DNV·GL

RULES FOR CLASSIFICATION

Ships

Edition January 2017

Part 4 Systems and components

Chapter 5 Rotating machinery - driven units

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DNV GL AS

FOREWORD

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

Any comments may be sent by e-mail to *rules@dnvgl.com*

CHANGES – CURRENT

This document supersedes the July 2016 edition.

Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Main changes January 2017, entering into force 1 July 2017

• General

— Various editorial updates.

• Sec.2 Water jets

— Sec.2 [3.1.2]: Ancillaries shall be handled by manufacturer as relevant.

• Sec.3 Podded and geared thrusters

— Sec.3 Table 1: Updated definition for steering system.
— Sec.3 [1.4.5]: Included control systems in certification.
— Sec.3 [2.4.3]: IACS UI SC242 is referred to in guidance note.
— Sec.3 [2.4.10]: Revised rules for crash stop with propulsion thrusters. Turning speed requirement of 2 rpm with quay test is removed. It is opened up for alternative procedures.
— Sec.3 [2.8.5]: Removed text regarding one pump per thruster.
— Sec.3 [1.4.9] and Sec.3 [3.1.2]: Ancillaries shall be handled by manufacturer as relevant.
— Sec.3 [2.4.13] and Sec.3 [9.1.1]: Steering gear tests for thrusters are now handled in Sec.3 and references to Ch.10 Sec.1 is removed.
— Sec.3 [9.1.7]: Dockside test removed (now a part of SG trial).

Editorial corrections

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

CONTENTS

Changes – current..3

Section 1 Propellers..8

1 General..8

1.1 Application..8

1.2 Documentation..8

1.3 Certification requirements..10

2 Design..12

2.1 General..12

2.2 Criteria for propeller blade dimensions..13

2.3 Pitch control mechanism and propeller hub..14

2.4 Fitting of propeller blades to the hub..16

3 Inspection and testing..17

3.1 General..17

3.2 Inspection and testing of parts..18

4 Workshop testing..18

4.1 General..18

5 Control and monitoring..18

5.1 General..18

6 Arrangement..20

6.1 General..20

6.2 Arrangement of propeller..20

6.3 Hydraulic system for pitch control..20

7 Vibration..20

7.1 General..20

8 Installation inspection..20

8.1 General..20

8.2 Fitting of propeller and propeller blades..20

8.3 Pitch marking..20

8.4 Hydraulic piping..21

9 Shipboard testing..21

9.1 Sea trial..21

Section 2 Water jets..22

1 General..22

1.1 Application..22

1.2 Documentation..22

1.3 Certification requirements.. 23
1.4 Definitions..25
2 Design..26
2.1 General..26
2.2 Design of components.. 26
3 Inspection and testing..27
3.1 General..27
3.2 Testing and inspection of parts.. 27
3.3 Assembling...27
4 Workshop testing...28
4.1 General..28
5 Control, alarm, safety functions and indications................ 28
5.1 General..28
5.2 Monitoring and bridge control...28
6 Arrangement.. 29
6.1 General..29
7 Vibration.. 30
7.1 General..30
8 Installation survey...30
8.1 Surveys.. 30
9 Shipboard testing... 30
9.1 General..30

Section 3 Podded and geared thrusters.................................... 32
1 General.. 32
1.1 Application... 32
1.2 Definitions..32
1.3 Documentation... 33
1.4 Certification requirements.. 35
2 Design..37
2.1 General..37
2.2 Shafting...37
2.3 Gear transmissions...38
2.4 Azimuth steering gear for thrusters.....................................38
2.5 Steering column and pod stay and underwater housing........40
2.6 Propeller.. 40
2.7 Bearings.. 41
2.8 Lubrication system...41
3 Inspection and testing..42

3.1 General......42
3.2 Assembling......42
4 Workshop testing......42
4.1 Testing of assembled unit......42
5 Control, alarm, safety functions and indication......42
5.1 General......42
5.2 Bridge control......43
6 Arrangement......45
6.1 General......45
6.2 Propulsion thrusters......46
7 Vibration......46
7.1 Torsional vibration......46
8 Installation inspection......47
8.1 Installation onboard......47
8.2 Install fastening to foundation......47
9 Shipboard testing......47
9.1 Sea trial......47

Section 4 Compressors......48
1 General......48
1.1 Application......48
1.2 Documentation......48
1.3 Certification required......50
2 Workshop testing......51
2.1 General......51
3 Design......52
3.1 General......52
3.2 Piping and arrangement......52
3.3 Crankshafts......53
3.4 Rotors for non-reciprocating compressors......55
3.5 Rotor casing for non-reciprocating compressors......55
4 Control and monitoring......56
4.1 General......56
5 Arrangement on-board......57
5.1 General......57
6 Vibration......57
6.1 Torsional vibration......57
7 Installation inspection......57
7.1 General......57

7.2 Vibration..58

Changes – historic...59

SECTION 1 PROPELLERS

1 General

1.1 Application

1.1.1 The rules in this section apply to propellers intended for propulsion, steering and manoeuvring, subject to certification.

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

1.1.2 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.

1.1.3 See Pt.6 Ch.6 Sec.1 concerning propellers for ships with ice strengthening.

1.1.4 See Pt.5 Ch.13 concerning additional requirements for propellers for naval vessels.

1.1.5 See Pt.6 Ch.2 Sec.7 concerning additional requirements related to redundant propulsion.

1.1.6 See Pt.6 Ch.3 Sec.1 and Pt.6 Ch.3 Sec.2 concerning additional requirements related to dynamic positioning systems.

1.2 Documentation

1.2.1 The builder shall submit the documentation required by Table 1. The documentation shall be reviewed by the Society as a part of the class contract.

Table 1 Documentation requirements

Object	*Documentation type*	*Additional description*	*Info*
Hub	C020 - Assembly or arrangement drawing		FI
	C030 – Detailed drawing	Detailed geometry, including: — verification details of fitting of hub to propeller shaft — hub cap with fins and cap bolts (as applicable) — blade fitting arrangement (as applicable). Material specification, properties and heat treatment.	AP
	C040 – Design analysis	Fitting calculation.	FI, R

Object	*Documentation type*	*Additional description*	*Info*
	Z162 - Installation manual	Shall follow each delivery.	FI, R
Blade	C030 - Detailed drawing	Detailed geometry, including blade flange, as applicable. Material specification, properties and heat treatment.	AP
	C040 – Design analysis	FE calculation (mandatory for special designs), including background documentation: — detailed hydrodynamic calculation — wake field data. (Blade geometry data file in ASCII format, preferably PFF may be requested).	FI, R
Controllable pitch servo mechanism	C030 - Detailed drawing	Detailed geometry of all load carrying parts, such as servo cylinder, piston and piston rod. Material specification, properties and heat treatment.	AP
Controllable pitch mechanism	S042 - Hydraulic control diagram	Including permissible operating servo pressures, specification of oil filter, and alarm list with setpoint and relay times.	AP
	Z161 - Operation manual	If pitch adjustment is used as load control of propeller driver.	FI, R
	C020 - Assembly or arrangement drawing		FI
	C030 - Detailed drawing	Detailed geometry of all load carrying parts, such as crank disc, push pull rod, cross head and sliding shoe. Material specification, properties and heat treatment.	AP
	C040 – Design analysis	Analysis including description of pitch propeller system is mandatory for new design.	FI, R
Control and monitoring system	I200 - Control and monitoring system documentation	According to Ch.9.	AP
AP = For approval; FI = For information; R = On request			

1.2.2 For general requirements for documentation, including definition of the info codes, see Pt.1 Ch.3 Sec.2.

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

1.2.4 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 [1.1.3] - [1.1.6]).

The manufacturing tolerance class (ISO 484) shall be specified on the propeller drawings.

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

— weight and buoyancy
— polar and diametrical mass moment of inertia in air
— polar and diametrical mass moment of inertia of entrained water (for zero and full pitch for CP propellers)
— predicted operational hydraulic pressure for controllable pitch propellers, when available.

