RULES FOR CLASSIFICATION OF

Ships / High Speed, Light Craft and Naval Surface Craft

PART 4 CHAPTER 5

NEWBUILDINGS
MACHINERY AND SYSTEMS – MAIN CLASS

Rotating Machinery, Driven Units

JULY 2011

DET NORSKE VERITAS AS

FOREWORD

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

The Rules lay down technical and procedural requirements related to obtaining and retaining a Class Certificate. It is used as a contractual document and includes both requirements and acceptance criteria.

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CHANGES

General

The present edition of the rules includes additions and amendments approved by the Executive Committee as of June 2011, and supersedes the January 2011 edition of the same chapter.

The rule changes come into force as indicated below.

Text affected by the main rule changes is highlighted in red colour in the electronic pdf version. However, where the changes involve a whole chapter, section or sub-section, only the title may be in red colour.

An overview of DNV service documents, their update status and historical "amendments and corrections" may be found through http://www.dnv.com/resources/rules_standards/.

Main changes coming into force 1 July 2011

- **Sec.1 Propellers**

— F 200 Arrangement of propeller
— Guidance for clearances was removed from Rules in 2009.

CONTENTS

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 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 fitting mechanism (e.g. 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 See Pt.6 Ch.2 (ship rules) concerning additional requirements related to Redundant Propellers class notations.

107 See Pt.6 Ch.7 (ship rules) concerning additional requirements related to Dynamic Propulsion Systems class notations.

108 The propeller shall be delivered with a NV certificate.

A 200 Documentation

201 Plans and particulars 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 load transmitting propeller parts made of steel, type of heat treatment shall be specified.

Relevant design parameters shall be given. As a minimum, the following shall be specified:

— engine power at maximum continuous rating (MCR)
— corresponding propeller rotational speed
— maximum ship speed
— design pressure of hydraulic pitch system (if any)
— relevant additional class notations (see A104-107).

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
— predicted operational hydraulic pressure for controllable pitch propellers, when available.

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

Table A1 Documentation

Application	*Documentation requirement*	*Status* 5)	*Reference to design requirements*
Mono-block fixed pitch propellers	Propeller drawing	A	See Classification Note 41.5
Built-up fixed pitch propellers and controllable pitch propellers	Blade drawing	A	See Classification Note 41.5
	Drawing of blade fitting mechanism	A	See B400
	Hub drawing	A	See B300 and Classification Note 41.5
	Propeller assembly drawing	I	
Controllable pitch propellers	Drawing of components in pitch control mechanism	A	See B300 and Classification Note 41.5
	Hydraulic diagram 1)	A	See F300 and Ch.6 Sec.5 H100 of the Rules for Classification of Ships
	Operation manual 2)	I	See E102
All propellers	Drawing of propeller fitting to shaft	A	See Ch.4 Sec.1
	Installation manual 3)	UR	
	Documentation for the control and monitoring system, including set-points and delays. 3)	A	See E100
Free wheeling propeller	Arrangement drawing of free wheeling propeller	I	See F200

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) Installation manual shall follow each delivery.
4) For requirements to documentation types, see Ch.9.
5) Status: For approval (A), For information (I), Upon request (UR).

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

Material	*Material constant U_1 (N/mm^2)*	*Material constant U_2 (-)*	*Minimum yield strength σ_y (N/mm^2)*	*Minimum tensile strength σ_B (N/mm^2)*
Mn-Bronze, CU1 (High tensile brass)	55	0.15	175	440
Mn-Ni-Bronze, CU2 (High tensile brass)	55	0.15	175	520
Ni-Al-Bronze, CU3	80	0.18	245	590
Mn-Al-Bronze, CU4	75	0.18	275	630
Martensitic stainless steel (12Cr 1Ni)	60	0.20	440	590
Martensitic stainless steel (13Cr 4Ni/13Cr 6Ni)	65	0.20	550	750
Martensitic stainless steel (16Cr 5Ni)	70	0.20	540	760
Austenitic stainless steel (19Cr 10Ni)	55	0.23	180	440

Forged steel and other materials will be especially considered.

Guidance note:

Fatigue properties in sea water 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 should be tested in "sea water". The specimen should be welded, according to an approved repair method, including post heat treatment as applicable. Surface roughness should be as for finished propellers. Material properties and chemical composition should be representative for the minimum material requirements.
- Bending of flat bars is preferred, but testing with rotating bending is also acceptable.
- Thickness of specimen should be at least 25 mm.
- Number of cycles to be at least 10^7 at a bending frequency not higher than 5 Hz.
- Number of tests should be minimum 25. Specimen shall be taken from at least two separate material charges.
- Testing should be performed according to the “Staircase method”.

