RULES FOR CLASSIFICATION

Ships

Edition October 2015

Part 4 Systems and components

Chapter 10 Steering gear
FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

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CHANGES – CURRENT

This is a new document.
The rules enter into force 1 January 2016.
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1 Introduction

1.1 Application

1.1.1 The rules in this section apply to electro hydraulic and hand hydraulic steering gear operating a rudder for the purpose of steering the vessel.

1.1.2 Steering gear, other than electro hydraulic type, will be accepted provided that safety and reliability can be documented to be equivalent to or better than the requirements of this section.

1.1.3 Requirements for rudders are given in Pt.3 Ch.14 and in Rules for Classification of High speed, light craft and naval surface craft HSLC Pt.3 Ch.5.

1.1.4 Requirements to steering of podded and geared thrusters are given in Ch.5 Sec.3. Requirements to steering of water jets are given in Ch.5 Sec.2.

1.1.5 For additional requirements for vessel navigation in ice (Ice, PC) see Pt.6 Ch.6 and for Ice breaker see Pt.5 Ch.10 Sec.10. For additional requirements for Naval and Naval support vessels see Pt.5 Ch.13. For additional requirements to vessels with additional notation Redundant propulsion (RP(1, x), RP(2, x), RP(3, x)) see Pt.6 Ch.2 Sec.7. For additional requirements to vessels with additional notation Dynamic positioning systems (DYNPOS and DPS) see Pt.6 Ch.3 Sec.1 and Pt.6 Ch.3 Sec.2.

1.2 Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Term</th>
<th>Unit</th>
<th>Rule reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_i</td>
<td>Pressurised area</td>
<td>mm^2</td>
<td>[2.11.19]</td>
</tr>
<tr>
<td>b</td>
<td>Breadth of key</td>
<td>mm</td>
<td>[2.12.12]</td>
</tr>
<tr>
<td>C_D</td>
<td>Average diametrical clearance of radial bearings</td>
<td>mm</td>
<td>[2.11.21] b)</td>
</tr>
<tr>
<td>c_e</td>
<td>Diameter ratio d/D</td>
<td>-</td>
<td>[2.12.8]</td>
</tr>
<tr>
<td>c_i</td>
<td>Diameter ratio d_i/d</td>
<td>-</td>
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</tr>
<tr>
<td>d</td>
<td>Rudder stock diameter</td>
<td>mm</td>
<td>[2.12.4] [2.12.8]</td>
</tr>
<tr>
<td>D</td>
<td>Outer diameter of hub</td>
<td>mm</td>
<td>[2.12.8]</td>
</tr>
<tr>
<td>D_{inner}</td>
<td>Inner diameter of hub</td>
<td>mm</td>
<td>[2.11.17]</td>
</tr>
<tr>
<td>d_i</td>
<td>Diameter of centre bore in rudder stock</td>
<td>mm</td>
<td>[2.12.8]</td>
</tr>
<tr>
<td>d_m</td>
<td>Mean diameter of cone</td>
<td>mm</td>
<td>[2.12.3] h)</td>
</tr>
<tr>
<td>d_s</td>
<td>Designed minimum rudderstock diameter below actuator</td>
<td>mm</td>
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</tr>
<tr>
<td>d_t</td>
<td>Diameter of rudder stock at top of cone</td>
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<td>E_e</td>
<td>Module of elasticity of hub</td>
<td>N/mm^2</td>
<td>[2.12.9]</td>
</tr>
<tr>
<td>E_i</td>
<td>Module of elasticity of rudder stock</td>
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<tr>
<td>e</td>
<td>Ram eccentricity</td>
<td>m</td>
<td>[2.11.19], Figure 1</td>
</tr>
<tr>
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<td>Description</td>
<td>Unit</td>
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<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------</td>
<td>--------------</td>
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<tr>
<td>F</td>
<td>Necessary force for pull up</td>
<td>kN</td>
<td>[2.12.10]</td>
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<tr>
<td>f_f</td>
<td>Material factor</td>
<td>-</td>
<td>[2.2.3]</td>
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<tr>
<td>F_{des}</td>
<td>Net radial force on rudderstock in way of actuator due to design torque</td>
<td>kNm</td>
<td>[2.11.21] a)</td>
</tr>
<tr>
<td>F_{MTR}</td>
<td>Net radial force on rudderstock in way of actuator due to rule rudder torque</td>
<td>kNm</td>
<td>[2.11.21] a)</td>
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<tr>
<td>H_{hub}</td>
<td>Height of hub</td>
<td>mm</td>
<td>[2.11.17]</td>
</tr>
<tr>
<td>h</td>
<td>Distance between upper and lower radial actuator bearing</td>
<td>mm</td>
<td>[2.11.21] b)</td>
</tr>
<tr>
<td>h_A</td>
<td>Vertical distance between force and bearing centre</td>
<td>mm</td>
<td>[2.11.21] b)</td>
</tr>
<tr>
<td>h_{eff}</td>
<td>Effective height of key contact with hub and shaft respectively</td>
<td>mm</td>
<td>[2.12.12]</td>
</tr>
<tr>
<td>k</td>
<td>Material utilisation factor</td>
<td>-</td>
<td>[2.12.3] i)</td>
</tr>
<tr>
<td>K</td>
<td>Taper of cone = l/\left(d_s-d_t\right)</td>
<td>-</td>
<td>[2.12.9]</td>
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<tr>
<td>k_b</td>
<td>Bending moment factor</td>
<td>-</td>
<td>[2.11.20]</td>
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<tr>
<td>k_{key}</td>
<td>Key factor</td>
<td>-</td>
<td>[2.12.12]</td>
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<td>l</td>
<td>Effective cone length</td>
<td>mm</td>
<td>[2.12.3] h)</td>
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<td>L</td>
<td>Distance between lower radial actuator bearing and neck bearing</td>
<td>mm</td>
<td>[2.11.21] b)</td>
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<td>L_t</td>
<td>Torque arm</td>
<td>m</td>
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<td>Effective bearing length of key</td>
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<td>M_{B}</td>
<td>Bending moment in rudderstock</td>
<td>kNm</td>
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<td>M_{TR}</td>
<td>Rule rudder torque</td>
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<td></td>
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<td>p</td>
<td>Surface pressure</td>
<td>N/mm^2</td>
<td>[2.12.8]</td>
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<tr>
<td>p_b</td>
<td>Surface pressure due to bending</td>
<td>N/mm^2</td>
<td>[2.12.7]</td>
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<td>p_{des}</td>
<td>Design pressure</td>
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<tr>
<td>p_r</td>
<td>Average/local surface pressure</td>
<td>N/mm^2</td>
<td>[2.12.3] h)</td>
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<tr>
<td>p_s</td>
<td>Permissible bearing surface pressure</td>
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<td>[2.14.3]</td>
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<tr>
<td>p_{test}</td>
<td>Test pressure</td>
<td>Bar</td>
<td>[4.1.1]</td>
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<tr>
<td>p_w</td>
<td>Maximum working pressure</td>
<td>Bar</td>
<td>[1.3.10]</td>
</tr>
<tr>
<td>R_{Ae}</td>
<td>Surface roughness of hub</td>
<td>μm</td>
<td>[2.12.9]</td>
</tr>
<tr>
<td>R_{Ai}</td>
<td>Surface roughness of rudder stock</td>
<td>μm</td>
<td>[2.12.9]</td>
</tr>
<tr>
<td>S</td>
<td>Safety factor (mechanical)</td>
<td>-</td>
<td>[2.11.11] - [2.11.12]</td>
</tr>
<tr>
<td>S_{c}</td>
<td>Safety factor for rudder stock connection</td>
<td>-</td>
<td>[2.11.9]</td>
</tr>
<tr>
<td>T_{des}</td>
<td>Design torque</td>
<td>kNm</td>
<td>[2.11.19]</td>
</tr>
<tr>
<td>T_{fr}</td>
<td>Friction torque</td>
<td>kNm</td>
<td>[2.12.3] h)</td>
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**Ships Pt.3 Ch.14 Sec.1**

**HSLC: Pt.3 Ch.5 Sec.1**
<table>
<thead>
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<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
<th>Reference</th>
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<tr>
<td>$T_W$</td>
<td>Maximum working torque</td>
<td>kNm</td>
<td>[1.3.12] [2.11.19]</td>
</tr>
<tr>
<td>$t$</td>
<td>Thickness of hub</td>
<td>mm</td>
<td>[2.11.17]</td>
</tr>
<tr>
<td>$w$</td>
<td>Weight in air of rudder and rudder stock</td>
<td>kg</td>
<td>[2.12.4]</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Angular deflection of rudder stock</td>
<td>rad</td>
<td>[2.11.21] b)</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Pull-up length</td>
<td>mm</td>
<td>[2.12.9]</td>
</tr>
<tr>
<td>$\Delta$</td>
<td>Shrinkage allowance</td>
<td>mm</td>
<td>[2.12.8]</td>
</tr>
<tr>
<td>$\Delta_{\text{max}}$</td>
<td>Calculated maximum shrinkage allowance</td>
<td>mm</td>
<td>[2.12.8]-[2.12.9]</td>
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<tr>
<td>$\Delta_{\text{min}}$</td>
<td>Calculated minimum shrinkage allowance</td>
<td>mm</td>
<td>[2.12.8]-[2.12.9]</td>
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<tr>
<td>$\theta$</td>
<td>Maximum permissible rudder angle</td>
<td>°</td>
<td>[2.11.19]</td>
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<tr>
<td>$\mu$</td>
<td>Friction coefficient</td>
<td>-</td>
<td>[2.12.6]</td>
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<tr>
<td>$\mu_{\text{pu}}$</td>
<td>Average friction coefficient for pull-up</td>
<td>-</td>
<td>[2.12.10]</td>
</tr>
<tr>
<td>$\nu_e$</td>
<td>Poisson’s ratio of hub</td>
<td>-</td>
<td>[2.12.8]</td>
</tr>
<tr>
<td>$\nu_i$</td>
<td>Poisson’s ratio for rudder stock</td>
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<td>[2.12.8]</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Cylinder neutral angle</td>
<td>°</td>
<td>[2.11.19]</td>
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<tr>
<td>$\sigma_m$</td>
<td>General primary membrane stress</td>
<td>N/mm$^2$</td>
<td>[2.11.14]</td>
</tr>
<tr>
<td>$\sigma_B$</td>
<td>Tensile strength</td>
<td>N/mm$^2$</td>
<td>[2.11.14]</td>
</tr>
<tr>
<td>$\sigma_Y$</td>
<td>Yield strength (or 0.2% proof stress)</td>
<td>N/mm$^2$</td>
<td>[2.11.14]</td>
</tr>
<tr>
<td>$\sigma_t$</td>
<td>Nominal design stress</td>
<td>N/mm$^2$</td>
<td>[2.11.15] Ch.7 Sec.4 [2.5.1]</td>
</tr>
<tr>
<td>$\sigma_f$</td>
<td>Minimum upper yield strength</td>
<td>N/mm$^2$</td>
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<tr>
<td>$\sigma_{\text{fit}}$</td>
<td>Tangential stress due to shrink fitting connection</td>
<td>N/mm$^2$</td>
<td>[2.11.13]</td>
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<tr>
<td>$\sigma_e$</td>
<td>Permissible equivalent stress</td>
<td>N/mm$^2$</td>
<td>[2.11.9]</td>
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<tr>
<td>$\sigma_{\text{bend}}$</td>
<td>Bending stress</td>
<td>N/mm$^2$</td>
<td>[2.11.9]</td>
</tr>
<tr>
<td>$\sigma_{\text{axial}}$</td>
<td>Axial stress</td>
<td>N/mm$^2$</td>
<td>[2.11.9]</td>
</tr>
<tr>
<td>$\sigma_N$</td>
<td>Nominal bending stress</td>
<td>N/mm$^2$</td>
<td>[2.11.16]</td>
</tr>
<tr>
<td>$T_{\text{nom}}$</td>
<td>Nominal shear stress</td>
<td>N/mm$^2$</td>
<td>[2.11.10]</td>
</tr>
</tbody>
</table>
1.3 Definitions

1.3.1 **Main steering gear** means the machinery necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions. For example this may include:

— rudder actuator(s)
— steering gear power units (if any)
— ancillary equipment
— the means of applying torque to the rudder stock (e.g. tiller or quadrant).