1.2.6 For instrumentation and automation, including computer based control and monitoring, see Ch.9.

1.3 Certification requirements

1.3.1 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.

1.3.2 Certificates shall be issued as per Table 2 and scope of testing and inspection of components as per Table 3.

Table 2 Certification required for propeller

Object	*Certificate type*	*Issued by*	*Certification standard**	*Additional description*
Propellers cast in one piece	PC	Society		
	MC			
	NDT			(See Pt.2 Ch.2 Sec.7 and Pt.2 Ch.2 Sec.10).
	TR			Dimension control (see [3.1.9]).
Separate blades	PC	Society		
	MC			
	NDT			(See Pt.2 Ch.2 Sec.7 and Pt.2 Ch.2 Sec.10).
	TR			Dimension control (see [3.1.9]).
Separate hubs	MC	Society		PC and MC may be issued by manufacturer for axillary propeller.
	NDT	Society		(See Pt.2 Ch.2 Sec.7 and Pt.2 Ch.2 Sec.10).
	NDT	Manufacturer		(See Pt.2 Ch.2 Sec.7 and Pt.2 Ch.2 Sec.10).
Hub cap with fins	TR	Manufacturer		Material and dimension control.
Blade bolts	PC	Society		PC may be issued by manufacturer for auxilliary propeller.
	MC	Manufacturer		
	NDT	Manufacturer		

Object	*Certificate type*	*Issued by*	*Certification standard**	*Additional description*
Controllable pitch mechanism	MC	Manufacturer		Crank disc, push pull rod, servo cylinder and cross head. Other parts of pitching mechanism upon request.
	NDT			NDT shall cover highly stressed areas, such as blade bolts, crank disk fillet, threads of push-pull rods, etc.
Pitch control and monitoring system	PC	Society		See Ch.9.

PC = product cert
MC = material cert
TR = test report
TA = Type approval
NDT = NDT report

*Unless otherwise specified the certification standard is the Society rules.

1.3.3 For general certification requirements, see Pt.1 Ch.3 Sec.4.

1.3.4 For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

1.3.5 The surveyor shall do visual inspection of parts. Visual inspection shall include random dimensional check with emphasis on critical dimensions, tolerances and stress raisers.

Manufacturer’s measurement report shall be presented for main items and shall be available upon request for minor components.

Manufacturer’s survey report shall be available upon request.

Table 3 Testing and inspection of components

Component	*Material test (chemical composition and mechanical properties)*	*Magnetic particle inspection or dye penetrant*	*Visual and dimensional inspection*
Propellers cast in one piece	Society	Society	Society[1)]
Separate blades	Society	Society	Society[1)]
Separate hubs	Society or manufacturer[2)]	Manufacturer[3)]	Society or manufacturer[2)]
Hub cap with fins			Manufacturer
Blade bolts	Society or manufacturer[2)]	Manufacturer	Manufacturer
Crank disc, push pull rod, servo cylinder and cross head. Other parts of pitching mechanism when found necessary	Manufacturer	Manufacturer[4)]	Manufacturer
The propeller shall be delivered with a Society’s certificate, see [1.1.1]. Reference is also given to [1.1.2].			

Component	*Material test (chemical composition and mechanical properties)*	*Magnetic particle inspection or dye penetrant*	*Visual and dimensional inspection*
1) See also [3.1.9]			
2) The Society if propulsion.			
3) Only required in A and C zones (see Pt.2 Ch.2 Sec.8 and Pt.2 Ch.2 Sec.11 [3]).			
4) Only required in highly stressed areas, such as blade bolts, crank disk fillet, threads of push-pull rods, etc.			

2 Design

2.1 General

2.1.1 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 4 may be accepted, provided sufficient documentation is presented.

Table 4 Material properties

Material	*Material constant* U_1 *[N/mm²]*	*Material constant* U_2 *[-]*	*Minimum yield strength* σ_y *[N/mm²]*	*Minimum tensile strength* σ_B *[N/mm²]*
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 shall 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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2.1.2 The requirements given in [2.2], [2.3], and [2.4] 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, tip fin propellers, cycloidal propellers etc.), the approval shall be based on special consideration.

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

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

2.2 Criteria for propeller blade dimensions

2.2.1 The following load conditions shall be considered:

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. shall also 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:

Class guideline DNVGL-CG-0039 offers detailed methods on how to assess the minimum safety factors in Table 5 for these load conditions.

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

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2.2.2 The propeller blades shall be designed with the minimum safety factors as given in Table 5, see also guidance note in [2.2.1]. 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 on the condition 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.

Table 5 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 0.6*R*	-	-	1.6
Reversible direction of rotation, exclusive tunnel thrusters	At 0.8*R*	-	1.5	-
Tunnel thrusters	At root section	2.2	-	-

2.2.3 Somewhat lower safety factors than given in Table 5 may be accepted after special consideration if dynamic stresses are documented by means of reliable measurements and/or advanced calculation method.

2.2.4 Blade root fillet shall be designed in order to maintain a safety factor in the fillet as required for the root section. Fillets with constant radius of 75% of root thickness, or multi-radius fillets of a "constant stress" design are considered to comply with this requirement.

2.2.5 For calculation of the blade stress of special propeller designs such as tip fin propellers, special profiles, etc., FE calculation shall be submitted with documented details of the hydrodynamic loads.

For calculation of the blade stress of these special propeller designs, in addition to the documents to be submitted according to [1.2], a blade geometry data file (ASCII format, preferably PFF) shall be submitted to the Society. Supplementary information for propellers of special designs can be requested by the Society.

2.2.6 If the propeller is subjected to an essential wear e.g. by abrasion in tidal flats or dredgers, a wear addition shall be provided to the thickness determined according to class requirements to achieve an equivalent lifetime.

2.2.7 If the propeller of azimuthing thruster is subjected to highly oblique inflow in transient conditions such as crash stop manoeuvring, the propeller blade shall be strengthened accordingly.

2.2.8 Regarding devices for improving propulsion efficiency, the rules for classification of ships Pt.3 Hull, has to be observed.

2.3 Pitch control mechanism and propeller hub

2.3.1 Mechanical components of a pitch control system and propeller hub shall be able to withstand the static loads with the safety factor against yield as specified in Table 6.

Table 6 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 for strengthening the servo cylinder	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 dimensioning for push-pull rods.

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

2.3.2 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 shall 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.

2.3.3 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.

2.3.4 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 7 into account:

Table 7 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

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

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

2.3.7 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:

Class guideline DNVGL-CG-0039 offers more information on how to assess the minimum safety factors in Table 5 for these load conditions.

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

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

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

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

Guidance note:

In order to provide the above statement a hub thickness in way of propeller blade corresponding to 70% of the required thickness of the propeller blade root section is considered enough as a minimum.

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

2.3.10 The degree of filtration of hydraulic oil shall correspond to maximum allowable particle size in the system or better. In addition, the selection and arrangement of filters shall provide for an uninterrupted supply with filtered oil, also during filter cleaning or exchange.

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 16889:2008.

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

2.3.11 For general design requirements for piping and ancillary equipment such as pipes, pumps, filters and coolers see Ch.6 and Ch.7, as found applicable.

2.3.12 If necessary for corrosion protection, a hub cap with sufficient strength to protect the shaft effectively from water ingress shall be fitted. If hub cap with fins are mounted any damage of the fins shall not harm the integrity of the cap.

Guidance note:

The hub cap should be thicker than the fin.

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

2.4 Fitting of propeller blades to the hub

2.4.1 The pre-tensioning of the blade bolts shall ensure friction forces sufficient to prevent sliding of the propeller flange with a safety factor greater than 1.0 when the propeller is exposed to forces as described in Table 6. If shear pins are fitted, the sum of friction and shear forces shall be considered. The blade retaining bolts shall be tightened in a controlled way to ensure an appropriate pretension. Pretension stress in the minimum section of the blade bolts shall be in the range of 50 to 70% of the bolt-material yield strength or maximum 56% of the tensile strength, whichever is the least. During operation any blade opening or loss of bolt pretension shall be prevented. The blade bolt stress shall not exceed yield strength of the bolt material.