U_1 (N/mm^2) to be taken as:

$$U_1 = \frac{U_{E7}}{1.3} - 2.0 \cdot \sigma_{E7}$$

Where:

U_{E7} = average fatigue amplitude (N/mm^2), corresponding to 10^7 cycles at zero mean stress (stress ratio, R = -1)
σ_{E7} = corresponding standard deviation (N/mm^2).

The factor of 1.3 reflects a correction related to tested number of cycles vs. the expected number of cycles experienced during a ships life time.

The factor of 2.0 is chosen to account for the scatter of fatigue strength.

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

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102 The requirements given in 200, 300, and 400 apply to all propellers of conventional design and arrangement, unless otherwise explicitly stated. For propellers not recognised as conventional by the Society (e.g. surface piercing propellers, cycloidal propellers etc.), the approval will be based on special consideration.

103 The combination of materials shall be such as to minimise galvanic corrosion.

104 The surface of the hub, conical bores, fillets and blades shall be smoothly finished.

B 200 Criteria for propeller blade dimensions

201 The load conditions to be considered are:

a) High cycle dynamic stresses (> 10^8 cycles) due to rotational propeller load variation in normal, ahead operation.
b) Low cycle dynamic stresses (< 10^6 cycles) due to propeller load variations in a seaway, manoeuvres, starting and stopping, reversing, repetitive ice shock loads etc. are also to be considered when dynamic stresses are not dominated by high cycle load variations, e.g. for propellers for which turning direction may be reversed and propellers running in undisturbed axial inflow.

Guidance note:

Classification Note 41.5 offers detailed methods on how to assess the minimum safety factors in Table B2 for these load conditions.

Alternative methods may also be considered on the basis of equivalence.

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202 The propeller blades shall be designed with the minimum safety factors as given in Table B2, see also Guidance Note in 201. The safety factors reflect the expected inaccuracies in the methods used for predictions of loads and stress calculations, as well as the influence of allowable material defects.

It is provided that manufacturing tolerance class I or S is specified according to ISO484 for propulsion propellers. (Tolerance class II or better for other propellers.)

Otherwise higher safety factors may be required, based upon special consideration.

Somewhat lower safety factors than given in table B2 may be accepted after special consideration if dynamic stresses are documented by means of reliable measurements and/or calculations.

Table B2 Minimum safety factors for propeller blades

Application	*Considered Section*	*Load condition*		
		Static	*Low cycle fatigue*	*High cycle fatigue*
All propellers, exclusive tunnel thrusters	At root section	-	-	1.8
	At 0.6R	-	-	1.6
Reversible direction of rotation, exclusive tunnel thrusters	At 0.8R	-	1.5	-
Tunnel thrusters	At root section	2.2	-	-

B 300 Pitch control mechanism and propeller hub

301 Hydraulic servo cylinders shall be designed according to Standard for Certification - Hydraulic Cylinders No. 2.9, paragraph 3.2.6, taking allowable stress as half of the minimum specified yield strength for materials specified in Table B1.

Other parts of the pitch control mechanism and propeller hub shall be able to withstand the static loads specified in Table B3.

Table B3 Minimum safety factors for static strength of propeller hub, pitch mechanism and blade fitting mechanism

Load condition	*Required safety factor*
Load transmitted when two of the blades are prevented from pitching (servo force acting on two blades)	1.0
Load transmitted when a propeller blade is exposed to maximum hydrodynamic load	2.0
Load corresponding to maximum servo pressure, with the load evenly distributed on all blades	1.3

Guidance note:

The latter load case is normally dimensioning for push-pull rods.

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302 Safety factors for static load conditions reflect the risk and criticality related to the specified load conditions, as well as the expected prediction quality of the acting loads. The minimum safety factors shall be against yielding, and are to be applied on acting load. Local geometrical stress concentrations may be neglected. Stresses referred to are equivalent stresses. It is provided that stresses are predicted according to good engineering practice.

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

304 Unless the propeller is intended for auxiliary purposes only, fatigue strength of pitch mechanism and propeller hub shall be considered taking the load conditions specified in Table B4 into account:

Table B4 Minimum safety factors for fatigue strength of propeller hub and pitch mechanism

Load condition	*Required safety factor*
Start and stop of propeller	1.5
Change of pitch setting in normal operating condition	1.5
Rotational load variation of propeller in normal, ahead operation (for propellers intended for propulsion only).	1.5

305 Fatigue strength related to each load condition can be calculated separately.

306 Number of cycles shall correspond to a realistic number of load variations, corresponding to the described condition.

307 Safety factors for dynamic load conditions reflect the risk and criticality related to the specified load conditions, as well as the expected prediction quality of the acting loads and fatigue strength of material. Safety factor shall be applied on acting dynamic load vs. fatigue strength of material. Influence of stress concentrations shall be taken into account in fatigue calculation. Stresses referred to shall be principal stresses. It is presumed that stresses and fatigue strength are predicted according to good engineering practice.

