wire manufacture

2.1.1 The wire shall be manufactured to one of the following wire standards or to an equivalent standard:

Round wire – ASTM A603, ASTM A586, EN 12485-10, EN 10264-2, ISO 2232, API 9A/ISO 10425

Shaped wire – EN 10264-3.

2.1.2 The minimum tensile strength of the wire shall be the tensile strength grade ordered. The tensile strength grade of the wires shall be maximum 2160 N/mm^2. If the upper tensile strength limit is not defined by the wire standard, it shall not exceed the minimum tensile strength by more than 260 N/mm^2.

2.1.3 If any of the specified wire tests fail to meet the actual specification, a further two test samples shall be selected from the same wire bundle and tested. If both tests meet the specification, the wire bundle is accepted as satisfactory.

2.1.4 If any of the above tests are performed on wires taken from an already manufactured wire rope, the testing shall follow the requirements of EN 12385, API 9A, ISO 10425 or equivalent.

2.2 Stranding and closing

2.2.1 The wire ropes shall be manufactured in accordance with the assessed and accepted design (see Sec.3). Winding, stranding and closing operations shall be carried out as detailed in the accepted Quality Plan.

2.2.2 The core of a stranded rope shall normally be an independent wire rope (IWRC).

2.2.3 Each wire rope segment shall be checked for dimensions (length and diameter). The manufacturer shall provide a statement indicating compliance with the purchaser's requirements.

2.2.4 Before welding of individual wires, a welding procedure qualification test shall be carried out. The procedure shall comprise tensile testing of the welded joint. The following requirement applies:

— Tensile strength to be min. 40% of the strength of the wires.

2.2.5 In addition, for spiral ropes the following apply:

— No welds of finished wire shall be made in the outer layer of the strand without notifying the purchaser.

Guidance note:
Welds in the outer layer should be made on the basis of mechanical failure and not material defects. If any recurrent material defect is found to be the reason for outer layer failure, then the entire wire should be removed and replaced.

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

— No welds of finished wire shall be made within 5 m of the socket in any layer of wires
— No welds of finished wire shall be closer to another weld than 10 lay lengths in any layer of wires.
— In the event of more than two wire breaks requiring welds, occurring within any layer of wires, no

further layers of wire shall be applied without a full investigation into the reasons and with the acceptance of the purchaser to continue.

— The positions of all welds of finished wire shall be recorded and reported to the purchaser for acceptance.

— All repairs shall be recorded in the final wire rope documentation.

2.2.6 The lubricating/blocking compound shall be applied on each layer of the strand during stranding providing internal lubrication and preventing water intrusion.

2.3 Surface sheathing

2.3.1 If sheathing of the wire rope is required by the purchaser, the process shall be carried out in accordance with the accepted Quality Plan.

2.3.2 Process controls should include measurements of overall diameter, sheathing thickness and tolerances, and continuous integrity tests.

2.3.3 All repairs shall be carried out in accordance with a repair procedure specification which shall be based on manufacturer's previous experience and which has produced appropriate repairs and shown satisfactory service performance over a prolonged period of time.

SECTION 5 MANUFACTURE AND ASSEMBLY OF SOCKETS AND ACCESSORIES

1 General

1.1 Scope

This section covers mechanical- and non-destructive tests to be carried out on sockets and pins and general manufacturing requirements to the socketing operation and bending limiter.

1.2 Quality plan

Prior to manufacturing a Quality Plan shall be established by the manufacturer and accepted by the purchaser. The Quality Plan shall describe activities to be performed, frequency and type of inspection/tests, criteria to be met as well as give reference to applicable controlling documents.

2 Sockets and pins

2.1 General

2.1.1 Sockets and pins shall be manufactured in accordance with the assessed and accepted design (see Sec.3).

2.1.2 For socket production testing normally one socket from the first production batch shall be sectioned and sample taken as per Figure 1. Additionally, production tests shall be carried out for sockets and pins using test coupons. These test coupons from which test specimens are prepared, shall be of equivalent cross section and be fully representative of the socket and where appropriate, shall not be cut, or partially cut from the socket until heat treatment has been completed. Test material and test specimen shall not be separately heat treated in any way.