2.4.2 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.

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

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

where:

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

2.4.4 Other means of propeller blade fitting mechanisms shall be especially considered.

3 Inspection and testing

3.1 General

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

3.1.2 All tests and inspections in [3.1.4] to [3.1.7] shall be carried out in the presence of a surveyor.

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

3.1.4 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 by the Society.

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

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

3.1.7 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.

3.1.8 For hub caps serving as corrosion protection a tightness test shall be carried out.

3.1.9 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 [4.1])
— for propellers running in nozzle or tunnel:
    — extreme radius of blades (for controllable pitch propellers with outer section at zero pitch).

See also [2.1.4].

For verification of blade edge thickness for ice classed propellers, see also Pt.6 Ch.6.

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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3.2 Inspection and testing of parts

3.2.1 Certificates shall be provided as required in Table 2.

3.2.2 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.8 and Pt.2 Ch.2 Sec.11 apply
— no defects are accepted in highly stressed areas of components in the pitching mechanism.

4 Workshop testing

4.1 General

4.1.1 The complete propeller shall be statically balanced in accordance with specified ISO 484 tolerance class (or equivalent) in presence of a surveyor. Dynamic balancing shall be carried out for propulsion propellers with tip speed exceeding 60 m/s. The manufacturer shall demonstrate that the assembled propeller shall be within the specified limits.

Guidance note:

For built-up propellers, the required static balancing may be replaced by an individual control of blade weight and gravity centre position.

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

5 Control and monitoring

5.1 General

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

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

5.1.3 A local control stand for pitch control shall be arranged.

5.1.4 Instrumentation and alarms shall be provided according to Table 8, if not otherwise approved.

Table 8 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 rotational speed	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/min 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 Ch.1.

1) To be provided when standby pump is required, see [6.3.1].

2) Applies only to propulsion propellers.

6 Arrangement

6.1 General

6.1.1 Bolts and nuts shall be properly secured, see [8.2.3].

6.2 Arrangement of propeller

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

6.2.2 The arrangement of attached free-wheeling propellers shall be especially considered.

6.3 Hydraulic system for pitch control

6.3.1 Unless the propeller is intended for auxiliary purposes only, for single propulsion plants where the pitch-control mechanism is operated hydraulically, at least two mutually independent, power-driven pump sets shall be installed.

6.3.2 For general requirements with respect to hydraulic systems, see Ch.6 Sec.5 [8.1].

7 Vibration

7.1 General

7.1.1 Not applicable.

8 Installation inspection

8.1 General

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

8.2 Fitting of propeller and propeller blades

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

8.2.2 For blade bolt pre-tensioning, see [3.1.1].

8.2.3 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.

8.3 Pitch marking

8.3.1 For pitch marking, see [3.1.4].

8.4 Hydraulic piping

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

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

8.4.3 System hydraulic oil shall be in accordance with maker's specification.

9 Shipboard testing

9.1 Sea trial

9.1.1 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.

9.1.2 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.

9.1.3 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/min. For controllable pitch propellers reversing shall be tested at maximum astern pitch of maximum permissible r/min.

9.1.4 For controllable pitch propellers, the function and setting of the safety valve shall be demonstrated to the satisfaction of the surveyor.

9.1.5 The filter for the servo oil shall be inspected after the sea trial.

SECTION 2 WATER JETS

1 General

1.1 Application

1.1.1 The rules in this section apply to axial water jets intended for main propulsion and steering for all types of vessels.

1.1.2 Ch.2 describes all general requirements for rotating machinery and forms the basis for all sections in Ch.3, Ch.4, Ch.5 and Ch.10.

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

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

1.2 Documentation

1.2.1 The manufacturer shall submit the documentation required by Table 1. The documentation shall be reviewed by the Society as a part of the certification contract.

Table 1 Documentation requirements

Object	*Documentation type*	*Additional description*	*Info*
Waterjet, fixed; Waterjet, variable	C020 - Assembly or arrangement drawing	Including cross section	FI
	C040 - Design analysis	Impeller thrust, vessel thrust and maximum reversing forces at crash stop	FI
	Z100 - Specification	Water jet pump characteristic, with operation limits including cavitation limits, see limit as for Table 5	FI
	Z100 - Specification	Normal operating parameters that define the permissible operating conditions, such as thrust, impeller speed, vessel speed, impeller speed. versus vessel speed, see limitations in Table 5	FI
Shafting	Z261 - Test report	Non-destructive testing (NDT)	FI
	C030 - Detailed drawing	Input shaft and impeller shaft shall be documented according to rules for shafting	AP
	C020 - Assembly or arrangement drawing	Bearing arrangement with particulars	AP
	C040 - Design analysis	Calculated lifetime of roller bearings	AP
	C030 - Detailed drawing	Seal box, if water lubricated	FI

Object	*Documentation type*	*Additional description*	*Info*
	C030 - Detailed drawing	All bolt connections carrying thrust or torque, specification of bolt material and tightening procedure (bolt pre-stress)	AP
Impeller	C030 - Detailed drawing	Including NDT specification	FI
	C040 - Design analysis	Impeller blade strength calculations	FI, R
Stator housing	C030 - Detailed drawing	With guide vanes	FI
	C040 - Design analysis	Strength calculations	FI, R
Stern flange	C030 – Detail drawing	Including bolting	AP
	C040 – Design analysis	Strength calculation	FI
Waterjet casing	C020 - Assembly or arrangement drawing	Including water inlet ducting	FI
	C030 - Detailed drawing	Cross section of unit.	FI
	C040 - Design analysis	Water inlet ducting, hydrodynamic	FI
	C040 - Design analysis	Housing strength calculations, see [2.2]	FI, R
Reversing arrangement; Steering arrangement	C020 - Assembly or arrangement drawing	Steering arrangement	AP
	C040 - Design analysis	Strength calculation of the steering and reversing mechanism	AP
	S042 - Hydraulic control diagram	Including relief valve setting and alarm list with set points	AP
Reversing deflector actuator	C030 - Detail drawing		AP
Steering deflector actuator	C030 - Detail drawing		AP
Control and monitoring system	I200 - Control and monitoring system documentation	According to Ch.9	AP
AP = For approval; FI = For information; R = On request			

1.2.2 For general requirements for documentation, including definition of the info codes, see Pt.1 Ch.3 Sec.2.

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

1.3 Certification requirements

1.3.1 Water jet parts, semi-products or materials shall be certified according to Table 2 and tested according to Table 3 and [3.2].

1.3.2 All piping systems shall be properly flushed, in accordance with the manufacturer’s specification. This shall be documented by a work certificate.

Table 2 Certification required

Object	*Certificate type*	*Issued by*	*Certification standard**	*Additional description*
Waterjet	PC	Society		
Impeller	PC	Society		*Required if manufactured by sub supplier*
	MC	Manufacturer		
	TR	Manufacturer		*Balancing - See* [3.2.4]
Stator housing	MC	Manufacturer		
Impeller housing	MC	Manufacturer		
Shafting	MC	Manufacturer		As required in Ch.4 Sec.1
Hydraulic actuators for reversing	PC	Society		*Required if manufactured by sub supplier*
	MC	Manufacturer		
Other reversing components	MC NDT	Manufacturer		
Hydraulic actuators for steering	PC	Society		*Required if manufactured by sub supplier*
	MC	Society		
Other steering components	MC	Manufacturer		
Bolts	TR	Manufacturer		
Ducting	MC	Manufacturer		If delivered integral with the water jet
Control and monitoring system	PC	Society		
*Unless otherwise specified the certification standard is the Society rules.				

1.3.3 For general certification requirements, see Pt.1 Ch.3 Sec.4.

1.3.4 For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

1.3.5 The surveyor shall do visual inspection of parts. Visual inspection shall include random dimensional check with emphasis on critical dimensions, tolerances and stress raisers.

Manufacturer’s measurement report shall be presented for main items and shall be available upon request for minor components.

