



# STANDARD FOR CERTIFICATION

**No. 2.9**

**Approval Programme No. 313**

## **OFFSHORE MOORING STEEL WIRE ROPES AND SOCKETS**

**MAY 2011**

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## ***Background:***

This is a new document which gives the procedure to be followed to obtain DNV approval for the manufacture of offshore mooring steel wire ropes and sockets in accordance with the requirements of OS-E304. It replaces relevant parts in the withdrawn CN No.2.5 regarding approval of steel wire rope manufacturers.

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## **1. General**

### **1.1 Scope**

This programme gives the procedure to be followed to obtain the Society's approval for the manufacture of offshore mooring steel wire ropes and sockets in accordance with the requirements of DNV-OS-E304.

### **1.2 Range of approval**

For stranded rope constructions approval is required for each wire rope class and limited to maximum tested wire rope diameter. For spiral rope constructions approval is required for each construction and limited to maximum tested wire rope diameter. However, for stranded rope constructions test data supplied for any construction within a class will cover wire ropes of all other constructions in the same class (for definition of classes, see API 9A), provided that the core is of the same type (fibre/steel).

Classification of steel wire rope constructions are according to ISO 17893. Examples of the more common classes, sizes and grades of stranded rope and spiral rope constructions are given in API 9A/ISO 10425.

Approval for long term mooring category will not cover mobile mooring category and vice versa.

A separate approval is required for each grade of finished sockets, steel forgings for sockets and steel castings for sockets and approval is limited to maximum weight and maximum wall thickness.

See also detailed range of approval in Appendix A.

### **1.3 Validity and Renewal**

The approval will be valid for four years. To maintain the approved status, the manufacturer must be re-inspected every four years. Application for renewal should be made not later than three months before the expiry date of the certificate.

Any essential changes made to the manufacturing process, equipment or procedures during the period of validity shall be reported to the Society. A re-inspection and/or re-testing may be required when deemed necessary by the Society.

New requirements for the manufacturer due to revision of this programme, i.e. imposed during the period of validity, shall take effect at the next extension, change or renewal of the approval, unless otherwise required by the Society.

### **1.4 Approval Procedure, General**

#### **1.4.1 Application**

Application for approval shall be sent to the local DNV office with the following information:

- Name and address of the manufacturer's works.
- A list of products for which approval is requested. The list shall include the relevant information specified in 1.2 and Appendix A.
- A brief description of manufacturing, testing and inspection facilities and equipment. The description need not be re-submitted in connection with application for extension of an existing approval unless changes have taken place.

#### **1.4.2 Works Inspection and Approval Testing**

After receipt and review of the application the surveyor will carry out a works inspection to verify that the necessary manufacturing, testing, and inspection facilities are available, procedures incorporating DNV's requirements are written, implemented and supervised by qualified personnel.

Unless otherwise specified herein, the testing procedures and test results shall comply with the appropriate requirements of the DNV-OS-E304.

Products shall be subjected to approval testing as described in sections 2 to 4. Approval tests, except for determination of chemical composition and metallographic examination, shall be witnessed by DNV's surveyor unless otherwise described in sections 2 to 4.

In case of newly built works or newly developed types of wire ropes, an increased number of wire ropes and dimensions for testing may be deemed necessary on a case by case evaluation.

In case the test results for the approval testing fail to meet the requirements given in the referred standards, retesting of certain tests for the same wire rope is in general not permitted. However, the manufacturer shall do an evaluation of the cause for the failure and implement preventive actions. The evaluation report shall be submitted to the local DNV office together with the approval report. New approval testing on new wire ropes

after implementation of preventive actions will generally be required.

#### **1.4.3 Submission of Approval Report**

On completion of approval testing, the manufacturer shall submit a complete approval report to the local DNV office. The report shall contain the approval information and the results from approval testing specified in sections 2 to 4. The report shall be signed and dated by the manufacturer's representative.

