PART 4 CHAPTER 5

ROTATING MACHINERY, DRIVEN UNITS

JULY 2005

CONTENTS

<table>
<thead>
<tr>
<th>Sec.</th>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Propellers</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Water Jets</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Podded and Geared Thrusters</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Compressors</td>
<td>21</td>
</tr>
</tbody>
</table>

DET NORSKE VERITAS

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

General
The present edition of the rules includes additions and amendments decided by the Board as of June 2005 and supersedes the January 2005 edition of the same chapter. The rule changes come into force on 1 January 2006.

This chapter is valid until superseded by a revised chapter. Supplements will not be issued except for an updated list of minor amendments and corrections presented in Pt.0 Ch.1 Sec.3. Pt.0 Ch.1 is normally revised in January and July each year.

Revised chapters will be forwarded to all subscribers to the rules. Buyers of reprints are advised to check the updated list of rule chapters printed Pt.0 Ch.1 Sec.1 to ensure that the chapter is current.

Main changes
• General
As a consequence of the extended use of podded propulsors, the existing requirements for podded and geared thrusters have been evaluated and updated.

The extended use of electro mechanical steering gear both for podded and geared azimuth thrusters has justified an update of the requirements for steering of thrusters generally and for electro mechanical steering especially. The requirements that have been added are based on equivalence to the electro hydraulic steering of conventional rudders.

• Sec.3 Podded and Geared Thrusters
— A101: Scope of rules has been changed such that requirements for control system and electric system apply also to auxiliary thrusters of less than 300 kW.
— A200: More detailed requirements for documentation for steering gear and for documentation of electrical motor control system for thrusters driven by electric motor.

Added requirements for documentation of connection stator-top-housing and rotor-to-shaft for podded thrusters and for documentation of capacity of support bearing.

Requirements have been added for:
— B103: shielding of POD internals
— B104: hydraulic components (and for piping arrangement)
— B105: cooling of podded thrusters
— B202: duplication of shaft seals for single unit installations
— B203: rope guard
— B400: azimuth steering based on revised rules for conventional rudders
— B416: control system for electro mechanical steering gear with respect to acceleration and shock load
— B417: rating for electro motor driving the steering gear
— B505: bilge system for podded thrusters
— B802: separate lubrication systems for installations with a limited volume of oil sump
— E105: duplication of sensors not easily replaceable
— F104: boundary to sea
— F203: steering gear emergency power supply
— H103 and H200: survey of assembly and installation of thrusters at yard

Requirements have been updated for:
— Table E1: monitoring of thrusters
— F202: thrusters compartment
— I101 - I110: sea trial testing.

Guidance note has been added covering:
— B803: lubrication oil cleanliness.

Corrections and Clarifications
In addition to the above stated rule requirements, a number of detected errors, corrections and clarifications have been made in the existing rule text.
## CONTENTS

**SEC. 1 PROPELLERS** .......................... 5

| A. General | 5 |
| A 100 Application | 5 |
| A 200 Documentation | 5 |
| B. Design | 6 |
| B 100 General | 6 |
| B 200 Criteria for propeller blade dimensions | 6 |
| B 300 Pitch control mechanism | 6 |
| B 400 Fitting of propeller blades to the hub | 7 |

| C. Inspection and Testing | 7 |
| C 100 General | 7 |
| C 200 Inspection and testing of parts | 7 |
| C 300 Certification of ancillaries | 7 |

| D. Workshop Testing | 8 |
| D 100 General | 8 |
| E. Control and Monitoring | 8 |
| E 100 General | 8 |
| F. Arrangement | 8 |
| F 100 General | 8 |
| F 200 Arrangement of propeller | 8 |
| F 300 Hydraulic system for pitch control | 8 |

| G. Vibrations | 8 |
| G 100 General | 8 |

| H. Installation Inspection | 9 |
| H 100 General | 9 |
| H 200 Fitting of propeller | 9 |
| H 300 Pitch marking | 9 |
| H 400 Hydraulic piping | 9 |

| I. Shipboard Testing | 9 |
| I 100 Sea trial | 9 |

**SEC. 2 WATER JETS** .......................... 10

| A. General | 10 |
| A 100 Application | 10 |
| A 200 Documentation | 10 |
| A 300 Definitions | 10 |
| B. Design | 11 |
| B 100 General | 11 |
| B 200 Design of components | 11 |

| C. Inspection and Testing | 11 |
| C 100 General | 11 |
| C 200 Certification of parts | 11 |
| C 300 Testing and inspection of parts | 12 |
| C 400 Assembling | 12 |

| D. Workshop Testing | 12 |
| D 100 General | 12 |

| E. Control, Alarm, Safety Functions and Indications | 12 |
| E 100 General | 12 |
| E 200 Monitoring and bridge control | 12 |

| F. Arrangement | 12 |
| F 100 General | 12 |
| F 200 Arrangement of propeller | 12 |

| G. Vibration | 13 |
| G 100 General | 13 |

| H. Installation Survey | 13 |
| H 100 Surveys | 13 |

| I. Shipboard Testing | 13 |
| I 100 General | 13 |

**SEC. 3 PODDED AND GEARED THRUSTERS** .......................... 14

| A. General | 14 |
| A 100 Application | 14 |
| A 200 Documentation | 14 |
| B. Design | 15 |
| B 100 General | 15 |
| B 200 Shafting | 15 |
| B 300 Gear transmissions | 15 |
| B 400 Azimuth steering gear | 16 |
| B 500 Steering column and pod stay and underwater housing | 16 |
| B 600 Propeller | 17 |
| B 700 Bearings | 17 |
| B 800 Lubrication system | 17 |

| C. Inspection and Testing | 17 |
| C 100 General | 17 |
| C 200 Certification of parts | 17 |
| C 300 Material and NDT testing | 17 |
| C 400 Assembling | 18 |

| D. Workshop Testing | 18 |
| D 100 Testing of assembled unit | 18 |

| E. Control, Alarm, Safety Functions and Indication | 18 |
| E 100 General | 18 |
| E 200 Bridge control | 18 |

| F. Arrangement | 20 |
| F 100 General | 20 |
| F 200 Propulsion thrusters | 20 |

| G. Vibration | 20 |
| G 100 Torsional vibration | 20 |

| H. Installation Inspection | 20 |
| H 100 Installation onboard | 20 |
| H 200 Install fastening to foundation | 20 |

| I. Shipboard testing | 20 |
| I 100 Sea trial | 20 |

**SEC. 4 COMPRESSORS** .......................... 21

| A. General | 21 |
| A 100 Application | 21 |
| A 200 Documentation | 21 |
| B. Design | 21 |
| B 100 General | 21 |
| B 200 Crankshafts | 21 |
| B 300 Rotors | 22 |
| B 400 Rotor casing | 22 |

| C. Inspection and Testing | 22 |
| C 100 General | 22 |
| C 200 Certification, testing and inspection of parts | 23 |

| D. Workshop testing | 23 |
| D 100 General | 23 |

| E. Control and Monitoring | 23 |
| E 100 General | 23 |

| F. Arrangement Onboard | 23 |
| F 100 General | 23 |

| G. Vibration | 23 |
| G 100 Torsional vibration | 23 |

| H. Installation Inspection | 24 |
| H 100 General | 24 |
| H 200 Vibration | 24 |
SECTION 1
PROPELLERS

A. General

A 100 Application

101 The rules in this section apply to propellers intended for propulsion, steering and manoeuvring, subject to certification. See Ch.2 Sec.1 A200 (for auxiliary thrusters, see also Sec.3 A101).

102 Ch.2 describes all general requirements for rotating machinery and forms the basis for all sections in Ch.3, Ch.4 and Ch.5.

103 The following items are recognised as parts of the propeller and are subject to approval:

— propeller blades
— blade bolts (if any)
— propeller hub
— pitch control mechanism (if any).

For fitting of the propeller to the shaft, see Ch.4 Sec.1.

104 See Pt.5 Ch.1 of the Rules for Classification of Ships concerning propellers for ships with ice strengthening.

105 See Pt.5 Ch.14 concerning additional requirements for propellers for naval vessels.

106 The propeller shall be delivered with a NV certificate.

A 200 Documentation

201 Plans and particular shall be submitted as applicable according to Table A1. The plans shall show clearly all scantling details and arrangements, as well as material specifications. For propeller blades, hubs or blade bolts made of steel, type of heat treatment and acceptance criteria (or reference to such) for ultrasonic testing shall be given. Design parameters, such as engine power, propeller rotational speed, maximum vessel speed and ice class shall be given, see also Ch.4 Sec.3 A101. The manufacturing tolerance class (ISO 484) shall be specified on the propeller drawings.

202 The following additional information shall also be submitted for the propeller:

— weight and buoyancy
— polar and diametrical mass moment of inertia.

203 For instrumentation and automation, including computer based control and monitoring, see Ch.9 Sec.1.

Table A1 Documentation

<table>
<thead>
<tr>
<th>Application</th>
<th>Component</th>
<th>For approval (A)</th>
<th>For information (I)</th>
<th>Reference to design requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mono-block fixed pitch propellers</td>
<td>Propellers cast in one piece</td>
<td>A</td>
<td></td>
<td>See Classification Note 41.5</td>
</tr>
<tr>
<td></td>
<td>Blades</td>
<td>A</td>
<td></td>
<td>See Classification Note 41.5</td>
</tr>
<tr>
<td></td>
<td>Blade bolts</td>
<td>A</td>
<td></td>
<td>See B400</td>
</tr>
<tr>
<td></td>
<td>Hub</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Built-up fixed pitch propellers and controllable pitch propellers</td>
<td>Pitch control mechanism</td>
<td>A</td>
<td></td>
<td>See B300</td>
</tr>
<tr>
<td></td>
<td>Schematic hydraulic diagram 1)</td>
<td>A</td>
<td></td>
<td>See F300 and Ch.6. Sec.5 H100 of the Rules for Classification of Ships</td>
</tr>
<tr>
<td></td>
<td>Operating instructions 2)</td>
<td>I</td>
<td></td>
<td>See E102</td>
</tr>
<tr>
<td>Controllable pitch propellers</td>
<td>Propeller fitting to shaft</td>
<td>A</td>
<td></td>
<td>See Ch.4 Sec.1</td>
</tr>
<tr>
<td></td>
<td>Installation instructions</td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Documentation for the control and monitoring system, including set-points and delays. 3)</td>
<td>A</td>
<td></td>
<td>See E100</td>
</tr>
<tr>
<td>All propellers</td>
<td>Arrangement of free wheeling propeller</td>
<td>I</td>
<td></td>
<td>See F200</td>
</tr>
<tr>
<td>Free wheeling propeller</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Including permissible operating servo pressures, specification of oil filter, and specification of minimum degree of oil cleanliness according to a recognised standard (for instance ISO 4406:1999 and ISO 16889:1999).