Manufacturer’s survey report shall be available upon request.

Table 3 Testing and inspection of components

	Ultra-sonic or X-ray testing	*Surface crack detection* [3]	*Pressure testing*	*Dimensional inspection*	*Visual inspection*	*Other*
Impeller		Manufacturer		Manufacturer	Society	Manufacturer[1]
Stator housing	Manufacturer[4]	Manufacturer		Manufacturer	Society	
Impeller housing	Manufacturer[4]	Manufacturer		Manufacturer	Society	
Shafting	According to Ch.4 Sec.1					
Hydraulic actuators for reversing and steering [5]	U-S or surface crack detection (manufacturer)[4]		Society or manufacturer[2]			
Other steering and reversing components		Manufacturer[4]			Manufacturer	
Bolts						
Ducting when delivered integral with the water jet	Manufacturer			Manufacturer	Society	

1) See [3.2.4].
2) Society for steering hydraulic actuators, manufacturer for reversing hydraulic actuators.
3) Crack detection in final condition.
4) NDT of welds upon request.
5) Hydraulic actuator includes cylinder, rod, cylinder end eye and rod end eye.

1.4 Definitions

1.4.1 The following definitions in Table 4 are used in this section.

Table 4 Definitions

Term	*Definition*
ducting	water streaming along the vessel's bottom and 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 builder
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
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
impeller housing	the water jet casing surrounding the impeller

Term	Definition
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
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
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

2 Design

2.1 General

2.1.1 For general design principles for machinery, see Sec.1 [2].

2.1.2 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.

2.1.3 The stresses in water jet components shall be considered based on loads due to the worst permissible operating conditions, taking into account:

— hydrodynamic loads, including varying hydrodynamic loads due to water flow disturbances introduced e.g. by the ducting or hull
— vessel accelerations versus water jet r/min.

2.1.4 Harmful impeller cavitation shall not occur when operating at full design speed on a straight course and at designated trim, giving the designed water head above the water intake.

Guidance note:

Harmful cavitation in this context is that cavitation which shall reduce shafting system and water jet component lifetime by introducing vibration or impeller erosion.

The water jet 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 water jet flow conditions. This phenomenon has showed to be of increasing importance with increasing water jet size.

To combat this, the water jet 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 water jets are the more important this advice become.

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

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

2.2 Design of components

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

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

2.2.3 Steering and reversing mechanisms shall be designed taking into account the worst permissible operational conditions.

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

2.2.5 Hydraulic actuators for steering shall comply with the requirements given in the Ch.10.

2.2.6 Hydraulic actuators for reversing shall comply with the requirements given in Ch.6 Sec.5 [8]. 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.

2.2.7 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.

3 Inspection and testing

3.1 General

3.1.1 The certification principles and the principles of manufacturing survey arrangements (MSA) are described in Pt.1 Ch.1 Sec.4.

Regarding material and testing specifications, see Pt.1 Ch.3.

3.1.2 Ancillaries not covered by Table 2 or Table 3 and are integrated as part of the water jet, shall be checked as found relevant by the water jet manufacturer.

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

3.2 Testing and inspection of parts

3.2.1 The inspection and testing described in the following are complementary to Table 3.

3.2.2 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.

3.2.3 Particulars concerning ducting inspections are stated in [8.1.5].

3.2.4 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.

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

3.3 Assembling

3.3.1 For fitting of the impeller to the shaft, see Ch.4 Sec.1 [2.3] to Ch.4 Sec.1 [2.7].

4 Workshop testing

4.1 General

4.1.1 Not applicable.

5 Control, alarm, safety functions and indications

5.1 General

5.1.1 Systems shall comply with the requirements in Ch.9.

5.2 Monitoring and bridge control

5.2.1 The monitoring of water jets (for propulsion) shall be in accordance with Table 5 in regard to: indications, alarms and requests for slowdown.

Table 5 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			
4.0 Operational limitations[1)]				
The ratio impeller r.p.m versus vessel speed	IR, HA, LR			Request for slow down
Maximum permissible vessel acceleration exceeded				Indication on bridge

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*

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/min 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 Ch.1.

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

5.2.2 Monitoring and bridge control shall also be in compliance with Ch.9 and Ch.10 Sec.1 [5.5] to Ch.10 Sec.1 [5.7].

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

6 Arrangement

6.1 General

6.1.1 The installation and arrangement of the water jet unit with auxiliaries shall comply with the manufacturer’s specification.

6.1.2 Ship external parts of the water jet shall be protected by guard rails or other suitable means.

7 Vibration

7.1 General

7.1.1 For requirements concerning whirling calculations and shaft alignment specification, see Ch.2.

7.1.2 For requirements concerning torsional vibration calculations for water jets, see Ch.2.

8 Installation survey

8.1 Surveys

8.1.1 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.

8.1.2 Impeller clearances shall be checked after installation and shaft alignment and shall be in accordance with the manufacturer's specification.

8.1.3 Normal procedures for shafting apply, see Ch.4 Sec.1 [7].

8.1.4 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.

8.1.5 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.

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

8.1.6 Pressure testing of piping shall be done according to Ch.6.

9 Shipboard testing

9.1 General

9.1.1 For general requirements related to the testing of control and monitoring, see Ch.9.
For testing of steering gear, Ch.10 Sec.1 [8] applies.

9.1.2 Final acceptance of the control system is dependent upon satisfactory results of the harbour testing and the final sea trial, as specified in items [9.1.3], [9.1.4] and [9.1.5].

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

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

9.1.5 The water jet speed versus vessel speed shall be noted and plotted against the manufacturers operational curves when inlet diameter exceeds 1000 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

1 General

1.1 Application

1.1.1 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 [3.2.2], [3.2.3], [5], and [9] apply to all thrusters.

The tunnel and other parts, that are welded or bolted to the hull and form a barrier against the ingress of seawater, 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.

1.1.2 For thrusters that are part of a dynamic positioning system, additional requirements are given in Pt.6 Ch.3 Sec.1 and Pt.6 Ch.3 Sec.2.

For thrusters that are installed in a vessel with additional class notation **RP** additional requirements are given in Pt.6 Ch.2 Sec.7.

For thrusters intended for navigation in ice, additional requirements are given in Pt.6 Ch.6.

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

1.1.4 The requirements in [2.4] are specific for steering gear for azimuth thrusters and replace the equivalent requirements in Ch.10 Sec.1, which apply to conventional rudders.

However, Ch.10 also gives requirements, depending on vessel type and size, which shall be complied with in addition to the requirements in [2.4].

1.1.5 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.

1.2 Definitions

1.2.1

Table 1 Definitions

Term	*Definition*
auxiliary thruster	thruster for all other purposes than propulsion and dynamic positioning
azimuth thruster	thruster capable of providing omni-directional thrust by being rotated around the vertical axis
declared steering angle limits	the operational limits in terms of maximum steering angle, or equivalent, according to manufacturer's guidelines for safe operation, also taking into account the vessel's speed or propeller torque/speed or other limitation
dynamic positioning thruster	thruster that is a part of a dynamic positioning system on board a vessel with a dynamic positioning class notations, see Pt.6 Ch.3 Sec.2 and Pt.6 Ch.3 Sec.1

Term	*Definition*
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")
propulsion thruster	thruster that is assigned to propulsion of the vessel. A propulsion thruster may also provide steering function
steering system	in this context to be understood as an azimuth thruster including its supporting systems, exact definition given in IACS UI SC242
thruster	a unit equipped with a propeller or impeller in order to produce thrust and 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)
tunnel thruster	thruster mounted in a tunnel for the purpose of providing lateral thrust for the vessel