The English language shall be used in the documentation. To facilitate evaluation of the report, it should be well organised, preferably by using the same order and indexing as described in this programme.

#### **1.4.4 Evaluation of Approval Report**

When received at the local DNV office, the approval report will be checked for completeness and then forwarded to the DNV Responsible Approval Centre for evaluation together with applicable checklists.

#### **1.4.5 Issue of Approval of Manufacturer Certificate**

Manufacturers whose works has been inspected and whose approval report has been reviewed with satisfactory result will be granted an "Approval of manufacturer certificate" and an entry made on DNV Exchange on the internet (<http://exchange.dnv.com/tari>).

#### **1.4.6 Suspension and Withdrawal of Approval of Manufacturer Certificate**

All or part of a manufacturer's scope of approval will be suspended or subsequently withdrawn when it is found that the manufacturer is no longer meeting the requirements for approval and identified issues are not adequately responded to and rectified within a defined timeframe. In these circumstances, the manufacturer will be notified in writing.

## **2. Approval Procedure, Steel Wire Ropes**

### **2.1 General**

Section 2 is supplementary to section 1 and applies to manufacturers of offshore mooring steel wire ropes.

Approval testing shall be carried out on representative samples of wires and wire ropes. The wire rope diameter and applied load shall be reported. A copy of the test machine calibration certificate shall be submitted to the local DNV office. Where relevant, the result of the visual inspection shall be reported.

### **2.2 General Manufacturer Information**

- An outline of the organisation structure including quality control responsibilities.
- Manufacturing process description, visualized in flow chart(s) indicating all process steps, and in particular the associated testing and inspection points.
- A list of the manufacturers written procedures for testing and inspection. The procedures need not to be submitted, but must be available for review at the manufacturer's works upon request.
- A list of equipment used for chemical analysis, mechanical testing, metallographic examination and dimensional measurements.
- Description of the qualifications of personnel engaged in testing and inspection.
- Procedure for product identification and traceability (including test samples).

### **2.3 Product Information**

For the wire ropes for approval, a list or table specifying:

- Wire rope classes.
- Wire rope constructions.
- Detailed strand constructions and designations.
- Range of dimensions.
- Applicable strength grades.
- Specified minimum breaking load.
- Types of surface finish.

### **2.4 Information on Manufacturing Route and Equipment**

#### **2.4.1 Wire manufacture**

- Steel types and grades.
- Description of wire drawing equipment, processes, treatment and finish.
- Specification for diameter tolerances.
- Specification for tensile strength and tolerances.
- Testing and inspection requirements.

— Description of finishing/coating process.

#### **2.4.2 Wire rope manufacture**

- Method of lay, performing, closing, length of lay.
- Type of core.
- Lubrication.
- Sheathing (if applicable).

### **2.5 Approval Testing, Mobile Mooring**

#### **2.5.1 Wire Testing**

As a minimum, the following tests shall be made and the results reported:

- Tensile test
- Torsion test
- Reverse bend test
- Tests to determine mass and adhesion of zinc coating.

The results shall comply with ISO 2232 or to an equivalent standard.

#### **2.5.2 Wire rope Testing**

One sample of the completed rope shall be break load tested according to procedure given in DNV-OS-E304 Sec. 7 A202. The sample shall be tested to destruction or alternatively withstand the prescribed load for 30 s without fracture. In the latter case the sample shall be visually inspected after unloading. The breaking load of the actual construction shall not be less than given in DNV-OS-E304 Ch. 2 Sec. 7 Table 4.

For constructions and diameters not covered in this document, reference is given to ANSI/API Spec. 9A Annex G or J.

### **2.6 Approval Testing, Long Term Mooring**

#### **2.6.1 General**

The testing procedures and test result shall comply with OS-E304 Ch.2 Sec.6

#### **2.6.2 Wire Testing**

As a minimum, the following tests shall be made and the results reported:

- Tensile test
- Elongation test
- Tests to determine mass and adhesion of zinc coating.