1.3.2 **Auxiliary steering gear** means the equipment other than any part of the main steering gear necessary for effecting movement of the rudder for the purpose of steering the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

**Guidance note:**
Auxiliary steering gear may share the tiller or similar component with the main steering gear.

1.3.3 **Steering gear control system** means the equipment by which orders are transmitted to the steering gear power units and other parts necessary for operating the steering gear.

Steering gear control systems may comprise:

— transmitters
— receivers
— programmable electronic units
— hydraulic control pumps
— associated motors
— associated motor controllers and frequency converters
— piping
— cables.

1.3.4 **Rudder actuator** means the component which converts directly hydraulic pressure into mechanical action to move the rudder.

1.3.5 **Rudder actuating mechanism** means the parts transmitting force from actuator to rudder stock, including tiller.

1.3.6 **Steering gear power unit** means:

— in the case of electric steering gear; an electric motor and its associated electrical equipment
— in the case of electro hydraulic steering gear; an electric motor and its associated electrical equipment and connected pump
— in the case of other hydraulic steering gear; a driving engine and connected pump.

1.3.7 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising:

— steering gear power units
— associated pipes and fittings
— rudder actuator.

The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.
1.3.8 Maximum ahead service speed
— For vessels complying with rules for ships: means the maximum speed corresponding to maximum nominal shaft RPM and corresponding engine MCR in service at sea on summer load waterline.
— For vessels complying with rules for HSLC: maximum service speed as defined in Pt.3 Ch.5 Sec.1, at full load condition.

1.3.9 Maximum astern speed is the estimated speed which the ship can attain at the designed maximum astern power at the deepest seagoing draught.

1.3.10 Maximum working pressure \( P_W \):
— For vessels complying with rules for ships: the maximum oil pressure in the system when the steering gear is operated according to [2.4.1] b.1).
— For vessels complying with rules for HSLC: the expected pressure in the system when the steering gear is operated according to [2.4.1] b.2).

1.3.11 Design pressure means the maximum pressure for which the actuator is designed.
Design pressure shall as a minimum be 1.25 times the maximum working pressure and shall not be less than the set pressure of the safety relief valve.

1.3.12 Maximum working torque \( T_W \) is the maximum torque in the steering gear when operating at maximum working pressure \( (P_W) \). Maximum working torque may be calculated according to formula in 2.11.19 by replacing the design pressure by the maximum working pressure.

1.4 Documentation requirements

1.4.1 Plans and particulars as listed in Table 1 shall be submitted for approval. The plans shall give full details of scantlings and arrangements as well as material specification and data necessary for verifying scantling calculations together with specified ratings.
Set pressure for all relief valves shall be specified.
Material specifications shall include mechanical properties and particulars about heat treatment.

Table 1 Documentation requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steering gear</td>
<td>C020 Arrangement</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z161 Operation manual</td>
<td>Operation instructions (Yard supply. See 6.2.4)</td>
<td>AP</td>
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<tr>
<td></td>
<td>Z110 Data sheet</td>
<td>Including spec. of rudder type</td>
<td>FI</td>
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<tr>
<td></td>
<td>I070 Instrument list</td>
<td>List of monitoring and alarms, including shutdowns of frequency converters.</td>
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</tr>
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<td>Z071 Failure mode and effect analysis</td>
<td>Functional failure analysis of steering gear and control system</td>
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<tr>
<td>Connection to rudderstock</td>
<td>C030 Detailed drawing</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z162 - Installation manual</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z265 - Calculation report</td>
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<td>R</td>
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<tr>
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<td>Drawing Specification</td>
<td>Section</td>
<td>Approval</td>
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<td>C020 Arrangement</td>
<td>Section drawing</td>
<td>FI</td>
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<td>C030 Detail drw. Including material spec. and NDT</td>
<td>Load transmitting bolts and pins.</td>
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<tr>
<td>Bearing</td>
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<td>Allowable bearing pressure</td>
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<td>Vane</td>
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<td>Applicable for rotary vane type</td>
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<td>Housing</td>
<td>C030 Detailed drawing</td>
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<td>Stopper / Dividing wall</td>
<td>C030 Detailed drawing</td>
<td>Applicable for rotary vane type</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>C050 Non-destructive testing (NDT) plan</td>
<td>Heat treatment or cool down procedure (See 2.2.4) is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
</tr>
<tr>
<td>Tiller</td>
<td>C030 Detailed drawing</td>
<td>Applicable for linked cylinder type</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>C050 Non-destructive testing (NDT) plan</td>
<td>Procedure is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>M060 Welding procedure (WPS)</td>
<td>Procedure is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>M061 Welding qualification</td>
<td>Procedure is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 Specification</td>
<td>Heat treatment or cool down procedure (See 2.2.4) is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
</tr>
<tr>
<td>Piston</td>
<td>C030 Detailed drawing</td>
<td>Applicable for linked cylinder type</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>C050 Non-destructive testing (NDT) plan</td>
<td>Procedure is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
</tr>
<tr>
<td>Piston rod</td>
<td>C030 Detailed drawing</td>
<td>Applicable for linked cylinder type</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>C050 Non-destructive testing (NDT) plan</td>
<td>Heat treatment or cool down procedure (See 2.2.4) is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
</tr>
<tr>
<td>Cylinder</td>
<td>C030 Detailed drawing</td>
<td>Applicable for linked cylinder type</td>
<td>AP</td>
</tr>
<tr>
<td>Component</td>
<td>Document Type</td>
<td>Classification</td>
<td>Approval Type</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------------</td>
<td>---------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>End cover</td>
<td>C030 Detailed drawing</td>
<td>Applicable for linked cylinder type</td>
<td>AP</td>
</tr>
<tr>
<td>Connecting rod</td>
<td>Z 240 Calculation report</td>
<td>Applicable for linked cylinder type</td>
<td>R</td>
</tr>
<tr>
<td>Tiller</td>
<td>C030 Detailed drawing</td>
<td>Applicable for ram type</td>
<td>AP</td>
</tr>
<tr>
<td>M060 Welding procedure</td>
<td>Procedure is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>M061 Welding qualification</td>
<td>Procedure is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>Z100 Specification</td>
<td>Heat treatment or cool down procedure (See 2.2.4) is subject to local approval (ie. Certifying station)</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>Ram</td>
<td>C030 Detailed drawing</td>
<td>Applicable for ram type</td>
<td>AP</td>
</tr>
<tr>
<td>Cylinder</td>
<td>C030 Detailed drawing</td>
<td>Applicable for ram type</td>
<td>AP</td>
</tr>
<tr>
<td>End cover</td>
<td>C030 Detailed drawing</td>
<td>Applicable for ram type</td>
<td>AP</td>
</tr>
<tr>
<td>Hydraulic system</td>
<td>S011 Hydraulic diagram</td>
<td>Hydraulic diagram</td>
<td>AP</td>
</tr>
<tr>
<td>Z060 Functional description</td>
<td>Total delivery capacity of steering gear hydraulic pumps</td>
<td>FI</td>
<td></td>
</tr>
<tr>
<td>Z100 Specification</td>
<td>Steering gear relief valve discharge characteristics (pressure-flow diagram)</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Foundation arrangement</td>
<td>Z030 Arrangement plan</td>
<td>Including type of foundation. (Yard supply)</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>C030 Detailed drawing</td>
<td>Fastening elements. Including bolts, stoppers, chocks and fitted elements. (Yard supply)</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 Specification</td>
<td>Cast resin chocks. Including material and design loads. (Yard supply)</td>
<td>AP, TA</td>
</tr>
</tbody>
</table>
For general requirements for documentation, including definition of the Info codes, see Pt.1 Ch.3 Sec.2.

For a full definition of the documentation types, see Pt.1 Ch.3 Sec.3.

For important components of welded construction (e.g. tiller), full details of the joints, welding procedure, filler metal and heat treatment after welding shall be specified on the plans.

Associated electrical equipment (motors, frequency converters, switchgear and control gear) is regarded as important equipment and documentation shall be submitted as required in Ch.8 Sec.1 [2.2].

Steering gear manufacturers who intend their product to comply with the requirements of the IMO Guidelines for non-duplicated rudder actuators shall submit additional documentation as given in App.A.

For rudders included under DP-control documentation of expected life time of bearings subjected to extra ordinary wear rate due to DP shall be submitted for approval.
1.5 Certification requirements

1.5.1 Steering gear components survey shall be documented according to Table 2 to Table 5. See also sub-section [3] below.