2.1.3 Test sample for production testing of the pin, shall be cut R/3 from the surface as shown in Figure 2. The longitudinal axis of the test specimens shall be one third radius below the surface. The test sample may also be taken from a prolongation of the pin.

2.1.4 Sockets or pins of the same nominal thickness originating from the same heat treatment charge and the same heat of steel, shall be combined into one test unit. Normally, for each test unit one tensile and three Charpy V-notch test specimens shall be taken.

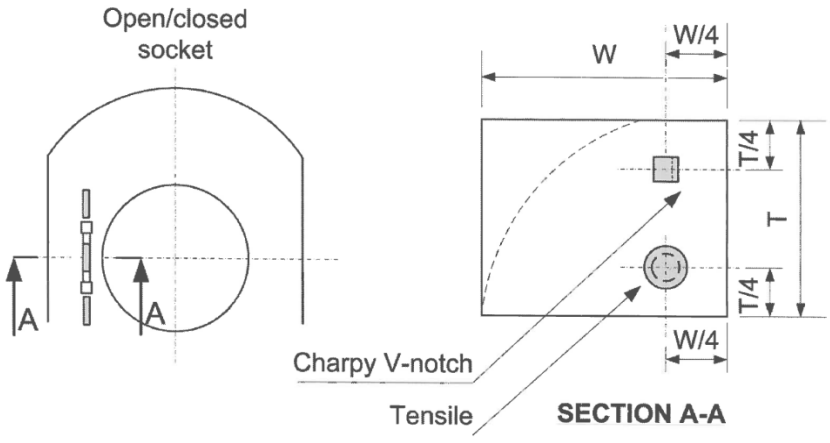

Figure 1 Sampling for mechanical testing of socket

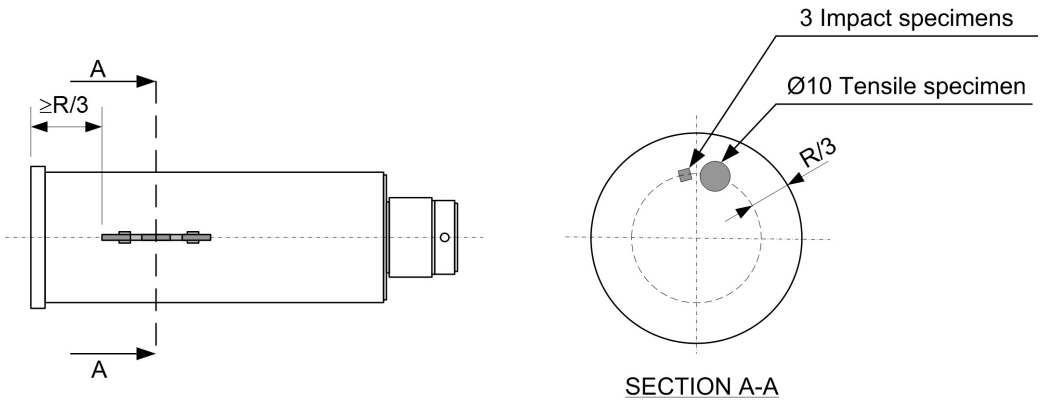

Figure 2 Sampling for mechanical testing of pin

2.2 Non-destructive testing

2.2.1 After heat treatment and machining but before coating (e.g. galvanising) the sockets/pins shall be non-destructively tested.

2.2.2 All the sockets/pins shall be 100% visually tested. For castings, the quality of the surface shall be as given in ASTM A703 Item 10.

2.2.3 The sockets/pins shall have defined critical areas subject to agreement. All of the sockets/pins shall be examined ultrasonically in critical and non-critical areas in accordance with the standards referred in Sec.2 [3.5].

2.2.4 For castings, ultrasonic indications less than 25 mm apart shall be evaluated as one discontinuity. The ultrasonic acceptance criteria are the following: No planar discontinuities are allowed in any location. In addition, Quality level 1 will be required down to a depth of T/4 from the surface and Quality level 2 for the remainder of the wall thickness. Quality level 3 is required for non-critical areas.