Guidance note:

Classification Note 41.5 offers more information on how to assess the minimum safety factors in Table B4 for these load conditions.

Alternative methods may also be considered on the basis of equivalence.

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308 The design shall be such that reasonably low stress concentrations are ensured.

309 For shrink fitted propellers, hub thickness must be sufficient to avoid stresses from the dynamic loading of propeller blades influencing significantly on the shrink fit and vice versa.

Guidance note:

A hub thickness in way of propeller blade corresponding to 70% of the required thickness of the propeller blade root section is normally considered as a minimum.

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310 The degree of filtration of hydraulic oil shall correspond to maximum allowable particle size in the system or better.

Guidance note:

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

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311 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.

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 Table B3. If shear pins are fitted, the sum of friction and shear forces shall 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 propulsion shall fulfil the following criterion:

$$S = \frac{U}{\sigma_A}$$

S = safety factor, not to be less than 1.5
σ_A = dynamic stress amplitude
U = allowable nominal stress amplitude in the threaded area, normally 35 N/mm^2 for machined threads and 60 N/mm^2 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.

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 travel 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.

108 The propeller blades shall be manufactured according to the specified tolerance class (ISO 484).

As a minimum, verification of the following is required:

— surface finish
— pitch (local and mean pitch)
— thickness and length of blade sections

— form of blade sections
— location of blades, reference line and blade contour
— balancing (see also D100)
— for propellers running in nozzle or tunnel:
extreme radius of blades (for controllable pitch propellers with outer section at zero pitch).

See also B104.

For verification of blade edge thickness for ice classed propellers, see also Pt.5 Ch.1 Sec.4 J403 (ship rules).

Guidance note:

Verification of blade section form may include the use of edge templates as specified for manufacturing tolerance classes S and I in ISO 484.

Equivalent methods can be accepted, for instance the use of multi-axial milling machines, which have proven to be capable of producing the specified geometry with such an accuracy that only a slight grinding is necessary to obtain the specified surface finish.

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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.

302 The control and monitoring systems for:

— propellers

shall be certified according to Ch.9.

Table C1 Category C certificates

Component	*Material certificate (chemical composition and mechanical properties)*	*Magnetic particle inspection or dye penetrant*	*Visual and dimensional inspection*
Propellers cast in one piece	NV	NV	NV 1)
Separate blades	NV	NV	NV 1)
Separate hubs	NV or W 2)	W 3)	NV or W 2)
Blade bolts	NV or W 2)	W	W
Crank disc, push pull rod, actuator cylinder and cross head. Other parts of pitching mechanism when found necessary	W	W 4)	W
The propeller shall be delivered with a NV certificate, see A108. Reference is also given to A103.			

1) See also C108
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 specified ISO 484 tolerance class (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 shall 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

System/Item	*Gr 1 Indication alarm load reduction*	*Gr 2 Automatic start of standby pump with alarm*	*Gr 3 Shutdown with alarm*	*Comments*
1.0 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			For propulsion, the following pitch settings shall 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.
2.0 Servo oil for CP-propeller				
Pressure	IL, IR, LA	AS 1)		The indicators shall be able to show sudden peaks in servo pressure.
Level	IL, LA			
Differential pressure over filter	HA 2)			

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), in vicinity of the monitored component
IR = Remote indication (presentation of values), in engine control room or another centralized control station such as the local platform/manoeuvring console
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.
SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above.

For definitions of Load reduction (LR) and Shut down (SH), see Pt.4 Ch.1 of the Rules for Classification of Ships.

1) To be provided when standby pump is required, see F301.
2) Applies only to propulsion propellers.

F. Arrangement

F 100 General

101 Bolts and nuts shall be properly secured, see H203.

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 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 shall 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. Vibration

G 100 General

101 Not applicable.

H. Installation Inspection

H 100 General

101 Installation of external components shall be carried out according to the maker's specifications.

H 200 Fitting of propeller and propeller blades

201 For fitting of propeller, see Ch.4 Sec.1.

202 For blade bolt pre-tensioning, see C101.

203 The surveyor shall verify that bolts and nuts are properly secured. In case bolts are fixed by welding, it shall be verified that only regions with low stress levels are affected.

H 300 Pitch marking

301 For pitch marking, see C104.

H 400 Hydraulic piping

401 Pipes shall have a suitable location and be properly clamped. Inspection and testing shall be possible.

402 The hydraulic system shall be flushed after assembly to a degree of cleanliness as specified by the maker.

403 System hydraulic oil to be in accordance with maker's specification.

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 shall 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 special consideration.

