Hydraulic cylinders
FOREWORD

DNV GL class guidelines contain methods, technical requirements, principles and acceptance criteria related to classed objects as referred to from the rules.

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CHANGES – CURRENT

This document supersedes the December 2015 edition of DNVGL-CG-0194.
Changes in this document are 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.

Changes July 2017

• Sec.1 General
  — Sec.1: Former Sec.1 and Sec.2 have been merged.
  — Sec.1: Requirements for plan approval and type approval are deleted.

• Sec.2 Design
  — Sec.2: Clarification on allowable stress.
  — Sec.2: Clarification on buckling calculation in alternative method.

• Sec.4 Production testing and certification
  — Sec.4: Pressure test increased to 1.5 times design pressure.

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.
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SECTION 1 GENERAL

1 Scope
This class guideline gives the requirements for which the Society bases the certification of hydraulic cylinders, including requirements for documentation, design, manufacturing and testing.

2 Application
This standard is applicable for hydraulic cylinders when referred to in the Society's rules or other relevant Society's standards (e.g. DNVGL-RU-SHIP Pt.4 Ch.6, DNVGL-OS-D101, DNVGL-OS-E101, DNVGL-ST-0378).

3 Reference
The requirements in this class guideline shall be applied in addition to Society rules or standards, where applicable.

4 Design approval
Approval of hydraulic cylinders in accordance with requirements of this class guideline shall be on a case by case basis or follow the procedure for type approval (see DNVGL-CP-0338).

5 Documentation
The following documentation shall be submitted by manufacturer prior start of design review:
— general assembly drawing of each hydraulic cylinder containing all dimensional data required for strength and buckling calculations
— maximum working and design pressure for both pushing and pulling (as applicable)
— safety relief valve set pressure
— hydrostatic test pressure
— maximum and minimum design temperature
— threads dimensional data
— material designations with reference to delivery standard
— extent of NDT
— strength calculation
— buckling calculation (load curve, if applicable)
— test report (for cylinder with internal mechanical locking mechanism)
— hydraulic cylinder application (e.g. drilling, steering, etc.)
— welding map/detail
— corrosion allowance.
SECTION 2 DESIGN

1 Arrangement of hydraulic cylinders

Hydraulic cylinders may be designed with the following features:

— single or double acting
— with internal locking mechanism at one or both ends
— an over centre valve providing hydraulic locking of the cylinder
— position indication in the piston rod
— different terminations (e.g. spherical bearings in each end, flanges, trunnion mountings)
— end covers may be threaded, welded, or bolted to the cylinder tube
— piston rod terminations may be threaded or welded to the piston rod
— piston rod may be of hollow or compact designs
— telescopic piston arrangement.

![Spherical bearings in both ends](image1)

![Flanged in both ends](image2)

![Trunnion mounted](image3)

2 Materials

2.1 Reference

Requirements in DNVGL-RU-SHIP Pt.2 Ch.2 or DNVGL-OS-B101 shall be followed, unless otherwise specified in this document.

2.2 Material certificates

Materials for cylinder tube, piston rod, end covers and end eyes shall be delivered with 3.1 material certificates (according to EN 10204 or equivalent). Approval of manufacturer is not required.
For cylinders intended for steering gear or water jet steering applications, VL certificate is required for the cylinder tube and piston rod. The end covers, end eye and piston shall be delivered with W certificates.

2.3 Impact testing
Cylinder tube, piston rod and end covers shall be charpy tested. Transverse charpy V-notch requirement (average) shall be 27J at minimum design temperature.

2.4 Cast iron
Grey cast iron and nodular cast iron of the ferritic/pearlitic and pearlitic type shall not be used for pressurised and load transferring parts of hydraulic cylinders.

2.5 End cover
Where the end cover is made from a rolled plate, the plate shall have through thickness (Z direction) properties.

3 Hydraulic cylinder for steering gear/water jet steering

3.1 Design pressure
Design pressure of hydraulic cylinder for steering gear/water jet steering shall be equal to 1.25 times of maximum working pressure.

3.2 Nominal design stress
If the hydraulic cylinder is an actuator type for steering gear/water jet steering, nominal design stress shall be in accordance with DNVGL-RU-SHIP Pt.4 Ch.10 Sec.1 [2.11.14].