Table 2 Certification required for Steering gear

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steering gear</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actuator assembly</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td>If actuator is supplied separately.</td>
</tr>
<tr>
<td>Piping/manifold</td>
<td>MC</td>
<td>Society</td>
<td>VL if $D_N &gt; 50$ mm, TR if $D_N &lt; 50$ mm ($D_N = \text{nominal diameter}$) (See Ch.6).</td>
<td></td>
</tr>
<tr>
<td>Hose</td>
<td>TA</td>
<td>MANUFACTURER</td>
<td></td>
<td>Type approval required (See Ch.6)</td>
</tr>
<tr>
<td>Piping flange/bolt</td>
<td>TR</td>
<td>MANUFACTURER</td>
<td></td>
<td>(See also Ch.6)</td>
</tr>
<tr>
<td>Valve/valve housing/fitting</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>MANUFACTURER</td>
<td></td>
<td>(see also Ch.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pumps are subject to Type test (see [4.1.2]) which shall be documented by makers test report.</td>
</tr>
<tr>
<td>Pump</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>MANUFACTURER</td>
<td></td>
<td>(see also Ch.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TR is required for standard bolts (of the shelf). MC is required for bolts uniquely made for the steering gear, and that are in particular critical</td>
</tr>
<tr>
<td>Bolts/pins</td>
<td>MC</td>
<td>MANUFACTURER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control system</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td>(see also Ch.9)</td>
</tr>
<tr>
<td>Motor, electric</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td>If &gt; 100kW (see also Ch.8)</td>
</tr>
<tr>
<td>Frequency converter</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td>If &gt; 100kW (see also Ch.8)</td>
</tr>
<tr>
<td>Switchgear</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td>If &gt; 100kW (see also Ch.8)</td>
</tr>
</tbody>
</table>
### Table 3 Certification required for rotary vane type actuator

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor</td>
<td>MC NDT</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vane</td>
<td>MC NDT</td>
<td>MANUFACTURER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing</td>
<td>MC NDT</td>
<td>Society</td>
<td>MANUFACTURER</td>
<td></td>
</tr>
<tr>
<td>Cover</td>
<td>MC NDT</td>
<td>MANUFACTURER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stopper/dividing wall</td>
<td>MC NDT</td>
<td>MANUFACTURER</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4 Certification required for linked cylinder type rudder actuator

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiller</td>
<td>MC NDT</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic cylinder assembly</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piston</td>
<td>MC NDT</td>
<td>MANUFACTURER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piston rod</td>
<td>MC</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder</td>
<td>MC NDT</td>
<td>Society</td>
<td>Classification Guideline for hydraulic cylinder CG-0194</td>
<td>Hydraulic cylinder for steering is subject to certification regardless of size</td>
</tr>
<tr>
<td>End cover</td>
<td>MC NDT</td>
<td>MANUFACTURER</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 5 Certification required for ram type rudder actuator

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiller</td>
<td>MC NDT</td>
<td>Society</td>
<td>MANUFACTURER</td>
<td></td>
</tr>
<tr>
<td>Ram</td>
<td>MC NDT</td>
<td>Society</td>
<td>MANUFACTURER</td>
<td></td>
</tr>
</tbody>
</table>
*Unless otherwise specified the certification standard is DNVGL Ship Rules.

1.5.2 For a full definition of the certificate types, see Pt.1 Ch.3 Sec.5.

1.5.3 Testing and inspection of components

**Table 6 Testing and inspection - general**

<table>
<thead>
<tr>
<th>Object</th>
<th>NDT</th>
<th>Pressure testing</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piping</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Hose</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Valve/Valve housing/fitting</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Weld</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Actuator assembly</td>
<td></td>
<td></td>
<td>W</td>
</tr>
</tbody>
</table>

**Table 7 Testing and inspection - rotary vane type rudder actuator**

<table>
<thead>
<tr>
<th>Object</th>
<th>NDT</th>
<th>Pressure testing</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Vane</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Housing</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Cover</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Stopper / dividing wall</td>
<td></td>
<td>W</td>
<td></td>
</tr>
</tbody>
</table>

**Table 8 Testing and inspection - linked cylinder type rudder actuator**

<table>
<thead>
<tr>
<th>Object</th>
<th>NDT</th>
<th>Pressure testing</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiller</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Piston</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Cylinder</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>End cover</td>
<td></td>
<td>W</td>
<td></td>
</tr>
</tbody>
</table>

**Table 9 Testing and inspection - ram type rudder actuator**

<table>
<thead>
<tr>
<th>Object</th>
<th>NDT</th>
<th>Pressure testing</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiller</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Ram</td>
<td></td>
<td>W</td>
<td></td>
</tr>
</tbody>
</table>
2 Design

2.1 General

2.1.1 The requirements in this sub-section give criteria for arrangement, function and capacity for steering gear ([2.1] - [2.8]) and strength of steering gear components ([2.11] - [2.12]).

2.1.2 Requirements for electric equipment and control systems are given in [5].

2.1.3 Steering gear shall be designed considering all relevant loads from internal and external forces.

Internal loads shall be based on:
— design pressure for actuator
— test pressure for actuator.

External loads shall be based on:
— maximum rule rudder torque from rudder
— maximum force from rudder.

Guidance note:
The rule requirements imply that the actuator and actuating mechanism have a strength equivalent to that required for the rudderstock.

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

2.1.4 In case the actuator induces a bending moment in the rudder stock, the effects on rudder stock, fitting of actuator, bearings and fastening arrangement shall be considered.

Such bending moments may originate from asymmetrical actuator forces on tiller/rotor, or when rudder stock bending deflections are larger than what is allowed by the clearances in bearing arrangement.

2.1.5 The influence of bending moment due to rudder stock deflection may be neglected if horizontal deflection in way of upper bearing at full rule rudder force is less than two times the diametrical bearing clearance. Otherwise, corresponding bending moment at full rudder force shall be taken into account, see [2.11.21].

2.1.6 Bending moment and reaction force at upper bearing caused by asymmetrical tiller/rotor forces at both maximum rule rudder force and maximum power of actuator (design pressure) shall be considered, including any operational mode where one or more actuators are not in use. Bending moment arm shall be taken as the distance between resulting bearing force and centre of upper bearing, see [2.11.21].

2.2 Materials

2.2.1 Materials for application in rudder actuator, power piping valves, flanges and fittings and all steering gear components transmitting mechanical forces to the rudder stock, excluding bolts, pins and keys, shall be of steel, nodular cast iron or other approved ductile material, duly tested in accordance with Pt.2. Exemptions are made to the requirement to Charpy-V testing.

In general, all materials shall have an elongation of not less than 12%.
The following materials may only be accepted upon special consideration:
— materials with tensile strength in excess of 650 N/mm$^2$
— grey cast iron for use in redundant parts with low stress level, excluding hydraulic cylinders
— structural steel for components exposed to internal hydraulic pressure.

2.2.2 Materials in bolts, pins and keys shall be of rolled, forged or cast steel in accordance with Pt.2. In general, such material shall have a minimum specified tensile strength in the range of 400 N/mm$^2$ to 900 N/mm$^2$. Higher tensile strength may be accepted upon special considerations related to ductility and fatigue properties versus application. Yield stress shall not be less than 200 N/mm$^2$.

2.2.3 In order to ensure that the material has sufficient fatigue strength, allowable stresses are reduced for high tensile materials. Hence:

Minimum upper yield strength (or 0.2% proof stress), $\sigma_f$ [N/mm$^2$] for use in calculation shall not to be taken greater than 70% of the ultimate tensile strength.

The material factor, $f_1$ for forgings (including rolled bars) and castings, shall be taken as:

$$f_1 = \left( \frac{\sigma_f}{235} \right)^a$$

where

$$a = 0.75 \text{ for } \sigma_f > 235 \text{ N/mm}^2$$
$$= 1.0 \text{ for } \sigma_f \leq 235 \text{ N/mm}^2$$
$$= 1.0 \text{ when calculating with additional load as described in [2.11.8], or when calculating at internal test pressure, } P_{\text{test}}, \text{ or bolts with significant pre stress.}$$

2.2.4 Nodular cast iron and cast steel parts where dimensional stability is important, e.g. tiller and rotor transmitting rudder torque by means of keyless conical or cylindrical connection shall be stress relieved. Test pull-up or controlled cool-down may be accepted as replacement for stress relief. The cool-down procedure shall be approved. Further, it shall be documented that the actual cool-down process is in accordance with the procedure.

2.2.5 Welded parts shall be stress relieved. Requirements for welded structures as given in Pt.2 Ch.4 is applicable

2.2.6 The materials used for pressurized components including the seals shall be suitable for the hydraulic oil in use.

2.3 Arrangement generally

2.3.1 Unless expressly provided otherwise, every ship shall be provided with a main steering gear and an auxiliary steering gear (see [2.6]).

2.3.2 The main steering gear and the auxiliary steering gear shall be so arranged that the failure of one of them will not render the other one inoperative.

Guidance note:
When considering fail scenarios for main/auxiliary steering gear in this context the tiller and connection to rudder stock is considered as a non-failing component.

---end---of---guidance---note---

**Guidance note:**
For guidance to hydraulic arrangements see Class Guideline CG-0040 "Schematic Principles for Steering Gear Hydraulics".

---end---of---guidance---note---

**2.3.3 Steering gear systems** shall be equipped with a locking system effective in all rudder positions. Locking may be provided by hydraulic system with shut-off valves directly fitted at the actuator. For steering gears with cylinder units which may be independently operated the shut-off valves do not have to be fitted directly on the cylinders.

**2.4 Main steering gear**

**2.4.1** The main steering gear shall:

a) be capable of operating the rudder for the purpose of steering the ship at maximum ahead service speed which shall be demonstrated

b) have capacity to turn the rudder from side to side according to requirements given below at maximum ahead service speed

1) For vessels complying with rules for ships the main steering gear shall comply with the following:
   — turning the rudder over from 35° on one side to 35° on the other and visa versa
   — turning rudder from 35° on either side to 30° on the other sides respectively within 28 seconds
   — for class notations **Tug** or **Offshore service vessel**, or **polar class notation**: **PC** with relevant qualifier, turning the rudder from 35° on either side to 30° on the other sides respectively within 20 seconds
   — for class notation **Icebreaker**, turning rudder from 35° on either side to 30° on the other sides respectively within 15 seconds
   — For class notation **Pusher**, turning the rudder from 35° on either side to 30° on the other sides respectively within 20 seconds.
   — turning rudder back to neutral position from any possible steering angle that intentionally or unintentionally may be initiated. See also [2.9] for over-balanced rudders and rudders of unconventional design.

2) For vessels complying with rules for HSLC the main steering gear shall have capacity to turn the rudder during the following:
   — steering performance (zig zag) test
   — turning circle test
   — low speed steering test
   — single unit steering (for vessels with twin units).

c) be operated by power when the rules require a rudder stock diameter above 120 mm in way of the tiller, excluding strengthening for navigation in ice

d) be so designed that neither steering gear nor rudderstock will be damaged at maximum astern speed and rudder angle.

**Guidance note:**
A rule rudder stock with diameter of 120 mm equals a rule rudder torque of 23.3 kNm.

---end---of---guidance---note---

**2.5 Auxiliary steering gear**
2.5.1 The auxiliary steering gear shall:

a) be capable of operating the rudder for the purpose of steering the ship at navigable speed and of being brought speedily into action.

b) have capacity to turn the rudder from side to side according to requirements given below

1) For vessels complying with rules for ships the auxiliary steering gear shall comply with the following:
   - turning the rudder over from 15° on one side to 15° on the other side in not more than 60 seconds with the ship on summer load waterline and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

2) For vessels complying with rules for HSLC the auxiliary steering gear shall have capacity to turn the rudder during the following:
   - steering performance (zig zag) test
   - low speed steering test
   - turning circle test
   - single unit steering (for vessels with twin units)

c) be operated by power when the rules require a rudder stock diameter above 230 mm in way of the tiller, excluding strengthening for navigation in ice.

Guidance note:
Speedily normally means less than 15 minutes.

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

Guidance note:
Manually operated steering gears are only acceptable when the operation does not require an effort exceeding 160 N under normal conditions.