1.3 Documentation

1.3.1 Documentation shall be submitted as required by Table 2.

Table 2 Documentation requirements

Object	*Documentation type*	*Additional description*	*Info*
Thruster	C020 - Assembly or arrangement drawing	Arrangement drawing of the thruster unit, including driver and intermediate shafting (yard supply)	AP
	C020 - Assembly or arrangement drawing	Sectional drawing of the whole thruster unit, including bearing arrangement	AP
	C020 - Assembly or arrangement drawing	Shaft brake/locking device arrangement (if applicable)	FI
	C040 - Design analysis	Shaft brake/locking device capacity calculation (if applicable)	FI
	C020 - Assembly or arrangement drawing	Sealing arrangement for flexibly mounted tunnel thrusters	AP
	C030 - Detailed drawing	Sectional drawings including all torque transmitting parts, e.g. shafts, couplings and gears	AP
	C030 - Detailed drawing	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	AP
	C040 - Design analysis	Component strength calculation for structural parts	FI, R
	C040 - Design analysis	Torsional vibration calculations (yard supply), see Ch.2 Sec.2	AP
	C040 - Design analysis	Torsional impact calculations. Applicable if high transient torque in electric motor drive (e.g. star-delta start), (yard supply), see Ch.2 Sec.2	AP, R
	C040 - Design analysis	Bearing life time calculations. Applicable if roller bearings	FI
	Z100 – Specification	Material, nominal surface pressure and clearance tolerances in case of fluid film bearings. Applicable if plain bearings	FI

Object	*Documentation type*	*Additional description*	*Info*
	C040 - Design analysis	For podded thrusters: heat balance calculation	FI
	S010 - Piping diagram (PD)	For podded thrusters: bilge system	AP
	Z060 – Functional description	For podded thrusters: bilge system	FI
	Z030 –Arrangement plan	Steering gear compartment for propulsion thrusters (yard supply)	FI
	Z050 - Design philosophy	Operational (design) limitations such as, but not limited to: — limitations in rotation of azimuth thrusters at high vessel speed — maximum vessel speed for lowering and lifting of retractable units	FI
	Z051 - Design basis	Maximum forces acting on the thruster unit under the most extreme allowable manoeuvre including crash stop	FI
	Z060 – Functional description	Load control system including description of the method used to control the load (CP-mechanism, frequency converter etc.)	FI, R
	Z100 – Specification	Specification of torque capacity of off-the-shelf gear transmissions used in steering motor arrangements (see footnote in [1.4.4])	FI
	Z161 - Operation manual	Operation instruction poster for control and steering of the thruster, including emergency operation. Shall be displayed on the navigation bridge and in the steering gear compartment	AP
	Z250 – Procedure	Assembling and adjustment procedures regarding gear mesh contact for drive gears and steering gears	FI, R
	Z250 – Procedure	For propulsion thrusters: crash stop procedure	FI
	Z051 - Design basis	Maximum start-up torque (K_{AP} factor, see class guideline DNVGL-CG-0036). Does not apply to thrusters which obtain the required scuffing safety factor (see Table 3) 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	FI
Fixation arrangement	C030 - Detailed drawing	Sectional drawings of slewing bearing and thruster support bearing	AP
Housing and structural part	C030 - Detailed drawing	Structural drawings (gear housing etc.) and connections to the tunnel or nozzle (if not covered by sectional drawings), including NDT specification	AP
Gears		See Ch.4 Sec.2	AP
Propeller		See Sec.1	AP
Propeller shaft seal	C030 - Detailed drawing		AP
Propeller nozzle	C030 - Detailed drawing		AP
Steering column	C030 - Detailed drawing	Including NDT specification	AP

Object	*Documentation type*	*Additional description*	*Info*
Steering gear actuator	C020 - Assembly or arrangement drawing	Steering gear assembly, including azimuth brake/locking device	AP
	C030 - Detailed drawing	Including all load transmitting parts	AP
	S042 - Hydraulic control diagram	Including alarm and indicator set points	AP
	Z060 – Functional description	Description of steering gear function and load limiting devices including maximum values	FI
	Z100 – Specification	Load data for azimuth gear, including capacity of azimuth brake	FI
	Z110 – Data sheet	Electrical motor for steering gear (if applicable), including motor rating according to IEC and torque versus speed characteristics of electrical motor	FI, R
	Z110 – Data sheet	Frequency converter set value of parameters, list of alarms, shutdowns and ramp functions (if applicable)	FI
Thruster seal	C030 - Detailed drawing	Sealing arrangement for steering column, see [2.5]	AP
Lubricating system	S010 - Piping diagram (PD)	Lubrication oil system including alarm and indicator set points	AP
Control and monitoring system	I200 - Control and monitoring system documentation		AP
AP = For approval; FI = For information; R = On request			

1.3.2 For general requirements for documentation, including definition of the info codes, see Pt.1 Ch.3 Sec.2.

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

1.4 Certification requirements

1.4.1 The complete thruster shall be delivered with certificate as required in Table 3 and tested and inspected as required in Table 4 . It shall be based on the design approval in [2], the component certification in [3], the workshop testing in [4] and relevant monitoring equipment in [5].

Table 3 Certification requirements

Object	*Certificate type*	*Issued by*	*Certification standard**	*Additional description*
Thruster	PC	Society		**Complete thruster**
Underwater housing	MC	Manufacturer		
Inboard housing	MC	Manufacturer		
Outer housing	MC	Society		Non rotating, forming barrier to sea
Steering column or rotating support	MC	Society		

Object	*Certificate type*	*Issued by*	*Certification standard**	*Additional description*
Propeller nozzle	MC	Society		
Control and monitoring systems	PC	Society		— Required for thrusters for propulsion and dynamic positioning duty
*Unless otherwise specified the certification standard is the Society rules.				

Table 4 Testing and inspection of components

	Ultra-sonic or X-ray testing	*Surface crack detection 2)*	*Pressure testing*	*Dimensional inspection*	*Visual inspection*	*Other*
Underwater housing		Manufacturer			Society	
Inboard housing		Manufacturer			Society	
Outer housing		Manufacturer			Society	
Propeller nozzle		Manufacturer			Society	
Steering column or rotating support	Manufacturer1)	Manufacturer			Society	

1) The test certificate shall refer to a recognized standard and approved acceptance levels.
2) Surface and crack detection (MPI or dye penetrant) is required in way of zones with stress risers and in welded connections. The extent and acceptance criteria shall be specified in the documentation submitted for approval.

1.4.2 For general certification requirements, see Pt.1 Ch.3 Sec.4.

1.4.3 For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

1.4.4 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*

Guidance note:

* 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.

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— 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.

1.4.5 Electrical equipment and control system shall be certified as required in Ch.8 and Ch.9.

1.4.6 For a definition of the certificate types, see Pt.1 Ch.3.

1.4.7 Welds in any part mentioned in [1.4.1], if specified during approval shall be ultrasonic tested. These tests shall be carried out at an appropriate stage of the manufacturing process. The test certificate shall refer to a recognized standard and approved acceptance levels.

1.4.8 Visual inspection shall be carried out of all parts mentioned in Table 4 and [1.4.4] unless otherwise defined in a manufacturing survey arrangements (MSA).

1.4.9 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 subjected to a quality control in accordance with the thruster manufacturer's quality system as found relevant. See also [3.1.2].

2 Design

2.1 General

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

2.1.2 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.

2.1.3 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. Sufficient ventilation shall be provided.

2.1.4 For general design requirements for piping and ancillary equipment such as pipes, pumps, filters and coolers, see Ch.6 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.

2.1.5 The cooling system shall be in accordance with Ch.6 Sec.5 [2].

2.1.6 For design and arrangement requirements for electric systems and control systems reference is made to Ch.10 Sec.1 [5] (for propulsion thrusters only) and Ch.8 and Ch.9.

2.2 Shafting

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

For podded thrusters there shall be a sufficient air gap between rotor and stator under all relevant operating conditions.

2.2.2 A shaft sealing box shall be installed to prevent water from entering into internal parts of the thruster or into the ship. The sealing arrangement shall protect the 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.

2.3 Gear transmissions

2.3.1 Gear transmissions shall be in accordance with the requirements in Ch.4 Sec.2 as far as applicable. The lifetime criteria given in Table 5 shall as a minimum be used for dimensioning the gears in the propeller drive line.