4 Buckling

4.1 Definition
The symbols used are as given below:

- \( I_1 \) = 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
- \( L_1 \) = length of the cylinder part from the center of its mounting, mm
- \( L_2 \) = visible length of the piston rod in fully extracted position from centre of its mounting, mm
- \( L \) = length of fully extracted hydraulic cylinder between mountings, mm
- \( F_E \) = buckling load, kN
- \( E \) = Young's modulus of elasticity = 206000 N/mm\(^2\)
- \( F_a \) = actual maximum load, kN
- \( P_{push} \) = maximum pushing pressure, MPa
4.2 Calculation of buckling load

1) \( I_1 \) and \( I_2 \) shall be calculated as:

\[
I_1 = \frac{\pi (d_0^4 - d_i^4)}{64}
\]

and

\[
I_2 = \frac{\pi (d_0^4 - d_i^4)}{64}
\]

2) A parameter, called as \( Z \), shall be determined as:

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

3) Buckling load is equal to:

\[
F_E = \frac{E \times \pi^2}{1000 \times L \times Z}
\]

4.3 Safety factor

Buckling safety factor resulted from method in [3.2] shall not be less than 4, therefore:

\[
SafetyFactor = \frac{F_E}{F_a} \geq 4
\]

If the hydraulic cylinder is subject to different pushing pressures at different stroke lengths (load/pressure vs. stroke curve), buckling safety factor in each loading condition shall not be less than 4.

4.4 Mounting effect on buckling calculation

The calculation method described in [3.2] is valid when the hydraulic cylinder is simply supported at both ends. For other mounting configurations, \( L_1 \) and \( L_2 \) shall be calculated as effective lengths described by Euler method.

4.5 Alternative calculation Method

4.5.1 Alternative buckling calculation methods may be accepted instead of the method described in [3.2]. In this case, the method shall be approved separately by the Society.

4.5.2 Where it is deemed that the alternative method produces as more accurate analysis of buckling (e.g. effect of bending moment caused by rotation of the mounting bearings has been considered), a safety factor not less than 2.7 may be accepted.

4.5.3 Hydraulic cylinders may be approved with safety factors less than 2.7 if the governing society rules and/or standard allows.

4.5.4 An approved alternative method will only be accepted for hydraulic cylinders manufactured by the company who submitted the method for approval.
5 Cylinder tube and piston rod

5.1 Thickness

The thickness of the cylinder tube and the pressurised hollow piston rods shall be calculated according to DNVGL-RU-SHIP Pt.4 Ch.7 Sec.4:

\[
t = \frac{pD_o}{20 \sigma_t e + p} + c
\]

where:
- \( t \) = required wall thickness, mm
- \( p \) = design pressure, bar
- \( D_o \) = outside diameter of cylinder tube, mm
- \( \sigma_t \) = nominal design stress, N/mm\(^2\)
- \( e \) = joint efficiency = 1 for seamless pipes
- \( c \) = corrosion allowance, minimum 0.3 mm

5.2 Nominal design stress

Nominal design stress shall be calculated according to DNVGL-RU-SHIP Pt.4 Ch.7 Sec.4 [2.5]. Mechanical properties of material shall be in accordance with relevant material delivery standard.

6 End cover

6.1 Strength

The design and thickness of the end cover shall be calculated according to a recognised standard such as EN14359 or EN13445. The allowable stress shall be in accordance with [4.2]. Calculations according to any other recognised codes may be accepted.

6.2 Bolt load

For bolted end covers, the bolt load shall be calculated in accordance with a recognised standard accepted by the Society.

7 Thread calculation

Threads shall be calculated according EN 14359 or equivalent. Shear, compressive and/or flaring stresses (where applicable) shall be calculated. Acceptance criteria may be taken from the standard.

8 End eyes

8.1 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:
\[
\sigma_t = \frac{F}{T \cdot (D - d)} \sqrt{\frac{D^2}{d^2} - \frac{D}{d}} + 1 \leq \sigma_y
\]

where:
\begin{align*}
F & = \text{cylinder traction force, N} \\
T & = \text{width of end eye, mm} \\
D & = \text{outer diameter of end eye = 2 R in Figure 6, mm} \\
d & = \text{inner diameter of end eye (outside bearing), mm} \\
\sigma_y & = \text{yield strength of the end eye material, N/mm}^2
\end{align*}

## 9 Welding

### 9.1

Only full penetration butt welds described in DNVGL-RU-SHIP Pt.4 Ch.7 Sec.4 Figure 17, DNVGL-RU-SHIP Pt.4 Ch.7 Sec.4 Figure 27 are acceptable for main pressurised joints. Welding procedures shall fulfil relevant parts in DNVGL-RU-SHIP Pt.2 Ch.4 or DNVGL-OS-C401, whichever is applicable. Otherwise, fatigue assessment shall be submitted to confirm the stress level in weld can withstand the intended load cycles.