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

2.6 Exceptions where auxiliary steering gear is not required

2.6.1 Auxiliary steering gear need not be fitted when the ship is provided with either:

a) two rudders, each with its own steering gear and capable of steering the vessel with any one of the rudders out of operation

b) approved alternative means of steering, capable of steering the vessel with the rudder out of operation and provided with approved remote control from the bridge. Such means may be:
   - azimuth thrusters
   - two or more independent propulsion units, located eccentric from the ships centre line

c) for non-propelled vessels.

2.6.2 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not be fitted provided that requirements below are complied with:

a) Isolation:
   1) a single failure in the main steering gear piping system or one of the power units can be isolated and steering capability can be maintained or speedily regained.

b) Capacity:
   1) for a passenger ship, the main steering gear shall be capable of operating the rudder as required in [2.4.1] b) while any one of the power units is out of operation
   2) for a cargo ship, the main steering gear shall be capable of operating the rudder as required in [2.4.1] b) while operating with all power units.
2.7 Additional requirements for vessels above 70 000 gross tonnage

2.7.1 In every ship of 70 000 gross tonnage and upwards, the main steering gear shall comprise two or more identical power units complying with the requirements given in [2.6.2].

2.8 Additional requirements for oil carriers, chemical carriers and liquefied gas carriers

2.8.1 Oil carriers, chemical carriers or liquefied gas carriers of 10 000 gross tonnage and upwards shall comply with the following:

a) The main steering gear shall be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems, excluding the tiller or components serving the same purpose, steering capability shall be regained in less than 45 seconds.

b) Capacity:

1) The main steering gear shall comprise of two independent and separate power actuating systems, each capable of meeting the requirements in [2.4.1] b).

2) Alternatively, at least two identical power actuating systems may be fitted which:
   — acting simultaneously in normal operation are capable of meeting the requirements in [2.4.1] b)
   — are able to detect loss of hydraulic fluid from one system
   — automatically isolates such a defect so that the other actuating system(s) remains fully operational.

Guidance note:
Steering gear complying with requirements in this paragraph are commonly referred to as "IMO steering gears".

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

2.8.2 For tankers of 10 000 gross tonnage and upwards but less than 100 000 dead weight tons duplication of actuator is not required provided that an equivalent safety level can be documented according to App.A and the following is complied with:

a) the main steering gear shall comprise two or more identical power units capable of operating the rudder according to [2.4.1] b) while operating with all power units.

b) after loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability shall be regained within 45 seconds.

Guidance note:
Steering gear complying with requirements in [2.8.2] are commonly referred to as "Appendix A steering gears". See App.A.

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

2.9 Over balanced rudders

2.9.1 Paragraphs in [2.9] are relevant for steering gear for over-balanced rudders and rudders of unconventional design. See also Pt.3 Ch.14 [3.1.5].

The influence of increased friction due to age and wear of bearings on steering gear torque capacity shall be duly considered. Unless such friction losses are accounted for and specified in submitted approval documentation, the friction coefficient for the bearing in worn condition shall be taken at least twice as when new.

2.9.2 Loss of steering torque due to a single failure in the steering gear power or control systems (inclusive failure in power supply) shall not cause a sudden turn of rudder.
2.9.3 Steering gear shall be capable of bringing the rudder from any rudder angle back to neutral position. This shall be verified by testing on sea trial.

2.10 Hydraulics and piping

2.10.1 Piping, joints, valves, flanges and other fittings shall comply with the requirements of Ch.6 for design pressure as defined in [1.3.11]. Piping intended for power piping shall comply with requirements to Class I pipes.

2.10.2 Hydraulic power operated steering gears shall be provided with:

a) arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system

b) a fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power operated. The storage tank shall be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a contents gauge

c) indicator for clogged filter on all filters with “by-pass” function

d) arrangement so that transfer between units can be readily effected.

Guidance note:
Specification of a pressure filter for maintaining suitable fluid cleanliness may be 16/14/11 according to ISO 4406:1999 and $\beta_{6-7} = 200$ according to ISO 16889:1999.

2.10.3 Hydraulic power actuating system for steering gear shall not to be used for other purposes.

2.10.4 For all vessels with non-duplicated actuators isolating valves directly fitted on the actuator shall be provided at the connection of pipes to the actuator.

2.10.5 Main and auxiliary steering gear shall be provided with separate hydraulic power supply pipes. When main steering gear is arranged in accordance with [2.6.2], each hydraulic power unit shall be provided with separate power pipes. Interconnections between power pipes shall be provided with quick operating isolating valves.

2.10.6 Relief valves shall be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. Relief valves shall comply with the following:

a) the setting pressure shall not be less than 1.25 times the maximum working pressure

Guidance note:
A relief valve located directly after hydraulic pump may have a set value that is lower. However not lower than maximum working pressure.
Such reduction in set value will normally not be accepted for arrangements with overbalanced rudders.

b) the setting of the relief valves shall not exceed the design pressure

c) the minimum discharge capacity of the relief valves shall not be less than the larger of:
   — 110 % of the total capacity of the pumps which can deliver through it (them)
   — oil flow corresponding to a rudder movement of 5 deg./second.

Under such conditions the rise in pressure shall not exceed 10 % of the setting pressure. In this regard, due consideration shall be given to extreme foreseen ambient conditions in respect of oil viscosity.
2.10.7 Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by a single failure shall be considered. For alarm requirement see [5.7] ”Monitoring”.

Guidance note:
"Hydraulic locking" includes all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic "by-pass" meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.

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

2.10.8 Flexible hoses may be used between two points where flexibility is required but shall not be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery. Hoses shall be type approved.

2.10.9 Hoses shall be high pressure hydraulic hoses according to recognised standards and suitable for the fluids, pressures, temperatures and ambient conditions in question. For detailed requirements for construction and testing of flexible hoses, see Ch.6 Sec.10 [4].

2.11 Actuator and actuating mechanism

2.11.1 Actuator housing and cylinders are considered as Class I pressure vessels with respect to testing and certification, except for Charpy-V testing which is not required.

2.11.2 The structural design of the actuator shall be chosen with due respect to transmission of reaction forces to the seating.

2.11.3 The construction shall be such that the local stress concentrations are minimised.

2.11.4 All welding joints within the pressure boundary of a rudder actuator or actuating mechanism shall be full penetration type or of equivalent strength.

2.11.5 Where rudder carrier and/or radial bearings are integrated in the actuator, the actuator shall be designed to withstand additional reaction forces due to bending moment set up in the rudder stock.

2.11.6 The actuator and actuating mechanism shall be designed to withstand all possible loads that can be generated from rudder or power unit during operation. As a minimum, sufficient strength in the following conditions shall be considered:
— rudder exposed to a load corresponding to rule rudder torque, \( M_{TR} \), and force, \( F_R \)
— actuator(s) working at design pressure, \( P_{des} \)
— actuator(s) exposed to internal test pressure, \( P_{test} \).

Relevant additional loading due to bolt pretension, shrink fitting of hubs, from supports and connected piping, etc. shall be duly considered.

2.11.7 Unless fatigue is suspected to be a possible mode of failure, fatigue strength needs not to be documented. Normally, this provides that:
— fillets are smooth and well rounded so that geometrical stress concentration factors do not exceed 1.5 (otherwise safety factor shall be increased correspondingly)
— static strength fulfils the criteria in [2.11.8]-[2.11.18].

2.11.8 If forces from one actuator can be transferred to another, for instance by means of a connecting rod, the actuator and actuating mechanism shall not be permanently damaged when exposed to the sum of
actuating forces (actuators working at design pressure). When calculating the material factor \( f_1 \) shall be taken as \( \sigma_y / 235 \).

2.11.9 Nominal equivalent stresses in actuator and actuating mechanism shall comply with the following:

\[
\sigma_e \leq \frac{235 \cdot f_1}{S} \left( 1 - \frac{\sigma_{fit}}{\sigma_f} \right) \quad [N/mm^2]
\]

where

- \( \sigma_e \) = permissible equivalent stress \([N/mm^2]\) according to the von Mises criterion
- \( S \) = safety factor [-] (see [2.11.11] and [2.11.12])
- \( f_1 \) = material factor [-]
- \( \sigma_f \) = minimum upper yield strength \([N/mm^2]\)
- \( \sigma_{fit} \) = static stress due to pretension or shrinkage \([N/mm^2]\) (see [2.11.13]).

**Guidance note:**
Nominal stresses should be taken as follows:

**Bending stress:**

\[
\sigma_{bend} = \frac{M_B}{W_b} 10^3 \quad [N/mm^2]
\]

**Axial stress:**

\[
\sigma_{axial} = \frac{F_A}{A_A} \quad [N/mm^2]
\]

**Shear stress:**

\[
\tau_{nom} = \frac{F_S}{A_S} \quad [N/mm^2] \quad \text{(from shear force)}
\]

\[
\tau_{nom} = \frac{T}{W_t} 10^3 \quad [N/mm^2] \quad \text{(from torque)}
\]

where loads acting on the component are defined as:

- \( M_B \) = bending moment \([Nm]\)
- \( T \) = torque \([Nm]\)
- \( F_A \) = axial force \([N]\)
- \( F_S \) = shear force \([N]\)

Further, geometrical parameters are defined as:

- \( A_A \) = cross sectional area \([mm^2]\)
- \( A_S \) = shear area \([mm^2]\)
- \( W_B \) = section modulus in bending \([mm^3]\)
- \( W_t \) = section modulus in torsion \([mm^3]\)
For bolted connections with high pretension the safety factor may be applied to the variable load, and the following equation may be applied:

\[
\sigma_{fit} + S \times \sigma \leq \sigma_f
\]

\[\sigma = \textit{stress due to variable load}\]

---end---of---guidance---note---

2.11.10 Tiller arms, vanes, pins, bolts and other components exposed to shear forces shall comply with the following criteria for nominal sectional shear stress:
For circular cross sections:

\[
\tau_{nom} \leq \frac{175 \cdot f_1}{\sqrt{3} \cdot S} \quad \text{N/mm}^2
\]

For other geometries:

\[
\tau_{nom} \leq \frac{155 \cdot f_1}{\sqrt{3} \cdot S} \quad \text{N/mm}^2
\]

2.11.11 When calculation is based on rule rudder torque (\(M_{TR}\)) safety factors as given in [2.11.9] and [2.11.10] shall not be taken less than 2.0 (ensuring equivalent strength as required for the rudder stock).

2.11.12 When calculation is based on actuator pressure, safety factors as given in [2.11.9] and [2.11.10] shall not be taken less than:

a) At design pressure, \(P_{des}\):
   - 1.5 for parts subject to reversed load
   - 1.25 for parts not subject to reversed load
   - 1.0 for parts when calculating with additional load as described in [2.11.8].

   \textit{Guidance note:}
   Parts subject to reversing loads are parts where the change of direction of load exposes the part to alternating strain and compression.

   ---end---of---guidance---note---

b) At internal test pressure, \(P_{test}\):
   - 1.2 for clamping bolts in pressurised parts.