2) Only in case pitch adjustment is used as load control of prime mover

3) For requirements to documentation types, see Ch.9.

B. Design

B 100 General

101 Materials for propellers shall comply with the requirements in Pt.2 Ch.1 and Pt.2 Ch.2.

For other materials, particulars of mechanical properties and chemical compositions shall be submitted to the Society. Fatigue properties different from the ones given in Table B1 may be accepted, provided sufficient documentation is presented.
**Table B1 Material properties**

<table>
<thead>
<tr>
<th>Material</th>
<th>Material constant</th>
<th>Material constant</th>
<th>Minimum yield strength $\sigma_y$ (N/mm$^2$)</th>
<th>Minimum tensile strength $\sigma_b$ (N/mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn-Bronze, CU1 (High tensile brass)</td>
<td>55</td>
<td>0.15</td>
<td>175</td>
<td>440</td>
</tr>
<tr>
<td>Mn-Ni-Bronze, CU2 (High tensile brass)</td>
<td>55</td>
<td>0.15</td>
<td>175</td>
<td>520</td>
</tr>
<tr>
<td>Ni-Al-Bronze, CU3</td>
<td>80</td>
<td>0.18</td>
<td>245</td>
<td>590</td>
</tr>
<tr>
<td>Mn-Al-Bronze, CU4</td>
<td>75</td>
<td>0.18</td>
<td>275</td>
<td>630</td>
</tr>
<tr>
<td>Martensitic stainless steel (12Cr 1Ni)</td>
<td>60</td>
<td>0.20</td>
<td>440</td>
<td>590</td>
</tr>
<tr>
<td>Martensitic stainless steel (13Cr 4Ni/13Cr 6Ni)</td>
<td>65</td>
<td>0.20</td>
<td>550</td>
<td>750</td>
</tr>
<tr>
<td>Martensitic stainless steel (16Cr 5Ni)</td>
<td>70</td>
<td>0.20</td>
<td>540</td>
<td>760</td>
</tr>
<tr>
<td>Austenitic stainless steel (19Cr 10Ni)</td>
<td>55</td>
<td>0.23</td>
<td>180</td>
<td>440</td>
</tr>
</tbody>
</table>

Forged steel and other materials will be especially considered.

**Guidance note:**
Fatigue properties $U_1$ (fatigue strength amplitude) and $U_2$ (relative reduction of fatigue strength with increasing mean stress) may be documented in accordance with the following recommended testing procedure:
- Material specimen without notches is to be tested in “sea water”. Surface roughness is to be as for finished propellers. Material properties and chemical composition are to be representative for the minimum material requirements.
- Bending of flat bars is preferred, but testing with rotating bending is also acceptable.
- Thickness of specimen is to be at least 25 mm.
- Tests are to be performed both with and without weld repairs.
- Number of cycles to be at least $10^7$ at a bending frequency not higher than 5 Hz.
- Minimum number of tests: 2 x 20 (with and without welding repairs). Specimen is to be taken from at least two separate material charges.
- Testing is to be performed according to the “Staircase method”.

$U_1$ to be taken as average fatigue amplitude (N/mm$^2$) corresponding to $10^7$ cycles at zero mean stress (stress ratio, $R = -1$), divided by a factor of 2, provided the standard deviation does not exceed 15% of the average value.

In case $U_2$ is to be documented, additional testing should be carried out as above, with a stress ratio, $R = 0$.

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

**Table B2 Minimum safety factors for propeller blades**

<table>
<thead>
<tr>
<th>Application</th>
<th>Considered Section</th>
<th>Load condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Static</td>
<td>Low cycle fatigue</td>
</tr>
<tr>
<td>All propellers, exclusive tunnel thrusters</td>
<td>At root section</td>
<td>-</td>
</tr>
<tr>
<td>Reversible direction of rotation, exclusive tunnel thrusters</td>
<td>At 0.6R</td>
<td>-</td>
</tr>
<tr>
<td>Tunnel thrusters</td>
<td>At root section</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**B 300 Pitch control mechanism**

**301** The pitch control mechanism shall be able to withstand the static forces transmitted when two of the blades are prevented from pitching (servo force acting on two blades) with a safety factor of at least 1.0 against yielding.

**302** Maximum servo force (servo pressure corresponding to set point to safety valve) is to be applied in the calculations. Guide pin is assumed to be located in the most critical position.

**303** Unless the propeller is intended for auxiliary purposes only, fatigue shall be considered taking the following into account:
- start and stop of propeller
- manoeuvring and position keeping as applicable
- change of pitch setting in normal, ahead condition
- rotational load variation of propeller in normal, ahead operation (for propellers intended for main propulsion only).

**304** The design shall be such that reasonably low stress concentrations are ensured.
The degree of filtration of hydraulic oil must correspond with maximum allowable particle size in the system.

Guidance note:
Specification of a pressure filter for maintaining suitable fluid cleanliness may be 16/14/11 according to ISO 4406:1999 and β-7 (c) = 200 according to ISO 16889:1999.

---end---of---Guidance---note---

For general design requirements for piping and ancillary equipment such as pipes, pumps, filters, coolers etc., see Ch.6 of the Rules for Classification of Ships and Ch.7 as found applicable.

B 400 Fitting of propeller blades to the hub

401 The pre-tensioning of the blade bolts shall ensure friction forces sufficient to prevent sliding of the propeller flange with a safety factor of at least 1.0 when the propeller is exposed to forces as described in 300. If shear pins are fitted, the sum of friction and shear forces is to be considered. Pretension stress in the minimum section of the blade bolts is not to exceed 70% of the bolt-material yield strength or 56% of the tensile strength, whichever is the least.

402 The blade bolt pre-stress shall be high enough to ensure that a certain minimum surface pressure between mating surfaces is obtained in all permissible operating conditions. However, the blade bolt stress shall not exceed yield strength of the bolt material.

403 High cycle dynamic stress amplitudes in the minimum thread section of the blade bolts for propellers intended for main propulsion shall fulfill the following criterion:

\[
S = \frac{U}{\sigma_A}
\]

\(S\) = safety factor, not to be less than 1.5
\(\sigma_A\) = dynamic stress amplitude
\(U\) = allowable nominal stress amplitude in the threaded area, normally 35 N/mm² for machined threads and 60 N/mm² for rolled threads.

404 Other means of propeller blade fitting mechanisms will be especially considered.

C. Inspection and Testing

C 100 General

101 Blade bolt pre-tensioning shall be carried out in the presence of a surveyor.

102 All tests and inspections in 104 to 107 shall be carried out in the presence of a surveyor.

For controllable pitch propellers, all connections shall be properly sealed.

103 For controllable pitch propellers, all connections shall be properly sealed.

104 For controllable pitch propellers intended for propulsion, the following pitch settings shall, as a minimum, be properly marked on the hub and blade flange:

- pitch at 70% radius is zero
- maximum pitch ahead (pitch limited by mechanical pitch stopper)
- maximum pitch astern (pitch limited by mechanical pitch stopper).

The correctness of pitch marks and the mechanical feedback of pitch setting shall be verified.

105 The function of the pitch stoppers shall be demonstrated. If pitch stoppers are located outside of the hub, it shall be verified that maximum deflection in each direction is less than inside the propeller hub.

106 After assembly, the complete servo system shall be properly flushed.

107 The complete controllable pitch propeller system shall be function tested and pressure tested as follows:

- hydraulic pitch control to 1.5 times design pressure
- tightness of propeller subject to 1 bar.

C 200 Inspection and testing of parts

201 Regarding certification schemes, short terms, manufacturing survey arrangement, and important conditions, see Ch.2 Sec.2.

202 NV certificate is required for separate blades.

203 Further certificates are required in accordance with Table C1.

204 With respect to non-destructive testing for detection of surface defects, the following acceptance criteria apply:

- for propeller blades and hubs, the criteria given in Pt.2 Ch.2 Sec.7 and Sec.10 apply
- no indications of defects are accepted in highly stressed areas of components in the pitching mechanism.

C 300 Certification of ancillaries

301 Pumps, electric motors, coolers, piping, filters, valves, etc. that are delivered as integral parts of the hydraulic operation and cooling systems, shall be checked as found relevant by the propeller manufacturer’s quality system.

Guidance note:
The control and monitoring system is subject to certification according to Ch.9, but will normally be an integrated part of the remote control system and they may be certified as one unit.

