Excerpt from ABS Rules Developed for Propeller Manufacturers

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Excerpt from ABS Rules
Developed for Propeller Manufacturers

American Bureau of Shipping

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Foreword

Purpose
This booklet is an excerpt from the ABS Rules. It has been created to support equipment manufacturers in identifying the appropriate ABS Rules for their products.

Application
Equipment manufacturers seeking to have their products approved for marine and offshore applications under ABS classification or certification will find this booklet a practical reference for determining which sections of the ABS Rules are applicable to their specific equipment types.

This excerpt does not replace or supersede the complete ABS Rules. Users are responsible for consulting the full text of the applicable Rules and ensuring compliance with the most current edition, including any published corrigenda and notices.

Additional Information
For questions regarding the applicability of specific Rules to your equipment. Please contact your local ABS office.

The ABS Rules are available in their complete form at American Bureau of Shipping (ABS) Eagle.org.

1 General

1.1 Application

This section applies to propellers intended for propulsion. It covers fixed pitch and controllable pitch propellers. Propellers for thrusters used for maneuvering and dynamic positioning are covered in Section 4-3-5. Performance of propellers, in respect of developing the designed output, is to be demonstrated during sea trials.

Additional requirements for propellers intended for vessels strengthened for navigation in ice are provided in Part 6.

1.2 Objective (2024)

1.2.1 Goals (2024)

Propellers covered in this Section are to be designed, constructed, operated, and maintained to:

Goal No.	Goal
PROP 1	provide sufficient thrust/power to move or maneuver the vessel when required.
PROP 2	provide redundancy and/or reliability to maintain propulsion.
AUTO 1	perform its function as intended in a safe manner.
AUTO 2	indicate the system operational status and alert operators of any essential machinery/systems that deviate from its defined design/operating conditions or intended performance.
AUTO 3	have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
AUTO 4	provide the equivalent degree of safety and operability from a remote location as those provided by local controls.
AUTO 5	be provided with a safety system that automatically leads the machinery being controlled to a fail-safe state in response to a fault which may endanger the safety of persons on board, machinery/equipment or environment.
AUTO 6	independently perform different functions, such that a single failure in one system will not render the others inoperative
MGMT 5.1	design and construct vessel, machinery, and electrical systems to facilitate safe access, ease of inspection, survey and maintenance.

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals as listed above.

Goal No.	Goal
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.2.2 Functional Requirements (2024)

In order to achieve the above stated goals, the design, construction, installation and maintenance of the propellers are to be in accordance with the following functional requirements:

Functional Requirement No.	Functional Requirements
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1	Propeller blades are to withstand the maximum rated power without any deformation or fatigue failure.
PROP-FR2	Components of controllable pitch propellers such as flange, pitch change mechanism, and stud bolts are to be designed to have adequate strength to withstand design pitch conditions.
PROP-FR3	Controllable pitch propeller systems are to be designed with redundancy to maneuver and maintain minimum vessel speed under any single failure condition.
PROP-FR4	Emergency provisions are to be provided such that failure of system/equipment is not to cause the escalation of hazards or the impairment of mitigation of/recovery from hazards and to safeguard the propulsion and maneuvering capability.
PROP-FR5	Failure of the hydraulic system for the propeller integrated with other system(s) is not to cause the escalation of hazards and is not to cause the other system(s) to be non-operational.
PROP-FR6	Appropriate pressure to hold the propeller in the hub and prevent deformation is to be maintained during fitting of the keyless propeller.
PROP-FR7	Significant change in propeller mass and polar moment of inertia due to PBCF device installation in existing vessels is to be accounted for in shaft alignment and vibration calculations.
PROP-FR8	Propellers are to fit tightly, and controllable pitch propeller control mechanism is to be protected from water ingress or oil leakage.
PROP-FR9	There are to be arrangements to protect the exposed parts of the propeller and the shaft against corrosion.
PROP-FR10	Means for circulating current protection from passing between the propeller, shaft and the hull is to be maintained.
PROP-FR11	After final pull-up of the propeller, there are to be arrangements to secure the nut to the tail shaft to prevent the propeller from loosening.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	*Shall be arranged and controlled such that the machinery operation will be as safe and effective as if it were under direct supervision. (SOLAS II-1)*
AUTO-FR2	*Be able to control the pitch of propeller from a local position, even in the case of failure in any part of the automatic or remote control systems. (SOLAS II-1)*
AUTO-FR3	Propeller pitch is to be controlled from control stations for direct control and monitoring of propulsion machinery.
AUTO-FR4	Provide visual and audible notification at all control and monitoring stations for any incorrect operation or abnormal condition.
Safety Management (MGMT)	
MGMT-FR1	Provide means in the system for testing of loss of system hydraulic pressure and be fitted with a by-pass for the main propulsion machinery to prevent further escalation of hazards.
Materials (MAT)	
MAT-FR1	Fatigue strength to be considered for designing to withstand cyclic loading.
MAT-FR2	Galvanic compatibility is to be considered when dissimilar metals are connected.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.2.3 Compliance **(2024)**

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

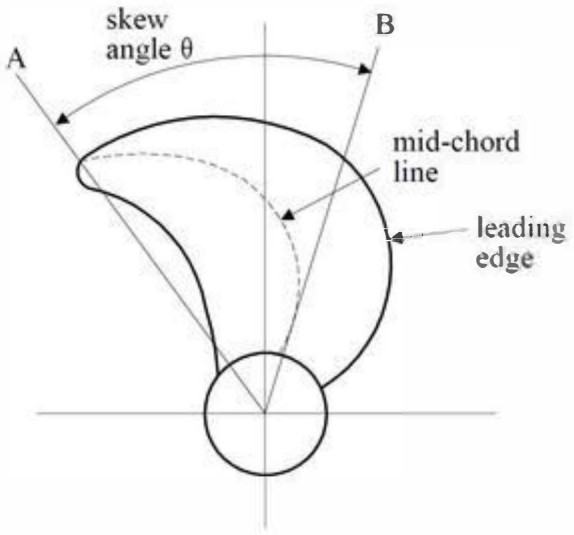
1.3 Definitions

For purpose of this section, the following definitions apply.

1.3.1 Skew Angle

Skew Angle (θ) of a propeller is the angle measured from ray 'A' passing through the tip of blade at mid-chord line to ray 'B' tangent to the mid-chord line on the projected blade outline. See 4-3-3/1.3.1 FIGURE 1.