2.11.13 For shrink fitted connections, tangential stress at the outer hub surface may be taken as follows:

\[
\sigma_{fit} = p \left( \frac{1 + c_e^2}{1 - c_e^2} - 1 \right) \quad [\text{N/mm}^2]
\]
where

\[ p = \text{actual pressure due to shrinkage [N/mm}^2\text{]} \]

\[ c_e = \text{diameter ratio d/D [-] at considered section.} \]

2.11.14 Any part of the actuator exposed to internal hydraulic pressure, the general primary membrane stress shall comply with the following:

\[
\sigma_m \leq \frac{\sigma_B}{A} \quad [\text{N/mm}^2]
\]

\[
\sigma_m \leq \frac{\sigma_y}{B} \quad [\text{N/mm}^2]
\]

where

\[ \sigma_m = \text{general primary membrane stress [N/mm}^2\text{]} \]

\[ \sigma_B = \text{specified minimum tensile strength of the material at ambient temperature [N/mm}^2\text{]} \]

\[ \sigma_y = \text{specified minimum yield strength (or 0.2\% proof stress) of the material at ambient temperature [N/mm}^2\text{]} \]

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

**Table 10 Permissible primary membrane stress**

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>Cast steel</th>
<th>Nodular cast iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>1.7</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

2.11.15 Actuators shall in general be designed in accordance with the requirements for pressure vessels in Ch.7 Sec.4 [2.1] to Ch.7 Sec.4 [2.6].

Hydraulic cylinder type actuator shall be in compliance with DNVGL-CG-0194 *Standard for hydraulic cylinders*

For determination of nominal design stress, \( \sigma_t \), factors A and B given in [2.11.14] apply.

For single actuator steering gear intended for tankers of 10 000 gross tonnage and upwards, but less than 100 000 deadweight tons (see [2.8.2]), A and B shall be according to App.A.

2.11.16 For rotor vanes and dividing walls exposed to hydraulic pressure, membrane stresses as given in [2.11.14] are not relevant. The following requirements related to nominal bending stress are considered equivalent:

\[
\sigma_N \leq \frac{1.5\sigma_B}{A} \left(1 - \frac{\sigma_y}{\sigma_f}\right) \quad [\text{N/mm}^2]
\]
\[ \sigma_N \leq \frac{1.5\sigma_Y}{B} \left( 1 - \frac{\sigma_{fu}}{\sigma_Y} \right) \text{[N/mm}^2\text{]} \]

where

\( \sigma_N = \) nominal bending stress [N/mm\(^2\)]

A and B are given in Table 10.

**2.11.17** The rotor/hub shall have sufficient thickness, to avoid that loading on tiller arms/rotor vanes introduces unacceptable stresses or insufficient local surface pressure between hub and rudder stock.

**Guidance note:**

An average hub thickness not less than 70\% of required vane root thickness (as derived from [2.11.9]-[2.11.16]) is normally considered to be sufficient.

Hub may be dimensioned according to the following:

Tiller and rotary vane hubs made of material with a tensile strength of up to 500 N/mm\(^2\) should satisfy the following conditions in the area where the force is applied, see Figure 1:

- Height of hub \( H_{hub} \geq 1,0 \cdot D_{inner} \text{[mm]} \)
- Outside diameter \( D \geq 1,8 \cdot D_{inner} \text{[mm]} \)

**Figure 1 Hub dimensions**

In special cases the outside diameter may be reduced to

- \( D = 1,7 \cdot D_{inner} \text{[mm]} \)
- but the height of the hub shall then be at least
  - \( H_{hub} = 1,14 \cdot D_{inner} \text{[mm]} \)
  - Where materials with a tensile strength greater than 500 N/mm\(^2\) are used, the section of the hub may be reduced by 10 \%.

**2.11.18** Rams, connection rods and piston rods for hydraulic cylinders shall comply with requirements for buckling strength as given in requirements for hydraulic cylinder, see Classification Guideline for Hydraulic Cylinders. Rotating links shall be provided with lubrication.
2.11.19 Design torque, $T_{des}$ of a steering gear shall be calculated from:

$$T_{des} = P_{des} L_t \sum_{i=1}^{n} A_i \frac{\cos \phi}{\cos \theta} \times 10^{-3} \text{ [kNm]}$$

where

- $P_{des} = \text{design pressure [N/mm}^2\text{]}$
- $L_t = \text{torque arm [m]}$ (see Figure 2)
- $A_i = \text{pressurised (projected) area [mm}^2\text{]}$ of piston or vane number "i". If areas of all pressurised pistons/vanes are identical, the term
  $$\sum_{i=1}^{n} A_i$$
  can be replaced by $n A$.

- $n = \text{number of pistons/vanes which may be simultaneously pressurised in normal operation}$
- $\phi = \text{cylinder neutral angle [°]}$ as defined in Figure 2 for linked cylinder type steering gear
  $\phi = 0°$ for ram and rotary vane type steering gear
- $\theta = \text{maximum permissible rudder angle [°]}$ for ram type steering gear (normally 35°)
  $\theta = 0°$ for linked cylinder and rotary vane type steering gear.
2.11.20 The actuator(s) shall not cause permanent deformations to the rudder stock when operated at maximum power. Hence, maximum design torque shall not exceed:

\[
T_{des} \leq 2f_1 \left( \frac{d_s}{42k_b} \right)^3 \text{ [kNm]}
\]

where

- \( d_s \) = designed minimum rudder stock diameter below tiller or rotor [mm]
- \( k_b \) = bending moment factor to be calculated from:
where 

\[ M_B = \text{bending moment [kN]} \text{ induced by the rudder actuator at the section in question (see [2.11.21])}. \]

In case forces from one actuator can be transmitted to another (see [2.11.8]), the sum of design loads from all actuators shall be considered in the calculation of maximum allowable \( T_{des} \). In this respect, \( f_1 \) may be replaced by \( \sigma_y/235 \).

**2.11.21** Bending moment, \( M_B \) in rudder stock induced by rudder actuator may originate from either:

a) Actuator forces acting on tiller. Bending moment in way of radial bearing shall be taken as greater of the following:

\[ M_B = F_{des} h_A \text{[kNm]} \]

or

\[ M_B = F_{MTR} h_A \text{[kNm]} \]

where

\[ h_A = \text{vertical distance between force and radial bearing centre} \]
\[ F_{des} = \text{net radial force on rudder stock in way of actuator, with actuator(s) working at design pressure} \]
\[ F_{MTR} = \text{net radial force on rudder stock in way of actuator, with actuator(s) working at a pressure corresponding to rule rudder torque, } M_{TR}. \]

b) Radial rotor bearing loads in rotary vane type steering gear, caused by rudder stock bending deflections, shall be taken into account when bending deflections of rudder stock in way of upper bearing exceeds two times the diametrical bearing clearance. Unless otherwise is substantiated, \( M_B \) at lower radial actuator bearing is then to be taken as the bending moment needed to force the rudder stock deflections within the above limits, simplified to:

\[ M_B = \frac{\pi \left( \beta - \frac{2C_D}{h} \right) d_s^4}{100(L + h)} \text{[kNm]} \]

where

\[ \beta = \text{angular deflection of rudder stock [rad], calculated at full rudder force, } F_R \text{ (see Pt.3 Ch.14 Sec.1 [2.1.1] and HSLC Pt.3 Ch.5, assuming the rudder stock to be freely supported in the actuator}} \]
\[ C_D = \text{average diametrical clearance of radial bearings [mm], after pull-up of rotor onto rudder stock} \]
\[ h = \text{distance between upper and lower radial actuator bearing [mm]} \]
\[ L = \text{distance between lower radial actuator bearing and neck bearing [mm]} \]
2.12 Connection between steering gear and rudder stock

2.12.1 The steering gear shall be fitted to the rudder stock in such a way that forces from the actuator are effectively transmitted to the rudder stock in all operating conditions. The connection shall not be damaged if the steering gear is operated at full power, taking into account possible arrangements for transmission of forces between actuators. Dismantling of connection shall be possible without causing damage to the rudder stock or steering gear.

2.12.2 The connection between steering gear and rudder stock shall have a torque capacity not less than the greatest of:
   a) Twice the rule rudder torque ($M_{TR}$).
   b) Vessels complying with the rules for classification of ships:
      — in case the torque is transmitted by friction alone:
        twice the design torque ($T_{des}$)
      — in case the torque is transmitted by a combination of friction and shear (i.e. keyed connections):
        1.5 times the design torque.
   c) Vessels complying with the rules for classification of HSLC:
      — the design torque.

2.12.3 Friction connections, with or without key, shall comply with the following:
   a) Tapered contact area shall be evenly distributed and shall not be less than 70% of total contact area.
   b) If oil (or similar) is used for fitting the design shall enable escape of oil from between the mating surfaces. Where necessary tapered connections shall be provided with suitable means to facilitate dismantling of the hub (e.g. oil grooves and bores to connect hydraulic injection pump).
   c) Tapered connections shall be secured against axial displacement between rudder stock and steering gear by means of a nut properly tightened and secured to the shaft.
   d) Tapered connections shall be designed so that correct pull-up easily can be verified (see [2.12.8] to [2.12.10]).
   e) Keyless tapered connections shall have a taper ≤1:15, while taper shall be ≤1:10 for keyed tapered connections.

Figure 3 Example of tapered rudder stock connection

f) Cylindrical connections shall be duly secured with regard to axial loads.

g) When special locking assemblies (see also [2.12.4] b) are applied for fitting of steering gear to rudder stock, the arrangement shall be such that their mutual influence on surface pressure is as small as
possible. In case the number of locking assemblies is less than three an arrangement shall be provided to prevent drop of the rudder and stock in case of a slip in the friction connection.

h) In order to fulfil the requirement in [2.12.2], average required surface pressure, \( p_r \) for transmission of torque shall as a minimum comply with the following:

\[
p_r \geq \frac{2T_{fr} \times 10^6}{\pi d_m^2 l \mu} \quad \text{[N/mm}^2]\]

where

\( T_{fr} \) = required friction torque [kNm] (see [2.12.4])
\( d_m \) = mean diameter of cone [mm]
\( l \) = effective cone length [mm]
\( \mu \) = friction coefficient [-] (see [2.12.6])

i) Permissible stresses in the friction surface of the hub due to surface pressure are limited by the material utilisation factor, \( k \) as follows:

\[
k = 0.5 \text{ for keyed connections} \]
\[
= 0.9 \text{ for nodular cast iron} \]
\[
= 0.95 \text{ for steel forgings and cast steel.} \]

Other materials are subject to special consideration.

The influence of bending moment (see [2.1.3]-[2.1.5] and [2.11.21]) and stress variation due to different hub wall thickness shall be taken into account. Hence, local surface pressure shall not exceed:

\[
p_r \leq k \sigma_f \frac{1-c_e^2}{\sqrt{3+c_e^4}} - p_b \quad \text{[N/mm}^2]\]

where

\( \sigma_f \) = minimum upper yield strength [N/mm\(^2\)]
\( p_{bf} \) = surface pressure due to bending moment [N/mm\(^2\)]. Need normally only to be considered at bigger end of cone (see [2.12.7]). For keyed connections \( p_b \) may normally be taken as zero when calculating with \( k = 0.5 \) (see [2.12.11])
\( c_e \) = diameter ratio rudder stock/hub at considered section [-] (see [2.12.8]).