Table C1 Category C certificates

<table>
<thead>
<tr>
<th>Component</th>
<th>Material certificate (chemical composition and mechanical properties)</th>
<th>Magnetic particle inspection or dye penetrant</th>
<th>Visual and dimensional inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellers cast in one piece</td>
<td>NV</td>
<td>NV</td>
<td>NV 1)</td>
</tr>
<tr>
<td>Separate blades</td>
<td>NV</td>
<td>NV</td>
<td>NV 1)</td>
</tr>
<tr>
<td>Separate hubs</td>
<td>NV or W 2)</td>
<td>W 3)</td>
<td>NV or W 2)</td>
</tr>
<tr>
<td>Blade bolts</td>
<td>NV or W 2)</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Crank disc, push pull rod, actuator cylinder and cross head. Other parts of pitching mechanism when found necessary</td>
<td>W</td>
<td>W 4)</td>
<td>W</td>
</tr>
</tbody>
</table>

1) The surveyor is to verify that the propeller blades are manufactured according to the specified tolerance class.
2) NV if propulsion.
3) Only required in A and C zones (see Pt.2 Ch.2 Sec.7 and Sec.10).
4) Only required in highly stressed areas, such as blade bolts, crank disk fillet, threads of push-pull rods, etc.
### D. Workshop Testing

**D 100 General**

101 The complete propeller shall be statically balanced in accordance with ISO 484 (or equivalent) in presence of a surveyor. Dynamic balancing may be required for propulsion propellers with tip speed exceeding 60 m/s. For built-up propellers, the required static balancing may be replaced by an individual control of blade weight and gravity centre position. The manufacturer is to demonstrate that the assembled propeller will be within the specified limits.

### E. Control and Monitoring

**E 100 General**

101 For controllable pitch propellers, governing and monitoring systems shall comply with the requirements of Ch.9.

102 Pitch adjustment shall not be used as load control system of prime mover, unless the propeller system is especially designed for this purpose.

103 A local control for pitch shall be installed.

104 Instrumentation and alarms shall be provided according to Table E1, if not otherwise approved.

### Table E1 Control and monitoring of propeller

<table>
<thead>
<tr>
<th>System/Item</th>
<th>Gr 1 Indication</th>
<th>Gr 2 Automatic start of standby pump with alarm 1)</th>
<th>Gr 3 Shutdown with alarm</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Pitch, speed and direction of rotation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propeller r.p.m.</td>
<td>IR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direction of rotation for reversible propellers</td>
<td>IR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propeller pitch for CP-propellers</td>
<td>IL, IR</td>
<td></td>
<td></td>
<td>For main propulsion, the following pitch settings are to be marked on the local pitch indicator: Mechanical pitch limits ahead and astern, pitch at full ahead running, maximum astern pitch and pitch at zero thrust.</td>
</tr>
<tr>
<td>2.0 Servo oil for CP-propeller</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td>IL, IR, LA</td>
<td>AS</td>
<td></td>
<td>The indicators are to be able to show sudden peaks in servo pressure.</td>
</tr>
<tr>
<td>Temperature</td>
<td>IL, HA</td>
<td></td>
<td></td>
<td>For shaft power &gt; 1 500 kW</td>
</tr>
<tr>
<td>Level</td>
<td>IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Differential pressure over filter</td>
<td>HA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Gr 1 Sensor(s) for indication, alarm, load reduction (common sensor permitted but with different set points and alarm shall be activated before any load reduction)
Gr 2 Sensor for automatic start of standby pump
Gr 3 Sensor for shutdown
IL = Local indication (presentation of values), i.e. in vicinity of the monitored component
IR = Remote indication (presentation of values), i.e. engine control room or other centralized control station
A = Alarm activated for logical value
LA = Alarm for low value
HA = Alarm for high value
AS = Automatic start of standby pump with corresponding alarm
LR = Load reduction, either manual or automatic, with corresponding alarm, either slow down (r.p.m. reduction) or alternative means of load reduction (e.g. g. pitch reduction), whichever is relevant. However, not to a load level devastating the vessels manoeuvring capability
SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above. Load reduction to a load level devastating the vessels manoeuvring capability may be accepted as an alternative to shut down if stated above.

1) To be provided when standby pump is required, see F301.

### F. Arrangement

**F 100 General**

101 Bolts and nuts shall be properly secured.

**F 200 Arrangement of propeller**

201 The arrangement and design of the propeller shall be such that satisfactory performance is maintained under all operating conditions.

202 Guidance for clearances between propeller and hull is given in the Rules for Classification of Ships Pt.3 Ch.3 Sec.2.

203 The arrangement of attached free-wheeling propellers will be especially considered.

**F 300 Hydraulic system for pitch control**

301 Unless the propeller is intended for auxiliary purposes only, at least two independent hydraulic pumps are to be fitted. If the power is less than 400 kW and each pump is driven directly by the unit it serves, an easily removable pump of each type may be approved as a standby pump.

302 For general requirements with respect to hydraulic systems, see the Rules for Classification of Ships Ch.6. Sec.5 H100.

### G. Vibrations

**G 100 General**

101 Not applicable.
H. Installation Inspection

H 100 General
101 Installation of external components is to be carried out according to the maker’s specifications.

H 200 Fitting of propeller
201 For fitting of propeller, see Ch.4 Sec.1.
202 For blade bolt pre-tensioning, see C102.

H 300 Pitch marking
301 For pitch marking, see C105.

H 400 Hydraulic piping
401 Pipes shall have a suitable location and a proper clamping. Inspection and testing shall be possible.

I. Shipboard Testing

I 100 Sea trial
101 For controllable pitch propellers, the pitch function and the servo pressure shall be demonstrated to the satisfaction of the surveyor. Also the function of the local pitch control shall be demonstrated, and the correctness of local pitch indicator shall be verified.
102 Unless the propeller is intended for auxiliary purposes only, the pitch behaviour with inactive servo (zero servo pressure) shall be demonstrated to the surveyor during sea trial.
103 The performance of the propeller shall be tested at both full ahead operation and full astern operation. For fixed pitch propellers reversing is to be tested at maximum permissible astern r.p.m. For controllable pitch propellers reversing shall be tested at maximum astern pitch of maximum permissible r.p.m.
104 For controllable pitch propellers, the function and setting of the safety valve shall be demonstrated to the satisfaction of the surveyor.
105 The filter for the servo oil shall be inspected after the sea trial.
SECTION 2
WATER JETS

A. General

A 100 Application

101 The rules in Sec.2 apply to axial water jets intended for main propulsion and steering for all types of vessel.

102 Ch.2 describes all general requirements for rotating machinery and forms the basis for all sections in Ch.3, Ch.4 and Ch.5.

103 The waterjet unit shall be delivered with a NV certificate.

104 Water jet units with main steering function are also regarded as steering gear for the vessel.

105 Water jet units for auxiliary steering purposes (i.e. not for propulsion) are only subject to classification after especial consideration.

A 200 Documentation

201 Plans, particulars and calculations shall be submitted according to Table A1.

202 Torsional shock vibration calculations may be required upon request.

Table A1 Documentation requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water jet arrangement</td>
<td>I</td>
</tr>
<tr>
<td>Cross section drawing of unit</td>
<td>I</td>
</tr>
<tr>
<td>Structural drawings (housing, mounting flanges etc.) and connections to the water inlet including NDT specification</td>
<td>I</td>
</tr>
<tr>
<td>Impeller including NDT specification</td>
<td>I</td>
</tr>
<tr>
<td>Shafting parts to be documented according to Ch.4 Sec.1</td>
<td>A</td>
</tr>
<tr>
<td>Stator housing (with guide vanes)</td>
<td>I</td>
</tr>
<tr>
<td>Steering arrangement</td>
<td>A</td>
</tr>
<tr>
<td>Reversing arrangement</td>
<td>A</td>
</tr>
<tr>
<td>Hydraulic actuators for steering and reversing, see B205</td>
<td>A</td>
</tr>
<tr>
<td>B206</td>
<td>A</td>
</tr>
<tr>
<td>Bearing arrangement with particulars</td>
<td>A</td>
</tr>
<tr>
<td>Seal box *</td>
<td>A</td>
</tr>
<tr>
<td>Stern flange with bolting</td>
<td>A</td>
</tr>
<tr>
<td>Water inlet ducting with respect to hydrodynamic design (see also Rules for Classification of HS, LC and NSC Pt.3 Ch.5 Sec.1 concerning strength)</td>
<td>I</td>
</tr>
<tr>
<td>All bolt connections carrying thrust or torque, specification of bolt material and tightening procedure (bolt pre-stress)</td>
<td>A</td>
</tr>
<tr>
<td>Control and monitoring system including set points and time delays, see Table E1**</td>
<td>A</td>
</tr>
<tr>
<td>Water jet pump characteristic, with operation limits including cavitation limits, see limit as for Table E1</td>
<td>I</td>
</tr>
<tr>
<td>Impeller thrust, vessel thrust and maximum reversing forces at crash stop</td>
<td>I</td>
</tr>
<tr>
<td>Normal operating parameters that define the permissible operating conditions, such as thrust, impeller r.p.m., vessel speed, impeller r.p.m. versus vessel speed, see limit as for Table E1</td>
<td>I</td>
</tr>
<tr>
<td>Calculated lifetime of roller bearings</td>
<td>A</td>
</tr>
<tr>
<td>Impeller blade strength calculations</td>
<td>UR</td>
</tr>
<tr>
<td>Strength calculation of the stern flange connection, B207</td>
<td>UR</td>
</tr>
</tbody>
</table>

B. Design

B 100 General

101 For general design principles for machinery, see Ch.2 Sec.3.

102 The water jet unit shall be capable of withstanding the loads imposed by all permissible operating modes, including the condition when the inlet of the suction is blocked.

103 The stresses in water jet components shall be considered based on loads due to the worst permissible operating condi-
tions, taking into account:

a) Hydrodynamic loads, including varying hydrodynamic loads due to water flow disturbances introduced e.g. by the ducting or hull.

b) Vessel accelerations versus water jet r.p.m.

c) Air suction as assumed in G103, transient cavitation, waves etc.

