SECTION 3 STEERING GEAR

1 General

1.1 Application

1.1.1 Scope

Unless otherwise specified, the requirements of this Section apply to the design arrangements, control systems, construction and testing of installations intended for rudder operation, and to the steering mechanism of thrusters used as means of propulsion.

However, the Society may accept, in particular for yachts of less than 24 m in length, arrangements deemed equivalent, notably taking into account the national regulations in force or the provided service and navigation notations.

a) The attention of Owners, designers, builders and other interested parties is drawn to the necessity of considering requirements particular to the yacht's flag Authority

b) Provisions equivalent to the requirements of this section can be accepted, depending on the Society' s agreement.

1.1.2 Cross references

In addition to the those provided in this Section, steering gear systems are also to comply with the requirements of:

- Ch 1, Sec 10, as regards sea trials
- Pt B, Ch 10, Sec 2, as regards the rudder and the rudder stock.

1.2 Documentation to be submitted

1.2.1 Documents to be submitted for all steering gear

Before starting construction, all plans and specifications listed in Tab 1 are to be submitted to the Society for approval.

1.3 Definitions

1.3.1 Main steering gear

Main steering gear is the machinery, rudder actuators, steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the yacht under normal service conditions.

1.3.2 Steering gear power unit

Steering gear power unit is:

- in the case of electric steering gear, an electric motor and its associated electrical equipment
- in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump
- in the case of other hydraulic steering gear, a driving engine and connected pump.

1.3.3 Auxiliary steering gear

Auxiliary steering gear is the equipment other than any part of the main steering gear necessary to steer the yacht in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.3.4 Power actuating system

Power actuating system is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.

1.3.5 Rudder actuator

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

1.3.6 Steering gear control system

Steering gear control system is the equipment by which orders are transmitted from the navigation bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.3.7 Maximum ahead service speed

Maximum ahead service speed is the greatest speed which the yacht is designed to maintain in service at sea.

1.3.8 Maximum astern speed

Maximum astern speed is the speed which it is estimated the yacht can attain at the designed maximum astern power.

- failure analysis in relation to the availability of the hydraulic power supply, where required by [3.4.3], item b).

1.3.9 Maximum working pressure

Maximum working pressure is the maximum expected pressure in the system when the steering gear is operated to comply with the provisions of [3.3.1] item b).

Table 1 : Documents to be submitted for steering gear

Item N°	Status of the review **(2)**	Description of the document **(1)**
1	I	Assembly drawing of the steering gear including sliding blocks, guides, stops and other similar components
2	I	General description of the installation and of its functioning principle
3	I	Operating manuals of the steering gear and of its main components
4	I	Description of the operational modes intended for steering in normal and emergency conditions
5	A	For hydraulic steering gear, the schematic layout of the hydraulic piping of power actuating systems, including the hydraulic fluid refilling system, with indication of: • the design pressure • the maximum working pressure expected in service • the diameter, thickness, material specification and connection details of the pipes • the hydraulic fluid tank capacity • the flash point of the hydraulic fluid
6	I	For hydraulic pumps of power units, the assembly longitudinal and transverse sectional drawings and the characteristic curves
7	A	Assembly drawings of the rudder actuators and constructional drawings of their components, with, for hydraulic actuators, indication of: • the design torque • the maximum working pressure • the relief valve setting pressure
8	I	Constructional drawings of the relief valves for protection of the hydraulic actuators, with indication of: • the setting pressure • the relieving capacity
9	A	Diagrams of the electric power circuits
10	A	Functional diagram of control, monitoring and safety systems including the remote control from the navigating bridge, with indication of the location of control, monitoring and safety devices
11	A	Constructional drawings of the strength parts providing a mechanical transmission of forces to the rudder stock (tiller, quadrant, connecting rods and other similar items), with the calculation notes of the shrink-fit connections
12	I/A	For azimuth thrusters used as steering means, the specification and drawings of the steering mechanism and, where applicable, documents 2 to 6 and 8 to 11 above

(1) Constructional drawings are to be accompanied by the specification of the materials employed and, where applicable, by the welding details and welding procedures.

(2) Submission of the drawings may be requested:
for approval, shown as "A"; for information, shown as "I".