Table 5 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 thrusters subject to frequent overload (intermittent load), relevant load and corresponding accumulated number of load cycles shall be applied, see also Ch.2 Sec.1 [2].	

The safety factors S_F, S_H, S_{HSS} and S_S shall be at least as specified in Ch.4 Sec.2 Table 5. The safety factors for gears in thrusters for dynamic positioning shall be as for propulsion gears.

2.4 Azimuth steering gear for thrusters

2.4.1 Steering gear for auxiliary and dynamic positioning thrusters need not comply with [2.4.2], [2.4.3], [2.4.4], [2.4.5], [2.4.7], requirements for safety valve set value in [2.4.8], [2.4.10] and [2.4.17].

2.4.2 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.

2.4.3 The steering gear for the thruster shall:

a) be capable of turning the thruster from one side to the other at declared steering angle limits at an average rotational speed of not less than 2.3 deg/sec with the ship running at maximum ahead service speed, which shall be demonstrated at sea trial
b) be capable of bringing the thruster back to neutral position from any allowable angle at maximum service speed.

Guidance note:

Additional statutory requirements according to SOLAS and interpretation given in IACS UI SC242 may apply.

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2.4.4 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.

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

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

2.4.7 Steering gear drivers shall be designed with a capacity not less than 125% of the maximum torque occurring during the steering gear test as described in [2.4.3]. See also [2.4.17] for electro motor rating.

2.4.8 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 the steering gear test as described in [2.4.3], however not exceeding the design torque in the system.

2.4.9 Hydraulic systems for steering gears shall not be used for other purposes than steering.

For propulsion thrusters the requirements given in Ch.10 Sec.1 [2.10] 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 and sufficient cooling capacity is available.

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

2.4.10 It shall be possible to execute a crash stop without inflicting damage to the vessel or its equipment. Non intuitive procedures shall be described in an operational guideline. The society reserves the right to require an instruction poster at the navigation bridge.

2.4.11 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.

2.4.12 Azimuth steering gears for dynamically positioning thrusters shall be designed for continuous running. See the Pt.6 Ch.3 Sec.1 [6.1] and Pt.6 Ch.3 Sec.2 [6.1].

2.4.13 Steering gear transmissions shall as far as applicable be in accordance with the requirements in Ch.4, regardless of power rating. The steering gear transmission shall be designed considering the relevant loads (see [1.3.1] and [2.4.6]).

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 should be considered as a static or low cycle fatigue case (1 000 cycles).
- Loads occurring at larger manoeuvre (course changing). This load 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 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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2.4.14 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 6.

Table 6 Safety factors

	S_F	S_H and S_{HSS}	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)			

2.4.15 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.

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

2.4.17 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.

2.5 Steering column and pod stay and underwater housing

2.5.1 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 [1.2.1]). FEM calculation may be required when analytical methods cannot give satisfactory accuracy. The maximum nominal stress shall not exceed 50% of the yield strength.

2.5.2 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.

2.5.3 The thruster structure like underwater housings, steering column and pod stay, etc. shall have 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 [1.2.1].

2.5.4 The sealing around the steering column and pod stay, at the hull penetration, shall be arranged such 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.

2.5.5 Podded thrusters shall be provided with a bilge system. The bilge system shall be provided with full redundancy for single podded thruster arrangements.

2.6 Propeller

2.6.1 The propeller and propeller components shall meet the relevant dimensional requirements in Sec.1. See also class guideline DNVGL-CG-0039.

2.6.2 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 securely beyond the specified service intervals.

2.6.3 Controllable pitch mechanism on thrusters that are used in a dynamic positioning system shall be designed for continuous operation.

2.7 Bearings

2.7.1 Fluid film bearings shall be designed in accordance with the requirements in Ch.4 Sec.2 [2.7.1].

2.7.2 Ball and roller bearings shall have a minimum L_{10a} (ISO 281) as specified in Ch.4 Sec.2 [2.7.2].

2.8 Lubrication system

2.8.1 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.

2.8.2 Podded 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.

2.8.3 The lubrication system shall include:

— an arrangement to take representative oil samples with respect to detecting water and particle contamination
— if necessary, a cooler to keep the oil temperature within the specified maximum temperature, when operating under the worst relevant environmental conditions (see [2.8.1])
— a filter of suitable fineness for gearing, hydraulics and bearings (see [2.7.2]).

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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2.8.4 For propulsion and dynamic positioning thrusters it shall be possible to change or clean filters without interrupting the oil supply.

2.8.5 If forced lubrication is required for operation of the thruster, single propulsion thruster installation shall have a standby pump with immediate action.

2.8.6 For thrusters where wind milling may be detrimental and considered as a normal 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.

2.8.7 For thrusters designed to operate at such low rotational shaft speeds that an attached pump (if needed) cannot supply sufficient oil pressure, the following shall 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.

3 Inspection and testing

3.1 General

3.1.1 The parts in a thruster shall be tested and documented as described in Table 3 and Table 4.

3.1.2 Ancillaries integrated as part of the thruster and not covered by Table 3 or Table 4, shall be checked as found relevant by the thruster manufacturer.

3.2 Assembling

3.2.1 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.

3.2.2 For assembling of other elements, see Ch.4 Sec.2 [3.4] and Sec.1 [3.1]. However, for auxiliary thrusters Sec.1 [3.1.1] and Sec.1 [3.1.2] need not be adhered to.

3.2.3 For propeller fitting, see Ch.4 Sec.1.

4 Workshop testing

4.1 Testing of assembled unit

4.1.1 For gear mesh checking, see Ch.4 Sec.2 [4.2] unless another procedure is approved.

4.1.2 For clutch operation, see Ch.4 Sec.2 [4.2].

4.1.3 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.10 Sec.1.

For other hydraulic systems the test pressure shall be as required in Ch.6 Sec.6. Regarding function testing of controllable pitch propellers, see Sec.1 [3.1].

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

4.1.5 Testing of electrical equipment such as motors and frequency converters shall comply with Ch.8.

4.1.6 Testing of instrumentation and control systems shall comply with Ch.9.

5 Control, alarm, safety functions and indication

5.1 General

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

5.1.2 For additional requirements to vessels with dynamic positioning class notations, see Pt.6 Ch.3 Sec.2 and Pt.6 Ch.3 Sec.1.

5.1.3 Alarms and indications shall be initiated, as applicable, for the faults given in Table 7. For electro-driven propulsion thrusters see also Ch.8 Sec.12 [1.6.5]. For steering gear see also Ch.10 Sec.1 [5]. Additionally, an alarm shall be initiated on the bridge in case of power failure of the alarm, control and safety system as required in Ch.9 Sec.2 [2.1].

5.1.4 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 controlled and navigated.

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

5.2 Bridge control

5.2.1 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 shall be arranged in accordance with Ch.8 Sec.2 [8.4].

Table 7 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.10 Sec.1 [5.7.4]. Identification of failed system
3.0 Pitch, speed and direction of rotation				
Propeller r/min	IR			Running indication for constant speed propellers

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*
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

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

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/min 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 Ch.1.

1) To be provided when stand-by pump is required, see [2.8]
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 [1.6.5]
7) To be provided when stand-by pump is required, see Sec.1 [6.3].

6 Arrangement

6.1 General

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

6.1.2 The arrangement of flexibly mounted tunnel 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.

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

6.1.4 Thrusters mounted to the hull by bolt connections which provide boundary to sea shall be protected by means of a seal.

6.2 Propulsion thrusters

6.2.1 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.

6.2.2 Propulsion thruster compartment is regarded as steering gear room and shall be arranged according to Ch.10 Sec.1 [6.2]. Local control of steering gear, propeller pitch or speed shall be in the thruster compartment.

6.2.3 For propulsion thrusters with rated power exceeding 2500 kW the steering gear shall be connected to an alternative source of power, according to the requirements in Ch.10 Sec.1 [5.3.1].

When operating on emergency power, the steering gear's capacity shall be as described in Ch.10 Sec.1 [2.5.1]. The requirement of 15° rudder angle on either side shall be replaced by the manufacturer's declared steering angle limits (see [1.1.5]), and the average rate of turn shall be not less than 0.5°/s.

