STANDARD FOR CERTIFICATION

No. 2.9

Type Approval Programme No. 5-778.93

HYDRAULIC CYLINDERS

OCTOBER 2009

DET NORSKE VERITAS

Veritasveien 1, NO-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

FOREWORD

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

Standards for Certification

Standards for Certification (previously Certification Notes) are publications that contain principles, acceptance criteria and practical information related to the Society's consideration of objects, personnel, organisations, services and operations. Standards for Certification also apply as the basis for the issue of certificates and/or declarations that may not necessarily be related to classification.

A list of Standards for Certification is found in the latest edition of Pt.0 Ch.1 of the “Rules for Classification of Ships” and the “Rules for Classification of High Speed, Light Craft and Naval Surface Craft”.

The list of Standards for Certification is also included in the current “Classification Services – Publications” issued by the Society, which is available on request. All publications may be ordered from the Society’s Web site http://webshop.dnv.com/global/.

The Society reserves the exclusive right to interpret, decide equivalence or make exemptions to this Standard for Certification.

This document is valid until superseded by a new revision or withdrawn.

Amendments and Corrections

This document replaces the October 2002 issue.

Main changes:

— section 1.3 is amended
— section 2.2.1 is revised
— section 2.2.3 is revised
— new sections 3.2, 3.3, 3.4, 3.5, 3.6 covering hydraulic cylinders for:
  - steering gear/water jet steering,
  - pitch control
  - offshore use
  - cranes and davits
  - watertight doors

  have been added
— section 3.7 - “Design evaluation” has been amended with respect to
  - materials
  - welding
— section 5 - “Certification Conditions” has been aligned with current practice.

Comments may be sent by e-mail to *rules@dnv.com*
Comprehensive information about DNV and the Society's services is found at the Web site http://www.dnv.com

Computer Typesetting (Adobe FrameMaker) by Det Norske Veritas

CONTENTS

1. Scope

1.1 General

This Standard for Certification gives the requirements on which Det Norske Veritas base their approval of hydraulic cylinders.

1.2 Objective

Approval of hydraulic cylinders is based upon the requirement in the relevant parts of this document and the following DNV documents:

— Det Norske Veritas Rules for Classification of Ships
— Det Norske Veritas Rules for High Speed, Light Craft and Naval Surface Craft (HS, LC and NSC)
— Det Norske Veritas Offshore Standards
— Det Norske Veritas Standard for Certification 2.22 Lifting Appliances.

The procedure for assessment of conformity of manufactured products (production) is not part of the scope of this Standard for Certification.

1.3 Application

The requirements of this Standard for Certification cover hydraulic cylinders for general use, for steering gear and steering and reversing of water jets, hydraulic cylinders for offshore use, hydraulic cylinders for cranes and davits, hydraulic cylinders for watertight doors and hydraulic cylinders with internal mechanical locking arrangements.

Det Norske Veritas does reserve the right to deviate from the requirements in this document in connection with approval of hydraulic cylinders of special design or for specific applications.

2. Approval, general

2.1 Procedures

Case-by-case approval procedure of hydraulic cylinders consist of the following elements:

— design assessment
— possible type testing
— certification.

The type approval procedure consists of the following elements:

— design assessment
— possible prototype testing (required for cylinders with internal mechanical lock)
— product certification
— certificate retention survey.

See Det Norske Veritas' Standard for Certification No. 1.2 for the general procedures regarding type approval.

2.2 Documentation to be submitted

Together with the application for approval, the following documentation shall be submitted:

— Main drawings for all types and sizes. All dimensions necessary for calculating the strength of the pressure exposed parts such as all diameters and lengths and dimensional drawings of the terminations (if approval is wanted for the terminations) of the cylinder shall be stated on the drawings. Stroke, build-in lengths and clearing between piston/cylinder tube and piston rod/stuffing box shall be given. The dimensions may be tabulated on the drawings if convenient. The following shall be stated on the drawings:
  - information on whether it is a single or double acting cylinder. The corresponding design pressures for push and pull shall be given
  - how the cylinder is supported to the structure, preferably by a principle sketch
  - reference to a design code
  - safety relief valve set pressure
  - test pressure
  - maximum and minimum design temperature.
  - threads: Diameter, pitch, lengths and tolerances.
  - corrosion allowances
  - exact designation of the materials used in all parts with reference to a recognized national/international material standard. Information on gaskets/sealing shall also be given
  - extent of material testing, or type of material certificate for each material
  - reference to a welding procedure specification for each weld
  - extent and type of non-destructive testing of welds.
  - information on marking for identification/traceability.
  - factory testing procedures.
— For jigger winches: Drawings of sheave houses and wheels.
— Calculation of the pressure exposed parts, cylinder terminations, flanges and threads including buckling calculation shall be submitted for pushing cylinders.
— Test report(s) as required by this document.
— A load curve giving the load over the stroke may be required.