FIGURE 1
Skew Angle (2024)



1.3.2 Highly Skewed Propeller

A *Highly Skewed Propeller* is one whose skew angle is more than 25°.

1.3.3 Propeller Rake

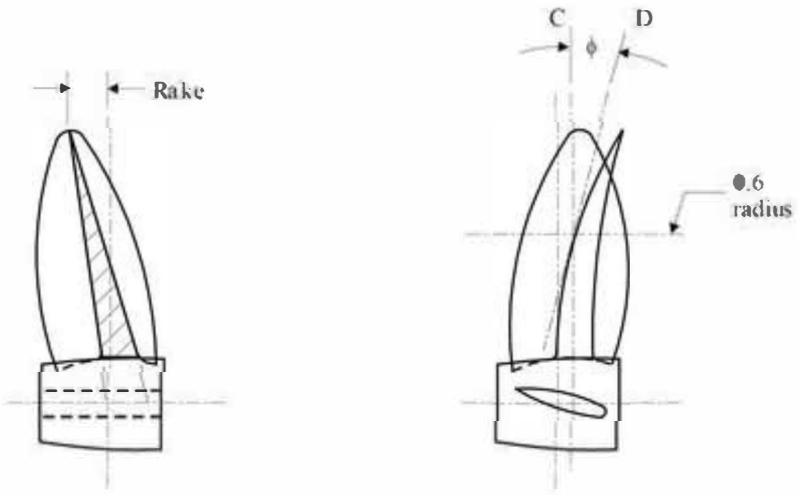
1.3.3(a) *Rake.*

Rake is the distance at the blade tip between the generating line and the line perpendicular to the propeller axis that meets the generating line at the propeller axis. See 4-3-3/1.3.3 FIGURE 2.

1.3.3(b) *Rake angle (ϕ).*

Rake angle of a propeller is the angle measured from the plane perpendicular to shaft centerline to the tangent to the generating line at a specified radius (0.6×radius for the purpose of this section). See 4-3-3/1.3.3 FIGURE 2.

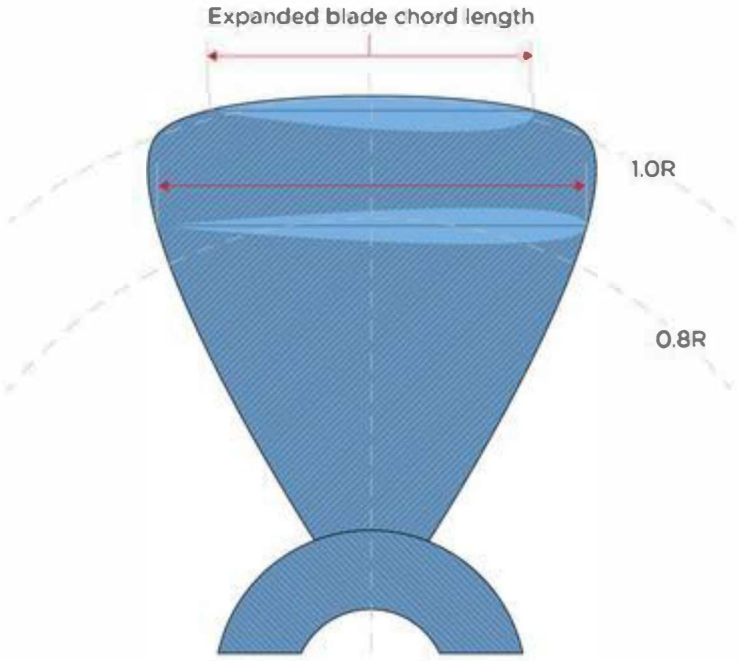
FIGURE 2
Rake and Rake Angle



1.3.4 Wide Tipped Blade Propeller

A propeller blade is to be considered as a wide tipped blade if the maximum expanded blade cord length occurs at or above 0.8*R*, with *R* being the distance measured from the centerline of the propeller hub.

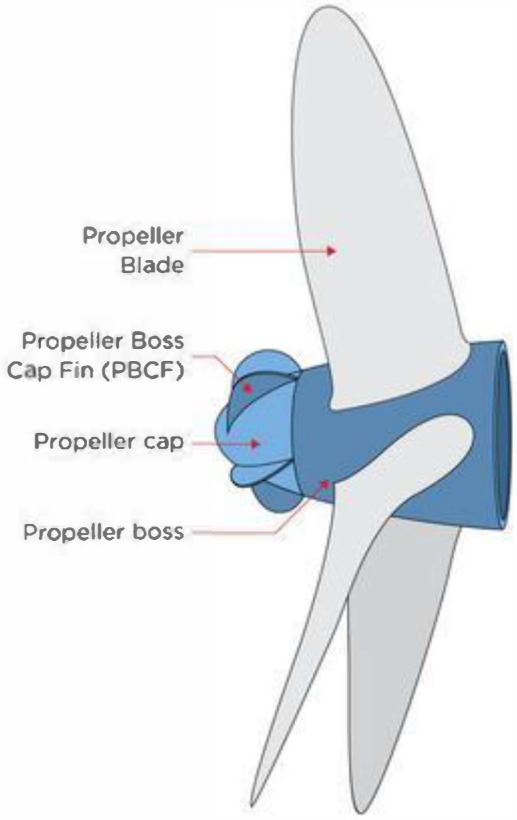
FIGURE 3
Wide Tip Blade Propeller (2024)



1.3.5 Propeller Boss Cap Fins (PBCF) **(2021)**

A PBCF is an energy saving device with post-swirl fins installed onto the boss cap of the propeller, rotating with the propeller and enhancing propeller efficiency.

FIGURE 4
Components of Propeller with PBCF (2024)



1.3.6 Cycloidal Propeller **(2024)**

A combined steering and propulsion device comprising a number of vertical blades arranged to rotate and revolve to give thrust in any desired direction.