Guidance note:

At full design speed on a straight course and with the vessel designated trim, giving the designed water head above the water intake, harmful cavitation will normally not occur. Harmful cavitation in this context is that cavitation which will reduce shafting system and waterjet component lifetime by introducing vibration or impeller erosion.

However, the waterjet may be exposed to operating conditions outside the intended design. Such situations may occur for instance due to increased vessel weight, increased hull resistance, vessel operating at deeper waters etc. In situations where operation exceeds the design premises, harmful impeller cavitation may occur as a consequence of abnormal waterjet flow conditions. This phenomenon has showed to be of increasing importance with increasing waterjet size.

To combat this, the waterjet should be designed with reasonable margin for cavitation, and care should be taken to avoid vessel overweight due to e.g. reasons mentioned in the above. The bigger the waterjets are the more important this advice become.

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

104 The water jet units shall be provided with inspection facilities for inspection of the shaft and impeller.

B 200 Design of components

201 The dimensions of the shafts and the shafting components, including bearings, shall comply with the requirements in Ch.4 Sec.1.

202 The impeller housing and stator housing shall be designed against fatigue considering impeller pulses and other flow pulses.

203 Steering and reversing mechanisms shall be designed in consideration of the worst permissible operational conditions.

204 The materials used in the hydraulic actuators shall be suitable for the expected environmental conditions.

205 Hydraulic actuators for steering shall comply with the requirements given in the Rules for Classification of Ships, HS, LC and NSC Ch.14.

206 Hydraulic actuators for reversing shall comply with the requirements given in the Rules for Classification of Ships Ch.6 Sec.5 H. However, if the hydraulic system for the reversing actuators is the same as for the steering system, the design and test pressure for the reversing actuators shall be the same as for the steering actuators. Higher nominal stresses may be accepted for the reversing actuator.

207 The critical details of the duct and connections to the hull structure shall be designed against extreme loads occurring during crash stop and fatigue considerations related to reversing, steering and impeller pulses.

C. Inspection and Testing

C 100 General

101 The certification principles and the principles of manufacturing survey arrangements (MSA) are described in Ch.2 Sec.2.

Regarding material and testing specifications, see Ch.2 Sec.3.

102 Welding procedures shall be qualified according to a recognised standard or Pt.2.

C 200 Certification of parts

201 Water jet parts, semi-products or materials shall be tested and certified according to Table C1 and 300 if not otherwise agreed in a MSA, see Ch.2 Sec.2 C100.

Guidance note:

The control and monitoring system is subject to certification according to Ch.9, but will normally be an integrated part of the remote control system and may be certified as one unit.

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

202 Non-destructive testing (NDT) for parts submitted for approval shall follow the approved specification. NDT for parts submitted for information shall be as per manufacturer’s specification.

<table>
<thead>
<tr>
<th>Table C1 Requirements for certification of parts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product certificate, only when sub-contracted</strong></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Impeller</td>
</tr>
<tr>
<td>Stator housing</td>
</tr>
<tr>
<td>Impeller housing</td>
</tr>
<tr>
<td>Impeller housing</td>
</tr>
<tr>
<td>Impeller housing</td>
</tr>
<tr>
<td>Other steering and reversing components</td>
</tr>
<tr>
<td>Hydraulic actuators for reversing and steering</td>
</tr>
<tr>
<td>Other steering and reversing components</td>
</tr>
<tr>
<td>Bolts</td>
</tr>
<tr>
<td>Ducting when delivered integral with the water</td>
</tr>
</tbody>
</table>

1) See 306.

2) NV for steering hydraulic actuators, W for reversing hydraulic actuators.

3) Crack detection in final condition.

4) NDT of welds upon request.

5) Hydraulic actuator include cylinder, rod, cylinder end eye and rod end eye.
C 300 Testing and inspection of parts

301 The inspection and testing described in the following are complementary to 200.

302 The visual inspections by the Society shall include random dimensional check of vital areas such as flange transition radius, bolt holes etc., in addition to the main overall dimensions.

303 Particulars concerning ducting inspections are stated in H105.

304 The impeller shall be statically balanced.

Guidance note:
VDI standard no. 2060 Quality class 6.3 or ISO 1940/1 Balance Guide G6.3 may be used as reference.

C 400 Assembling

401 For fitting of the impeller to the shaft, see Ch.4 Sec.1 B300 to B700.

D. Workshop Testing

D 100 General

101 Not applicable.

E. Control, Alarm, Safety Functions and Indications

E 100 General

101 The systems shall comply with the requirements in Ch.9.

E 200 Monitoring and bridge control

201 The monitoring of water jets (for propulsion) shall be in accordance with Table E1 in regard to: indications, alarms and requests for slowdown.

F. Arrangement

F 100 General

101 The installation and arrangement of the water jet unit with auxiliaries shall comply with the manufacturers specification.

202 Monitoring and bridge control shall also be in compliance with Ch.9 and Ch.14 Sec.1 E500 to E700.

203 Frequent corrections in the steering control system, when the vessel is on straight course, shall be avoided if practicable.

Guidance note:
The actual corrections should be read preferably by monitoring the control signal. Alternatively, direct measurements on mechanical feedback device from the water jet can be used.

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

Table E1 – Control and monitoring of water jets

<table>
<thead>
<tr>
<th>System/Item</th>
<th>Gr 1 Indication</th>
<th>Gr 2 Automatic start of</th>
<th>Gr 3 Shut down with</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>load reduction</td>
<td>stand-by pump with alarm</td>
<td>alarm</td>
<td></td>
</tr>
<tr>
<td>1.0 Steering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of steering and reversing signal</td>
<td>A, LR</td>
<td></td>
<td>Request for slow down</td>
<td></td>
</tr>
<tr>
<td>2.0 Hydraulic oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td>IR, LA, LR</td>
<td></td>
<td>Request for slow down</td>
<td></td>
</tr>
<tr>
<td>Level in supply tank</td>
<td>IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0 Lubricating oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>IR, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure (if forced lubrication)</td>
<td>IR, LA, LR</td>
<td></td>
<td>Request for slow down</td>
<td></td>
</tr>
<tr>
<td>Level in oil tank (if provided)</td>
<td>IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0 Operational limitations(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The ratio impeller r.p.m versus vessel speed</td>
<td>IR, HA, LR</td>
<td></td>
<td>Request for slow down</td>
<td></td>
</tr>
<tr>
<td>Maximum permissible vessel acceleration exceeded</td>
<td></td>
<td></td>
<td>Indication on bridge</td>
<td></td>
</tr>
</tbody>
</table>

1) These requirements are only valid for waterjets with inlet diameter in excess of 1000 mm.

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

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

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

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---
G. Vibration

G 100 General

101 For requirements concerning whirling calculations and shaft alignment specification, see Ch.4 Sec.1.

102 For requirements concerning torsional vibration calculations for diesel driven water jets, see Ch.3 Sec.1 G. For turbine driven water jets, see Ch.3 Sec.2 G.

103 Calculations shall evaluate the torque variations deriving from water jet load shedding from full load down to 20% and back to full load again due to aeration of water jet. See Ch.3 Sec.1 for diesel engines and Ch.3 Sec.2 D303 for gas turbines.

Guidance note:
Great care should be taken in assuring that the ducting dimensions agree with the water jet designer’s drawings. The ducting designer should be consulted for use of possible dimensional checking equipment, such as templates especially made for that purpose.

106 All piping systems shall be properly flushed, in accordance with the manufacturers specification. This shall be documented by a work certificate.

107 Pressure testing of piping shall be done according to Ch.6 of the Rules for Classification of Ships.

H. Installation Survey

H 100 Surveys

101 The fastening of the water jet to the hull and the structural strengthening around the water jet unit with ducting shall be carried out in agreement with the approved drawings.

102 Impeller clearances shall be checked after installation and shaft alignment and shall be in accordance with the manufacturers specification.

103 Normal procedures for shafting apply, see Ch.4 Sec.1 H.

104 Thrust bearing axial clearances after installation shall be verified to be in accordance with the manufacturer specification, unless verified during assembly of the water jet.

105 The ducting shall be manufactured in accordance with drawings and specifications from the water jet designer. The surfaces shall be smooth and free from sharp edges or buckling that could give raise to turbulence in the water flow and thereby adversely affect water jet operating conditions.

I. Shipboard Testing

I 100 General

101 For general requirements related to the testing of control and monitoring, see Ch.9.

For testing of steering gear, Ch.14 Sec.1 I applies.

102 Final acceptance of the control system is dependent upon satisfactory results of the harbour testing and the final sea trial, as specified in items 103, 104 and 105.

103 Attention shall be paid to combinations of operational functions. Testing of all combinations of functions shall be carried out.

104 Indication and alarm (if applicable) of operation outside the specified operation limits shall be checked. This applies to acceleration as well as impeller r.p.m. versus vessel speed.

105 The water jet r.p.m. versus vessel speed shall be noted and plotted against the manufacturers operational curves. The surveyor shall verify the correct reading of values, and the results shall be submitted to the approval centre after completion of test.
SECTION 3

PODDED AND GEARED THRUSTERS

A. General

A 100 Application

101 The rules apply to thruster plants intended for propulsion, propulsion and steering, dynamic positioning and, if above 300 kW, for auxiliary duty. However, the requirements in C203, C204, E, and I apply to all thrusters.

The tunnel and other parts that are welded to the hull and form the barrier against the ingress of sea water, shall always be subject to approval, also for auxiliary units of 300 kW or less.

Thrusters of unconventional design are evaluated based on equivalence and may be accepted provided that safety and reliability can be documented to be equivalent or better than the requirements of this section.

102 For thrusters that are part of a Dynamic Positioning System, additional requirements are given in Pt.6 Ch.7 (rules for ships).

For thrusters that are installed in a vessel with additional notation RP or RPS additional requirements are given in Pt.6 Ch.2 (rules for ships).