2.2.1 Type Approval

Type approval is offered for identical products manufactured in series. Type approval is mandatory for hydraulic cylinders used for cleating service (locking cylinders). The review of the design and documentation will be done based on the requirements in this Standard for Certification and relevant parts of the following:

— Det Norske Veritas Rules for Classification of Ships
— Det Norske Veritas Rules for Classification of High Speed Light Craft and Naval Surface Craft
— Det Norske Veritas Offshore Standards
— Det Norske Veritas Standard for Certification 2.22 Lifting Appliances.

When compliance with the requirements is acquired, a type approval certificate will be issued, and the original of the certificate will be sent to the manufacturer through his local DNV office. Agreements may be made for other arrangements. The Type Approval certificate will normally have a validity period of 4 years and may be renewed and/or revised upon a written request. Modification of designs and adding of new designs may be included after being reported, regardless of expire date of the certificate

2.2.2 Objects classed by DNV

Drawings and documentation shall be submitted to the local DNV office in at least 1-fold for each delivery. The local office will pre-examine and register the documentation package and submit it to the appropriate approval centre. The submittal shall include the following information:

— name of yard and building number
— the task for the cylinder.

2.2.3 Objects not classed by DNV

Drawings and documentation shall be submitted in 3-fold for

each delivery to the local DNV office. The local office will pre-examine. The local DNV office will submit the documentation to the appropriate approval centre. The submittal shall include the following information:

— name of ship or rig
— name of project and copy of the original request for design approval in case of delivery to a land based project
— the task for the cylinder.

For both groups of objects the following apply:

The review of the design and documentation will be done based on the requirements in this Standard for Certification and relevant parts of the following as applicable:

— Det Norske Veritas Rules for Classification of Ships
— Det Norske Veritas Rules for High Speed, Light Craft and Naval Surface Craft
— Det Norske Veritas Offshore Standards
— Det Norske Veritas Standard for Certification 2.22 Lifting Appliances.

3. Design

3.1 Composition

Hydraulic cylinders may be designed with the following features:

— single or double acting
— with or without damping in one or both ends
— (self-) locking (mechanical) arrangements in one or both ends. An indicator to show the lock engagement may be fitted
— position indication in the piston rod
— different terminations. The most common termination is spherical bearings in each end, however, other types of terminations such as flanges, trunnion mountings and sheaves house(s) for wire operation (jigger winch cylinders) will also be accepted. The cylinder tube termination may be placed on the cylinder wall
— the piston rod may be externally guided
— end covers may be threaded or welded (or both) to the cylinder tube
— piston rod terminations may be threaded or welded (or both) to the piston rod
— piston rod may be of hollow or compact designs.

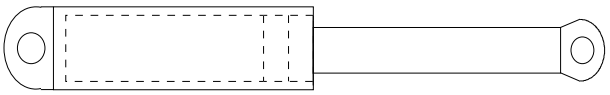

Figure 3-1
Spherical bearings in both ends

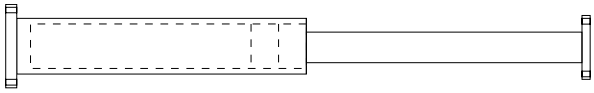

Figure 3-2
Flanged in both ends

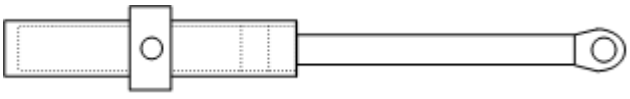

Figure 3-3
Trunnion mounted

The above are only illustrative examples. Other features may be accepted and will be evaluated from case to case.