2.2.5 For forgings the acceptance criteria shall be in accordance with DNVGL-OS-E302 Ch.2 Sec.1 [3.6]. For duplex stainless steel forgings the acceptance criteria are given in DNV-OS-F101 Appendix D Sub-section element D500.

2.2.6 Specified sockets subject to ultrasonic examination shall in addition, undergo radiographic examination in accordance with ASTM A 703 Supplementary requirements S5. Radiographic examination shall not be confined to critical areas of the casting as defined by design high stress including sharp changes of section and feeder locations, also non-critical areas where there is a high probability of finding sand inclusions, shrinkage cavities etc. shall be examined. Number of sockets to be tested shall be according to Table 1. The acceptance criteria shall be severity level 3, or better, for all imperfection categories except that critical areas shall be subjected to the acceptance criteria of ASME Section VIII, Division 1, Appendix 7.

Table 1 Radiographic examination of sockets

Number of sockets	*Frequency*
1-19	First and last socket
20-49	First, last and one intermediate socket selected by the purchaser
50-99	First, last and two intermediate sockets selected by the purchaser

2.2.7 All the sockets/pins shall be examined 100% by magnetic particle testing or liquid penetrant testing following the standards given in Sec.2 [3.5]. The acceptance criteria for cast sockets shall be in accordance with ASTM E 125, Severity Degree 2 or better for surface indications Type II through V and 3/16” max. for Type I except that critical areas shall be subjected to the acceptance criteria of ASME Section VIII, Division 1, Appendix 7. For forged sockets, the acceptance criteria shall be in accordance with DNVGL-OS-E302 Ch.2 Sec.2 [3.7]. For duplex stainless steel forgings the acceptance criteria are given in DNV-OS-F101 Appendix D.

2.3 Repairs

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

2.3.2 Where the repair entails removal of more than 5% of the diameter or thickness on castings, 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.

2.3.3 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 thickness or 25 mm, whichever is smaller. All other weld repairs are considered minor.

2.3.4 Major weld repairs require the approval of the purchaser 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.

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

2.3.6 All weld repairs shall be done by qualified welders using qualified procedures in accordance with DNVGL-OS-C401.

2.3.7 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 manufacturer's recommendations.

2.3.8 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.

2.3.9 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 [2.2].

2.4 Corrosion protection

2.4.1 The sockets shall be protected against corrosion attacks throughout the design life. This shall normally be accomplished by using a combination of coating and anodes.

2.4.2 For wire ropes without plastic sheathing: If there is a possibility of electric contact between socket and individual wires, either current drain to the wires shall be taken into account in the anode design calculation, or the socket strength/fatigue calculation shall not take benefit of the cathodic proctection.

3 Socketing

3.1 Socketing procedures

Socketing procedures shall as a minimum be according to applicable sections of ISO 17558 or equivalent standards. Socketing shall be performed by personnel qualified by the manufacturer and carried out in compliance with procedures and check lists worked out by the manufacturer and evaluated and accepted by the purchaser. Such procedures should as a minimum include:

— minimum bending radius of rope during handling
— control of even distribution of individual wires at rope termination prior to socket pouring
— determination of tolerances for angular and parallel offsets of rope and socket axis
— control of angularity and parallelism of rope and socket axis before casting of resin (i.e. position of socket related to rope).

3.2 Verification of properties

3.2.1 Verification of the compressive strength and modulus of elasticity of the socketing compound shall be addressed using ISO 604. The test samples shall be 40 mm cubes cast in multi-cavity moulds. The resin cubes shall be post cured at 80ºC for two hours prior to testing.

