HYDRAULIC CYLINDERS

OCTOBER 2002
FOREWORD

DET NORSKE VERITAS is an autonomous and independent Foundation with the objective of safeguarding life, property and the environment at sea and ashore.

DET NORSKE VERITAS AS is a fully owned subsidiary Society of the Foundation. It undertakes classification and certification of ships, mobile offshore units, fixed offshore structures, facilities and systems for shipping and other industries. The Society also carries out research and development associated with these functions.

DET NORSKE VERITAS operates a world-wide network of survey stations and is authorised by more than 120 national administrations to carry out surveys and, in most cases, issue certificates on their behalf.

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 the Introduction booklets to the "Rules for Classification of Ships" and the "Rules for Classification of High Speed, Light Craft and Naval Surface Craft". In “Rules for Classification of Fixed Offshore Installations”, only those Standards for Certification that are relevant for this type of structure, have been listed.

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://exchange.dnv.com.

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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 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

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 application (incl. water jet applications) and hydraulic cylinders with internal mechanical locking arrangements.

Det Norske Veritas does, however, 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
  - 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 for pushing cylinders
- Test report(s) as required by this document

2.2.1 Type Approval
Type Approval is offered for identical products manufactured in series. 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 nearest 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/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 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 at least 2-fold to the local DNV office for each delivery. The local office will pre-examine the documentation and submit it 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

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.

Fig. 1 Spherical bearings in both ends

Fig. 2 Flanged in both ends

Fig. 3 Trunnion mounted

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

3.2 Design evaluation

3.2.1 General
This document forms the basis for a DNV approval when design approval is required/specified by the purchaser.

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

3.2.3 Materials
Unless otherwise specified in the Rules for the different hydraulic systems, materials for the cylinder tube, piston rods and end connections are to be delivered with material works certificate (= 3.1B certificate acc. to EN 10204 or equivalent) with documented results from charpy testing. Charpy-V notch requirement: 27J at minimum design temperature as average of 3. No single result below 70 % of 27J.

Note:
For cylinders intended for steering gear or water jet steering applications NV material certificates with the same test extent are required for the same parts.

3.2.4 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.

\[ I_1 = \frac{\pi (D_o^4 - D_i^4)}{64} \text{ mm}^4 \]

\[ I_2 = \frac{\pi (d_o^4 - d_i^4)}{64} \text{ mm}^4 \]

where:

- \( I_1 \) = moment of inertia for the cylinder tube, mm
- \( I_2 \) = moment of inertia for the piston rod, mm
- \( D_o \) = 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 = \(2.06 \times 10^5\) N/mm\(^2\) for carbon steel

L = length between mountings in fully extracted position \((L_1 + L_2)\), mm

\[
Z = \frac{L_1}{L_1} + \frac{L_2}{L_2} + \left(\frac{1}{L_2} - \frac{1}{L_1}\right) \times \frac{L}{2\pi \sin(2\pi \frac{L_1}{L})}
\]

\(L_1\) = 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, N

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 load, 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:

\[
P_{eu} = \frac{\pi^2 \times E \times L}{2 \times L^2}
\]

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 than the referred one. In that case the method is to be approved by the Society.

Relevant parameters which shall 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 with such a calculation method.

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

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

3.2.5 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.

3.2.6 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:

\[
t = \frac{p \times R}{20 \times \sigma_t \times e - 0.5 \times p + c}
\]

where:

\(t\) = required wall thickness, mm

\(p\) = design pressure, bar

\(R\) = internal cylinder tube radius, mm

\(\sigma_t\) = 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.

3.2.7 Threaded connections

Thread stresses shall be calculated using the following formula:

\[
\sigma_t = \frac{1.03 \times F}{L \times (d - 1.23 \times p)} \leq \sigma_y
\]

where:

\(\sigma_t\) = combined stress in the threads, N/mm\(^2\)

\(F\) = force taken up by threads, N

\(L\) = full thread engagement length = \(n \times p\), mm

\(n\) = number of engaged threads

\(p\) = pitch, mm

\(d\) = nominal diameter of the threads, mm

\(\sigma_y\) = yield strength of the weakest threaded part, N/mm\(^2\)
3.2.8 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. For working pressures above 250 bar tapered threads shall be used for sealing.

3.2.9 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).

3.2.10 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:

\[ \sigma_y = \frac{F}{T \times (D - d)} \left( \frac{D^2 - D}{d^2} + 1 \right) \leq \sigma_y \]

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
- \( \sigma_y \) = yield strength of the end eye material, N/mm²

Fig. 5 End eye

3.2.11 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.

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 MPI 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 MPI 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 consists 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 materials for the cylinder tube, the piston rod and end connections are at least to be delivered with material work’s certificate (= 3.1B material certificate according to EN 10204 or equivalent) unless otherwise required by the different Rules or by the purchaser. For cylinder intended for steering gear or for steering of water jet units NV material certificates are required for the same parts.

5.1.3 Welding

Filler metals are to be of approved type. Welded butt joints and welds for oil supply studs and branches are to be of full penetration type. Welding production test may be required. 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, MPI.

5.1.4 Non-destructive testing

All welds are subject to 100% NDE. Magnetic particle inspection, dye penetrant or ultra-sonic testing 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 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 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 expire date of the certificate to verify that the conditions for the approval are complied with.