Guidance note:
Contact surface roughness (\( R_a \)) should normally not exceed 1.6 \( \mu \)m/3.5 \( \mu \)m for oil injection fittings/dry fittings, respectively.

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

2.12.4 Required torque to be transmitted by means of friction, \( T_{fr} \) is related to both rule rudder torque, \( M_{TR} \) and design torque, \( T_{des} \). \( T_{fr} \) shall be taken as follows:

a) For keyed rudder stock connections detrimental mutual micro-movements between hub and rudder stock shall be avoided in all normal operating conditions. Therefore, the key is considered as a securing device and \( T_{fr} \) shall then not be taken less than maximum calculated working torque of steering gear, \( T_W \) [kNm].
After special consideration, a lower friction capacity may be accepted for tight key connections. However, \( T_{fr} \) shall not be taken less than 0.25\( T_W \) (See also [2.12.11] – [2.12.15]).

b) For hubs joined to rudder stock by means of special locking assemblies or by means of tapered connection with intermediate sleeve, which transmit torque and axial forces by means of friction alone, the influence of axial forces shall be taken into account. Axial force shall correspond to twice the weight of the rudder and rudder stock in air, i.e. \( T_{fr} \) shall comply with the following:

\[
T_{fr} \geq \sqrt{(S_c \cdot T)^2 + (2w \cdot d)^2 \cdot 10^{-10}} \text{ [kNm]}
\]

c) For other keyless shrink fit connections, \( T_{fr} \) shall comply with the following:

\[
T_{fr} \geq S_c \cdot T \text{ [kNm]}
\]

\( S_c = \) safety factor for connection to rudder stock (see [2.12.5])
\( T = \) calculation torque (\( T_{des} \) or \( M_{TR} \)) [kNm]
\( w = \) weight in air of rudder and rudder stock [kg]
\( d = \) rudder stock diameter [mm].

---

Figure 4 Example of special locking assemblies: Friction rings
2.12.5 Minimum required safety factor, $S_c$ for calculation of connection to rudder stock shall be taken from Table 11:

**Table 11 Safety factors for connection to rudder stock**

<table>
<thead>
<tr>
<th>Rule relevance</th>
<th>Calculation torque</th>
<th>$S_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All vessels</td>
<td>$M_{TR}$</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>$T_{des}$ for loads as described in [2.11.8]</td>
<td>1.0</td>
</tr>
<tr>
<td>Vessels complying with rules for ships</td>
<td>$T_{des}$, keyless connections (except for loads as described in [2.11.8])</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>$T_{des}$, stresses in keyed connections (except for loads as described in [2.11.8])</td>
<td>1.5</td>
</tr>
<tr>
<td>Vessels complying with rules for HSLC</td>
<td>$T_{des}$</td>
<td>1.0</td>
</tr>
</tbody>
</table>

2.12.6 Unless otherwise documented and especially agreed upon, friction coefficient, for torque transmission between surfaces of steel or nodular cast iron shall not be taken higher than:

$$\mu = \begin{cases} 
0.14 & \text{for oil injection fitting} \\
0.17 & \text{for dry fitting.} 
\end{cases}$$

Friction coefficient for other materials will be specially considered.

2.12.7 Surface pressure, $p_b$ at lower end of hub due to bending moment may be taken as:

$$p_b = \frac{3.5M_B \mu}{d_m I_i^2} 10^6 \quad \text{[N/mm}^2]\]$$

where
$M_B$ = bending moment [kNm], see [2.1.3]-[2.1.5] and [2.11.21]
$l_t$ = length of hub [mm].

2.12.8 Shrinkage allowance corresponding to a certain surface pressure may be calculated according to the following provided that the hub wall thickness does not have large variations, either circumferentially or longitudinally:

$$\Delta = d \left[ \frac{p}{E_e \left( 1 - c_e^2 + \nu_e \right)} + \frac{p}{E_i \left( 1 - c_i^2 - \nu_i \right)} \right] [\text{mm}]$$

where

$\begin{align*}
   p & = \text{surface pressure [N/mm}^2\text{]}.
   d & = \text{rudder stock diameter [mm]}
   E_e & = \text{module of elasticity of hub [N/mm}^2\text{]}
   E_i & = \text{module of elasticity of rudder stock [N/mm}^2\text{]}
   c_i & = \text{diameter ratio} d_i/d [-]
   c_e & = \text{diameter ratio} d/D [-]
   D & = \text{outer diameter of hub [mm]}
   d_i & = \text{diameter of centre bore in rudder stock [mm]}
   \nu_e & = \text{Poisson’s ratio of hub [-]}
   \nu_i & = \text{Poisson’s ratio for rudder stock [-]}
\end{align*}$

For calculation of minimum shrinkage allowance on basis of minimum required average surface pressure, see [2.12.3] h), mean values of $D$, $d$ and $d_i$ shall be applied.

For calculation of maximum shrinkage allowance on basis of maximum permissible surface pressure, see [2.12.3] i), values of $D$, $d$ and $d_i$ refer to the considered section.

2.12.9 Pull-up lengths, for tapered connections shall fulfil the following:

$$\delta \geq K \left( \Delta_{\text{min}} + 2(R_{Ai} + R_{Ae}) \times 10^{-3} \right) \text{ [mm]}$$

And

$$\delta \leq K \left( \Delta_{\text{max}} + 2(R_{Ai} + R_{Ae}) \times 10^{-3} \right) \text{ [mm]}$$

$\delta$ shall not be taken less than 2 mm for keyless connections and 1 mm for keyed connections, respectively.

Where

$\begin{align*}
   K & = \text{taper of cone} = l_t/(d_i-d_e) [-]
   d_t & = \text{diameter of rudder stock at top of cone [mm]} (d_e, \text{see [2.11.20]})
   \Delta_{\text{min}} & = \text{calculated minimum shrinkage allowance according to [2.12.8] [mm]}
   \Delta_{\text{max}} & = \text{calculated maximum shrinkage allowance according to [2.12.8] [mm]}
   R_{Ae} & = \text{surface roughness of hub [μm]}
   R_{Ai} & = \text{surface roughness of rudder stock [μm]}
\end{align*}$
Guidance note:
Specified pull-up length should cover a range of minimum 0.5 mm.

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

2.12.10 For tapered connections necessary force for pull-up, F may be found from:

\[
F = \pi d_{pu} \mu_p \left( \frac{1}{2K} + \mu_{pu} \right) 10^{-3} \quad [kN]
\]

where

\( \mu_{pu} \) = average friction coefficient for pull-up (for oil injection: usually in the range 0.01 to 0.03. For dry fitting: usually in the range 0.1 to 0.2, typically 0.15).

2.12.11 Keyways shall not be located in areas with high bending stresses in the rudder stock. Fillets in keyways shall be provided with sufficient radii. Fillet radius larger than 2% of key breadth is normally considered as satisfactory.

2.12.12 The key shear stress and surface pressures in the rudder stock and hub keyways shall be calculated taking into account the friction torque depending on method for verification of frictional fitting.

Shear stress, \( \tau \) in key:

\[
\tau = \frac{S_c T - k_{key} T_{fr} \sigma_p}{d_{m} L_{eff} b} 10^6 \quad [N/mm^2]
\]

Side pressure, \( \sigma_p \) (for contact with rudder stock and hub):

\[
\sigma_p = \frac{S_c T - k_{key} T_{fr} \sigma_p}{d_{m} L_{eff} h_{eff}} 10^6 \quad [N/mm^2]
\]

where

\( T \) = calculation torque (\( M_{TR} \) or \( T_{des} \)) [kNm]

\( k_{key} \) = factor determined by expected accuracy of the method for verification of fitting:

<table>
<thead>
<tr>
<th>Verification method</th>
<th>( k_{key} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diametrical expansion of hub</td>
<td>1.0</td>
</tr>
<tr>
<td>Interference, cylindrical connection</td>
<td>1.0</td>
</tr>
<tr>
<td>Pull-up force, dry fitting</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 12 Correction for verification method
Steering gear

<table>
<thead>
<tr>
<th>Pull-up length</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt tightening (clamped connections)</td>
<td>0.7</td>
</tr>
</tbody>
</table>

\[ T_{fr} = \text{torque capacity of friction connection [kNm], can be derived from formula in [2.12.3] h} \]
\[ S_c = \text{safety factor, (see [2.12.5])} \]
\[ L_{off} = \text{effective bearing length of key [mm]} \]
\[ b = \text{breadth of key [mm]} \]
\[ h_{off} = \text{effective height of key contact with shaft and hub, respectively [mm]. I.e. key chamfer and keyway fillets shall be accounted for.} \]

In case two keys are fitted, uneven loading shall be considered, reducing the load by only 2/3 of the value achieved when calculating with one key.

2.12.13 Shear stresses in key, \( \tau \) [N/mm\(^2\)] as calculated in [2.12.12] shall not exceed:

\[
\begin{align*}
\frac{\sigma_f}{\sqrt{3}} & \quad \text{in case } T_{fr} \geq T_W \\
\frac{\sigma_f}{2\sqrt{3}} & \quad \text{in case } T_{fr} < T_W
\end{align*}
\]

See also [2.12.4]a).

2.12.14 Maximum permissible surface pressures for key and keyway, \( \sigma_p \) [N/mm\(^2\)] as calculated in [2.12.12] shall not exceed the values found from Table 13:

<table>
<thead>
<tr>
<th>Table 13 Maximum permissible surface pressures for key and keyway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key material</td>
</tr>
<tr>
<td>Keyway material, rudder stock</td>
</tr>
<tr>
<td>Keyway material, hub</td>
</tr>
</tbody>
</table>

2.12.15 Connection between steering gear and rudder stock by means of split type hub shall additionally comply with the following:

— if split on both sides; minimum two clamping bolts shall be fitted on each side
— if split on one side; minimum two clamping bolts shall be fitted
— one or two keys shall be fitted.
2.13 Stopper arrangement

2.13.1 Suitable stopping arrangements, mechanically limiting the maximum rudder angle, shall be provided. The stoppers may be an integrated part of the rudder actuator. In such case strength of stopper and relevant load carrying parts of actuator shall be evaluated for load from MTR. The load shall be distributed on active stoppers. For calculation purposes the number of active stoppers shall not be taken higher than three. See also requirement for rudder angle limiter in [5.5.5].

2.14 Bearings

2.14.1 Bearing hardness shall be at least 65 Brinell less than the mating surface.

2.14.2 Synthetic bearing materials shall be type approved.

2.14.3 The maximum permissible surface pressure $p_s$ for the bearings in the steering gear arrangement shall be taken in accordance with the maker’s specification. Values shall be documented by tests.