1.5 Plans and Particulars to be Submitted **(2024)**

The following plans and particulars are to be submitted for review:

1.5.1 Fixed Pitch Propellers of Conventional Design

Material

Design characteristics of propeller

Dimensions and tolerances

Propeller plan

Blade thickness calculations

1.5.2 Controllable Pitch Propellers of Conventional Design

As per 4-3-3/1.5.1

Hub and hub to tail shaft flange attachment bolts

Propeller blade flange and bolts

Internal mechanism

Hydraulic piping control system

Instrumentation and alarm system

Strength calculations for internal mechanism

1.5.3 Highly Skewed Propellers and Other Unconventional Design Propellers **(2024)**

In addition to the foregoing, where propeller blade designs are of the types for which the Rules do not provide simplified blade thickness calculations, such as:

- Highly skewed propellers with $\theta > 50°$;
- High skewed propellers made of other than Type 4 materials with $50° \geq \theta > 25°$;
- Controllable pitch propellers with $\theta > 25°$;
- Cycloidal propellers

propeller load and stress analyses demonstrating adequacy of blade strength are to be submitted.

1.5.4 Keyless Propellers

Where propellers are to be fitted to the shaft without keys, stress calculations for hub stresses and holding capacity, along with fitting instructions, are to be submitted.

1.5.5 Propeller Boss Cap Fins (PBCF) **(2021)**

Where propeller boss cap fins are fitted to propellers, detailed drawings of the arrangement including, but, not limited to the following:

i. Assembly drawing including material specifications
ii. Cap
iii. Vane or Fin blade
iv. Stress calculations including fatigue

3 Materials

3.1 Propeller and PBCF Materials **(2024)**

4-3-3/3.1 TABLE 1 shows the properties of materials used for propellers. See 2-3-14/3 and Section 2-3-15 of the ABS *Rules for Materials and Welding (Part 2)* for full details of the materials. The material of the PBCF device is to be similar to that of the propeller.
Commentary:

Other equivalent material that is also galvanically compatible to the propeller is acceptable.

End of Commentary

Where an alternative material specification is proposed, detailed chemical composition and mechanical properties are to be submitted for approval (for example, see Sections 2-3-14 and 2-3-15 of the ABS *Rules for Materials and Welding (Part 2)*). The *f* and *w* values of such materials to be used in the equations hereunder are subject to ABS technical assessment and approval submittal of complete material specifications including corrosion fatigue data to 10^8 cycles.

TABLE 1
Propeller Materials

		Tensile strength			Yield strength			Elongation, % Gauge Length	
Type	*Material*	*N/mm^2*	*kgf/mm^2*	*lb/in.^{2}*	*N/mm^2*	*kgf/mm^2*	*lb/in.^{2}*	*4d*	*5d*
2	Manganese bronze	450	46	65,000	175	18	25,000	20	18
3	Nickel-manganese bronze	515	53	75,000	220	22.5	32,000	18	16
4	Nickel-aluminum bronze	590	60	86,000	245	25	36,000	16	15
5	Manganese-nickel-aluminum bronze	630	64	91,000	275	28	40,000	20	18
CF-3	Stainless steel	485	49	70,000	205	21	30,000	35	32

3.3 Stud Materials

The material of the studs securing detachable blades to the hub is to be of at least Grade 2 forged steel or equally satisfactory material; see 2-3-7/3 of the ABS *Rules for Materials and Welding (Part 2)* for specifications of Grade 2 forged steel.

3.5 Material Testing **(2024)**

Materials of propeller cast in one piece and materials of blades, hub, studs and other load-bearing parts of controllable pitch propellers are to be tested in the presence of a Surveyor. For requirements of material testing, see 2-3-14/3 and Section 2-3-15 and Section 2-3-9 of the ABS *Rules for Materials and Welding (Part 2)*.

Surveyor's attendance of the material testing of propellers not exceeding 1.5 m (60 in.) in diameter is not required provided they are part of a manufacturer's standard product line. Manufacturer's certified mill test reports will be accepted upon a satisfactory surface inspection by the Surveyor.

5 Design

5.1 Blade Thickness - Fixed Pitch Propeller **(2024)**

Propeller blades of thrusters (as defined in 4-3-5/1.5) and wide-tip blades of ducted propellers are to be in accordance with the provisions of Section 4-3-5. The thickness of the propeller blades of conventional design ($\theta \le 25°$) is not to be less than that determined by the following equations:

$$t_{0.25} = S\left[K_1\sqrt{\frac{AH}{C_nCRN}} \pm \left(\frac{C_s}{C_n}\right)\left(\frac{BK}{4C}\right)\right]$$

$$A = 1.0 + \frac{6.0}{P_{0.70}} + 4.3P_{0.25}$$

$$B = \left(\frac{4300wa}{N}\right)\left(\frac{R}{100}\right)^2\left(\frac{D}{20}\right)^3$$

$$C = (1 + 1.5P_{0.25})(Wf - B)$$

where (units of measures are given in SI (MKS, and US) units respectively):

a = expanded blade area divided by disc area

a_s = area of expanded cylindrical section at 0.25 radius; mm^2 (mm^2, in^2)

C_n = section modulus coefficient at the 0.25 radius. C_n is to be determined by the following equation:

$$C_n = \frac{I_0}{U_f W T^2}$$

If the calculated C_n value exceeds 0.10, the required thickness is to be computed with C_n = 0.10.

C_s = section area coefficient at 0.25 radius and is to be determined by the following equation:

$$C_s = \frac{a_s}{WT}$$

The values of C_s and C_n, computed as stipulated above, are to be indicated on the propeller drawing. If the C_n value exceeds 0.10, the required thickness is to be computed with C_n = 0.10

For vessels below 61 m (200 ft) in length, the required thickness is to be computed with the assumed values of C_n = 0.10 and C_s = 0.69.

D = propeller diameter; m (m, ft.)

f, w = material constants from the following table:

Material type (see 4-3-3/3.1)	*SI and MKS units*		*US units*	
	f	w	f	w
2	2.10	8.3	68	0.30
3	2.13	8.0	69	0.29
4	2.62	7.5	85	0.27
5	2.37	7.5	77	0.27
CF-3	2.10	7.75	68	0.28

Note:

The f and w values of materials not covered in the above table are subject to ABS technical assessment and approval.

H = power at rated speed; kW (PS, hp)

I_0 = moment of inertia of expanded cylindrical section at 0.25 radius about a straight line through the center of gravity parallel to the pitch line or to the nose-tail line; mm^4 (mm^4, in^4)

K = rake of propeller blade, in mm (in.) (positive for aft rake and negative for forward rake)

K_1 = coefficient as given below

	SI	*MKS*	*US*
K_1	337	289	13

N = number of blades

$P_{0.25}$ = pitch at one-quarter radius divided by propeller diameter, corresponding to the design ahead condition

$P_{0.70}$ = pitch at seven-tenths radius divided by propeller diameter, corresponding to the design ahead condition

R = rpm at rated speed

S = factor, as given below. If greater than 1.025, equate to 1.025.