For thrusters intended for navigation in ice, additional requirements are given in Pt.5 Ch.1 (rules for ships).

103 Ch.2 describes all general requirements for rotating machinery and forms the basis for all sections in Ch.3, Ch.4 and Ch.5.

104 The requirements in B400 are specific for steering gear for azimuth thrusters and replace the equivalent requirements in Ch.14 Sec.1, which apply to conventional rudders.

However, Ch.14 also gives requirements, depending on vessel type and size, which shall be complied with in addition to the requirements in B400.

105 Definitions

A thruster is a unit equipped with a propeller or impeller in order to produce thrust.

Geared thruster: Thruster with a lower gear or lower and upper gear.

Podded thruster: Thruster with the prime mover directly attached to the propeller shaft (often called "pod or podded propulsor").

A thruster is considered to be the complete assembly; from the propeller with nozzle (if applicable) to the input shaft at the upper gear or slip ring unit (if applicable).

Azimuth thruster: An azimuth thruster is capable of providing omni-directional thrust by being rotated around the vertical axis.

A propulsion thruster is a thruster that is assigned to propulsion of the vessel. A propulsion thruster may also provide steering function.

A dynamic positioning thruster is a thruster that is a part of a dynamic positioning system on board a vessel with the class notations: DYNPOS-AUTS, DYNPOS-AUT, DYNPOS-AUTR and DYNPOS-AUTRO.

An auxiliary thruster is a thruster for all other purposes than propulsion and dynamic positioning.

106 For HS, LC and NSC the following rules also apply:

— machinery in general: HSC Code 9.1.1 to 9.1.14, HSC Code 9.7 and 9.8 (passenger craft), and HSC code 9.9 (cargo craft)


A 200 Documentation

201 Basic operation and load information to be submitted

For all thrusters except tunnel thrusters:

— information about any operational (design) limitations which may apply to the thruster unit (such as limitations in rotation of azimuth thrusters at high vessel speed, maximum vessel speed for lowering and hoisting of retractable units)

— description of crash stop operation including the functionality of the load control system during the most extreme allowable manoeuvre

— maximum forces acting on the thruster unit under the most extreme allowable manoeuvre including crash stop procedure

Guidance note:

Crash stop operation is a set of defined actions required for stopping the vessel from maximum ahead speed, in the shortest stopping distance, without damaging the equipment.

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

— description of steering gear function and load limiting devices including maximum values, delays and ramp functions

— steering gear operation instructions, including emergency operation

— data sheet for electrical motor for steering gear, including motor rating according to IEC and torque versus speed characteristics of electrical motor

— steering gear frequency converter set value of parameters, list of alarms, shutdowns and ramp functions. (if applicable)

— steering gear brake capacity, and slip value (if applicable)

— specification of capacity of planetary gear certified according to C203.

For all thrusters:

— starting procedure for electrical motors for propeller drive including documentation of maximum start-up torque (K_AB factor see. Classification Note 41.2). This documentation requirement does not apply to thrusters which obtain the required scuffing safety factor (see Table B2) with a peak torque factor K_AP of 1.5 or higher and have equivalent mass moment of inertia of motor higher than equivalent mass moment of inertia of the propeller

— functional description of the load control system including description of the method used to control the load (CP-mechanism, frequency converter etc).

Description of which parameters are used to measure/monitor the load (torque meter, current, etc.). Maximum values, delays and ramp functions to be described, as well as monitoring system including the power supply for each system.

For requirements to documentation types, see Ch.9.

202 Plans and particulars as listed in Table A1 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 scantlings calculations together with specified ratings.

Material specifications shall include mechanical properties and particulars about heat treatment.

---e-n-d---of---C-h-a-p-t-e-r---s-t-r-e-a-m---
Table A1 - Plans and particulars to be submitted

<table>
<thead>
<tr>
<th>Required documentation</th>
<th>Status</th>
<th>Rule reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrusters arrangement</td>
<td>A B</td>
<td></td>
</tr>
<tr>
<td>Assembly (sectional drawings)</td>
<td>A B</td>
<td></td>
</tr>
<tr>
<td>Structural drawings (gear housing) and connections to the tunnel or nozzle</td>
<td>A B503</td>
<td></td>
</tr>
<tr>
<td>Bearing arrangement</td>
<td>I B700</td>
<td></td>
</tr>
<tr>
<td>Sealing boxes exposed to sea</td>
<td>A B202, B203, B504, B602</td>
<td></td>
</tr>
<tr>
<td>Mounting to the hull</td>
<td>A F104</td>
<td></td>
</tr>
<tr>
<td>Sealing arrangement for flexibly mounted thrusters</td>
<td>A F102</td>
<td></td>
</tr>
<tr>
<td>For podded thrusters: sectional drawing of electric motor including particulars of stator-to-housing and rotor-to-shaft connections and defined air gap with tolerances</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Bilge system for podded thrusters</td>
<td>I B505</td>
<td></td>
</tr>
<tr>
<td>Steering column</td>
<td>A B500</td>
<td></td>
</tr>
<tr>
<td>Gears inclusive azimuth gear</td>
<td>A B301, B400</td>
<td></td>
</tr>
<tr>
<td>Shafts, couplings</td>
<td>A B201</td>
<td></td>
</tr>
<tr>
<td>Propeller</td>
<td>A B600</td>
<td></td>
</tr>
<tr>
<td>Propeller nozzle</td>
<td>A Pt.3 Ch.3 Sec.2 (ship rules)</td>
<td></td>
</tr>
<tr>
<td>General arrangement drawings of steering gear compartment for propulsion thrusters</td>
<td>I F103, F201, F202</td>
<td></td>
</tr>
<tr>
<td>Arrangement of steering gear</td>
<td>I B400, F202</td>
<td></td>
</tr>
<tr>
<td>Sectional drawing of steering gear and thrust support bearing</td>
<td>A B400</td>
<td></td>
</tr>
<tr>
<td>Detail drawings of steering gear load transmitting parts (shafts, pinions or equal).</td>
<td>A B413</td>
<td></td>
</tr>
<tr>
<td>Load data for azimuth gear</td>
<td>I B413</td>
<td></td>
</tr>
<tr>
<td>Piping diagrams for cooling, lubrication and hydraulic systems (pitch and azimuth) including functional description, description of main operation modes, list of main components, set values for safety valve, alarm set points and delay times, indicator positions and pump capacity</td>
<td>A B409, B800</td>
<td></td>
</tr>
<tr>
<td>Torsional vibration calculation, see G</td>
<td>A G100</td>
<td></td>
</tr>
<tr>
<td>Calculated life times of rolling bearings</td>
<td>I B702</td>
<td></td>
</tr>
<tr>
<td>Calculation of capacity for thrust runner support bearings</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>Torsional impact vibrations calculation</td>
<td>UR</td>
<td></td>
</tr>
<tr>
<td>Pendulum vibrations calculation</td>
<td>UR</td>
<td></td>
</tr>
<tr>
<td>Component strength (i.e. for steering column) calculation</td>
<td>UR</td>
<td></td>
</tr>
<tr>
<td>Assembling and adjustment procedures regarding gear mesh contact for drive gears and steering gears if applicable</td>
<td>UR</td>
<td></td>
</tr>
<tr>
<td>Functional failure analysis of steering gear and control system</td>
<td>UR</td>
<td></td>
</tr>
<tr>
<td>Electrical equipment</td>
<td>A B106, B417, B106, B416, E100</td>
<td></td>
</tr>
<tr>
<td>Control systems</td>
<td>A B106, B416, E100</td>
<td></td>
</tr>
</tbody>
</table>

A = for approval
I = for information
UR = upon request

B. Design

B 100 General

101 The thruster shall be capable of withstanding the loads imposed by all allowable operating conditions including effects of thermal expansion elastic deformations.

102 In-dock inspection of thrust gear shall be made possible either through proper inspection openings, or by other means (e.g. fibre optical instruments) without extensive dismantling.

103 Podded thrust internals shall be shielded in order to provide safe entrance/accessibility to perform necessary maintenance and inspection without risk of damage neither to equipment nor personnel.

104 For general design requirements for piping and ancillary equipment such as pipes, pumps, filters and coolers, see Ch.6 of the Rules for Classification of Ships and Ch.7 as found applicable.

Hydraulic components shall be chosen in consideration of the expected level of contamination the system will be exposed to during its lifetime.

Flange connections for piping systems shall be located as far as practicable outside the podded thruster.

Flanges and valves inside podded thrusters shall be arranged to minimise the consequence of leakage, i.e. by drip trays and leakage drain to safe location.

105 The cooling system shall be in accordance with Ch.8 Sec.3 D200.

106 For design and arrangement requirements for electro systems and control systems reference is made to Ch.14 Sec.1 E (for propulsion thrusters only) and Ch.8 and Ch.9.

B 200 Shafting

201 The dimensions of the shafts and the shafting components shall be in accordance with Ch.4 Sec.1.

202 A shaft sealing box shall be installed to prevent water from gaining access to internal parts of the thruster or into the ship. The sealing arrangement shall protect steel shafts from seawater, unless corrosion-resistant steel especially approved by the Society is used.

For single thruster arrangements the shaft seal shall be duplicated and means for leakage detection shall be provided.

203 Shaft seals shall be protected by a rope guard and rope cutter.

B 300 Gear transmissions

301 Gear transmissions shall be in accordance with the requirements in Ch.4 Sec.2 as far as applicable. In general the lifetime criteria given in Table B1 may be used for dimensioning the gears in the propeller drive line.

Table B1 Thruster type and load cycles

<table>
<thead>
<tr>
<th>Type of thruster</th>
<th>Minimum number of input shaft revolutions at full power (N₀ load cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propulsion</td>
<td>1·10¹⁰</td>
</tr>
<tr>
<td>Dynamic positioning</td>
<td>5·10⁸</td>
</tr>
<tr>
<td>Auxiliary</td>
<td>5·10⁷</td>
</tr>
</tbody>
</table>

1) For thrusters subject to frequent overload (intermittent load), relevant load and corresponding accumulated number of load cycles are to be applied, see also Ch.4 Sec.3 A101.