   Guidance note:
   It is a condition that expected lifetime of bearings as a minimum correspond to normal steering gear inspection and planned docking interval, unless otherwise specified in the makers operating instruction delivered with the product.

2.14.4 Loading of bearings shall be determined taking the following loads from the actuator into account (as applicable):
   — radial forces
   — axial forces
   — bending moment.

2.14.5 Expected life time of bearings where the main steering gear is included under DP-control shall not to be less than 10 000 hours.

   Guidance note:
   For calculation of bearing life time, continuous operation at average loading in a DP condition should be considered. The least favourable combination of ambient temperature and manufacturing tolerances should be taken into account.

2.14.6 Steering gear included under DP-control shall be provided with an arrangement enabling the measurement of wear of the vertical bearing.
2.15 Oil seals

2.15.1 Oil seals between non-moving parts, forming part of the external pressure boundary, shall be of the metal upon metal type or of an equivalent type.

2.15.2 Oil seals between moving parts, forming part of the external pressure boundary, shall be duplicated so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

3 Inspection and Testing

3.1 General

3.1.1 The certification principles are described in Pt.1 Ch.1 Sec.4. The principles of manufacturing survey arrangement is described in Pt.1 Ch.1 Sec.4 [2.5].

3.2 Inspection and testing of parts

3.2.1 Steering gear components shall be inspected and tested according to Table 2 to Table 5. Visual inspection of components shall be performed to verify compliance with approved drawings. Emphasis shall be paid to critical dimensions, clearances and stress raisers.

3.2.2 NDT shall be performed according to manufacturers approved specification.

3.2.3 Steering gear shall be delivered with a DNV GL product certificate.

3.2.4 Autopilots are required to be type approved according to applicable IMO performance standard.

3.2.5 The control and monitoring systems for steering gears shall be certified according to Ch.9.

3.2.6 Associated electrical equipment (motors, frequency converters, switchgear and controlgear) is regarded as essential equipment and shall be delivered with a DNVGL Product Certificate. (see Ch.8 Sec.1 [2.3.1])

4 Workshop Testing

4.1 General

4.1.1 The rule requirements related to the testing of class I pressure vessels, piping and related fittings apply. The steering gear is subject to internal pressure testing for a test pressure, \( P_{\text{test}} \), 1.5 times the design pressure. Holding time shall be sufficient for detection of leakages, however not less than 15 minutes (see Ch.6 Sec.5 [8.5.2]).

4.1.2 Each type of power unit pump shall be subjected to a type test.

a) The type test shall be for duration of not less than 100 hours.

b) The test arrangements shall be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure.
c) During the test, idling periods shall be alternated with periods at maximum delivery capacity at maximum working pressure.

d) The passage from one condition to another should occur at least as quickly as on board.

e) During the whole test no abnormal heating, excessive vibration or other irregularities are permitted.

f) After the test, the pump shall be dismantled and inspected.

Type tests may be waived for a power unit which has been proven to be reliable in marine service.

4.1.3 The assembled steering gear is subject to function test and setting of safety valve in workshop. If the manufacturer does not have the facilities to perform function test in loaded condition the test may be limited to a no-load condition.

5 Power Supply, Control and Monitoring

5.1 General

5.1.1 Main and auxiliary steering gear power units shall be:
 — arranged to restart automatically when power is restored after a power failure
 — capable of being brought into operation from a position on the navigating bridge.

5.1.2 Electro motors for steering gear shall at least have a rating of S6-25% for electro hydraulic systems and S3-40% for electro mechanical systems according to IEC60034-1. Additional class notations or special types of vessels may require other ratings.

5.2 Main power supply

5.2.1 Power supply shall be arranged with redundancy. A separate circuit shall be provided for each power unit, however two circuits are considered sufficient in case of more than two power units.

5.2.2 Each of the separate circuits shall be fed from the main switchboard, alternatively one may be fed from the emergency switchboard.

5.2.3 In ships of less than 1 600 gross tonnage, if provided with an auxiliary steering gear independent of electrical power supply, the main steering gear may be fed by one circuit from the main switchboard.

5.3 Emergency power supply

5.3.1 Where the rudder stock is required to be over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply shall be provided automatically within 45 seconds. Exceptions will be granted for fishing vessels and other vessels not required to comply with SOLAS. The alternative power supply may either be from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power shall be used only for this purpose.

The alternative power supply shall be sufficient to supply the steering gear power unit which complies with the requirements in [2.5], and its associated control system and the rudder angle indicator.

5.3.2 In every ship of 10 000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 minutes of continuous operation and in any other ship for at least 10 minutes.

5.3.3 Where the alternative power source is a generator, or an engine driven pump, starting arrangements shall comply with the requirements relating to the starting arrangements of emergency generators.
5.4 Control gear and associated protective functions

5.4.1 Steering gear circuits for electro hydraulic steering gear shall only trip upon short circuit. However if additional over-current trip is used the release current shall be at least 200% of the full load current with a time delay of minimum 60 seconds.

Steering gear motor circuits obtaining their power supply via an electronic converter, e.g. for speed control, and which are limited to full load current are exempt from the requirement to provide protection against excess current, including starting current, of not less than twice the full load current of the motor.

5.4.2 An overload alarm shall be activated when the current exceeds full load working current.

5.4.3 The protective shutdown functions associated with the steering gear shall be limited to those necessary to prevent immediate machinery breakdown. Any protective shutdown shall initiate an alarm.

5.5 General requirements, steering gear control system

5.5.1 Steering gear control system is defined in [1.3.3].

5.5.2 Steering gear motors shall be remotely controlled from the bridge and locally controlled from the steering gear compartment. When remote control is arranged from two or more positions, the arrangement shall be such that the motor can be started independently from any of these positions.

5.5.3 Steering gear control shall be provided as follows:

a) For the main steering gear, both on the navigating bridge and in the steering gear compartment.

b) When the main steering gear is arranged in accordance with [2.6.2] by two independent control systems, both shall be operable from the navigating bridge. In case the control system consists of an hydraulic telemotor, a second independent system operable from the bridge need not be fitted, except in oil carriers, chemical carriers or liquefied gas carriers of 10 000 tons gross and upwards.

c) For the auxiliary steering gear, in the steering gear compartment and, if power operated, it shall also be operable from the navigating bridge. Any control system for auxiliary steering gear shall be independent of the control system for the main steering gear.

5.5.4 Any main and auxiliary steering gear control system operable from the navigatign bridge shall comply with the following:

a) If electric, it shall be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit.

b) Means shall be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves.

c) The system shall be capable of being brought into operation from a position on the navigating bridge.

d) Short circuit protection only shall be provided for steering gear control supply circuits.

e) Failure detection and response to failures shall be arranged in accordance with Ch.9 Sec.2 [2] and Ch.9 Sec.3 [1.2.4].

Guidance note:
The least critical condition is normally to freeze the rudder in its present position. For systems and/or operational modes where midship position is considered to be the least critical condition, this may also be accepted

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

5.5.5 The actuator shall be equipped with necessary device in order to limit maximum helm angle of rudder enforced by the steering gear. Such a device shall be:
— activated at smaller helm angle than limited by the mechanical stopper arrangement
— synchronised with the physical actuator position and overriding the control system.

5.6 Arrangement of electric and control systems

5.6.1 The electric power circuits shall be separated as far as practicable throughout their length.

5.6.2 When two or more control systems are used, these shall be kept separated and not be located in the same enclosure (cabinet, desk, panel), unless a flame retardant partition is installed between the control systems within the enclosure. Cables and pipes shall be separated as far as practicable throughout the length.

5.6.3 The requirement in [5.6.2] may be waived for main steering stand provided the systems are separated as far as practicable and cables and components are securely installed.

5.6.4 Steering order devices for control systems may be operated by the same lever shaft.

5.6.5 Steering mode and steering station selectors may also be operated by the same shaft, provided the arrangement is of reliable construction.

5.6.6 If additional steering stations are arranged with control circuits branched off from a main steering station, it shall be possible to disconnect each such circuit by a multipole switch on the main steering station.

5.7 Monitoring

5.7.1 Alarm and indication requirements are specified in Table 14.

5.7.2 All alarms associated with steering gear faults shall be indicated on the navigating bridge and in machinery space. The alarm indicators on bridge shall be readily observable from main steering stand.

5.7.3 The rudder angle indicating system shall be independent of any control system. For vessels complying with the rules for classification of ships the rudder angle indicating system shall be so arranged that a single failure in power supply or anywhere in the indicating system does not cause loss of rudder angle indication on the bridge.

5.7.4 Where hydraulic locking, caused by a single failure, may lead to loss of steering, an alarm, which identifies the failed system, shall be provided.

Guidance note:
This alarm should be activated when there is disagreement between the given order versus control system output/execution.
For instance when:
— position of the variable displacement pump control system does not correspond with given order, or
— incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

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

5.8 Additional Requirements for vessels with DP notation

5.8.1 For steering gears under DP-control, the sensors for high temperature alarm and the temperature indication of the steering gear hydraulic oil system (see Table 14) shall be located in oil inlet to actuator.
**Table 14 Control and monitoring of steering gear**

<table>
<thead>
<tr>
<th>System/Item</th>
<th>Gr 1 Indication/Alarm</th>
<th>Gr 2 Automatic start of standby pump with alarm</th>
<th>Gr 3 Shut down with alarm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 General</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rudder position</td>
<td>IR, IL</td>
<td></td>
<td></td>
<td>Local and on bridge</td>
</tr>
<tr>
<td>Auto pilot</td>
<td>A</td>
<td></td>
<td></td>
<td>Indication at bridge and machinery space for “running”.</td>
</tr>
<tr>
<td>Hydraulic locking</td>
<td>A</td>
<td></td>
<td></td>
<td>Shall identify failed system</td>
</tr>
<tr>
<td><strong>2.0 Power actuating system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El. Power failure</td>
<td>A</td>
<td></td>
<td></td>
<td>Indication at bridge and machinery space for “running”.</td>
</tr>
<tr>
<td>El. Phase failure</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El. Motor overload</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3.0 Hydraulic system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System tank – oil level</td>
<td>IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage tank – oil level</td>
<td>IL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic oil - Temperature</td>
<td>HA, IL</td>
<td></td>
<td></td>
<td>Applies for steering gears under DP control only. Sensor shall be located in oil inlet to actuator.</td>
</tr>
<tr>
<td><strong>4.0 Steering gear control system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power failure</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disconnection of bridge control</td>
<td>IR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control failure</td>
<td>A</td>
<td></td>
<td></td>
<td>See [5.5.4] e)</td>
</tr>
</tbody>
</table>

Gr 1 Sensor(s) for indication and alarm.
Gr 2 Sensor for automatic start of standby pump
Gr 3 Sensor for shut down

IL = Local indication (presentation of values), i.e. in vicinity of the monitored component
IR = Remote indication (presentation of values), i.e. on bridge or other manoeuvring stand
A = Alarm activated for logical value
LA = Alarm for low value
HA = Alarm for high value

1) Low level alarm in separate steering gear control system oil tanks may be substituted by low pressure alarm. It is provided that each of the systems is able to control the main steering gear alone, and that oil leakage in one system has no effect on the other one.
6 Arrangement for Installation Onboard

6.1 Fastening arrangement to foundation

6.1.1 The fastening arrangement for fixing the steering gear to the foundation shall be designed to withstand all possible loads generated from rudder or power unit during operation. As a minimum sufficient strength and capacity in the following conditions shall be considered with safety factors as specified in [6.1.2]:

— rudder exposed to a load corresponding to rule rudder torque, $M_{TR}$
— actuator working at design pressure, $P_{des}$.