A 200 Documentation

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

Table A1 Documentation requirements	
Water jet arrangement	I
Cross section drawing of unit	I
Structural drawings (housing, mounting flanges etc.) and connections to the water inlet including NDT specification	I
Impeller including NDT specification	I
Shafting parts to be documented according to Ch.4 Sec.1	A
Stator housing (with guide vanes)	I
Steering arrangement	A
Reversing arrangement	A
Hydraulic actuators for steering and reversing, see B205 and B206	A
Bearing arrangement with particulars	A
Seal box *	A
Stern flange with bolting	A
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)	I
All bolt connections carrying thrust or torque, specification of bolt material and tightening procedure (bolt pre-stress)	A
Control and monitoring system including set points and time delays, see Table E1**	A
Water jet pump characteristic, with operation limits including cavitation limits, see limit as for Table E1	I
Impeller thrust, vessel thrust and maximum reversing forces at crash stop	I
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	I
Calculated lifetime of roller bearings	A
Impeller blade strength calculations	UR (I)
Strength calculation of the stern flange connection, B207	UR (A)
Strength calculation of the steering and reversing mechanism	UR (A)
Housing strength calculation, see B200	UR (I)
*) Type approval is required for oil lubricated standard design. **) For requirements for documentation types, see Ch.9	
A = For approval I = For information UR(A) = Upon request; for approval UR(I) = Upon request; for information	

A 300 Definitions

301 The rules in Sec.2 use the nomenclature as defined below.

Ducting

Water streaming along the vessel bottom flows into a duct, leading the water to the water jet. The duct forms an integral part of the vessel hull. It is normally manufactured at the yard.

Impeller

The rotating hub with blades. The impeller is connected to the shaft. The impeller is usually cast in one piece. Alternatively, the blades are welded onto the hub.

Stator housing

By leading the water flow through a row of stationary vanes downstream of the impeller, the swirl added to the water by the impeller is reduced, and the longitudinal speed of the water flow is increased. The vanes are usually formed as an integral part of the water jet housing.

Impeller housing

The water jet casing surrounding the impeller.

Steering nozzle

The water flow is lead through a passageway that can be tilted horizontally in relation to the vessel's longitudinal axis, thereby changing the direction of the water jet flow. This creates a turning moment used for steering the vessel.

Reversing bucket

For reversing purposes, the water jet incorporates components that can force its entry into the water flow thereby turning the water jet discharge to be thrown somewhat forwards. This creates a reversing force that acts on the vessel. The flow is either thrown forwards in an angle directed below the vessel, or to both of the sides of the water jet. The components used for this purpose is denoted a bucket.

Hydraulic actuators

Used for either steering or reversing as the driving force that impose the reversing bucket or acts on the steering nozzle to create a change in the water flow direction.

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 conditions, 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.

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 impeller 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.

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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.

202 The control and monitoring systems for:

— water jets

shall be certified according to Ch.9.

Table C1 Requirements for certification of parts

	Product certificate, only when sub-contracted	*Documentation by certificates*						
		Material certificate	*Ultra-sonic or X-ray testing*	*Surface crack detection* 3)	*Pressure testing*	*Dimensional inspection*	*Visual inspection*	*Other*
Impeller	NV	W		W		W	NV	W 1)
Stator housing		W	W 4)	W		W	NV	
Impeller housing		W	W 4	W		W	NV	
Shafting	According to Ch.4 Sec.1 C							
Hydraulic actuators for reversing and steering 5)	NV	NV or W 2)	U-S or surface crack detection (W)4)		NV or W 2)			
Other steering and reversing components		W		(W) 4)			W	
Bolts		TR						
Ducting when delivered integral with the water jet		W	W			W	NV	

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.

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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.

Table E1 – Control and monitoring of water jets

System/Item	*Gr 1 Indication alarm load reduction*	*Gr 2 Automatic start of stand-by pump with alarm*	*Gr 3 Shut down with alarm*	*Comment*
1.0 Steering				
Loss of steering and reversing signal	A, LR			Request for slow down
2.0 Hydraulic oil				
Pressure	IR, LA, LR			Request for slow down
Level in supply tank	IL, LA			
3.0 Lubricating oil				
Temperature	IR, HA			
Pressure (if forced lubrication)	IR, LA, LR			Request for slow down
Level in oil tank (if provided)	IL, LA			

Table E1 – Control and monitoring of water jets (Continued)

System/Item	*Gr 1 Indication alarm load reduction*	*Gr 2 Automatic start of stand-by pump with alarm*	*Gr 3 Shut down with alarm*	*Comment*
4.0 Operational limitations1)				
The ratio impeller r.p.m versus vessel speed	IR, HA, LR			Request for slow down
Maximum permissible vessel acceleration exceeded				Indication on bridge

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), in vicinity of the monitored component
IR = Remote indication (presentation of values), in engine control room or another centralized control station such as the local platform/manoeuvring console
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
SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above.