The results shall comply with DNV-OS-E304 Ch.2 Sec.4 B101 as appropriate.

#### **2.6.3 Wire Rope Testing**

For description of tests reference is made to DNV-OS-E304 Ch.2 Sec.6 A200. The breaking load of the actual construction shall not be less than given in ANSI/API Spec. 9A Annex G or J.

## **3. Approval Procedure, Sockets**

### **3.1 General**

Section 3 is supplementary to section 1 and applies to manufacturers of finished sockets for offshore mooring steel wire ropes.

### **3.2 Range of Approval**

- Approval is required for each grade.
- Approval is limited to maximum weight and maximum wall thickness
- Starting material from manufacturers approved for forgings/castings for offshore mooring sockets
- Approval is limited and linked to manufacturer of starting material. Where material from a number of suppliers is used, separate approval is required for each supplier.

### **3.3 Approval Information**

#### **3.3.1 Specification for Chemical Composition**

This shall include, but not necessarily be limited to:

- permissible range for Carbon, Manganese, Silicon and all other intentionally added elements, e.g. Chromium, Molybdenum, Nickel, Aluminium, Niobium, Vanadium, Titanium
- maximum limits for residual and impurity elements including Phosphorus, Sulphur, Copper (unless added), Tin, Antimony, Arsenic, Boron
- maximum limit for Nitrogen.

### 3.3.2 Manufacturing Records

Records or data for the manufacture of the starting material shall be part of the approval report and include:

- Starting material supplier, product form and dimensions
- The chemical composition as determined by ladle analysis.
- The prior austenite grain size of starting material
- Examination for non-metallic inclusions, macro etching for segregation, and testing for hardenability if available
- Flow diagram(s) showing the principal process steps and the associated inspection points involved in converting materials into finished sockets. Where any operation is sub-contracted (e.g. heat treatment, machining, inspection) the name of the company shall be given
- Heat treatment furnace details, furnace calibration records
- Procedure(s) for heat treatment. The procedure(s) must give all relevant details including but not necessarily restricted to: Furnace loading (hot or cold loading, number of and arrangement of items in the furnace etc), temperatures and holding times, furnace controls and records, furnace unloading (max time for removal from furnace to quenching in bath), holding time in quench bath
- Procedure(s) for mechanical testing of full size products. The procedure(s) must give all relevant details including sketches showing the position of test pieces
- Procedure(s) for non-destructive testing and personnel qualification records
- For castings, procedure(s) for repair by welding
- Records of load testing machine including type, capacity and calibration reports
- Details of corrosion protection.

## 3.4 Approval Testing

### 3.4.1 Test Material

At least two sockets from two different production batches shall be subjected to the tests detailed in 3.4.2 to 3.4.5. Sockets 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.

For tests where the size of socket body is too small to provide a suitable test piece, tests may be carried out on sample material which shall be of the same specification and heat treatment.

Location of test sample for mechanical testing shall comply with requirements given in DNV-OS-E304 Ch.2 Sec.5 B, Figure 1. Middle Charpy V-notch test specimen shall be located at W/4.

### 3.4.2 Mechanical Testing, Sockets for Mobile Mooring

Test pieces need to be taken either from full sized sockets or as separate 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.

One tensile and three Charpy V-notch test specimens shall be tested from for each socket. Impact Charpy V-notch testing shall be carried out at 0, -20 and -40°C. The specified minimum properties at -20° C shall be met.

### 3.4.3 Mechanical Testing, Sockets for long term Mooring

Test pieces need to be taken from full sized sockets. Separate test coupons are not acceptable.

One tensile and three Charpy V-notch test specimens shall be tested from for each socket. Impact Charpy V-notch testing shall be carried out at 0, -20 and -40°C. The specified minimum properties at -20° C shall be met.