SI & MKS units	*US units*
1.0 for D ≤ 6.1m	1.0 for D ≤ 20 ft
$\sqrt{\frac{(D+24)}{30.1}}\ for\ D > 6.1m$	$\sqrt{\frac{(D+79)}{99}}\ for\ D > 20ft$

$t_{0.25}$ = minimum required thickness at the thickest part of the blade section at one quarter radius; mm (mm, in.)

T = maximum designed thickness of blade section at 0.25 radius from propeller drawing; mm (mm, in.)

U_f = maximum nominal distance from the moment of inertia axis to points of the face boundary (tension side) of the section; mm (mm, in.)

W = expanded width of a cylindrical section at 0.25 radius; mm (mm, in.)

5.3 Blade Thickness - Controllable-pitch Propeller

Controllable pitch propeller blades of thrusters (as defined in 4-3-5/1.5) and wide-tip blades of ducted controllable pitch propellers are to be in accordance with the provisions of Section 4-3-5. The thickness of the controllable pitch propeller blade of conventional design (θ ≤ 25°) is not to be less than determined by the following equation:

$$t_{0.35} = K_2\sqrt{\frac{AH}{C_nCRN}} \pm \left(\frac{C_s}{C_n}\right)\left(\frac{BK}{6.3C}\right)$$

$$A = 1.0 + \frac{6.0}{P_{0.70}} + 3P_{0.35}$$

$$B = \left(\frac{4900wa}{N}\right)\left(\frac{R}{100}\right)^2\left(\frac{D}{20}\right)^3$$

$$C = (1 + 0.6P_{0.35})(Wf - B)$$

where the symbols used in these formulas are the same as those in 4-3-3/5.1 except as modified below:

a_s = area of expanded cylindrical section at 0.35 radius; mm^2 (mm^2, in^2)

C_n = section modulus coefficient at the 0.35 radius and is to be determined by the following equation:

$$C_n = \frac{I_0}{U_f WT^2}$$

If the calculated C_n value exceeds 0.10, the required thickness is to be computed with C_n = 0.10.

C_s = section area coefficient at 0.35 radius and is to be determined by the following equation:

$$C_s = \frac{a_s}{WT}$$

The values of C_s and C_n, computed as stipulated above, are to be indicated on the propeller drawing. If the C_n value exceeds 0.10, the required thickness is to be computed with C_n = 0.10

For vessels below 61 m (200 ft) in length, the required thickness is to be computed with the assumed values of C_n = 0.10 and C_s = 0.69.

I_0 = moment of inertia of expanded cylindrical section at 0.35 radius about a straight line through the center of gravity parallel to the pitch line or to the nose-tail line; mm^4 (mm^4, in^4)

K_2 = coefficient as given below

	SI	*MKS*	*US*
K_2	271	232	10.4

P_{35} = pitch at 0.35 radius divided by D

T = maximum designed thickness of blade section at 0.35 radius from propeller drawing; mm (mm, in.).

$t_{0.35}$ = required minimum thickness of the thickest part of the blade section at 0.35 radius; mm (mm, in.)

W = expanded width of a cylindrical section at 0.35 radius; mm (mm, in.)

5.5 Blade Thickness - Highly Skewed Fixed-pitch Propeller

5.5.1 Propeller Blades with Skew Angle θ; where 25°< θ ≤ 50°

The provisions of 4-3-3/5.5.1 is applicable to fixed pitch propellers having a skew angle over 25° but not exceeding 50°, and made of Type 4 material only. For propellers of other materials, see 4-3-3/5.5.2. Where the skew angle is greater than 50°, see 4-3-3/5.5.3.

5.5.1(a) *Blade thickness at 0.25 radius*. **(2024)**

The maximum thickness at 0.25 radius is to be not less than the thickness required in 4-3-3/5.1 for fixed pitch-propellers multiplied by the factor *m* as given below:

$$m = \sqrt{1 + 0.0065\,(\theta - 25)}$$

5.5.1(b) *Blade thickness at 0.6 radius*. **(2024)**

The maximum thickness of blade section at 0.6 radius is to be not less than that obtained from the following equations:

$$t_{0.6} = K_3 \cdot \sqrt{(1 + C_{0.9})\left(1 + \frac{2C_{0.9}}{C_{0.6}}\right)\left(\frac{H\,D\Gamma}{R P_{0.6} Y}\right)^{0.5}}$$

$$\Gamma = \left(1 + \frac{\theta - 25}{\theta}\right)\left(\phi^2 + 0.16\phi \cdot \theta \cdot P_{0.9} + 100\right)$$

where

$C_{0.6}$ = expanded chord length at the 0.6 radius divided by propeller diameter

$C_{0.9}$ = expanded chord length at the 0.9 radius divided by propeller diameter

K_3 = a coefficient as given below:

	SI	*MKS*	*US*
K_3	12.6	6.58	1.19

$P_{0.6}$ = pitch at the 0.6 radius divided by propeller diameter

$P_{0.9}$ = pitch at the 0.9 radius divided by propeller diameter

$t_{0.6}$ = required thickness of the blade section at 0.6 radius; mm (mm, in.)

Y = minimum specified yield strength of type 4 propeller material; N/mm^2 (kgf/mm^2, psi). See 4-3-3/3.1 TABLE 1.

θ = skew angle in degrees (see 4-3-3/1.3.1)

ϕ = rake angle in degrees [see 4-3-3/1.3.3(b)] at 0.6 radius, positive for aft rake

H , D , and R are as defined in 4-3-3/5.1.

5.5.1(c) Blade thickness between 0.6 and 0.9 radii.

The maximum thickness at any radius between 0.6 and 0.9 radii is to be not less than that obtained from the following equation:

$$t_x = 3.3D + 2.5\,(1 - x)\,(t_{0.6} - 3.3D)\,\text{mm};\ \text{or}$$

$$t_x = 0.04D + 2.5\,(1 - x)\,(t_{0.6} - 0.04D)\,\text{in.}$$

where:

t_x = required minimum thickness of the thickest part of the blade section at radius ratio x

$t_{0.6}$ = thickness of blade section at the 0.6 radius as required by 4-3-3/5.5.1(b)

x = ratio of the radius under consideration to D /2; 0.6 < x ≤0.9

5.5.1(d) Trailing edge thickness at 0.9 radius.