The safety factors Sₚ against tooth fracture, Sₚ at pitch, Sₚ at peak, Sₚ against pitting, spalling and case crushing and Sₚ against scuffing shall be at least as specified in Table B1 in Ch.4 Sec.2. The safety factor for gears in thrusters for dynamic positioning is to be as for propulsion gears.
Azimuth steering gear

The requirements in 400 apply to steering gear for thrusters.

Steering gear for auxiliary and dynamic positioning thrusters need not comply with 402, 403, 404, 405, 407, requirement for safety valve set value in 408, 410 and 417.

Steering arrangement for the vessel shall comply with the following requirements:

- The vessel shall be provided with two steering gears, each with strength and capacity as specified below.
- A single failure shall neither lead to loss of steering of the vessel, nor consequential damage to the thrusters.

The steering gear for the thruster shall:

- be capable of operating the thruster for the purpose of steering the vessel at maximum ahead service speed, which shall be demonstrated at sea trial.
- have capacity to turn the thruster from side to side according to steering gear test. (See Ch.14 Sec.1 B401 b.)
- be capable of bringing the thrusters back to neutral position from any allowable angle at maximum service speed.

The thrusters shall be prevented from sudden turning in the case of power failure, failure in the steering control system or any other single failure, except failure in steering column and support bearings.

It shall be possible to lock the thruster in a neutral position to allow it to produce thrust in the case that its steering gear is inoperative.

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

Steering gear drivers shall be designed with capacity not less than 125% of maximum torque occurring during steering gear test as described in Ch.14 Sec.1 B401 b. (See also 417 for electro motor rating.)

The steering gear arrangement shall be provided with a load limiting device (limiting torque/ pressure as applicable), such as relief valve or frequency converter limiter.

The load limiting device shall have a set value not less than 125% of torque occurring during steering gear test as described in Ch.14 Sec.1 B401 b), however not exceeding design torque in the system.

Hydraulic system for steering gear shall normally not be used for other purposes than steering.

For propulsion thrusters the requirements in Ch.14 Sec.1 B1000 apply.

Guidance note:
Steering hydraulic may share the oil sump with systems for propeller pitch control and/or internal lubrication. This is provided that impurity from one system is not transmitted to the other systems.

Azimuth thrusters designed for reversing the thrust by turning the unit shall be able to do so at a turning rate minimum 2 r.p.m, at vessels manoeuvring speed up to 7 knots.

Azimuth steering gears are to have a margin against self-locking in order to avoid “stick slip” effects. The total drive train efficiency (excluding the driving motor) shall not be less than 0.65.

Azimuth steering gears for dynamically positioning thrusters shall be designed for continuous running (ref. Pt.6 Ch.7 Sec.1 E605, rules for ships).

Steering gear transmissions shall as far as applicable be in accordance with the requirements in Ch.4. The steering gear transmission shall be designed considering the relevant loads (see A201).

Guidance note:
Typically the following load cases shall be considered:
- Maximum torque corresponding to relief valve setting pressure (steering gear design pressure $p_{SV}$) for hydraulic operation, respectively max torque for electric motor operation. This can normally be considered as a static or low cycle fatigue case (1 000 cycles).
- Loads occurring at larger manoeuvre (course changing). This load normally corresponds to the maximum working pressure $p_{W}$ and will typically occur in the range from 5 000 to 100 000 times during the vessels lifetime.
- Loads occurring due to course keeping corrections (auto pilot load). This is normally a high cycle load case and more than 5·10⁷ course corrections (load cycles) may be expected during the vessels lifetime.

For reduction gears, the safety factors $SF$ against tooth fracture, $SH$ and $SH_{SS}$ against pitting, spalling and case crushing and $SS$ against scuffing shall be at least as specified in Table B2.

Inspection of azimuth gear and pinion shall be possible either through proper inspection openings or by other means (e.g. fibre optical instruments) without extensive dismantling.

The control system for electro motors driving steering pinion directly shall be designed to avoid abrupt acceleration and shock loads in mechanical parts.

The electro motor driving the steering gear shall at least have a rating according to IEC60034-1:
- For electro hydraulic arrangement: S6-25.
- For electro motor directly driving pinion:
  - S1 - for torque corresponding to maximum torque occurring during steering gear test, and for the entire speed range including zero rpm.

Steering column and pod stay and underwater housing

The maximum load, including the load normally corresponds to the maximum working pressure $p_{W}$ and will typically occur in the range from 5 000 to 100 000 times during the vessels lifetime.

This can normally be considered as a static or low cycle fatigue case, respectively max torque for electric motor operation.

Typically the following load cases shall be considered:
- Maximum torque corresponding to relief valve setting pressure (steering gear design pressure $p_{SV}$) for hydraulic operation, respectively max torque for electric motor operation. This can normally be considered as a static or low cycle fatigue case (1 000 cycles).
- Loads occurring at larger manoeuvre (course changing). This load normally corresponds to the maximum working pressure $p_{W}$ and will typically occur in the range from 5000 to 100 000 times during the vessels lifetime.
- Loads occurring due to course keeping corrections (auto pilot load). This is normally a high cycle load case and more than 5·10⁷ course corrections (load cycles) may be expected during the vessels lifetime.

For reduction gears, the safety factors $SF$ against tooth fracture, $SH$ and $SH_{SS}$ against pitting, spalling and case crushing and $SS$ against scuffing shall be at least as specified in Table B2.

The sealing around the steering column and pod stay, at the hull penetration, shall be arranged so that any leakage can be detected and drained before water can gain access to water sensitive parts, such as slewing bearing and gears. Existing de-
The chosen version shall be automatically activated within 30 s after shutdown. **805** For thrusters designed to operate at such low rotational shaft speeds that an attached pump (if needed) cannot supply sufficient oil pressure, the following will be accepted:

- either an extra electric oil pump that is activated at a given pressure, or
- 2 electric main pumps of the same capacity, one of which is arranged as a standby pump with immediate action. These 2 electric pumps are to be supplied from different sides of main distribution.

C. Inspection and Testing

C 100 General

101 Regarding certification schemes, short terms, MSA and important conditions, see Ch.2 Sec.2.

102 The parts in a thruster may be tested and documented as described in 200, or the entire testing and documentation is handled by the manufacturer’s quality system, or combinations of both. Such certification schemes are to be settled in a MSA.

C 200 Certification of parts

201 The complete thruster shall be delivered with a DNV product certificate.

202 NV certificates are required for the following components and the certification requirements are given in the respective references or in this section:

- pinions and wheels for propeller drive, see Ch.4 Sec.2
- pinions and wheels for azimuth steering, see Ch.4 Sec.2*
- shafts, see Ch.4 Sec.1
- clutches, see Ch.4 Sec.3
- couplings, see Ch.4 Sec.4
- propeller, see Sec.1
- propeller nozzle, see Pt.3 Ch.3 Sec.2 of the Rules for Classification of Ships
- hydraulic motor for steering, see Ch.6 Sec.6 of the Rules for Classification of Ships.

* For propulsion thrusters which have high speed hydraulic motor or electric motor (equivalent to rudder actuator) which is combined with “of the shelf”, mass produced gear boxes, the certification of the gearboxes may be based on function testing only, provided that:

- vessel has two or more independent propulsion thrusters
- vessel is fully maneuverable with one thruster locked in worst possible condition (other thruster(s) in operation)
- each thruster is provided with two or more steering gear actuators
- the gearboxes shall be conservatively chosen and able to handle all relevant loads for the steering gear
- easily replaceable.

203 The control and monitoring system shall be certified according to Ch.9 for:

- propulsion thrusters
- dynamic positioning system.

204 Electrical equipment to be certified as required in Ch.8.

C 300 Material and NDT testing

301 Material certificates containing chemical composition and mechanical properties are required for:

---end---of---Guidance---note---
— underwater housing (W)
— inboard housing (W)
— outer housing (non rotating forming barrier to sea) (NV)
— steering column or rotating support (NV)
— propeller nozzle (NV).

302 Ultrasonic test certificate (W) is required for:
— steering column
— welds in any part mentioned in 301, if specified in approval.

The ultrasonic test shall be carried out at an appropriate stage of the manufacturing process. The test certificate shall refer to a recognised standard and approved acceptance levels.

303 Surface crack detection (MPI or dye penetrant) is required in way of zones with stress raisers and in welded connections for:
— steering column (W)
— housings (W). (If specified in approval.)

The extent and acceptance criteria shall be specified in the documentation submitted for approval.

304 Visual inspection shall be carried out of all parts mentioned in 200 and 300 unless otherwise defined in a MSA.

305 Ancillaries, which are not part of the steering gear, such as pumps, electric motors, coolers, piping, filters and valves, that are delivered as integral parts of the lubrication, hydraulic operation and cooling systems of the thruster, shall be checked by the thruster manufacturer’s quality system as found relevant.

C 400 Assembling

401 Assembling of the drive gears regarding tooth contact shall be in accordance with the approved procedure and in the presence of the surveyor. The surveyor shall check access through inspection openings.

402 For assembling of other elements, see Ch.4 Sec.2 C500 and Sec.1 C100. However, for auxiliary thrusters Sec.1 C102 and 103 need not be adhered to.

403 For propeller fitting, see Ch.4 Sec.1 H208.

D. Workshop Testing

D 100 Testing of assembled unit

101 For gear mesh checking, see Ch.4 Sec.2 D100 unless other procedure is approved.

102 For clutch operation, see Ch.4 Sec.2 D200.

103 All hydraulic systems for steering, lubrication and pitch control shall be function and pressure tested.

For the steering system the test pressure shall be 1.5 times the design pressure $p_D$ as required in the rules for steering gear Ch.14 Sec.1.