For definitions of Load reduction (LR) and Shut down (SH), see Pt.4 Ch.1 of the Rules for Classification of Ships.

1) These requirements are only valid for waterjets with inlet diameter in excess of 1 000 mm.

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.

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F. Arrangement

F 100 General

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

102 Ship external parts of the water jet shall be protected by guard rails or other suitable means, see Rules for Classification of HS, LC and NSC Pt.3 Ch.5 Sec.1 C200.

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.

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.

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.

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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.

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 when inlet diameter exceeds 1 000 mm. 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 C202, C203, 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)
- propulsion and lift devices: HSC Code 9.6.1 to 9.6.5.

107 The complete thruster shall be delivered with NV certificate that is based on the design approval in B, the component certification in C, the workshop testing in D and relevant monitoring equipment in E.

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 (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 for stopping the vessel from maximum ahead speed in the shortest stopping distance without damaging the equipment.

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— 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 torque capacity of reduction gear certified according to C202.

For all thrusters:

— starting procedure for electrical motors for propeller drive including documentation of maximum start-up torque (K_{AP} 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 scantling calculations together with specified ratings.

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

Table A1 - Plans and particulars to be submitted for approval

Required documentation	*Status*	*Rule reference*
Thrusters arrangement	A	B
Assembly (sectional drawings)	A	B
Structural drawings (gear housing) and connections to the tunnel or nozzle including material specification and NDT specification	A	B503
Bearing arrangement	I	B700
Sealing boxes exposed to sea	A	B202, B203, B504, B602
Mounting to the hull	A	F104
Sealing arrangement for flexibly mounted thrusters	A	F102
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	A	
Bilge system for podded thrusters	I	B505
Steering column including material specification and NDT specification	A	B500
Gears inclusive azimuth gear	A	B301, B400
Shafts, couplings	A	B201
Propeller	A	B600
Propeller nozzle	A	Pt.3 Ch.3 Sec.2 (ship rules)
General arrangement drawings of steering gear compartment for propulsion thrusters	I	F103, F201, F202
Arrangement of steering gear	I	B400, F201

Table A1 - Plans and particulars to be submitted for approval (Continued)		
Required documentation	*Status*	*Rule reference*
Sectional drawing of steering gear and thruster support bearing	A	B400
Detail drawings of steering gear load transmitting parts (shafts, pinions or equal).	A	B413
Load data for azimuth gear	I	B413
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	A	B409, B800
Torsional vibration calculation, see G. Not required for auxiliary thrusters below 500 kW	A	G100
Calculated life times of rolling bearings	I	B702
Calculation of capacity for thruster support bearings	I	
Torsional impact vibration calculation	UR	
Pendulum vibration calculation	UR	
Component strength (i.e. for steering column) calculation	UR	
Assembling and adjustment procedures regarding gear mesh contact for drive gears and steering gears if applicable	UR	
Functional failure analysis of steering gear and control system	UR	
Electrical equipment	A	B106, B417, E100
Control systems	A	B106, B416, E100
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 thruster gears shall be made possible either through proper inspection openings, or by other means (e.g. fibre optical instruments) without extensive dismantling.

103 Podded thruster 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.

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	
Type of thruster	*Minimum number of input shaft revolutions at full power (N_L load cycles)*
Propulsion 1)	$1 \cdot 10^{10}$
Dynamic positioning	$5 \cdot 10^{8}$
Auxiliary	$5 \cdot 10^{7}$
1) For thusters subject to frequent overload (intermittent load), relevant load and corresponding accumulated number of load cycles shall be applied, see also Ch.2 Sec.3 A101.	

The safety factors S_F against tooth fracture, S_H against pitting, S_{HSS} against subsurface fatigue (surface hardened gears only) and S_S against scuffing shall be at least as specified in Table B1 in Ch.4 Sec.2. The safety factors for gears in thrusters for dynamic positioning shall be as for propulsion gears.

B 400 Azimuth steering gear

401 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.

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

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

403 The steering gear for the thruster shall:

a) 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
b) have capacity to turn the thruster from side to side according to steering gear test. See Ch.14 Sec.1 B401 b.
c) be capable of bringing the thrusters back to neutral position from any allowable angle at maximum service speed.

404 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.

405 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.

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

407 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.

408 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.

409 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.

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410 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.

411 Azimuth steering gears shall 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.

412 Azimuth steering gears for dynamically positioning thrusters shall be designed for continuous running. See Pt.6 Ch.26 Sec.1 E600 (rules for ships).

413 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_D) 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 $5 \cdot 10^7$ course corrections (load cycles) may be expected during the vessels lifetime.

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414 For reduction gears, the safety factors S_F against tooth fracture, S_H against pitting, S_{HSS} against subsurface fatigue (surface hardened gears only) and S_S against scuffing shall be at least as specified in Table B2.