### 9.2

The steering edge between the end cover and tube shall not be greater than 3 mm, when hydraulic cylinder is designed for more than 15000 full load cycles.

![Figure 4 Steering edge](image)

## 10 Nondestructive testing

- all welded joints shall be subjected to visual inspection
- all longitudinal butt weld joints in cylinder (if applicable), shall be subjected to 100% radiographic testing
— all cross and T-joints welds shall be subject to minimum 20% magnetic particle testing (MT) or 20% penetrant testing (PT) whichever is applicable, in addition 20% ultrasonic testing (UT) shall be applied.
— 25% of the length of circumferential butt welded joints in cylinder shall be subjected to radiographic testing.

11 Telescopic hydraulic cylinders

Telescopic hydraulic cylinders are hydraulic cylinders with more than one piston rod. In addition to performing control calculation of the strength of the different pressurised parts against the internal pressure these cylinders shall also be calculated for buckling as described in [3.2]: an equivalent moment of inertia for piston rods shall be calculated equal to summation of moment of inertia of each piston rod. Similarly, equivalent visible length is equal to visible length of all piston rods at full stroke.
SECTION 3  MECHANICAL LOCKING CYLINDER

1 General

Hydraulic cylinders with internal mechanical locking mechanisms shall be type approved (DNVGL-RU-SHIP Pt.4 Ch.6 Sec.1 Table 5). In order to obtain a type approval certificate for such cylinders type tests as described in [2] shall be carried out in presence of DNV GL surveyor.

2 Type tests

2.1 Endurance test

The test shall be performed with the test object in the horizontal position. The lock shall be engaged and disengaged for 1500 cycles. One cycle shall include one engaging and one disengaging. The lock shall be activated with hydraulic oil through the oil supply studs at the cylinder design pressure during this test. The cylinder lock shall be pre-stressed with an external load corresponding to 5% of the design load. One sample of each cylinder size/lock type shall 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 shall 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 shall be subject to 100% MT (or 100% PT, whichever is applicable) and there should be no unacceptable indications. The test shall be witnessed by a Society's surveyor who shall sign the test report.

2.2 Static strength test

The strength of locking mechanism shall be tested as below:

— 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 shall 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 shall be subject to 100% MT (or 100% PT, whichever is applicable) and there should be no unacceptable indications. The test shall be witnessed by a Society's surveyor who shall sign the test report.

2.3

Prototype tests in [2.1] and [2.2] carried out on a hydraulic cylinder with a specific internal mechanical locking mechanism may be accepted for qualification of other hydraulic cylinder designs so long as they feature the same locking mechanism.
SECTION 4 PRODUCTION TESTING AND CERTIFICATION

1 General
The product certification procedure consists of the following (see Sec.2):

— review of material certificates
— review of welding workshop approval certificate, if applicable, otherwise: review of welder’s qualification certificates, review of the welding procedure specification, review of reports from nondestructive testing of welds, witness weld preparations/setup and monitor welding operations
— dimensional check in accordance with approved drawings (as listed in approval letter or type approval certificate)
— hydraulic pressure testing/functional testing.

After above successful steps and with reference to approval letter or type approval certificates, a product certificate may be issued and shall accompany each cylinder/delivery.

1.1 Hydraulic pressure testing
Hydraulic cylinders shall be hydraulically pressure tested to minimum 1.5 times the design pressure or 1.5 times the safety relief valve set pressure, whichever is the greatest, before paint or any coating is applied on the cylinders. The test pressure shall be applied to both sides of the piston head in sequence. Hydraulic testing shall be performed in the presence of a DNV GL surveyor, unless otherwise agreed.

The pressure test shall be such that it does not result in general membrane stress in any part of the component during the test exceeding 90% of Yield stress. No leakage or permanent deformation is permitted.

1.2 Testing of hydraulic locking cylinders (where the mechanism is internal)
The following test shall be carried out for 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 shall 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.

1.3 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
— DNV GL product certificate number, if applicable
— charge number for the materials used in the cylinder tube and the piston rod.

Additional marking may be done at the manufacturer’s option.
Changes – Historic

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This is a new document.
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