The edge thickness at 0.9 radius measured at 5% of chord length from the trailing edge is to be not less than 30% of the maximum blade thickness required by 4-3-3/5.5.1(c) above at that radius.

5.5.2 Propeller of Other Than Type 4 Materials with Skew Angle θ; where 25°< θ ≤ 50° **(2024)**

For propellers made of materials other than Type 4 and with skew angle 25° < θ ≤ 50°, design analyses as indicated in 4-3-3/5.7 are to be carried out and submitted for ABS technical assessment and approval.

5.5.3 Propeller Blades with Skew Angle θ > 50° **(2024)**

For propellers with the maximum skew angle exceeding 50°, design analyses as indicated in 4-3-3/5.7 are to be carried out and submitted for ABS technical assessment and approval.

5.7 Blades of Unusual Design **(2024)**

For propellers of unusual design, such as those indicated in 4-3-3/5.5.2 and 4-3-3/5.5.3, controllable pitch propeller of skewed design (θ > 25°), skewed propeller (θ > 25°) with wide-tip blades, cycloidal propellers, controllable pitch propellers with wide-tip blades, rim driven blades, etc., ABS technical assessment and approval are to be carried out based on submittal of propeller load and stress analyses. The analyses are to include, but be not limited to the following:

- Description of method to determine blade loading;
- Description of method selected for stress analysis;
- Ahead condition is to be based on propulsion machinery's maximum rating and full ahead speed;
- Astern condition is to be based on the maximum available astern power of the propulsion machinery as required in 4-1-1/7.**5** and is to include crash astern operation;
- Fatigue assessment;
- Allowable stress and fatigue criteria.

5.9 Blade-root Fillets

Fillets at the root of the blades are not to be considered in the determination of blade thickness.

5.10 Built-up Blades

The required blade section is not to be reduced in order to provide clearance for nuts. The face of the flange is to bear on that of the hub in all cases, but the clearance of the spigot in its counterbore or the edge of the flange in the recess is to be kept to a minimum.

5.11 Strengthening for Navigation in Ice **(2024)**

For vessels to be assigned with optional *Ice Class* notations, propellers are to be designed in accordance with Part 6, Chapter 1 for the applicable ice class.

5.13 Controllable Pitch Propellers - Pitch Actuation System

5.13.1 Blade Flange and Mechanisms

The strength of the propeller blade flange and pitch changing mechanism of controllable-pitch propellers subjected to the forces from propulsion torque is to be at least 1.5 times that of the blade at design pitch conditions.

5.13.2 Stud Bolt Area

The sectional area of the stud bolts at the bottom of the thread, *s*, is to be determined by the following equations:

	SI units	MKS units	US units
s	$\frac{0.056 W k f t_{0.35}^2}{r n}$ mm^2		$\frac{0.0018 W k f t_{0.35}^2}{r n}$ in^2
k	$\frac{621}{U + 207}$	$\frac{63.3}{U + 21.1}$	$\frac{90,000}{U + 30,000}$

where

s = area of one stud at bottom of thread

n = number of studs on driving side of blade

r = radius of pitch circle of the studs; mm (mm, in.)

k = material correction factor for stud materials better than ABS Gr. 2 forged steel

U = ultimate tensile strength of the stud material; N/mm^2 (kgf/mm^2, psi)

See 4-3-3/5.1 for f and 4-3-3/5.3 for W and $t_{0.35}$.

5.13.3 Blade Pitch Control

5.13.3(a) Bridge control

Where the navigation bridge is provided with direct control of propulsion machinery, it is to be fitted with means to control the pitch of the propeller.

5.13.3(b) Duplication of power unit **(2024)**

At least two hydraulic power pump units for the pitch actuating system are to be provided and arranged so that the transfer between pump units can be readily effected. For propulsion machinery spaces intended for unattended operation (optional *ACCU* or *ABCU* notation), automatic start of the standby pump unit is to be provided.

The emergency pitch actuating system [as required by 4-3-3/5.13.3(c).iii] is accepted as one of the required hydraulic power pump units, provided it is no less effective.

5.13.3(c) Emergency provisions

To safeguard the propulsion and maneuvering capability of the vessel in the event of any single failure in either the remote pitch control system or the pitch actuating system external to the propeller shaft and oil transfer device (also known as oil distribution box), the following are to be provided:

i. Manual control of pitch at or near the pitch-actuating control valve **(**usually the directional valve or similar).
ii. The pitch is to remain in the last ordered position until the emergency pitch actuating system is brought into operation.
iii. An emergency pitch actuating system. This system is to be independent of the normal system up to the oil transfer device, provided with its own oil reservoir and able to change the pitch from full ahead to full astern.
iv. Where at least two **(2)** independent propulsion systems are fitted on the vessel each one provided with its own pitch control system, and with one propulsion system temporarily out of service **(**until the emergency pitch control is connected), the vessel can manoeuver and maintain a speed of 7 knots or one-half of the design speed whichever is the lesser, the requirements as per 4-3-3/5.13.3**(**c).iii need not be applied, provided the system details are clearly indicated in the operating manuals.

5.13.3(d) Integral oil systems

Where the pitch actuating hydraulic system is integral with the reduction gear lubricating oil system and/or clutch hydraulic system, the piping is to be arranged such that any failure in the pitch actuating system does not leave the other system(s) non-operational.

5.13.3(e) Provisions for testing

Means are to be provided in the pitch actuating system to simulate system behavior in the event of loss of system pressure. Hydraulic pump units driven by main propulsion machinery are to be fitted with a suitable by-pass for this purpose.

5.13.3(f) Multiple propellers

For vessels fitted with more than one controllable pitch propeller, each of which is independent of the other, only one emergency pitch actuating system [as required by 4-3-3/5.13.3(c).iii] need be fitted, provided it is arranged such that it can be used to provide emergency pitch-changing for all propellers.

5.13.3(g) Hydraulic piping

Hydraulic piping is to meet the requirements of 4-6-7/3.

5.13.4 Instrumentation

All controllable pitch propeller systems are to be provided with instrumentation as provided below:

5.13.4(a) Pitch indicators.

A pitch indicator is to be fitted on the navigation bridge. In addition, each station capable of controlling the propeller pitch is to be fitted with a pitch indicator.