Table B2 Safety factors			
	S_F	S_H and S_{H_ss}	S_S
Azimuth steering gear - for surface hardened - for not surface hardened	 1.5 1.5	 1.15 1.0	 1.4* 1.2*
* Not applicable to slow speed gears (pitch line speed < 2 m/s)			

415 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.

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

417 The electro motor driving the steering gear shall at least have a rating according to IEC60034-1:

a) For electro hydraulic arrangement: S6-25.
b) 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.

B 500 Steering column and pod stay and underwater housing

501 The maximum local stress in the steering column and pod stay shall not exceed 0.8 times the yield strength of the material under the most extreme allowable (possible) manoeuvre (see A201). FEM calculation may be required when analytical methods cannot give satisfactory accuracy (relevant stress concentration factors are sometimes difficult to find in literature). The maximum nominal stress shall not exceed 50% of the yield strength.

502 The steering column and pod stay shall be designed to withstand the fatigue loads arising from thrust variations and other hydrodynamic loads and accelerations. This applies to parent material as well as to any welds.

503 The thruster structure as underwater housings, steering column and pod stay etc. shall have a stiffness sufficient to avoid harmful deformations which may cause damage to internal shafting, sealing, bearings and gear mesh when subjected to the loads defined in A201.

504 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 designs with a proven service record may be accepted with other sealing arrangements.

505 The podded thruster shall be provided with a bilge system.

The bilge system shall be provided with full redundancy for single podded thruster arrangements.

B 600 Propeller

601 The propeller and propeller components shall meet the relevant dimensional requirements in Sec.1. See also Classification Note 41.5.

602 Special attention shall be paid to the sealing for propeller blades, in order to prevent ingress of water into the oil system. The sealing shall be designed to ensure that expected lifetime is safely beyond the specified service intervals.

603 Controllable pitch mechanism on thrusters that are used in a dynamic positioning system, shall be designed for continuos operation.

B 700 Bearings

701 Fluid film bearings shall be designed in accordance with the requirements in Ch.4 Sec.2 B701.

702 Ball and roller bearings shall have a minimum L_{10a} (ISO 281) as specified in Ch.4 Sec.2 B702.

B 800 Lubrication system

801 The lubrication system shall be designed to provide all bearings, gear meshes and other parts requiring oil with adequate amount of oil for both lubrication and cooling purposes. This shall be maintained under all environmental conditions as stated in Ch.1 of the Rules for Classification of Ships.

802 Thrusters where the total circulated lube oil quantity V_{oil} (in litres) is less than 0.1 × P (P = propeller power in kW) shall have separate lube oil system for each bearing assembly.

803 The lubrication system shall include:

— an arrangement to take representative oil samples with respect to detecting water and particle contamination
— a filter of suitable fineness for gearing, hydraulics and bearings (see 702)

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

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— if necessary, a cooler to keep the oil temperature within the specified maximum temperature, when operating under the worst relevant environmental conditions (see 801)
— for propulsion and dynamic positioning thrusters it shall be possible to change or clean filters without interrupting the oil supply
— if forced lubrication is required for operation of the thruster, single propulsion thruster installation shall have a standby pump with immediate action. On vessels with two or more independent and equal sized propulsion thrusters one pump per thruster will normally be accepted.

804 For propulsion thrusters where wind milling may be detrimental and considered as a normal working condition, there shall be either:

— a shaft brake designed to hold (statically) twice the highest expected wind milling torque, or
— one pump available in windmilling condition. This pump shall be additional to any standby pump required by other parts of rules.

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 shall 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 shall be settled in a MSA.

C 200 Certification of parts

201 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
— hydraulic motor for steering (to be handled as a pump), 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 "off 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 manoeuvrable 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 with regard to required safety factors and able to handle all relevant loads for the steering gear
  — easily replaceable.

202 The control and monitoring systems for:

— propulsion thrusters
— dynamic positioning thrusters

are to be certified according to Ch.9.

203 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:

— 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 C101 and 102 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 Ch.14 Sec.1.

For other hydraulic systems the 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 leak 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 H100.

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 push button, this must be arranged in accordance with Ch.8 Sec.2 H400.