Guidance note:

This requirement is based on IACS Unified Interpretation SC 242 which is considered equivalent to the SOLAS requirement of an alternative source of power for steering gears where the required rudder-stock diameter is above 230 mm.

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7 Vibration

7.1 Torsional vibration

7.1.1 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).

7.1.2 For all thrusters other than those covered by [7.1.1] 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.2 Sec.2 [2.3.3].

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 shall not be accepted for propulsion plants. Verification of application factors through measurements may be required (if vessel speed > 10 knots and K_A < 1.2).

8 Installation inspection

8.1 Installation onboard

8.1.1 For accessible thruster gears, the requirements in Ch.4 Sec.2 [8] apply.

8.1.2 For shaft alignment, propeller fitting and assembly of shafting components, the requirements in Ch.4 Sec.1 [8] apply.

8.1.3 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.

8.2 Install fastening to foundation

8.2.1 The mounting and installation of the thrusters shall be in accordance to approved drawings and according to manufacturer's specification (see also Ch.2 Sec.1 [6]).

9 Shipboard testing

9.1 Sea trial

9.1.1 For propulsion thrusters the steering capability shall be tested and turning speed shall be verified to be in compliance with [2.4.3].

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

9.1.3 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. Recordings shall be compared with acceptance criteria in [2.4.3]

9.1.4 The steering gear's capability to bring the thruster back to neutral position from any allowable angle ([2.4.2]) shall be verified by testing on sea trial.

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

9.1.6 Crash stop test shall be performed according to manufacturer's procedure.

9.1.7 The control, alarm and safety functions shall be tested for compliance with the approved alarm list, see Table 2 and Table 7.

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

9.1.9 Accessible thruster gears shall be inspected as in Ch.4 Sec.2 [9].

SECTION 4 COMPRESSORS

1 General

1.1 Application

1.1.1 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)
— cargo refrigeration (for ships having additional class notation **RM**) see Pt.6 Ch.4 Sec.10
— evaporated cargo compression (for ships having class notation **Tanker for liquefied gas**)
— inert gas production (when such a system is required by SOLAS and for ships having additional class notations **Inert**) see Pt.6 Ch.5 Sec.8.

1.1.2 Design approval is required for all compressors listed in [1.1.1] with a shaft power exceeding 200 kW.

1.1.3 Compressors shall carry a name plate with the following information:

— manufacturer
— year of construction
— effective suction rate [m^3/h]
— discharge pressure [bar]
— speed [r/min]
— power requirement [kW].

1.2 Documentation

1.2.1 The manufacturer shall submit the documentation required by Table 1. The documentation shall be reviewed by the Society as a part of the certification contract.

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

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

Table 1 Documentation requirements

Object	*Documentation type*	*Additional description*	*Info*
Compressor	C020 - Assembly or arrangement drawing	Cross section.	FI
	I110 – List of controlled and monitored points	Alarm set points and delay times.	AP
	S010 - Piping diagram (PD)	Compressed medium, lubrication and cooling.	AP
	Z110 – Data sheet	Medium, design pressure for all stages, working temperature, capacity, maximum shaft power and maximum rotational speed.	FI

Object	*Documentation type*	*Additional description*	*Info*
	C030 - Detailed drawing	Applicable for reciprocating compressors. Crankshaft.	AP
	M010 – Material specification	Applicable for reciprocating compressors. Crankshaft.	AP
	C040 - Design analysis	Applicable for reciprocating compressors. Crankshaft.	AP, R
	C050 – Non-destructive testing (NDT) plan	Applicable for reciprocating compressors. Crankshaft.	FI
	C030 - Detailed drawing	Applicable for reciprocating compressors. Connecting rod.	FI
	M010 – Material specification	Applicable for reciprocating compressors. Connecting rod	FI
	C030 - Detailed drawing	Applicable for reciprocating compressors. Cylinder and cylinder head with bolts.	FI
	M010 – Material specification	Applicable for reciprocating compressors. Cylinder and cylinder head with bolts.	FI
	C040 - Design analysis	Applicable for reciprocating compressors. Documentation of torsional vibration in reciprocating compressors, see [6.1.1].	FI
	C030 - Detailed drawing	Applicable for rotary and centrifugal compressors. Rotors with blades. AP, if > 1 000 kW and rotor with blades.	FI
	M010 – Material specification	Applicable for rotary and centrifugal compressors. Rotors with blades. AP, if > 1 000 kW and rotor with blades.	FI
	C050 – Non-destructive testing (NDT) plan	Applicable for rotary and centrifugal compressors. Rotors with blades.	FI
	C040 - Design analysis	Applicable for rotary and centrifugal compressors. Burst speed rotors with blades. Required , if > 1 000 kW and rotor with blades.	AP, R
	C030 - Detailed drawing	Applicable for rotary and centrifugal compressors. Rotor casing. AP, if > 1 000 kW and rotor with blades.	FI
	M010 – Material specification	Applicable for rotary and centrifugal compressors. Rotor casing. AP, if > 1 000 kW and rotor with blades.	FI
	C040 - Design analysis	Applicable for rotary and centrifugal compressors. Rotor casing strength.	FI, R

Object	Documentation type	Additional description	Info
	C040 - Design analysis	Applicable for rotary and centrifugal compressors. Rotor casing containment. Required, if > 1 000 kW and rotor with blades.	FI, R
	Z261 - Test report	Non-destructive testing (NDT) of crankshaft and rotors: UT, MT, dimension.	FI
AP = For approval; FI = For information; R = On request			

1.2.4 For general requirements for documentation, including definition of the info codes, see Pt.1 Ch.3 Sec.2.

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

1.3 Certification required

1.3.1 The certification principles are described in Pt.1 Ch.3 Sec.3. The principles of manufacturing survey arrangement (MSA) are described in Pt.1 Ch.1 Sec.4 [2.5].

Guidance note:

It is advised to establish an MSA with sub-suppliers delivering materials or parts mentioned in Unresolved reference: 300[3.3]. 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.

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

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

1.3.3 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 2 Certification required

Object	*Certificate type*	*Issued by*	*Certification standard**	*Additional description*
Compressor Crankshaft Connecting rod	PC	Society		
	MC	Manufacturer		
	TR	Manufacturer		Material
Cylinder with head Rotors Rotor casing	TR	Manufacturer		Material
	MC	Manufacturer		
	MC	Manufacturer		

Object	*Certificate type*	*Issued by*	*Certification standard**	*Additional description*
PC = product cert *MC* = material cert *TR* = test report *TA* = Type approval NDT – NDT report *Unless otherwise specified the certification standard is the Society rules.				

Table 3 Testing and inspection of components

Object	*Ultrasonic testing*	*Crack detection*	*Pressure testing*	*Dimension control*	*Additional description*
Compressor			Manufacturer		Function test
Crankshaft	Manufacturer	Manufacturer		Manufacturer	
Connecting rod					
Cylinder with head			Manufacturer		
Rotor	Manufacturer	Manufacturer		Manufacturer	
Rotor housing			Manufacturer		

1.3.4 For general certification requirements, see Pt.1 Ch.3 Sec.4.

1.3.5 For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

1.3.6 The surveyor shall do visual inspection of parts. Visual inspection shall include random dimensional check with emphasis on critical dimensions, tolerances and stress raisers.

Manufacturer’s measurement report shall be presented for main items and shall be available upon request for minor components.

Manufacturer’s survey report shall be available upon request.

2 Workshop testing

2.1 General

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

2.1.2 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 surveyor.

3 Design

3.1 General

3.1.1 Starting air compressors shall satisfy the requirements given in Ch.6 Sec.5 [9.3].

3.1.2 Refrigerating compressors shall satisfy the requirements given in Pt.6 Ch.4 Sec.10.

3.1.3 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.

3.1.4 Compressors for hydro carbons are subject to special consideration.

Compressors intended for offshore installation and following offshore regime (offshore standards and codes) shall comply with a recognised national or international standard.