Reaction forces due to bending set up in rudder stock and radial/axial forces shall be taken into account as applicable.
Relevant additional loading due to thermal expansion etc. shall be duly considered.

6.1.2 The safety factors applicable for acting forces shall not be taken less than:
When calculating against $M_{TR}$: $S = 2.0$
When calculating against $P_{des}$: $S = 1.5$

6.2 Steering gear compartment

6.2.1 The steering gear compartment shall be:
— readily accessible and, as far as practicable, separated from machinery spaces
— provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements shall include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

6.2.2 Electrical power units shall be placed on elevated platforms or comply with enclosure type IP44 in order to safeguard against water splash.

6.2.3 Local steering control shall be arranged to enable steering by a single person.

Means of communication to navigating bridge shall be available from this control position.
Rudder indicator and heading information shall be visible from this control position.
Heading information shall be automatically updated when power is restored after a power failure.

6.2.4 Operation instructions shall be permanently displayed on the bridge and in steering gear compartment. The operation instruction shall provide the operator with information of the steering system, consisting of control system and steering gear. Further the operation instruction shall give instruction of the different operation modes that are available and how to switch between the operation modes
The instruction shall contain:
— arrangement and function of steering gear and control system
— instruction for how to handle failure modes
— Procedure for change-over to/from local control and other operation modes
— procedure for change-over between control modes on the bridge and in steering gear compartment
— procedure for operation of power units in the different operation modes.

Guidance note:
Examples of operation modes may be steering gear operation by “follow up” mode, "Non follow up" mode, local control from steering gear compartment or other pre-defined modes which request that steering gear is operated differently.

---end---of---guidance---note---
7 (Intentionally left blank)

7.1

7.1.1

8 Installation

8.1 Connection between steering gear and rudder stock

8.1.1 Contact area of conical connections shall be (minimum 70%) verified by means of paint test (e.g. toolmaker blue) in presence of the surveyor. Circumferential or full length non-contact bands are not acceptable.

8.1.2 Test pull-up to control the contact area may be required before final assembly for conical keyless connections intended for injection fitting, when calculations are considered inaccurate due to a non-symmetric design or other relevant reasons. Pull-up length during test pull-up shall not be less than final pull-up length.

8.1.3 Final connection of steering gear to rudderstock shall be performed according to approved procedure, in presence of the surveyor.

8.2 Fastening to foundation

8.2.1 For mounting on metallic chocks the clearance between mating surfaces shall be checked with feeler gauge and shall be less than 0.1 mm unless otherwise approved.

8.2.2 For mounting on epoxy resin, it shall be checked that:
   — the resin is type approved
   — the mixing, casting and curing is carried out as per maker’s instructions
   — the cleanliness of tank top and bedplate before casting is as per maker’s instructions
   — the area and height of resin are within approved dimensions
   — the resin is properly cured before bolt tightening.

8.2.3 Stoppers taking load in longitudinal and/or transversal direction (as applicable) shall be checked according to the arrangement drawing.

8.2.4 The tightening of the holding down bolts shall be checked versus approved specification.

9 Shipboard Testing

9.1 Shipboard testing

9.1.1 After installation on board the vessel, and prior to seatrial the steering gear shall be subjected to the required hydrostatic and running tests.
The test shall as a minimum comprise of:

a) hydrostatic testing
   — parts of steering gear that has not been pressure tested at workshop shall be tested at 1.5 times design pressure
   — assembly shall be tested at minimum 1.5 times maximum working pressure
b) function testing of the steering gear
c) testing alarms and indicators
d) autostart test of power units
e) testing all start and stop functions
f) test control transfer between bridge and local control
g) test safety valve setting (if not performed during Workshop test)
h) testing function and setting of overcurrent protection
i) test and check functions and settings in frequency converter (if applicable)
j) checking mechanical rudder indicator.

9.1.2 On double rudder installations where the two units are synchronised by mechanical means, mutual adjustment shall be tested.

9.2 Trials

9.2.1 The steering gear shall be tested on sea trial in order to demonstrate the function of the steering gear and that the rule requirements have been met. Design requirements in [2.4.1] need not be proved at trials by going with maximum astern speed and maximum rudder angle.

The test shall include the following:

a) Testing of steering gear function and capacity. Acceptance criteria are given in [2.4.1] and [2.5.1].
b) The steering gear power units, including transfer between steering gear power units.
c) The isolation of one power actuating system, checking the time for regaining steering capability.
d) The hydraulic fluid recharging system.
e) The emergency power supply required in [5.3].
f) The steering gear controls, including transfer of control and local control.
g) The means of communication between the steering gear compartment and the wheelhouse. Also the engine room if applicable.
h) Where steering gear is designed to avoid hydraulic locking this feature shall be demonstrated.
i) Steering gear for over-balanced rudders or rudders of unconventional design (such as flap rudders) shall additionally be tested turning the rudder over from maximum rudder angle on one side to maximum rudder angle on the other side and vice versa, see [2.4].
   Test items d) and g) may be carried out and completed at the dockside.

9.2.2 The trial shall be performed under the following operational conditions:

For vessels complying with the rules for classification of ships:

— loaded on summer load waterline. If this can not be done alternative trial conditions may be specially considered. See [9.2.4] and [9.2.5]
— running ahead at maximum service speed corresponding to maximum nominal shaft RPM and maximum continuous rating (MCR) of the main engine(s) and if equipped with controllable pitch propeller(s), the propeller pitch shall be at the maximum design pitch corresponding to the nominal shaft RPM and MCR of the main engine(s).
For vessels complying with the rules for HSLC:
— full load condition
— running ahead at maximum service speed as defined in HSLC Pt.3 Ch.5
— both in calm water and, as far as practically possible, in a sea state corresponding to upper part of operational condition.

9.2.3 A record of the steering gear parameters during test shall be presented to the attending surveyor. As minimum the following parameters shall be logged: vessel speed and propulsion engine speed, steering angle, hydraulic pressure and time used for moving of rudder as defined.

9.2.4 When performance test is carried out at reduced draught with partly submerged rudder, calculations showing corresponding rudder force and torque for the trials shall be submitted on request.

9.2.5 Ships fitted with semi-spade rudders shall be tested with the rudders completely submerged. However, when satisfactory results are proved by sister ships, tests according to [9.2.4] with partly submerged rudder may be accepted. Calculations of the expected rudder force and torque for the trials shall be submitted. If test results for sister vessels are not available, steering gear test with rudder partly submerged may be accepted upon special consideration in each case.

9.3 Additional requirements for vessels with DP notation

9.3.1 For steering gears included under DP-control it shall be verified that the steering gear is designed for continuous operation by testing according Pt.6 Ch.3 Sec.1 [3.6.10] and Pt.6 Ch.3 Sec.2 [3.6.9].
APPENDIX A ADDITIONAL REQUIREMENTS FOR NON-DUPLICATED RUDDER ACTUATORS

1 General

1.1 Application

1.1.1 The requirements given in this Section are in compliance with IMO “Guidelines” for the acceptance of non-duplicated rudder actuators for oil carriers, chemical carriers and liquefied gas carriers of 10 000 gross tonnage and upwards but of less than 100 000 tonnes deadweight.

1.2 Documentation

1.2.1 In addition to documentation required in Sec. 1 [1.4], the following shall be submitted:

a) A detailed stress analysis of the pressure retaining parts of the actuator, exposed to design pressure (for information)
b) Detailed calculations showing the suitability of the design for the intended service (upon request).
c) Where considered necessary because of the design complexity or manufacturing procedures: fatigue analysis and fracture mechanics analysis (upon request). In connection with these analyses, all foreseen dynamic loads should be taken into account.

Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending upon the complexity of the design.

2 Design

2.1 General

2.1.1 Special consideration shall be given to the installation of sealing arrangements, to testing and inspection and to the provision of effective maintenance.

2.2 Dynamic loads for fatigue and fracture mechanics analyses

2.2.1 Where applicable, dynamic loads for evaluation of fatigue strength and fracture mechanics shall comprise both the case of high cycle and cumulative fatigue.

2.3 Allowable stresses

2.3.1 For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure the allowable stresses shall not exceed:

\[
\begin{align*}
\sigma_m & \leq f \\
\sigma_1 & \leq 1.5 f \\
\sigma_{\text{bend}} & \leq 1.5 f \\
\sigma_1 + \sigma_{\text{bend}} & \leq 1.5 f \\
\sigma_m + \sigma_{\text{bend}} & \leq 1.5 f
\end{align*}
\]
where

\[ \sigma_m = \text{general primary membrane stress} \ [\text{N/mm}^2] \]
\[ \sigma_{bend} = \text{nominal bending stress} \ [\text{N/mm}^2] \]
\[ f = \text{the lesser of:} \]
\[ \frac{\sigma_b}{A} \text{ or } \frac{\sigma_y}{B} \]
\[ \sigma_b = \text{specified minimum tensile strength of the material at ambient temperature} \ [\text{N/mm}^2] \]
\[ \sigma_y = \text{specified minimum yield strength (or 0.2% proof stress) of the material at ambient temperature} \ [\text{N/mm}^2] \]

A and B shall be taken as follows:

df

<table>
<thead>
<tr>
<th>Table 1 Permissible stresses</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td><strong>Steel</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
</table>

For other materials A and B will be especially considered.

See also Sec.1 [2.11.14].

2.3.2 Burst test

2.3.3 Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test and the detailed stress analysis required by [1.2] need not to be provided.

2.3.4 The minimum bursting pressure, \( P_B \) shall be calculated as follows:

\[ P_B = P_{des} A \frac{\sigma_{ba}}{\sigma_b} \ [\text{N/mm}^2] \]

where

\( P_{des} \) = design pressure [N/mm²] as defined Sec.1 [2.11]
\( \sigma_{ba} \) = actual tensile strength [N/mm²]
\( \sigma_b \text{ and } A \) = as defined in Sec.1 [2.11.14]

3 Inspection and Testing

3.1 Non-destructive testing

3.1.1 The rudder actuator shall be subjected to suitable and complete non-destructive testing to detect the following:
— surface flaws
— volumetric flaws.

If recognised test methods are expected to fail, testing may be omitted, provided that the risk and consequence of material defects are especially considered. Magnetic particle testing (MT) shall be carried out for all machined surfaces of the housing and cover.

The procedures and acceptance criteria for non-destructive testing shall be in accordance with requirements of recognised standards.

If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.
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