Table E1 Control and monitoring of thrusters

System/Item	*Gr 1 Indication alarm load reduction*	*Gr 2 Automatic start of stand-by pump with alarm*	*Gr 3 Shut down with alarm*	*Comment*
1.0 Lubricating oil				
Pressure	IL 2), LA	AS 1)		If forced lubrication oil system
Temperature	IL, HA 2)			
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			Applicable to power units on propulsion thrusters
Azimuth brake engaged 5)	IR			If applicable. Manual release shall be possible. Additional indication on bridge.
Interlocking of actuators 4)	A			See Ch.14 Sec.1 E704. Identification of failed system

Table E1 Control and monitoring of thrusters (Continued)

System/Item	*Gr 1 Indication alarm load reduction*	*Gr 2 Automatic start of stand-by pump with alarm*	*Gr 3 Shut down with alarm*	*Comment*
3.0 Pitch, speed and direction of rotation				
Propeller r.p.m.	IR			Running indication for constant speed propellers
Direction of rotation for reversible Propellers	IR			
Propeller pitch for CP-propellers	IL, IR			For main propulsion, the following pitch settings shall 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. For auxiliary and dynpos thrusters; max., min. and zero pitch is sufficient
4.0 Servo oil for CP-propeller				
Pressure	IL, LA	AS 7)		
Level	IL, LA 2)			
Differential pressure over filter	HA			Applicable for propulsion thrusters
5.0 Electrical prime mover 6)				
Load (torque) 2)	IR, HA 3)			Additional indication on bridge.
6.0 Bilge system				
Level	HA			For dry pods

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), in vicinity of the monitored component
IR = Remote indication (presentation of values), in engine control room or another centralized control station such as the local platform/manoeuvring console
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. go. pitch reduction), whichever is relevant
SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above.

For definitions of Load reduction (LR) and Shut down (SH), see Pt.4 Ch.1 of the Rules for Classification of Ships.

1) To be provided when stand-by pump is required, see B800
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
6) Regarding electric motors, see Ch.8 Sec.12 A604
7) To be provided when stand-by pump is required, see Sec.1 F300.

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. See 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.

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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 frequencies 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 and forced vibrations shall be submitted.

Forced torsional vibration calculation 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 excitation, see Ch.3 Sec.1 G302 h.

Guidance note:

Propeller excitation for extreme steering manoeuvres can be taken as 3 times the excitation for normal operation (straight ahead), unless otherwise substantiated.

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Application factors below $K_A = 1.10$ for normal operation will not be accepted for propulsion plants. Verification of application factors through measurements may be required (normally if vessel speed > 10 knots and $K_A < 1.2$).

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 shall be performed according to manufacturer's procedure.

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

108 The control, alarm and safety functions shall be tested, see Table E1 for compliance with the approved alarm list, ref. Table A1.

109 Podded thrusters shall be inspected internally after sea trial and full load test for leakage or any other abnormalities.

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:

— those with pressure above 40 bars
— starting air
— instrument air including working compressors applied as back-up
— breathing gas (monobaric and hyperbaric systems)
— refrigerating (for ships having additional class notations **Reefer, 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 listed in 101 with a shaft power exceeding 200 kW.

103 Compressors shall be delivered with NV certificate unless waived, see Ch.2 Sec.2 A102.

A 200 Documentation

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

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

Documentation of strength through tests will be accepted as an alternative to calculations.

Table A1 Documentation

Component	*Drawing*	*Material specification*	*Calculations*	*Miscellaneous*
Compressor cross section	I			
Crankshaft	A	A	Shaft strength: UR	NDT: I
Connecting rod	I	I		
Cylinder and -head with bolts	I	I		
Rotors (w/ blades)	A 1)/I	A1)/I	Burst speed: UR1)	NDT: I
Rotor casing	A1)/I	A1)/I	Strength: UR Containment: UR1)	
Internal piping	I			
Particulars: — medium — design pressure for all stages — working temperature — working capacity — maximum shaft power and –speed	I			
Alarm set points and delay times	A			

A = For approval
I = For information
UR = Upon request
NDT = Non-destructive testing
1) = If > 1 000 kW and rotor with blades.

202 For documentation of torsional vibration in reciprocating compressors, see G101.

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 should be sufficiently higher than the working pressure in order to have suitable margins for

setting of the safety valve.

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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 I300 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 DNV-OS-E402 and, if applicable, to national regulations. 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.

108 Compressors for instrument- and control air receivers shall deliver sufficient air for the intended instruments. The compressors shall be provided with proper filtering equipment in order to deliver air free from oil, moisture and other contamination according to Pt.4 Ch.6 Sec.5 I204 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. The Guidance note 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 especially considered.