3.2.2 For each socket pour a minimum sampling of six cubes shall be taken during the pouring process. One of these cubes shall be used to determine the Barcol hardness (EN 59) and the specific gravity of the mix (Note: Different sample sizes may be used for the Barcol test only e.g. 70 mm cube or 70 mm diameter disc.) The remaining five cubes can be used to determine the compressive strength and compressive modules. As a minimum, however, values for compressive strength and compressive modulus shall be established for the first three socket pours, the middle three socket pours and the near final three socket pours. The results shall comply with the properties specified in Sec.2 [4.1]. Samples not tested shall be stored for a period to be agreed between the manufacturer and purchaser

3.2.3 If a relationship based on many years of experience can be established between density versus compressive strength/E-modulus and density versus hardness, the amount of testing subject to agreement may be reduced to testing of density only. However, if the density drops below 1.65 g/cm^3, full testing according to [3.2.1] and [3.2.2] shall be performed.

4 Bend stiffener

If bend stiffeners are required by the purchaser, they shall be manufactured in accordance with the accepted Quality Plan.

SECTION 6 TESTS OF STEEL WIRE ROPE INTENDED FOR LONG TERM MOORING

1 General

1.1 Scope

This section covers requirements to testing of wire ropes intended for long term mooring in order to determine that the minimum certified breaking load of the wire rope has been equalised.

1.2 Description of tests

1.2.1 The tests shall be carried out according to recognised standard such as ISO 3108 or equivalent.

1.2.2 The type of tests required are described in Sec.3 [2.2] and [3.2]. Normally, the following 3 tests shall be performed:

— one modulus/load to MBL test assembly (test sockets may be used on each end)
— one open socket production type test assembly
— one closed socket production type test assembly.

1.2.3 Regarding the production type test assemblies, the rope samples shall be fitted in one end with a socket identical to the approved design and using the same methods, procedures and materials as those used to produce the rope/socket connection for in-service use.

1.2.4 The number of tests may be reduced to 2 if the modulus/load to MBL test is combined with one of the production type test assemblies.

1.2.5 In the event that all of the sockets are of the same type (open or closed), a minimum of two tests from different manufactures, shall be required one of which shall be a type test.

1.2.6 In the case of only a small number of wire ropes (≤ 3) to be delivered, the number of tests may be reduced to one by agreement.

1.2.7 Test acceptance criteria are given in Sec.3 [2.2] (wire rope) and [3.2] (socket).

SECTION 7 TESTS OF STEEL WIRE ROPE INTENDED FOR MOBILE MOORING

1 General

1.1 Scope

This section covers requirements to testing of wire ropes intended for mobile mooring in order to determine that the minimum certified breaking load of the wire rope has been achieved

1.2 Description of tests

1.2.1 Every manufactured length of wire rope shall be subjected to a breaking load test. However, in the case that the manufactured lengths are produced on the same machine with the same machine settings, according to the same wire rope design and by using wires to the same wire specification, the number of break load tests may be reduced after special consideration and in agreement with the Purchaser

1.2.2 The breaking load shall be determined by testing to destruction a sample cut from the finished wire rope. The test length shall be taken as at least 30 times the rope diameter between the grips. The actual breaking load shall not be less than given in Table 2 for the dimension concerned. For other wire rope constructions and/or diameters the breaking load shall be in accordance with the requirements of a recognised national or international standard subject to agreement.

1.2.3 If facilities are not available for pulling the complete section of six strands ropes to destruction, the breaking load may be determined by testing separately 10% of all wires from each strand. The breaking load of the rope is then considered to be:

$$Smbs = f\ t\ k_1\ (kN)$$

f = average breaking load of one wire (kN)
t = total number of wires
k_1 = spinning loss factor as given in Table 1.

Table 1 Spinning factor k_l

Rope construction group	*Rope with FC*	*Rope with IWRC*
6 × 19	0.86	0.80
6 × 36	0.84	0.78

Table 2 Test loads and masses for six strand steel wire ropes

Rope with fibre core (FC)				
Construction groups	*Nominal diameter (mm)*	*Minimum required breaking strength in kN*		*Approximate mass (kg/100 m)*
		1570 N/mm2	*1770 N/mm2*	
6 × 19 group	24 26 28 30	299 351 407 468	337 396 459 527	214 251 291 334
6 × 19 group and 6 × 36 group	32 36 40 44 48 52 56 60	530 671 829 1 000 1 190 1 400 1 620 1 860	598 757 934 1 130 1 350 1 580 1 830 2 100	380 480 593 718 854 1 000 1 160 1 330
Rope with independent wire-rope core (IWRC)				