5.13.4(b) Monitoring. **(2024)**

Individual visual and audible alarms are to be provided at the engine room control station to indicate hydraulic oil low pressure and high temperature and hydraulic tank low level. A high hydraulic oil pressure alarm is to be fitted if required by the proposed system design and, if fitted, is to be set below the relief valve setting.

For vessels assigned with optional *ACC* or *ACCU* notations, see 4-9-2/15.3 TABLE 2 and 4-9-5/17 TABLE 1 for monitoring on the navigation bridge and in the centralized control station respectively.

5.15 Propeller Fitting

5.15.1 Keyed Fitting

For shape of the keyway in the shaft and size of the key, see 4-3-2/5.7, 4-3-2/1.3.5 FIGURE 2 and 4-3-2/5.11.

5.15.2 Keyless Fitting **(2024)**

5.15.2(a) Design criteria.

The factor of safety against slip of propeller hub on tail shaft taper at 35°C (95°F) is to be at least 2.8 under the action of maximum continuous ahead rated torque plus torque due to torsional vibrations. See Part 6, Chapter 1 for propellers requiring ice strengthening. For oil injection method of fit, the coefficient of friction is to be taken no greater than 0.13 for bronze/steel propeller hubs on steel shafts. The maximum equivalent uniaxial stress (von Mises-Hencky criteria) in the hub at 0°C (32°F) is not to exceed 70% of the minimum specified yield stress or 0.2% proof stress of the propeller material

Stress calculations and fitting instructions are to be submitted (see 4-3-3/1.5.4) and are to include at least the following:

- Theoretical contact surface area;
- The maximum permissible pull-up length at **0**°C (**3**2°F**)** as limited by the maximum permissible uniaxial stress specified above;
- The minimum pull-up length and contact pressure at **35**°C (9**5**°F**)** to attain a safety factor against slip of 2.8;
- The proposed pull-up length and contact pressure at fitting temperature
- The rated propeller ahead thrust.

5.15.2(b) Nomenclature.

The symbols used are defined as follows.

A = 100% of contact surface area between propeller hub and shaft taper (i.e, $A = \pi D_s L$); mm^2 (in^2). Oil grooves may be ignored. The propeller hub forward and aft counterbore lengths (ℓ_1 and ℓ_2 in 4-3-3/5.15.2 FIGURE 5) and the forward and aft inner edge radii (r_1 and r_2 in 4-3-3/5.15.2 FIGURE 5), if any, are to be excluded.

B = dimensionless constant based on $\mu, \theta,$ and S

c = coefficient, dependent on the type of propulsion drive: 1.0 for drives such as turbine, geared diesel, electric, and direct diesel with elastic coupling; and 1.2 for direct diesel drive. This value is to be increased for cases where extremely high pulsating torque is expected in service.

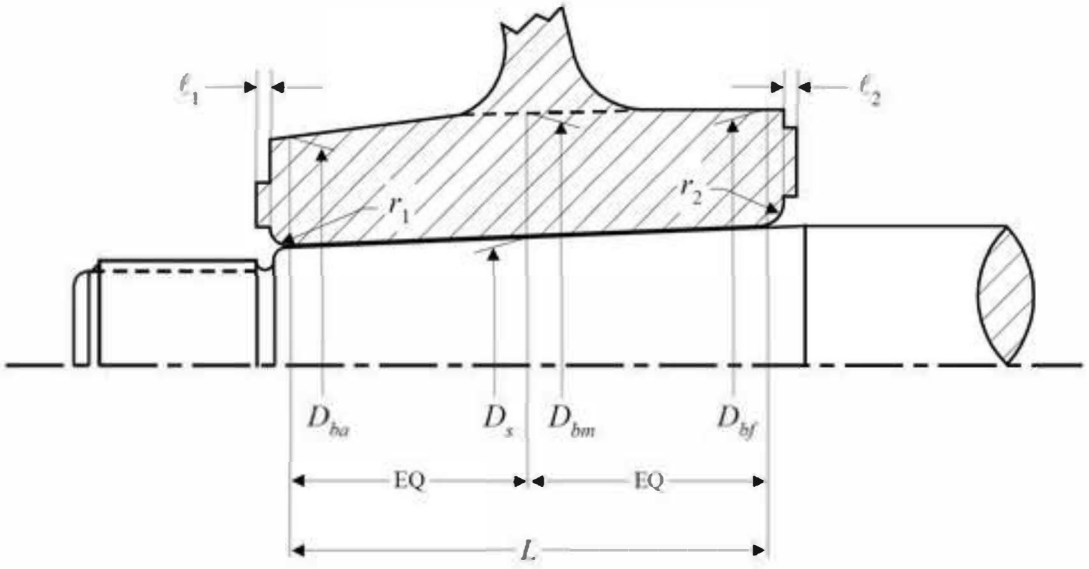
D_b = mean outer diameter of propeller hub corresponding to D_s ; mm (mm, in.) D_b is to be calculated as the mean of D_{bm} D_{bf} and D_{ba}, outer diameters of hub corresponding to D_s , the forward point of contact and the aft point of contact, respectively, see 4-3-3/5.15.2 FIGURE 5.

$$D_b = \frac{D_{ba} + D_{bm} + D_{bf}}{3}$$

D_{bm} = mean outer diameter of propeller boss, in mm (mm, in.), at the axial position corresponding to D_s , see 4-3-3/5.15.2 FIGURE 5.

D_s = diameter of shaft at mid-point of the taper in axial direction; mm (mm, in.), taking into account the exclusion of forward and aft counterbore length and the forward and aft edge radii, see 4-3-3/5.15.2 FIGURE 5.

FIGURE 5
Theoretical Contact Surface Between Hub and Shaft



E_b = modulus of elasticity of hub material, see 4-3-3/5.15.2 TABLE 2

E_s = modulus of elasticity of shaft material, see 4-3-3/5.15.2 TABLE 2

F_v = shear force at propeller/shaft interface; N (kgf, lbf)

H = power at rated speed; kW (PS, hp)

K = ratio of D_b to D_s, see 4-3-3/5.15.2 FIGURE 5.

L = contact length, in mm (in.), see 4-3-3/5.15.2 FIGURE 5

P = mean propeller pitch; mm, (mm, in.)

$P_{\min}$ = minimum required mating surface pressure at 35°C (95°F); N/mm^2 (kgf/mm^2, psi)

P_t = minimum required mating surface pressure at temperature *t*; N/mm^2 (kgf/mm^2, psi)

$P_{\max}$ = maximum permissible mating surface pressure at 0°C; N/mm^2 (kgf/mm^2, psi)

Q = rated torque corresponding to *H* and *R*; N-mm (kgf-mm, lbf-in.)