Guidance note:

The stresses in the crankpin fillet may fulfil the following criterion:

$$\sigma_b \leq \frac{\sigma_f}{S}$$

σ_b = the bending stress amplitude in the fillet (N/mm^2)
σ_f = the fatigue strength (N/mm^2)
S = 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 shall be calculated as follows:

$$\sigma_f = (0.33\ \sigma_B + 40)\ k_m$$

σ_B = ultimate tensile strength of the material (N/mm^2)
k_m = material factor, see Table B1

Table B1 Material factor	
Material	k_m
Forged steel	1.0
Cast steel	0.8
Nodular cast iron	0.9

The bending stress amplitude shall be evaluated as follows:

$$\sigma_b = 0.7\ \sigma_{nom}\ \alpha$$

0.7 = factor to correlate the pulsating bending stress range into an equivalent single amplitude reversed stress
α = fatigue notch factor for bending
σ_{nom} = M_B / W_B (N/mm^2)

M_B = bending moment in the middle of the web nearest the centre of the bearing span

$$M_B = \frac{k_d \pi D^2 p\, a\, b}{40L}$$

D [1)] = cylinder bore (mm)
p [1)] = design pressure (bar)
L = distance between the centres of two adjacent bearings (mm), see Fig. 1
a = distance from the centre of a bearing to the center of the web nearest the center of the bearing span (mm), see Fig. 1
b = L – a, (b ≥ a) (mm)
k_d = design factor, see Table B2

1) For multicylinder arrangements on one bearing span, use the maximum of the individual pD^2.

$$W_B = B\, W^2 / 6$$

W_B = sectional modulus of the web
B = width of the web (mm), see Fig. 1
W = thickness of the web (mm).

Table B2 Design factor	
Design	k_d
In line	1.00
V-90, W-90	1.15
V-60, W-60	1.50
V-45, W-45	1.75

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

$$\alpha = 1 + \eta\,(\alpha_{th} - 1)$$

η = notch sensitivity factor
α_{th} = 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)

σ_y = the yield strength of the material (N/mm^2)
R = the actual fillet radius (mm)

$$\alpha_{th} = 3.0\ f(A/d)\ f(W/d)\ f(B/d)\ f(R/d)$$

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 = pin overlap (mm), see Fig. 1
d = diameter of the crankpin (mm).

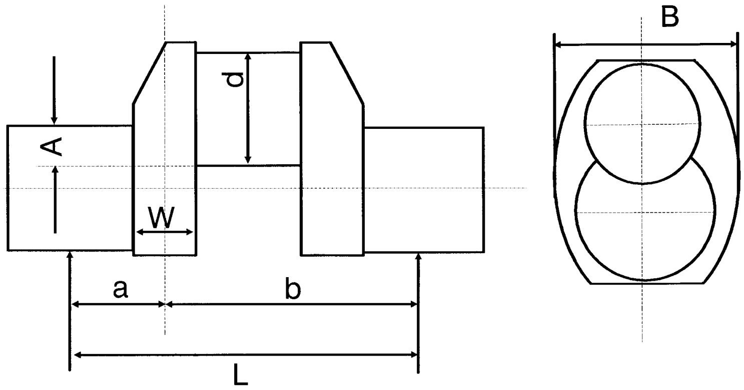

Fig. 1
Crank throw for compressor

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202 For keyway connection, see Ch.4 Sec.1 B500.

B 300 Rotors

301 Calculation of the rotor strength shall be carried out in accordance with recognised standards.

B 400 Rotor casing

401 The strength of the casing may be documented by calculations in accordance with recognised standards.

402 Proof tests may be used to establish the allowable design pressure of the rotor casing. The proof test shall be carried out in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I, or other recognised standards.

403 Containment shall be fulfilled for blade and or disc failure respectively, at 110% of rated speed.

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 should at least verify that the premises for using W and TR are fulfilled.

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

C 200 Certification, testing and inspection of parts

201 Certificates for product and material according to Table C1.

202 All parts subject to pressure of the compressors shall be hydraulically pressure tested (W) to 1.5 times the design pressure for the respective parts. The test pressure need not exceed the design pressure by more than 70 bars.

Table C1 Requirement for testing, inspection and certification

Component	*Material certificate*	*Ultrasonic testing*	*Crack detection*	*Hydraulic testing*	*Dimension inspection*	*Other*
Crankshaft	W	W	W		W	
Connecting rod	TR					
Cylinder with head	TR			W		
Rotors	W	W	W		W	
Rotor casing	W			W		

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 Control and monitoring shall be in accordance with Table E1.

Table E1 Control and monitoring of compressors

System/Item	*Gr 1 Indication alarm load reduction*	*Gr 2 Automatic start of stand-by pump with alarm*	*Gr 3 Shut down with alarm*	*Comment*
1.0 Bearings				
Temperature	HA			For shaft power > 1 500 kW
2.0 Lubricating oil				
Pressure	IL, LA			
3.0 Compressed medium				
Pressure	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), in vicinity of the monitored component
IR = Remote indication (presentation of values), in engine control room or another centralized control station such as the local platform/manoeuvring console
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
SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above.

For definitions of Load reduction (LR) and Shut down (SH), see Pt.4 Ch.1 of the Rules for Classification of Ships.

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 500 kW, torsional vibration analysis shall be determined according to the requirements given in Ch.3 Sec.1 G300 and G400, as applicable.

The permissible limits of any component in the system shall not be exceeded.

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.