For other hydraulic systems test pressure shall be as required in Ch.6 Sec.6 of the Rules for Classification of Ships. Regarding function testing of controllable pitch propellers, see Sec.1 C100.

104 The thruster unit shall be subjected to leakage testing (internal pressure, soap water test or similar).

E. Control, Alarm, Safety Functions and Indication

E 100 General

101 For instrumentation and automation, including computer based control and monitoring, the requirements in this item are additional to those given in Ch.9.

102 Additional requirements for vessels with class notations DYNPOS-AUTS, DYNPOS-AUT, DYNPOS-AUTR and DYNPOS-AUTRO see the Rules for Classification of Ships, Pt.6 Ch.7 Sec.3 F100.

103 Alarms and indications shall be initiated, as applicable, for the faults given in Table E1. For electro-driven propulsion thrusters see also Ch.8 Sec.12 A604.

For steering gear see also Ch.14 Sec.1 Table E1.

Additionally, an alarm shall be initiated on the bridge in case of power failure of alarm, control and safety system as required in Ch.9 Sec.2 C100.

104 Any alarm condition in the thruster plant shall initiate an alarm on the bridge with individual or group-wise indication. For HS, LC and NSC, all alarms shall have individual indication on the bridge.

The alarm indicators on the bridge shall be readily observed at the position from which the vessel is normally controlled and navigated.

105 Essential and important sensors and components which are not easily replaceable shall be duplicated

E 200 Bridge control

201 It shall be possible to stop the propeller from the bridge by means of a system independent of the remote control system.

If the independent stop facility is arranged as an emergency stop pushbutton, this must be arranged in accordance with Ch.8 Sec.2 H400.
### Table E1 Control and monitoring of thrusters

<table>
<thead>
<tr>
<th>System/Item</th>
<th>Gr 1</th>
<th>Gr 2</th>
<th>Gr 3</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Indication</strong></td>
<td><strong>Automatic start of standby pump</strong></td>
<td><strong>Shut down</strong></td>
<td><strong>Comment</strong></td>
</tr>
<tr>
<td></td>
<td>alarm</td>
<td>with alarm</td>
<td>with alarm</td>
<td></td>
</tr>
<tr>
<td>Gr 1</td>
<td>Gr 2</td>
<td>Gr 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td>IL&lt;sup&gt;2&lt;/sup&gt;, LA</td>
<td>AS</td>
<td></td>
<td>If forced lubricating oil system</td>
</tr>
<tr>
<td>Temperature</td>
<td>IL, HA&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level</td>
<td>IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 1.0 Lubricating oil

- **Pressure**: IL<sup>2</sup>, LA, AS
- **Temperature**: IL, HA<sup>2</sup>
- **Level**: IL, LA

#### 2.0 Steering system

- **Azimuth angle**: IL
- **Hydraulic oil pressure**: IL, LA
- **Hydraulic oil supply tank level**: IL, LA
- **Hydraulic pump motor overload, power and phase failure**: A
- **Azimuth brake engaged**: IR
- **Interlocking of actuators**: A

#### 3.0 Pitch, speed and direction of rotation

- **Propeller r.p.m.**: IR
- **Direction of rotation for reversible Propellers**: IR
- **Propeller pitch for CP-propellers**: IL, IR

#### 4.0 Servo oil for CP-propeller

- **Pressure**: IL, LA, AS
- **Level**: IL, LA<sup>3</sup>
- **Differential pressure over filter**: HA

#### 5.0 Electrical prime mover

- **Load (torque)**: IR, HA<sup>3</sup>

#### 6.0 Bilge system

- **Level**: HA

---

**Gr 1 Sensor(s) for indication, alarm, load reduction (common sensor permitted but with different set points and alarm shall be activated before any load reduction)**

**Gr 2 Sensor for automatic start of standby pump**

**Gr 3 Sensor for shutdown**

- **IL**: Local indication (presentation of values), i.e. in vicinity of the monitored component
- **IR**: Remote indication (presentation of values), i.e. engine control room or other centralized control station
- **A**: Alarm activated for logical value
- **LA**: Alarm for low value
- **HA**: Alarm for high value
- **AS**: Automatic start of standby pump with corresponding alarm
- **LR**: Load reduction, either manual or automatic, with corresponding alarm, either slow down (r.p.m. reduction) or alternative means of load reduction (e.g. pitch reduction), whichever is relevant. However, not to a load level devastating the vessels maneuvering capability
- **SH**: Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above. Load reduction to a load level devastating the vessels maneuvering capability may be accepted as an alternative to shut down if stated above.

1) To be provided when stand-by pump is required, see B802

2) Not required for auxiliary thrusters

3) Set point to be according to approved rating

4) For single pod installations

5) For electro-mechanical steering systems
F. Arrangement

F 100 General

101 The installation of a thruster, including alignment shall be such as to give satisfactory performance under all operating conditions.

102 The arrangement of flexibly mounted side thrusters shall provide effective protection against flooding. Such thrusters shall be placed in a separate watertight compartment, unless the flexible sealing arrangement contains two separate effective sealing elements. An arrangement for indication of leakage into the space between the inner and outer sealing shall be provided. The arrangement shall allow inspection of such sealings during bottom survey without extensive dismantling.

103 Azimuth thrusters shall be mounted in a watertight compartment unless the penetration through the hull is situated above the deepest loaded waterline.

104 Thrusters mounted to the hull by bolt connections which provide boundary to sea should be protected by means of seal or gasket. Resin epoxy is not considered as sealing.

F 200 Propulsion thrusters

201 When propulsion is provided by thrusters with underwater gear or when access to the internal parts of the thruster is not possible from inside the vessel, there shall be at least 2 separate, equal sized thrusters.

202 Propulsion thruster compartment shall be arranged according to Ch.14 Sec.1 F200.

Local control of steering gear, propeller pitch or speed shall normally be in the thruster compartment.

203 For vessels with total installed propulsion power above 7 000 kW the steering gear shall be connected to an alternative power supply, or connected to the emergency power circuit. (Reference to Ch.14 Sec.1 B500 and E301.)

Guidance note:
This requirement is considered equivalent to SOLAS requirement for alternative power supply for rudderstock above 230 mm.

---end---of---Guidance---note---

G. Vibration

G 100 Torsional vibration

101 For electric or hydraulic motor driven tunnel thrusters calculation of the first and second natural frequency shall be submitted.

Natural frequency are not permitted in the range of 0.8-1.2 blade order frequency at MCR unless the vibratory torque is documented to be within approved limits (accepted $K_A$ factor).

102 For all thrusters other than those covered by 101 calculations of natural frequencies including Holzer tables shall be submitted.

Forced torsional vibrations shall be made for normal operation as well as for extreme steering manoeuvres. The excitation used for extreme steering manoeuvres shall be substantiated. For propeller and diesel engine excitation, see Ch.3 Sec.1 G302 h.

Guidance note:
Propeller excitation at a steering angle other than a neutral position can be taken as 3 times nominal torque, unless otherwise substantiated.

---end---of---Guidance---note---

H. Installation Inspection

H 100 Installation onboard

101 For accessible thruster gears, the requirements in Ch.4 Sec.2 H apply.

102 For shaft alignment, propeller fitting and assembly of shafting components, the requirements in Ch.4 Sec.1 H apply.

103 Sub assemblies and parts mounted at yards or workshops other than the thruster manufacturer’s shall be carried out according to the thruster manufacturer’s instructions and verified to the surveyor’s satisfaction.

H 200 Install fastening to foundation

201 The mounting and installation of the thrusters shall be in accordance to approved drawings and according to manufacturer’s specification.

I. Shipboard testing

I 100 Sea trial

101 The requirements in Ch.14 Sec.1 I apply for propulsion thrusters.

102 Steering and reversing functions shall be tested under the most severe permissible conditions.

103 Steering torque (derived from electric current or hydraulic pressure) shall be measured and recorded continuously during the steering gear test. In addition steering torque in auto pilot mode shall be recorded.

104 The steering gear’s capability to bring the thruster back to neutral position from any allowable angle (B402) shall be verified by testing on sea trial.

105 For multiple thruster plants, the manoeuvrability properties shall be tested with one thruster inactive.

106 Crash stop test to be performed according to manufacturer’s procedure.

107 Verification of design criteria in B410 may be done at the dockside.

108 Temperatures of cooling air, cooling water and at least one of winding temperatures shall be recorded for podded thrusters.

109 Podded thrusters shall be inspected internally after sea trial and full load test for leakage or any other abnormalities, at the discretion of the attending surveyor.

110 Accessible thruster gears shall be inspected as in Ch.4 Sec.2 I.
SECTION 4
COMPRESSORS

A. General

A 100 Application

101 The rules apply to all types of compressors intended for the following systems:

- starting air
- instrument air
- breathing gas (monobaric and hyperbaric systems)
- refrigerating (for ships having additional class notations Reeler, RM or RM(Container)) see Pt.5 Ch.10 Sec.3 B600 of the Rules for Classification of Ships
- evaporated cargo compression (for ships having class notation Tanker for Liquefied Gas).
- inert gas production (when such a system is required by SOLAS).

102 Design approval is required for all compressors with a shaft power exceeding 200 kW.

103 The rules also apply to all types of compressors intended for systems with pressure above 40 bars, irrespective of the functions mentioned in 101 and limitations in 102.

A 200 Documentation

201 Plans and particulars according to Table A1 shall be submitted for design approval.

The plans shall include necessary details with regard to scantlings and arrangements as well as material specifications and heat treatments.

For compressors of special type and design, the extent of the documentation shall be considered in each case.

Documentation of burst test will be accepted as an alternative to calculations.