3.2 Hydraulic cylinders for steering gear/water jet steering

The design of hydraulic cylinders for steering gear and water jet steering is to be in accordance with the Rules for Classification of Ships Pt.4, Ch.14. The design pressure is to be 1.25 times the maximum working pressure. The allowable stress is to be the lowest of the following:

$$\sigma_m \leq \frac{\sigma_B}{A} N/mm^2$$

$$\sigma_m \leq \frac{\sigma_y}{B} N/mm^2$$

where:

σ_m = general primary membrane stress [N/mm^2]
σ_B = specified minimum tensile strength of the material at ambient temperature [N/mm^2]
σ_y = specified minimum yield strength (or 0.2% proof stress) of the material at ambient temperature [N/mm^2].

A and B are coefficients of utilisation, given by the following table for steel and cast steel (for other materials, A and B are subjects to special consideration):

Table 3-1 Permissible primary membrane stress

	Steel	*Cast steel*
A	3.5	4
B	1.7	2

For steering gears complying with the Rules for Classification of Ships Pt.4 Ch.14 Appendix A (non-duplicated rudder actuators for tankers of 10 000 gross ton, but less than 100 000 dwt) increased values of A and B are required according to Pt.4 Ch.14 Appendix A, table B1.

3.3 Hydraulic cylinders for pitch control

Hydraulic cylinders for pitch control shall be in compliance with this document.

3.4 Hydraulic cylinders for offshore use

Hydraulic cylinders for offshore use shall be in compliance with this document and Det Norske Veritas Offshore Standards.

3.5 Hydraulic cylinders for cranes and davits

Cylinders for shipboard cranes that are not covered by class (**CRANE** or **Crane Vessel**) with a load carrying capacity not exceeding 20 tons, may be accepted with the manufacturers' product certificate on the following conditions:

— The manufacturer must be considered a recognised manufacturer, i.e. a manufacturer having passed an initial production audit.
— The cylinder is subject to serial production, i.e. production of identical cylinders over a period of one - two months.
— The exception may be agreed on a case-by-case basis and shall be agreed in advance.
— The manufacturer shall apply for such exception in due time by submitting one copy of documentation on the cylinder, including all main dimensions and material specifications enclosed to the application, enabling DNV to carry out an independent review calculation as found appropriate.
— Extent of NDE and pressure testing shall be agreed in each case.

Hydraulic cylinders that do not meet the conditions listed in Det Norske Veritas Standard for Certification 2.22 Lifting Appliances, index 13 of Table A1 of Sec.1, or with a load carrying capacity exceeding 20 tonnes or for offshore cranes or for cranes to be included in class (**CRANE** or **Crane Vessel**) DNV approval and certification is mandatory.

The documentation to be submitted for approval shall meet the approval procedure as described in this document.

The design calculations submitted for approval shall be based on the maximum obtainable pressure. Alternatively, if the maximum dynamic force applied on the crane is known, this may be used as basis for the design calculations. Different outreach positions may have to be evaluated. Based on individual considerations, a buckling safety factor down to 2.3 may be accepted.

Materials shall fulfil the requirements given in section 3.2.3.

Requirements regarding cylinder wall thickness are described in section 3.2.8.

Welds shall normally be full penetration welds. Other weld geometries than full penetration welds may be accepted on a case-by-case basis provided that acceptable stresses (both with respect to fatigue and static strength) can be documented. This will primarily be applicable for cylinders used for pushing only (e.g. jib cylinders).

Hydraulic cylinders for cranes other than those mentioned may be accepted based on the manufacturer's product certificate and consequently do not need DNV design approval. See also Det Norske Veritas Standard for Certification 2.22 Lifting Appliances index 13 of Table A1 of Sec.1.

3.6 Hydraulic cylinders for watertight doors

Hydraulic cylinders for cleating and manoeuvring of watertight doors and hatches shall be design approved and be delivered with the Society's certificate regardless of pressure and size. Cleating cylinders where the locking mechanism is placed inside the cylinder are to be type approved according to the requirements in section 4.

3.7 Design evaluation

3.7.1 General

This document forms the basis for a DNV approval when design approval is required by the relevant DNV Rules.

3.7.2 Type testing

Test procedure for type testing will be agreed upon in each case.

3.7.3 Materials

Materials for the cylinder tube, piston rods and end connections are to be delivered with material works certificate (= 3.1 certificate according to latest revision of EN 10204 or equivalent). The material for these parts is to be Charpy tested. Charpy-V notch requirement: 27J at –20°C.