1.4 Symbols

1.4.1 The following symbols are used for strength criteria of steering gear components:

V_{AV} : Maximum service speed, in knots, as defined in Pt B, Ch 10, Sec 2

d_s : Rule diameter of the rudder stock in way of the tiller, in mm, defined in Pt B, Ch 10, Sec 2 and calculated with a material factor k = 1

d_{se} : Actual diameter of the upper part of the rudder stock in way of the tiller, in mm

(in the case of a tapered coupling, this diameter is measured at the base of the assembly)

T_R : Rule design torque of the rudder stock, in kN.m, calculated as defined in Pt B, Ch 10, Sec 2, [2.1.3] for ahead condition

T_E : For hand emergency operation, design torque due to forces induced by the rudder, in kN.m, given by the following formulae:

$$T_E = 0{,}62 \cdot \left(\frac{V_E + 2}{V_{AV} + 2}\right)^2 \cdot T_R$$

where:

- $V_E = 7$ where $V_{AV} \leq 14$
- $V_E = 0{,}5\ V_{AV}$ where $V_{AV} > 14$

T_G : For main hydraulic or electrohydraulic steering gear, torque induced by the main steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 1: for hand-operated main steering gear, the following value is to be used:

$T_G = 1{,}25.T_R$

T_A : For auxiliary hydraulic or electrohydraulic steering gears, torque induced by the auxiliary steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 2: for hand-operated auxiliary steering gear, the following value is to be used:

$T_A = 1,25.T_E$

T'_G : For steering gear which can activate the rudder with a reduced number of actuators, the value of T_G in such conditions

σ : Normal stress due to the bending moments and the tensile and compression forces, in N/mm^2

τ : Tangential stress due to the torsional moment and the shear forces, in N/mm^2

σ_a : Permissible stress, in N/mm^2

σ_c : Combined stress, determined by the following formula:

$$\sigma_c = \sqrt{\sigma^2 + 3\tau^2}$$

R_m : Value of the minimum guaranteed tensile strength of the material at ambient temperature, in N/mm^2

R'_m : Value of the minimum guaranteed tensile strength of the material in as-welded condition, in N/mm^2

$R_{p0,2}$: Value of the minimum guaranteed yield strength of the material at ambient temperature, in N/mm^2

$R'_{p0,2}$: Value of the minimum guaranteed yield strength of the material in as-welded condition, in N/mm^2

R_{eH} : Design yield strength, in N/mm^2, calculated as follow:

- For steel:
  - if $R_m \geq 1,4\ R_{p0,2}$ $R_{eH} = R_{p0,2}$
  - if $R_m < 1,4\ R_{p0,2}$ $R_{eH} = 0,417\ (R_{p0,2} + R_m)$
- For aluminium:
  - if $R'_{P0,2} \geq 0,7\ R'_m$ $R_{eH} = 0,7\ R'_m$
  - if $R'_{P0,2} < 0,7\ R'_m$ $R_{eH} = R'_{P0,2}$

2 Design and construction - Requirements applicable to all yachts

2.1 Mechanical components

2.1.1 General

a) All steering gear components and the rudder stock are to be of sound and reliable construction to the satisfaction of the Society

b) Any non-duplicated essential component is, where appropriate, to utilise anti-friction bearings, such as ball bearings, roller bearings or sleeve bearings, which are to be permanently lubricated or provided with lubrication fittings

c) The construction is to be such as to minimise local concentration of stress

d) All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

2.1.2 Materials and welds

a) All steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be made of steel or other approved ductile material complying with the requirements of the Rule Note NR216 Materials and Welding. In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2

b) The use of grey cast iron is not permitted, except for redundant parts with low stress level, subject to special consideration by the Society. It is not permitted for cylinders

c) The welding details and welding procedures are to be submitted for approval

d) All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

Table 2 : Scantling of components protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_G	• if $T_G \leq 1,25\ T_R$: $\sigma_a = 1,25\ \sigma_0$ • if $1,25\ T_R < T_G < 1,50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T_G \geq 1,50\ T_R$: $\sigma_a = 1,50\ \sigma_0$ where $\sigma_0 = 0,55\ R_{eH}$
Normal operation, with a reduced number of actuators	T'_G	• if $T'_G \leq 1,25\ T_R$: $\sigma_a = 1,25\ \sigma_0$ • if $1,25\ T_R < T'_G < 1,50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T'_G \geq 1,50\ T_R$: $\sigma_a = 1,50\ \sigma_0$ where $\sigma_0 = 0,55\ R_{eH}$
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and $0,8\ T_A$	$0,69\ R_{eH}$
Emergency operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,69\ R_{eH}$
Emergency operation achieved by hand	T_E	$0,69\ R_{eH}$