Compressors for hydro carbons intended for ship system and subjected to classification shall comply with a recognised standard. Required documentation shall be specially agreed.

3.1.5 Compressors intended for inert gas production shall satisfy the requirements given in Pt.6 Ch.5 Sec.8.

3.1.6 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 Ch.6 Sec.5 [9.2.4].

3.2 Piping and arrangement

3.2.1 All compressors shall be protected by safety valves for every compressor stage. The safety valves shall be set to open at the design pressure. For starting air compressors, see also Ch.7 Sec.5 [2.2].

For reciprocating compressors where one compressor stage comprises several cylinders which can be shut off individually, each cylinder shall be equipped with a safety valve.

Guidance note:

The design pressure should be sufficiently higher than the working pressure in order to have margins for setting of the safety valve.

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

3.2.2 The piping to and from air compressors shall be arranged to prevent condensation from entering the cylinders.

3.2.3 For air compressors, the following apply:

— After the final stage, all air compressors shall be equipped with a water trap and an after-cooler.
— Water traps, after-coolers and the compressed air spaces between the stages shall be provided with discharge devices at their lowest points.
— Unless the cooling water spaces of air compressors and coolers are provided with open discharges they shall be fitted with safety valves or rupture discs of sufficient cross-sectional area. High-pressure stage air coolers shall not be located in the air compressor cooling water space.

Guidance note:

Exemption may be granted in case suitability of protecting devices for cooling water casing is verified by testing in the presence of a surveyor.

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

— For air compressors the compressed air temperature, measured directly at the discharge from the individual stages, shall not exceed 160°C for multi-stage compressors or 200°C for single-stage compressors. For discharge pressures of up to 10 bar, temperatures may be higher by 20°C.

3.3 Crankshafts

3.3.1 Crankshafts for reciprocating compressors shall include a safety factor against fatigue failures. Calculation method and safety factor shall comply with a recognised standard.

The crankshafts and connecting rods of reciprocating compressors shall be made of forged steel, cast steel or nodular cast iron. The use of special cast iron alloys shall be agreed with the Society.

Guidance note:

For air compressors of working pressure up to 40 bar the diameters of shaft journals and crank pins may be determined as follows:

$$d_k = 0.126 \cdot \sqrt[3]{D^2 \cdot p_c \cdot C_1 \cdot C_w \cdot (2 \cdot H + f \cdot L)}$$

For refrigerant compressors the diameters of shaft journals and crank pins may be determined as follows:

$$d_k = 0.115 \cdot \sqrt[3]{D^2 \cdot p_c \cdot C_1 \cdot C_w \cdot \left(0.3 \cdot H + f \cdot L\right)}$$

.

d_k = minimum pin/journal diameter [mm]

D = cylinder bore for single-stage compressors [mm]

D_{Hd} = cylinder bore of the second stage in two-stage compressors with separate pistons

1.4 × D_{Hd} for two stage compressors with a stepped piston (see Figure 1)

$\sqrt{{D_{Nd}}^2 - {D_{Hd}}^2}$

for two-stage compressors with a differential piston (see Figure 1)

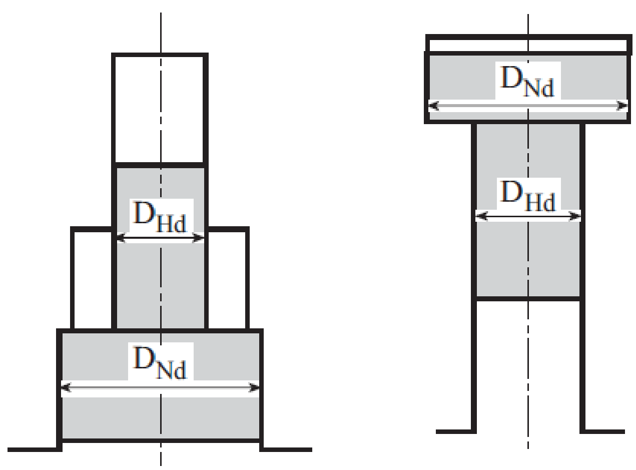

Figure 1 Stepped piston (left) and differential piston (right)

p_c = design pressure P_R, applicable up to 40 [bar]

H = piston stroke [mm]

L = distance between main bearing centres where one crank is located between two bearings [mm]. L shall be substituted by L_1 = 0.85 × L where two cranks at different angles are located between two main bearings, or by L_2 = 0.95 × L where 2 or 3 connecting rods are mounted on one crank.

f = 1.0 where the cylinders are in line

For V- or W type:

1.2 where the cylinders are at 90°

1.5 where the cylinders are at 60°

1.8 where the cylinders are at 45°

C_1 = coefficient according to Table 4 [–]

Z = number of cylinders

C_w = material factor according to Table 5 or Table 6 [–]

R_m = minimum tensile strength [N/mm^2].

Table 4 Values of C_1

Z	1	2	4	6	≥ 8
C_1	1.0	1.1	1.2	1.3	1.4

Table 5 Values of C_w for steel shafts

R_m	C_w
400	1.03
440	0.94
480	0.91
520	0.85
560	0.79
600	0.77
640	0.74
≥ 680	0.70
720[1)]	0.66
≥ 760[1)]	0.64
Only for drop forged shafts	

Table 6 Values of C_w for nodular cast iron shafts

R_m	C_w
370	1.20
400	1.10
500	1.08
600	0.98
700	0.94
≥ 800	0.90

Where increased strength is achieved by a favourable configuration of the crankshaft, smaller values of d_k may be approved.

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

3.3.2 For keyways connection, see Ch.4 Sec.1 [2.5].

3.4 Rotors for non-reciprocating compressors

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

3.5 Rotor casing for non-reciprocating compressors

3.5.1 The strength of the casing shall be documented by calculations in accordance with recognised standards.

3.5.2 Alternatively 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.

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

4 Control and monitoring

4.1 General

4.1.1 Control and monitoring shall be in accordance with Table 7.

4.1.2 Each compressor stage shall be fitted with a pressure gauge with a scale indicating the relevant maximum working pressure.

4.1.3 For reciprocating compressors where one compressor stage comprises several cylinders which can be shut off individually, each cylinder shall be equipped with a pressure gauge.

Table 7 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			Applicable for forced lubrication
Sump Level [1)]	IL or IR			Applicable for splash lubrication
3.0 Compressed medium				
Pressure	IL			See [4.1.2] and [4.1.3]

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/min 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 Ch.1.

1) For compressors with shaft power less than 500 kW dipstick is considered adequate indicator.

5 Arrangement on-board

5.1 General

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

6 Vibration

6.1 Torsional vibration

6.1.1 For reciprocating compressors with shaft power exceeding 500 kW, torsional vibration analysis shall be determined according to the requirements given in Ch.2 Sec.2.

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

7 Installation inspection

7.1 General

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

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

7.2 Vibration

7.2.1 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.

CHANGES – HISTORIC

July 2016 edition

Main changes July 2016, entering into force 1 January 2017

• Sec.1 Propellers

— Sec.1: Updated text related to hub caps with fins (and cap bolts).
— Sec.1 [1.2.5]: Polar and diametrical mass moment of inertia of entrained water to be specified.

• Sec.2 Water jets

— New Sec.2 [2.1.4]: Requirements have been moved from guidance note in Sec.2 [2.1.3].

• Sec.3 Podded and geared thrusters

— Sec.3 [2.4.3] a): The paragraph has been rephrased to reflect the IACS UI SC242 / MSC.1 Circ 1416 regarding steering for thrusters.
— New Sec.3 [2.8.4] and Sec.3 [2.8.5]: Requirements moved from guidance note in Sec.3 [2.8.3].

• Sec.4 Compressors

— Sec.4 [4.1.4] and Sec.4 Table 7: Requirement for temperature measurement of compressed medium has been deleted.

October 2015 edition

This is a new document.

The rules enter into force 1 January 2016.

Amendments January 2016

• General

— Only editorial corrections have been made.