Table 2 Test loads and masses for six strand steel wire ropes (Continued)

Rope with fibre core (FC)				
Construction groups	*Nominal diameter (mm)*	*Minimum required breaking strength (kN)*		*Approximate mass (kg/100 m)*
		1570 N/mm2	*1770 N/mm2*	
6 × 19 group	24	323	364	241
	26	379	428	283
	28	440	496	328
	30	505	569	376
6 × 19 group and 6 × 36 group	32	573	646	428
	36	725	817	542
	40	895	1 010	669
	44	1 080	1 220	810
	48	1 290	1 450	964
	52	1 510	1 710	1 130
	56	1 750	1 980	1 310
	60	2 010	2 270	1 510
	64	2 290	2 580	1 710
	68	2 590	2 920	1 930
6 × 36 group	72	2 900	3 270	2 170
	76	3 230	3 640	2 420
	80	3 580	4 040	2 680
	84	3 950	4 450	2 950
	88	4 330	4 880	3 240
	92	4 730	5 340	3 540
	96	5 160	5 810	3 850
	100	5 590	6 310	4 180
	104	6 050	6 820	4 520
	108	6 520	7 360	4 880
	112	7 020	7 910	5 250
	116	7 530	8 490	5 630
	120	8 060	9 080	6 020
	124	8 600	9 700	6 430
	128	9 170	10 330	6 850

SECTION 8 IDENTIFICATION AND RECORDS

1 General

1.1 Identification

1.1.1 All parts shall be clearly marked and identifiable to ease quality control, handling, assembly and installation.

1.1.2 Each wire rope segment shall be marked at each end with a unique identifier traceable to appropriate certification.

1.2 Records

1.2.1 The socket manufacturer shall maintain traceable records of the following and present them to the purchaser on request:

— steelmaking process and chemical composition
— heat treatment
— mechanical testing
— inspection
— repair.

1.2.2 Each wire rope segment shall be supplied with one certificate. The certificate should refer to the following:

— purchase order No.
— design verification reports
— sheathing process reports (if relevant)
— 3.2 Inspection Certificates for the sockets including the resin
— 3.2 Inspection Certificates for the individual wires.

1.2.3 In addition the certificate should contain the wire rope construction and rope built up and a statement saying that the wire rope has been manufactured and inspected and found to be in accordance with this standard.

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 as listed in Table 1.

Table 1 DNV GL Rules for classification - offshore units

Reference	*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 steel wire ropes and sockets 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-RP-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 steel wire ropes and sockets shall be designed according to requirements given in Ch.2 Sec.3. 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---of---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 Steel wire ropes and sockets shall be manufactured at works which have been approved by DNV GL. Approved manufacturers are published on DNV GL Exchange on the Internet.

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.

2.4.3 Detailed programmes for approval are given in DNV Standards for Certification No.2.9.

2.5 Survey during manufacture

2.5.1 Survey during manufacture of mooring steel wire ropes and sockets shall be based on attending tests and inspections, monitoring manufacturing, and review of records.

2.5.2 With respect to individual wire testing, min. 5% of the wires to be assembled into a rope shall be selected by the DNV GL surveyor and testing witnessed by the same person.

2.6 Certification of sockets

Sockets 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 unit identification, where known
- manufacturer's name
- number and dimensions of sockets
- identification marking of sockets
- heat number and chemical composition
- results of mechanical tests
- details of heat treatment of test material
- results of any supplementary and additional test requirements specified.

2.7 Certification of mooring steel wire ropes

Mooring steel wire ropes 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 unit identification, where known
- manufacturer's name
- description of products and dimensions
- type of wire rope construction and method of manufacture
- surface sheathing (if relevant)

— identification marking
— results of break load test and mechanical tests
— confirmation of dimensional measurements and inspections

DNV GL

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