R = rpm at rated speed

S = factor of safety against slippage at 35°C (95°F)

T = rated propeller thrust; N (kgf, lbf)

t_{ref} = 35°C (95°F)

v = ship speed at rated power; knots (knots, knots)

α_b = coefficient of linear expansion of propeller hub material; mm/mm°C, (mm/mm°C, in./in.°F); see 4-3-3/5.15.2 TABLE 2

α_s = coefficient of linear expansion of shaft material; mm/mm°C (mm/mm°C, in./in.°F); see 4-3-3/5.15.2 TABLE 2 minimum

$\delta_{\min}$ = pull-up length at 35°C (95°F); mm (mm, in.)

δ_t = minimum pull-up length at temperature *t*; mm (mm, in.)

$\delta_{\max}$ = maximum permissible pull-up length at 0°C (32°F); mm (mm, in.)

θ = half taper of shaft; e.g. if taper =1/15, θ = 1/30

σ_y = yield stress or 0.2% proof stress of propeller material; N/mm^2 (kgf/mm^2, psi)

μ = coefficient of friction between mating surfaces; to be taken as 0.13 for fitting methods using oil injection and hubs of bronze of steel

v_b = Poisson's ration of hub material, see 4-3-3/5.15.2 TABLE 2

v_s = Poisson's ratio of shaft material, see 4-3-3/5.15.2 TABLE 2

TABLE 2
Material Constants

Material	Modulus of Elasticity			Poisson's Ratio	Coefficient of Expansion	
	N/mm^2	kgf/mm^2	psi		mm/mm°C	in./in.°F
Cast and forged steel	20.6×10^4	2.1×10^4	29.8×10^6	0.29	12.0×10^{-6}	6.67×10^{-6}
Bronzes, Types 2 & 3	10.8×10^4	1.1×10^4	15.6×10^6	0.33	17.5×10^{-6}	9.72×10^{-6}
Bronzes, Types 4 & 5	11.8×10^4	1.2×10^4	17.1×10^6	0.33	17.5×10^{-6}	9.72×10^{-6}

5.15.2(c) Equations.

The taper on the tail shaft cone is not to exceed 1/15. Although the equations given below are for ahead operation, they provide adequate safety margin for astern operation also.

The minimum mating surface pressure at 35°C (95°F), P_{min}, is to be:

$$P_{\min} = \frac{ST}{AB}\left[-S\theta + \sqrt{\mu^2 + B\left(\frac{F_v}{T}\right)^2}\right] \text{ N/mm}^2 \left(\text{kgf/mm}^2, \text{psi}\right)$$

The rated propeller thrust, T, submitted by the designer is to be used in these calculations. In the event that this is not submitted, one of the equations in 4-3-3/5.15.2 TABLE 3 may be used, subject to whichever that yields the larger value of $P_{\min}$.

TABLE 3
Estimated Propeller Thrust, T

SI units (N)	MKS units (kgf)	US units (lbf)
$1762\frac{H}{v}$ or $57.4\times10^6\cdot\frac{H}{PR}$	$132\frac{H}{v}$ or $4.3\times10^6\cdot\frac{H}{PR}$	$295\frac{H}{v}$ or $0.38\times10^6\cdot\frac{H}{PR}$

The shear force at interface, F_v, is given by

$$F_v = \frac{2cQ}{D_s}\,\text{N}\,(\text{kgf}, \text{lbf})\,;$$

Constant B is given by:

$$B = \mu^2 - S^2\theta^2$$

The corresponding (i.e. at 35°C (95°F)) minimum pull-up length, $\delta_{\min}$, is:

$$\delta_{\min} = P_{\min}\frac{D_s}{2\theta}\left[\frac{1}{E_b}\left(\frac{K^2+1}{K^2-1}+v_b\right)+\frac{1}{E_s}(1-V_s)\right]\text{mm (in.)};$$

$$K = \frac{D_b}{D_s}$$

The minimum pull-up length, δ_t, at temperature, *t*, where *t* < 35°C (95°F), is:

$$\delta_t = \delta_{\min} + \frac{D_s}{2\theta}(\alpha_b - \alpha_s)(t_{ref} - t)\text{ mm (in.)}$$

The corresponding minimum surface pressure, P_t, is:

$$P_t = P_{\min}\frac{\delta_t}{\delta_{\min}}\text{ N/mm}^2\left(\text{kgf/mm}^2, \text{psi}\right)$$

The maximum permissible mating surface pressure, $P_{\max}$, at 0°C (32°F) is:

$$P_{\max} = \frac{0.7\sigma_y\left(K^2-1\right)}{\sqrt{3K^4+1}}\text{ N/mm}^2\left(\text{kgf/mm}^2, \text{psi}\right)$$

and the corresponding maximum permissible pull-up length, $\delta_{\max}$, is:

$$\delta_{\max} = \frac{P_{\max}}{P_{\min}}\delta_{\min}\text{mm (in.)}$$

5.17 Retrofitting Existing Vessels with Propeller Boss Cap Fins **(2024)**

The influence from the change in propeller mass and polar moment of inertia due to the installation of the PBCF device is to be considered insofar as the effects on vessel's shaft alignment and vibration characteristics are concerned. An evaluation is to be conducted when there is a change of 4% or more in the propeller mass or in the polar moment of inertia of the propeller (including boss cap, hub, etc.) of a conventional propulsion shafting arrangement.

Commentary:

This criterion of "4% or more" may be revised on the basis of evaluating additional records /data on service experience and computational models/analyses to be made on similarly grouped type of applications (such as on size/type of vessel, power train, shafting arrangement, engine operating /critical speeds etc.).

End of Commentary

7 Certification

7.1 Material Tests

Propeller materials are to be tested in the presence of a Surveyor. See 4-3-3/3.5.

7.3 Inspection and Certification (2021)

Finished propellers are to be inspected and certified at the manufacturer's plant by a Surveyor. The blade forms, pitch, blade thickness, diameters, etc. are to be checked for conformance with approved plans. The entire surface of the finished propeller is to be examined visually and by liquid penetrant method. See 2-3-14/3.21 of the ABS *Rules for Materials and Welding (Part 2)*. All finished propellers are to be statically balanced in the presence of the Surveyor. As far as practicable, reference is to be made to the provisions of ISO 484 for these purposes. Also, please see Sections 2-3-14 and 2-3-15 of the ABS *Rules for Materials and Welding (Part 2)* for additional requirements for Survey.