Note:

For cylinders intended for steering gear or water jet steering applications Charpy test is required. 3.2 material certificates are required for the cylinder tube and piston rod. 3.1 certificates are required for the end cover and piston. Reference is made to the Rules for Classification of Ships Pt.4 Ch.14, Sec.1 Table C3.

---e-n-d---of---N-o-t-e---

Where the end cover is made from a rolled plate, the plate shall have through thickness (Z-direction) properties corresponding to quality class Z25 or better.

3.7.4 Buckling

The submitted documentation shall include buckling calculation if the cylinders are to be used for pushing. The following method may be used for control of buckling.

$$I_1 = \frac{\pi(D_0{}^4 - D_i{}^4)}{64} \text{mm}^4$$

$$I_2 = \frac{\pi(d_0{}^4 - d_i{}^4)}{64} \text{mm}^4$$

where:

I_1 = moment of inertia for the cylinder tube, mm^4
I_2 = moment of inertia for the piston rod, mm^4
D_o = outer diameter of the cylinder tube, mm
D_i = inner diameter of the cylinder tube, mm
d_o = outer diameter of the piston rod, mm
d_i = inner diameter of the piston rod, mm

$$P_E = \frac{E \times \pi^2}{1000 \times L \times Z}$$

where:

E = Young's Modulus of Elasticity = 2.06×10^5 N/mm^2 for carbon steel
L = length between mountings in fully extracted position ($L_1 + L_2$), mm

$$Z = \frac{L_1}{I_1} + \frac{L_2}{I_2} + (\frac{1}{I_2} - \frac{1}{I_1}) \times \frac{L}{2\pi} \sin(2\pi \frac{L_1}{L})$$

L_1 = length of the cylinder part from the centre of it's mounting, mm
L_2 = visible length of the piston rod in fully extracted position from centre of it's mounting, mm

The argument for $\sin(2\pi \frac{L_1}{L})$ is to be given in radians

P_E = buckling load, kN

Acceptance criteria:

$$\frac{P_E}{P_a} \geq 4$$

where:

P_a = actual max. load = $\frac{\pi \times p}{4} \times D^2$

As a control calculation, an Euler break load may be found for a cylindrical bar with the same dimensions as the piston rod and with a length corresponding to the fully extracted cylinder:

$$P_{eu} = \frac{\pi^2 \times E \times I}{2 \times L^2}$$

The following shall occur in most cases:

$$P_{eu} > P_E$$

A lower buckling safety factor than 4.0 may be accepted for more accurate calculation methods. In that case the method is to be approved by the Society. Relevant parameters which may be included in such a method is:

— yield strength of piston rod material
— bending moments caused by the rotation of the mounting bearings
— guiding length
— clearance between gland and piston rod
— actual deflection curve.

However, the lowest acceptable safety factor will normally not be less than 2.7 regardless of calculation method.

Concerning buckling calculations of hydraulic cylinders for cranes reference is made to Det Norske Veritas Standard for Certification 2.22 Lifting Appliances.

Scantlings of hydraulic cylinders are to comply with the requirements in Det Norske Veritas Rules for Classification of Ships.

3.7.5 Piston rods

Piston rods for both pushing and pulling are to be dimensioned taking into account the bending moment caused by the rotation of the end eye bearing. Special attention is to be given threaded or welded connection between end eye and rod.

3.7.6 Cylinder tube, piston rods and end covers

The cylinder tube, the hollow piston rods with pressure in rod and the end cover are to be dimensioned according to Det Norske Veritas Rules for Classification of Ships or equivalent. The wall thickness of the cylinder tube and hollow piston rods with pressure in the rod is to be dimensioned according to the following:

$$t = \frac{p \times R}{10 \times \sigma_t \times e - 0.5 \times p} + c$$

where:

t = required wall thickness, mm
p = design pressure, bar
R = internal cylinder tube radius, mm
σ_t = allowable stress, design stress, N/mm^2
e = welding factor = 1 for seamless pipes
c = corrosion allowance, usually 0.3 mm.

End covers are to be dimensioned according to Det Norske Veritas Rules for Classification of Ships or equivalent.