### 3.4.4 Non-destructive testing

Unless otherwise required the entire surface and volume of the sockets shall be tested using a suitable NDT method.

The visual examination shall cover at least the following features:

- Faults arising from the manufacturing process including flaws and cracks;
- Faults arising from the machining process;
- Distortion and/or cracks arising from the heat treatment process;
- Faults arising from the surface finish or the finishing process;
- Any indications which might be cracks.

Test reports of non-destructive testing shall be submitted to local DNV office, giving the extent of testing, methods of testing, basis for acceptance, and qualification of NDT personnel.

### **3.4.5 Load Testing**

For design verification of the socket, one complete socket from the same batch must be load tested to the minimum certified breaking load of the wire rope for duration of 30 seconds. 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. A steel cone may be placed in the socket body as alternative for the steel wire rope.

Sockets will be considered to have passed the test if the following tests are found satisfied;

- The pin can be removed from the socket and replaced without unreasonable application force.
- MT inspection of the pin and socket is carried out with no relevant indications.

## **4. Approval Procedure, Forging Plants and Foundries**

### **4.1 General**

Section 4 is supplementary to section 1 and linked to section 3 and applies to manufacturers of steel castings and forgings for sockets.

### **4.2 Range of Approval**

- Approval required for each grade
- Approval is limited to maximum weight and maximum wall thickness
- For forgings; starting material shall be obtained from any DNV approved steel manufacturer
- For castings; approval is also limited to casting method.

### **4.3 Approval Information**

#### **4.3.1 Specification for Chemical Composition**

This shall include, but not necessarily be limited to:

- permissible range for Carbon, Manganese, Silicon and all other intentionally added elements, e.g. Chromium, Molybdenum, Nickel, Aluminium, Niobium, Vanadium, Titanium
- maximum limits for residual and impurity elements including Phosphorus, Sulphur, Copper (unless added), Tin, Antimony, Arsenic, Boron
- maximum limit for Nitrogen.

#### **4.3.2 Manufacturing Records**

Records or data for the manufacture of the starting material shall be part of the approval report and include:

- Starting material supplier, product form and dimensions
- The chemical composition as determined by ladle analysis.
- The prior austenite grain size of starting material
- Examination for non-metallic inclusions, macro etching for segregation, and testing for hardenability if available
- Flow diagram(s) showing the principal process steps and the associated inspection points involved in converting materials into semi finished sockets. Where any operation is sub-contracted (e.g. heat treatment, machining, inspection) the name of the company shall be given.
- For forgings, forging reduction ratio used in the qualification tests, from cast ingot/slab to forged component shall be recorded and reported.
- Heat treatment furnace details, furnace calibration records
- Procedure(s) for heat treatment. The procedure(s) must give all relevant details including but not necessarily restricted to: Furnace loading (hot or cold loading, number of and arrangement of items in the furnace etc), temperatures and holding times, furnace controls and records, furnace unloading (max time for removal from furnace to quenching in bath), holding time in quench bath
- Procedure(s) for non-destructive testing and personnel qualification records For castings, procedure(s) for repair by welding
- For castings, procedure(s) for repair by welding.

#### **4.3.3 Temperature uniformity of furnaces**

An extensive survey of heat treatment furnaces is required in order to assure uniform temperature and reliable control and checking of temperature.

Calibration of furnaces shall be verified by measurement and recording of temperature (surface and internal), using a calibration test piece with dimensions equivalent to the maximum size of forging manufactured for



semi-finished socket. Thermocouples shall be placed both on the surface and in a drilled hole located to the mid-thickness position of the calibration block.

Temperature shall be monitored by a recorder with resolution sufficient to clearly define all aspects of the heating, holding and cooling process. From the recording of temperature of calibration block a comparison shall be made with respect to recorded furnace temperature. The chart of time and temperature showing the output from monitoring calibration block thermocouples and furnace control thermocouples shall be submitted.

Evidence of furnace surveys and calibration shall be provided.