Table 3 : Scantling of components not protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_R	0,55 R_{eH}
Normal operation, with a reduced number of actuators	lower of T_R and 0,8 T'_G	0,55 R_{eH}
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and 0,8 T_A	0,69 R_{eH}
Emergency operation, with a reduced number of actuators	lower of T_R and 0,8 T'_G	0,69 R_{eH}
Emergency operation achieved by hand	T_E	0,69 R_{eH}

2.1.3 Scantling of components

The scantling of steering gear components is to be determined considering the design torque M_T and the permissible value σ_a of the combined stress, as given in:

- Tab 2 for components which are protected against overloads induced by the rudder
- Tab 3 for components which are not protected against overloads induced by the rudder.

2.1.4 Tillers, quadrants and rotors

a) The scantling of the tiller is to be determined as follows:

- the depth H_0 of the boss is not to be less than $0,75.d_s$
- torsional modulus of the boss of tiller is to be not less than the following formula:

$$w_T > \frac{M_T}{\tau_{am}} \cdot 10^3$$

where:

M_T : Applied torque, in kN.m, to be as the greatest value obtain from Tab 2 or Tab 3, as applicable

τ_{am} : Allowable shear stress, in N/mm², of the material constituting the boss of the tiller. Allowable shear stress, in N/mm², are to be taken as:

- 70 / k for steel
- 30 / k for aluminium

with k defined in Pt B, Ch 10, Sec 2, [1.4]

w_T : Torsional modulus, in cm³, of the tiller boss

- Combinaitions of stresses induced by force due to torque in the tiller arm in way of the end fixed to the boss is to in accordance with the following formulae:

$$\sigma_{VMam} \geq \sqrt{\sigma_B^{\,2} + 3\tau_B^{\,2}}$$

where:

σ_{VMam} : Von Mises stress, in N/mm², to be taken as:

- 170/k for steel
- 74/k for aluminium

σ_B : Bending stress, in N/mm², induced by force due to torque M_T to be calculated as follow:

$$\sigma_b = \frac{M_T}{L} \cdot \frac{L'}{w_B} \cdot 10^3$$

and:

$\sigma_B \leq \sigma_{am}$

σ_{am} : Allowable stress, in N/mm², of the material constituting the boss of the tiller. Allowable shear stress, in N/mm² are to be taken as:

- 120/k for steel
- 52/k for aluminium

with k defined in Pt B, Ch 10, Sec 2, [1.4]

τ_B : Shear stress, in N/mm², induced by force due to torque M_T to be calculated as follows:

$$\tau_b = \frac{M_T}{L} \cdot \frac{10^2}{A_{SH1}}$$

and

$\tau_B \leq \tau_{am}$

τ_{am} : Allowable shear stress, in N/mm², of the material constituting the boss of the tiller. Allowable shear stress, in N/mm², are to be taken as:

- 70 / k for steel
- 30 / k for aluminium,

with k defined in Pt B, Ch 10, Sec 2, [1.4]

M_T : Applied torque, in kN.m, to be as the greatest value obtain from Tab 2 or Tab 3, as applicable

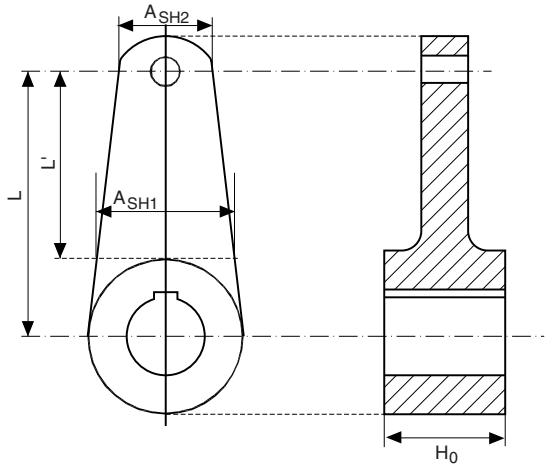
L : Distance, in mm, from the centreline of the rudder stock to the point of application of the load on the tiller (see Fig 1)