3.7.7 Threaded connections

Thread stresses shall be calculated using the following formula:

$$\sigma_t = \frac{1.03 \times F}{L \times \pi (d - 1.23 \times p)} \leq \frac{\sigma_y}{1.8}$$

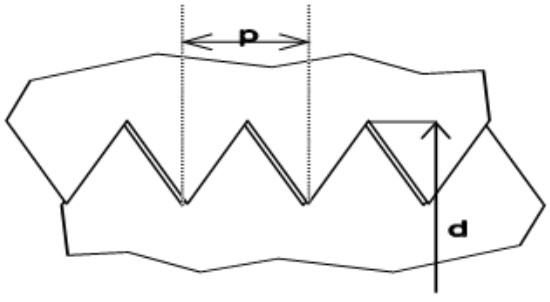

Figure 3-4
Threads

where:

σ_t = combined stress in the threads, N/mm^2
F = force taken up by threads, N
L = full thread engagement length = n × p, mm
n = number of engaged threads
p = pitch, mm
d = nominal diameter of the threads, mm
σ_y = yield strength of the weakest material, N/mm^2.

3.7.8 Threaded connections acting as sealing

Parallel threads, which shall provide sealing against leakage to the outside on different parts of a hydraulic cylinder, shall be provided with O-ring seals or equivalent. The O-ring material shall be specified and shall be suitable for the intended purpose.

3.7.9 Other sealing arrangements

The material used in seals shall be specified and shall be suitable for its intended purpose with good sealing properties and proper resistance against the hydraulic fluid. A statement from the seal manufacturer or a test report may be required. Sealing between the stuffing box and the cylinder tube shall be positioned in the stuffing box at least 2 mm away from the threaded part of the cylinder tube and shall consist of an O-ring with support ring(s).

3.7.10 End eyes for traction cylinders

The highest stresses in the end eyes for traction use will appear along the contact surface between the bearing and the end eye. The tension shall be calculated according to the following:

$$\sigma_t = \frac{F}{T \times (D - d)} \sqrt{\frac{D^2}{d^2} - \frac{D}{d} + 1} \leq \sigma_y$$

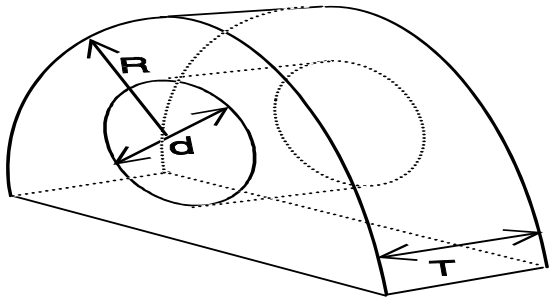

Figure 3-5
End eye

where:

F = cylinder traction force, N
T = width of end eye, mm
D = outer diameter of end eye = 2 R in fig. 5, mm
d = inner diameter of end eye (outside bearing), mm
σ_y = yield strength of the end eye material, N/mm^2.

3.7.11 Jigger winches

Sheave houses and bolt(s) for the wheel(s) are subject to design approval and shall be submitted together with the drawings for the hydraulic cylinder. The direction of the wire entry and exit from the wheels and the wire force is to be given. All welds on a sheave house are to be welded from one side and are to be executed as full penetration welds.

3.7.12 Welding

The length of the steering edge on the end cover inside the cylinder tube is allowed to be max. 3 mm long i.e. small enough to be burned away during welding. Non-compliance with this requirement will limit the approved number of operating cycles to 15 000 over the life span.

4. Prototype testing of hydraulic locking cylinders

4.1 General

Hydraulic self-locking cylinders with the mechanical locking device placed inside the cylinder are to be type approved. The following prototype test procedures of the lock apply:

4.2 Endurance test

The test procedure shall be approved by DNV before commencement of the test. The test is to be performed with the test object in horizontal position. The lock is to be engaged and disengaged for 1500 cycles. One cycle is to include one engaging and one disengaging. The lock is to be activated with hydraulic oil through the oil supply studs at the cylinder design pressure during this test. The cylinder shall be pre-stressed with a load corresponding to 5% of the design load. One sample of each cylinder size/lock type is to be tested; i.e. a lock placed at the stuffing box does not qualify a lock placed at the opposite end.

After the testing the cylinder is to be dismantled for inspection of all the different parts of the lock. No loss of material or visible deformation is allowed upon completion of the test. All parts of the lock are to be subjected to an MT test and shall have zero indication of cracks. The test is to be witnessed by a DNV Surveyor who shall sign the test report.

4.3 Static strength test

One sample of each cylinder size /lock type is to be tested, i.e. a lock placed at the stuffing box does not qualify a lock placed at the opposite end.