Temperature uniformity determined according to methods described in ASTM A 991 or equivalent standard is acceptable.

#### **4.4 Approval Testing, Steel forgings for Sockets**

##### **4.4.1 Test Material**

At least two forgings from two different production batches shall be subjected to the tests detailed in 4.4.2 to 4.4.5. Sockets 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.

For tests where the size of forging is too small to provide a suitable test piece, tests may be carried out on sample material which shall be of the same specification and heat treatment. 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.

##### **4.4.2 Chemical composition**

The chemical composition shall comprise the elements C, Si, Mn, P, S, Cu, Al, Cr, Ni, Mo, V, Nb, Ti, Sn, Sb, As, B and N, as well as any other element intentionally added.

The chemical composition results shall comply with the corresponding requirements in DNV-OS-E304.

In case an element is found to have content outside the expected range for the steel type/grade in question, that is, for elements not particularly specified with max. and min. limits in the relevant standard, this will be subject to special consideration.

The maximum allowable limit for each of the impurity elements is  $\text{Sn} \leq 0.02\%$ ,  $\text{Sb} \leq 0.02\%$  and  $\text{As} \leq 0.03\%$ , unless otherwise agreed.

##### **4.4.3 Heat Treatment Sensitivity Study, QT Condition**

A heat treatment sensitivity study simulating production conditions shall be applied in order to verify mechanical properties and establish limits for temperature and time combinations. At least seven samples of full cross section shall be heat treated and subjected to tensile and Charpy V-notch testing. Unless otherwise agreed or required, the following heat treat conditions apply for the samples:

- 1) Austenitisation at  $\text{Ac}_3+30^\circ\text{C}$  for 60 minutes. Tempering at  $610^\circ\text{C}$  for 60 minutes.
- 2) Austenitisation at  $\text{Ac}_3+60^\circ\text{C}$  for 60 minutes. Tempering at  $610^\circ\text{C}$  for 60 minutes.
- 3) Austenitisation at  $\text{Ac}_3+90^\circ\text{C}$  for 60 minutes. Tempering at  $610^\circ\text{C}$  for 60 minutes.
- 4) Austenitisation at  $\text{Ac}_3+60^\circ\text{C}$  for 60 minutes. Tempering at  $590^\circ\text{C}$  for 60 minutes.
- 5) Austenitisation at  $\text{Ac}_3+60^\circ\text{C}$  for 60 minutes. Tempering at  $650^\circ\text{C}$  for 60 minutes.
- 6) Austenitisation at  $\text{Ac}_3+60^\circ\text{C}$  for 60 minutes. Tempering at  $590^\circ\text{C}$  for 120 minutes.
- 7) Austenitisation at  $\text{Ac}_3+60^\circ\text{C}$  for 60 minutes. Tempering at  $650^\circ\text{C}$  for 120 minutes.

##### **4.4.4 Temper Embrittlement Testing, QT Condition**

The material's resistance to temper embrittlement shall be tested. At least two samples of full cross section shall be heat treated and subjected to Charpy V-notch testing. Unless otherwise agreed or required, the following heat treat conditions apply for the samples:

- Austenitisation at  $\text{Ac}_3+60^\circ\text{C}$  for 60 minutes. Tempering at  $590^\circ\text{C}$  for 60 minutes. Rapid cooling in water.
- Austenitisation at  $\text{Ac}_3+60^\circ\text{C}$  for 60 minutes. Tempering at  $590^\circ\text{C}$  for 60 minutes. Slow cooling inside furnace for at least 40 minutes down to  $300^\circ\text{C}$ .
- Test temperatures shall be 0,  $-20$  and  $-40^\circ\text{C}$ .
- The specified minimum properties at  $-20^\circ\text{C}$  shall be met
- The material's resistance to strain aging shall be tested. At least one sample of sufficient size shall be heat treated, strained 5% and subsequently heated to  $250^\circ\text{C}$  and held for one hour.
- Charpy V-notch testing shall be carried out at 0,  $-20$  and  $-40^\circ\text{C}$ .