The surfaces of stainless steel propellers are to be suitably protected from the corrosive effect of the industrial environment until fitted on the vessel. See 2-3-15/3 of the ABS *Rules for Materials and Welding (Part 2)*.

9 Installation, Tests and Trial

9.1 Keyed Propellers (2024)

The sides of the key are to have a true fit in the keyways of the propeller hub and the shaft. See also 4-3-2/5.11 for tail shaft propeller-end design.

The keyways in the hub and shaft are to be checked to confirm they are parallel to avoid any wedging action by the key when the propeller is driven up. The key is to fit snugly in both propeller and shaft so that there will be no possibility of play at either side of the key.

9.3 Controllable Pitch Propellers - Fit of Studs and Nuts

Studs, nuts and bolts are to have tight-fitting threads and are to be provided with effective means of locking. Effective sealing arrangements are to be provided in way of the bolt or stud holes against sea water ingress or oil leakage. Bolts, nuts and stud are to be of corrosion resistant materials or adequately protected from corrosion.

9.5 Protection Against Corrosion

The exposed steel of the shaft is to be protected from the action of the water by filling all spaces between cap, hub and shaft with a suitable material. The propeller assembly is to be sealed at the forward end with a well-fitted soft-rubber packing ring.

i. When the rubber ring is fitted in an external gland, the hub counterbore is to be filled with suitable material, and clearances between shaft liner and hub counterbore are to be kept to a minimum.
ii. When the rubber ring is fitted internally, ample clearance is to be provided between liner and hub. The rubber ring is to be sufficiently oversize to squeeze into the clearance space provided; and, where necessary, a filler piece is to be fitted in way of the propeller-hub keyway to provide a flat unbroken seating for the rubber ring.

The recess formed at the small end of the taper by the overhanging propeller hub is also to be packed with rust-preventive compound. See 4-3-2/5.13 for sealing requirements and 4-3-2/1.3.5 FIGURE 2 for typical arrangements.

9.6 Noncorrosive, Non-pitting Alloys

The sealing arrangements above are not required where the tail shaft is fabricated of corrosion-resistant, pitting-resistant alloy unless required by the manufacturer.

9.7 Circulating Currents

Where means are provided to prevent circulating currents from passing between the propeller, shaft and the hull, a warning notice plate is to be provided in a visible place cautioning against the removal of such protection.

9.9 Keyed and Keyless Propellers - Contact Area Check and Securing (2024)

The propeller hub to tail shaft taper contact area is to be checked in the presence of a Surveyor. A good fit of the propeller hub on the shaft taper is essential. There is to be a good uniform contact across the length of the taper. The actual contact area is to be not less than 70% of the theoretical contact area. Non-contact bands extending circumferentially around the propeller hub or over the full length of the hub are not acceptable. Installation is to be in accordance with the procedure referred to in 4-3-3/5.15.2(a) and final pull-up travel is to be recorded.

In the final assembly, the propeller is to be driven up beyond the mark at which an acceptable fit was obtained.

After final pull-up, propellers are to be secured by a nut and the nut is to be secured to the shaft against loosening. See also 4-3-2/5.11.

9.11 Controllable Pitch-Propellers - Hydraulic System (2025)

9.11.1 Hydrostatic Testing (2025)

The completed piping system of the controllable pitch propeller hydraulic system is to be hydrostatically tested at a pressure equal to 1.5 times the design pressure in the presence of a Surveyor. Relief-valve operation is to be verified.

9.11.2 Pitch Response Testing (2025)

A test procedure is to be prepared and proposed by the pitch control system manufacturer or integrator, and reviewed and witnessed to the satisfaction of the ABS Surveyor.

The following testing requirements of the control system of controllable pitch propellers apply to all new buildings and to all replacements, modifications, repairs, or re-adjustments that may affect the pitch control or response characteristics for main propulsion:

i. Pitch Response Testing:
A full range of tests is to be carried out to determine the pitch response and verify that it coincides with the combinator curve of the propeller*. The tests are to be carried out for at least three positions of the control lever in ahead and astern directions (e.g., dead slow ahead/astern, half ahead/astern, full ahead/astern).
Note:
* The combinator curve is the relationship between the propeller pitch setting and the propeller speed.
The tests are to be carried out in normal and emergency operating conditions.

ii. Tests that are not affected by the control position may be carried out from one control position only.

iii. Test of the fail-to-safe characteristics:
A test of the fail-to-safe characteristics of the propeller pitch control system is to be carried out to demonstrate that failures in the pitch command and control or feedback signals are alarmed and do not cause any change of thrust. Such failures are to be clearly identified and included in the test procedure.

iv. Parameters to be recorded:
The list of the parameters to be recorded during the pitch response test is to be established by the pitch control system manufacturer or integrator and agreed with ABS. This should include at least the following parameters:

- Position of the control handle
- Rotational speed of the propeller.
- Response time between the pitch change order (modification of the lever position) and the instant when the pitch and propeller speed have reached their final position.
- Propelling thrust variation during the transfer of the control from one location to another one.

v. Test resultsTests are to demonstrate:

- That the propelling thrust is not significantly altered when transferring control from one location to another and in case of failures in the pitch command and control or feedback signals.
- That the pitch response times measured during the test do not exceed the maximum value to be defined by the pitch control system manufacturer or integrator.

9.13 Sea Trial

The designed performance of the propeller at rated speed is to be demonstrated during sea trial. For controllable pitch propellers, the blade pitch control functions, from full ahead through full astern, are to be demonstrated. The emergency provisions in 4-3-3/5.13.3(c) are also to be demonstrated.

3 Propulsion, Maneuvering and Dynamic Positioning Systems

Self-propelled units and those receiving notations related to propulsion assist thrusters and athwartship thrusters are to be fitted to thrusters that comply with the following:

- Main propulsion thrusters Section 4-3-5 of the *Marine Vessel Rules*
- Waterjets Section 4-3-6 of the *Marine Vessel Rules*
- Podded Propulsors Section 4-3-8 of the *Marine Vessel Rules*
- Contra-Rotating Propellers Section 4-3-9 of the *Marine Vessel Rules*

Dynamic positioning systems, including their thrusters, are to comply with the ABS *Guide for Dynamic Positioning Systems*.