Table A1 Documentation

<table>
<thead>
<tr>
<th>Component</th>
<th>Drawing</th>
<th>Material specification</th>
<th>Calculations</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor assembly</td>
<td>I</td>
<td></td>
<td>Shaft strength: UR</td>
<td></td>
</tr>
<tr>
<td>Crankshaft</td>
<td>A</td>
<td>A</td>
<td>Torsional vibration calculations: A</td>
<td>NDT</td>
</tr>
<tr>
<td>Connecting rod</td>
<td>I</td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder and -head with bolts</td>
<td>I</td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotors (w/ blades)</td>
<td>A</td>
<td>A</td>
<td>UR</td>
<td>NDT</td>
</tr>
<tr>
<td>Casing</td>
<td>A</td>
<td>A</td>
<td>Containment calculations: UR</td>
<td></td>
</tr>
<tr>
<td>Internal piping</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particulars:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- medium</td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- design pressure for all stages</td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- working temperature</td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- working capacity</td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- maximum shaft power and –speed</td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alarm set points and delay times</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A = For approval
I = For information
UR = Upon request
NDT = Non-destructive testing plan

B. Design

B 100 General

101 All compressors shall be protected by suitable safety valves. The safety valves shall be set to open at the design pressure. For starting air compressors, see also Ch.7 Sec.6 B200.

Guidance note:
The design pressure must be sufficiently higher than the working pressure in order to have suitable margins for setting of the safety valve.

---end-of-Guidance-note---

102 The piping to and from the compressor shall be arranged in order to prevent condensation from entering the cylinders.

103 Starting air compressors shall satisfy the requirements of Ch.6 Sec.5 J of the Rules for Classification of Ships.

104 Refrigerating compressors shall satisfy the requirements of Pt.5 Ch.10 Sec.3 B600 of the Rules for Classification of Ships.

105 Compressors intended for breathing gas systems shall comply with the requirements in the Rules for Certification of Diving Systems Pt.6 Ch.1 Sec.4. Means shall be provided to avoid oil or poisonous gases from entering the breathing air system.

106 Gas compressors will be especially considered and shall normally comply with a recognised national or international standard.

107 Compressors intended for inert gas production shall satisfy the requirements of Pt.5 Ch.4 Sec.16 of the Rules for Classification of Ships.

B 200 Crankshafts

201 Crankshafts shall include a satisfactory safety factor against fatigue failures. Various calculation methods may be used. Item 102 gives one method for evaluation of safety against fatigue in the web fillets. The method applies for crankshafts made of forged and cast steel and nodular cast iron intended for one or multistage compressors with the cylinders arranged in line, V or W. More detailed methods may be espe
Guidance note:
The stresses in the crankpin fillet are to fulfil the following criterion:

\[ \sigma_b \leq \frac{\sigma_f}{S} \]

\[ \sigma_b = \text{the bending stress amplitude in the fillet (N/mm}^2) \]
\[ \sigma_f = \text{the fatigue strength (N/mm}^2) \]
\[ S = \text{the minimum safety factor} \]

For the fatigue criteria mentioned below, the following minimum safety factor applies:

\[ S = 1.4 \]

This safety factor includes the influence of torsional stresses in the fillets, which for the sake of simplicity are neglected in this method.

The fatigue strength is to be calculated as follows:

\[ \sigma_f = (0.33 \sigma_B + 40) k_m \]

\[ \sigma_B = \text{ultimate tensile strength of the material (N/mm}^2) \]
\[ k_m = \text{material factor, see Table B1} \]

The bending stress amplitude is to be evaluated as follows:

\[ \sigma_b = 0.7 \sigma_{nom} \alpha \]

\[ 0.7 = \text{factor to correlate the pulsating bending stress range into an equivalent single amplitude reversed stress} \]
\[ \alpha = \text{fatigue notch factor for bending} \]
\[ \sigma_{nom} = \frac{M_B}{W_B} (\text{N/mm}^2) \]
\[ M_B = \text{bending moment in the middle of the web nearest the centre of the bearing span} \]
\[ W_B = \text{sectional modulus of the web} \]

\[ M_B = \frac{k_d \pi D^2 P a b}{40L} \]

\[ D = \text{cylinder bore (mm)} \]
\[ P = \text{design pressure (bar)} \]
\[ L = \text{distance between the centres of two adjacent bearings (mm), see Fig. 1} \]
\[ a = \text{distance from the center of a bearing to the center of the web nearest the center of the bearing span (mm), see Fig. 1} \]
\[ b = L - a, (b \geq a) (\text{mm}) \]
\[ k_d = \text{design factor, see Table B2} \]

1) For multicylinder arrangements on one bearing span, use the maximum of the individual PD².

\[ W_B = B W^2 / 6 \]

\[ B = \text{width of the web (mm), see Fig. 1} \]
\[ W = \text{thickness of the web (mm)} \]

Guidance note:
The fatigue notch factor for bending may be calculated as follows:

\[ \alpha = 1 + \eta (\alpha_{th} - 1) \]

\[ \eta = \text{notch sensitivity factor} \]
\[ \alpha_{th} = \text{theoretical stress concentration factor (referred to web bending stress)} \]

\[ \eta = 0.62 + 0.2 \log R + \sigma_y 10^{-4} \log (400 / R) \]

(if calculated > 1, \( \eta = 1 \) applies)

\[ \sigma_y = \text{the yield strength of the material (N/mm}^2) \]
\[ R = \text{the actual fillet radius (mm)} \]

\[ f(A/d) = 1 - 0.8 A/d \]
\[ f(W/d) = 1 + 2.2 (W/d - 0.35) \]
\[ f(B/d) = 1 + 0.4 (B/d - 1.45) \]
\[ f(R/d) = \frac{0.22}{\sqrt{R/d}} \]
\[ A = \text{pin overlap (mm), see Fig. 1} \]
\[ d = \text{diameter of the crankpin (mm)}. \]

C. Inspection and Testing

C.100 General

101 The certification principles are described in Ch.2 Sec.2. The principles of manufacturing survey arrangement (MSA) are described in Ch.2 Sec.2 C100.

Guidance note:
It is advised to establish an MSA with sub-suppliers delivering materials or parts mentioned in 300. This applies also to those documented by work certificate (W) and test report (TR), and

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

202 For keyway connection, see Ch.4 Sec.1 B500.
should at least verify that the premises for using W and TR are fulfilled.

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

102 Material documentation is described in Ch.2 Sec.3.

### Table C1 Requirement for testing, inspection and certification

<table>
<thead>
<tr>
<th>Component</th>
<th>Product certificate</th>
<th>Material certificate</th>
<th>Ultrasonic testing</th>
<th>Crack detection</th>
<th>Hydraulic testing</th>
<th>Dimension inspection</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>NV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Function test (NV)</td>
</tr>
<tr>
<td>Crankshaft</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td></td>
<td></td>
<td>W</td>
<td>Capacity test (NV)</td>
</tr>
<tr>
<td>Connecting rod</td>
<td>TR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder with head</td>
<td>TR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotors</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td></td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Casing</td>
<td>W</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W</td>
<td></td>
</tr>
</tbody>
</table>

### D. Workshop testing

#### D 100 General

101 Function testing and setting of the safety valves shall be carried out on each compressor in the presence of a surveyor.

102 A capacity test shall be carried out with the compressor running at design condition (rated speed, pressure, temperature, type of gas, etc.). The capacity test may be waived for compressors produced in series and when previous tests have been carried out on similar compressors with satisfactory result. The capacity test shall be witnessed by a DNV surveyor.

### E. Control and Monitoring

#### E 100 General

101 Compressors shall be supplied with an alarm for high pressure.

102 Compressors with shaft power exceeding 1500 kW shall be supplied with an alarm for high bearing temperature.

### Table E1 Control and monitoring of compressors

<table>
<thead>
<tr>
<th>System/Item</th>
<th>Gr 1 Indication alarm load reduction</th>
<th>Gr 2 Automatic start of stand-by pump with alarm 1</th>
<th>Gr 3 Shut down with alarm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Bearings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>HA</td>
<td></td>
<td></td>
<td>For shaft power &gt; 1 500 kW</td>
</tr>
<tr>
<td>2.0 Lubricating oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure (if forced lubrication)</td>
<td>IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Gr 1 Sensor(s) for indication, alarm, load reduction (common sensor permitted but with different set points and alarm shall be activated before any load reduction)

Gr 2 Sensor for automatic start of standby pump

Gr 3 Sensor for shutdown

IL = Local indication (presentation of values), i.e. in vicinity of the monitored component

IR = Remote indication (presentation of values), i.e. engine control room or other centralized control station

A = Alarm activated for logical value

LA = Alarm for low value

HA = Alarm for high value

AS = Automatic start of standby pump with corresponding alarm

LR = Load reduction, either manual or automatic, with corresponding alarm, either slow down (r.p.m. reduction) or alternative means of load reduction (e.g. pitch reduction), whichever is relevant. However, not to a load level devastating the vessel's manoeuvring capability

SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above. Load reduction to a load level devastating the vessel's manoeuvring capability may be accepted as an alternative to shut down if stated above.

### F. Arrangement Onboard

#### F 100 General

101 Air compressors shall be arranged and located so as to minimise the intake of oil or water contaminated air.

### G. Vibration

#### G 100 Torsional vibration

101 For reciprocating compressors with shaft power exceeding 200 kW, torsional vibration calculations shall be determined according to the requirements in Ch.3 Sec.1 G300 as relevant.
H. Installation Inspection

H 100  General

101  After installation onboard, the compressor and the system to which it is connected, shall be function tested under working conditions. See also Ch.6 Sec.5.

102  The function test shall include testing of any control and safety functions.

H 200  Vibration

201  For resilient mounted reciprocating compressors, the vibration shall be observed by the surveyor and considered with regards to hooked-up connections. See also Ch.3 Sec.1.