#### **4.4.5 Strain Age Testing**

- The material's resistance to strain aging shall be tested. At least one sample of sufficient size shall be heat treated, strained 5% and subsequently heated to 250°C and held for one hour.
- Charpy V-notch testing shall be carried out at 0, -20 and -40°C.

#### **4.4.6 Metallographic examination**

Two macro specimens shall be taken showing longitudinal section showing the metal flow in the direction of the main load path. Macro sections shall be etched and to be photographed at 1×. No cracks, laps or surface imperfections are permitted.

Photomicrographs showing the microstructure at 100× and 500× magnifications shall be presented. One set to be taken near the surface and one set from the mid-wall thickness of the forging. The ferrite grain size shall be reported. The applied etching methods for the metallographic examination to be stated in the report.

### **4.5 Approval Testing, Steel Castings for Sockets**

#### **4.5.1 Test Material**

- At least two castings from two different production batches shall be subjected to the tests detailed in 4.5.2 to 4.5.3. Sockets 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.
- For tests where the size of casting is too small to provide a suitable test piece, tests may be carried out on sample material which shall be of the same specification and heat treatment. 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.

#### **4.5.2 Heat Treatment Sensitivity Study, QT Condition**

A heat treatment sensitivity study simulating production conditions shall be applied according to requirements given in 4.4.3.

#### **4.5.3 Metallographic examination**

Two macro specimens shall be taken showing longitudinal section. Macro sections shall be etched and to be photographed at 1×. No porosity, shrinkage or other casting defects are permitted.

Photomicrographs showing the microstructure at 100× and 500× magnifications shall be presented. One set to be taken near the surface and one set from the mid-wall thickness of the casting. The ferrite grain size shall be reported. The applied etching methods for the metallographic examination to be stated in the report.

## **5. References**

- 1) DNV-OS-E304 Offshore Mooring Steel Wire ropes
- 2) ISO 17893 Steel wire ropes – Vocabulary, designation and classification
- 3) ANSI/API Spec 9A Specification for Wire Rope
- 4) ISO 10425 Steel Wire Ropes for the Petroleum and Natural Gas Industries-Minimum Requirements and Terms for Acceptance
- 5) ISO 2232 Round drawn wire for general purpose non-alloy steel wire ropes and for large diameter steel wire ropes – Specifications
- 6) ASTM A991 Standard Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products

## Appendix A

### Range of approval

Approval category		Product category	Brief description
Steel Wire Ropes and Sockets	Steel Wire Ropes	Steel Wire Ropes for mobile offshore mooring	For stranded rope constructions approval is required for each wire rope class. However, approval for any construction within a class will cover wire ropes of all other constructions in the same class provided that the core is of the same type (fibre/steel) For spiral rope constructions approval is required for each construction Maximum approved diameter is limited to tested diameter
		Steel Wire Ropes for long term offshore mooring	
	Sockets for Steel Wire Ropes <sup>1)</sup>	Sockets for mobile offshore mooring	Approval is required for each grade Approval is limited to maximum weight and maximum wall thickness
		Sockets for long term offshore mooring	Starting material from manufacturers approved for forgings/castings for offshore mooring sockets Approval is limited to manufacturers of starting material
Steel forgings <sup>2)</sup>		Forgings for offshore mooring wire rope sockets	Approval required for each grade Approval is limited to maximum weight and maximum wall thickness Starting material from approved manufacturers
Steel castings <sup>2)</sup>		Castings for offshore mooring wire rope sockets	Approval required for each grade and Approval is limited to maximum weight and maximum wall thickness Approval is limited to casting method
1) Applicable to manufacturers of finished sockets			
2) Approval category “Sockets for Steel Wire Ropes” also apply if forging plants and foundries supply finished sockets.			