- Pressurise the cylinder to 80% of the design pressure.
- With an external force test the lock for proper engagement.
- Increase the pressure 20% and retest the lock for proper engagement.
- Continue the increase of pressure in steps of 20% until the lock fails to engage.

After the testing the cylinder is to be dismantled for inspection of all the different parts of the lock.

The lock shall not fail to engage until the pressure has reached 200% of the design pressure. No loss of material or visible deformation is allowed upon completion of the test. All parts of the lock are to be subjected to an MT test and shall have zero indication of cracks. The test is to be witnessed by a DNV Surveyor who shall sign the test report.

5. Certification conditions

5.1 Manufacture, workmanship, inspection and testing

5.1.1 Product certification

Each cylinder is subject to product certification by a DNV Surveyor. Alternatives to this, such as a manufacturing survey arrangement may be established. Product certification shall not take place before approved drawings are made available to the certifying Surveyor. In case of a short delivery time where stamped drawings are non-existent at the time of product certification, a written confirmation that the cylinder drawings will be approved shall be at hand from the approval body. The product certification procedure consist of the following:

- check of material certificates
- certification of the welding procedure specification
- non destructive testing of welds
- dimensional check of critical measures
- hydraulic pressure testing/functional testing.

and is described below.

A product certificate where the results from the below-required tests are given is to be issued and shall accompany each cylinder/delivery. The certificate shall give unique identification of the cylinders. The approved drawings for the design shall be listed as well as information on where the cylinders are to be installed. Finally the DNV Surveyor shall sign the certificate.

5.1.2 Material certificates

The requirements are given in section 3.7.3.

5.1.3 Welding

Filler metals are to be of approved type. The welding procedure specifications are to be qualified. Welded butt joints and welds for oil supply studs and branches are to be of full penetration type. Welding production test may be required for thicknesses > 38 mm. Preheating is to be used when necessitated by the dimensions and the material composition. Further reference is made to relevant parts of Det Norske Veritas Rules for Classification of Ships.

Oxy-acetylene welding is not to be used for cylinder diameters greater than 102 mm or wall thickness exceeding 10 mm.

Welds on sheave houses for jigger winches are subject to dye penetrant examination or magnetic particle inspection, MT.

5.1.4 Non-destructive testing

All welds are subject to 100% NDE. Magnetic particle inspection, MT, dye penetrant, PT, or ultra-sonic testing, UT, will be accepted where radiographic examination is prevented by the geometry.

5.1.5 Dimensional check

Measures such as zero stroke/max. stroke and other measures considered vital/critical are to be verified against approved drawings.

5.1.6 Hydraulic pressure testing

Hydraulic cylinders are to be hydraulically pressure tested to minimum 1.3 times the design pressure alternatively 1.3 times the safety relief valve set pressure, whichever is the greatest, before paint or any coating is applied on the cylinders. The test pressure is to be applied to both sides of the piston head in sequence.

For hydraulic cylinders for steering gear and water jet steering the test pressure is to be 1.5 times the design pressure. For hydraulic cylinders for reversing of water jets the test pressure is 1.3 times the design pressure.

No leakage from or permanent deformation of any part shall occur.

5.1.7 Product certification of hydraulic locking cylinders

Engage the lock. Release the pressure and apply an external load on the piston rod corresponding to 50% of the design pressure in the direction where the lock takes up the force. Apply the force for 1 minute. Release the force and perform the below hydraulic function test of the lock.

The rod is to be kept in locked position without the hydraulic pressure applied. The lock shall disengage by applying hydraulic pressure below the design pressure.

For hydraulic locking cylinders equipped with inductive switches for control of locked and unlocked position the following apply in addition: The function of the switches shall be checked by connecting a test lamp to the switch and driving the cylinder in and out of the locked position 10 times.

5.1.8 Marking

Hydraulic cylinders shall be permanently marked in order to enable unique traceability to a product certificate or a type approval certificate. The marking shall at least consist of the following:

- manufacturers name or trade mark
- type designation
- charge number for the materials used in the cylinder tube and the piston rod.

Additional marking may be done at the manufacturer's option.

5.2 Type Approval Certificate renewal

For retention and renewal of the type approval, a DNV Surveyor shall perform a survey before the expiry of the certificate to verify that the conditions for the approval are complied with.