L′ : Distance, in mm, between the point of application of the above load and the root section of the tiller arm under consideration (see Fig 1)

w_B : Section modulus of the tiller, in cm³, of the section in way of the end fixed to the boss

A_{SH1} : Shear root section of the tiller arm, in cm², (see Fig 1).

Figure 1 : Tiller arm



- the shear section of the tiller arm in way of the point of application of the load is to be in accordance with the following formula:

$$\tau_{am} \geq \frac{M_T}{L \cdot A_{SH2}} \cdot 10^2$$

where:

M_T : Applied torque, in kN.m, to be as the greatest value obtain from Tab 2 or Tab 3, as applicable

L : Distance, in mm, from the centreline of the rudder stock to the point of application of the load on the tiller (see Fig 1)

A_{SH2} : Shear section of the tiller, in cm², of the section in way of the point of application of the load (see Fig 1).

τ_{am} : Allowable shear stress, in N/mm², of the material constituting the boss of the tiller. Allowable shear stress, in N/mm², are to be taken as:

- 70/k for steel
- 30/k for aluminium

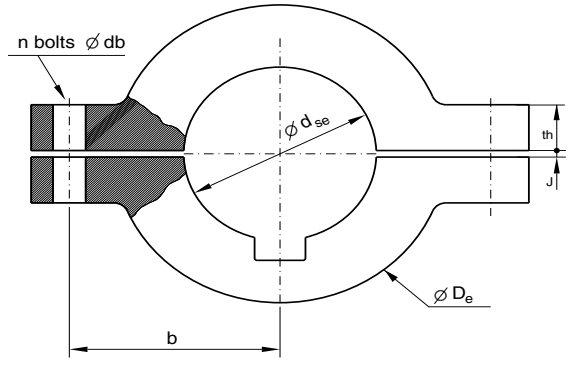
with k defined in Pt B, Ch 10, Sec 2, [1.4]

- in the case of double arm tillers, the section modulus of each arm is not to be less than one half of the section modulus required by the above formula.

b) The scantling of the quadrants is to be determined as specified in a) for the tillers. When quadrants having two or three arms are provided, the section modulus of each arm is not to be less than one half or one third, respectively, of the section modulus required for the tiller

Arms of loose quadrants not keyed to the rudder stock may be of reduced dimensions to the satisfaction of the Society, and the depth of the boss may be reduced by 10 per cent

Figure 2 : Bolted tillers



c) Keys are to satisfy the following provisions:

- Tiller fitted with keys are to in metallic material
- the key is to be in accordance with requirements of Pt B, Ch 10, Sec 2, [10.3]
- the width of the key is not to be less than $0,25.d_s$
- the thickness of the key is not to be less than $0,10.d_s$
- the ends of the keyways in the rudder stock and in the tiller (or rotor) are to be rounded and the keyway root fillets are to be provided with small radii of not less than 5 per cent of the key thickness

d) Bolted tillers and quadrants are to satisfy the following provisions:

- For arrangement such as shown in Fig 2, the diameter of bolts is not to be less than the value d_b, in mm, calculated from the following formula:

$$d_b = 153 \sqrt{\frac{T_R}{n(b + 0,5 d_{se})} \cdot \frac{235}{R_{eb}}}$$

where:

n : Number of bolts located on the same side in respect of the stock axis (n is not to be less than 2)

b : Distance between bolts and stock axis, in mm (see Fig 2)

R_{eb} : Yield stress, in N/mm², of the bolt material

- For other arrangement, direct calculations are to be made to check the following stresses in bolts:
  - tensile stresses in N/mm² to be less than the allowable tensile stress of bolts material
  - shear stresses in N/mm² to be less than the allowable shear stress of bolt material
- the thickness of each of the tightening flanges of the two parts of the tiller is not to be less than the following value:

$$1,85 \cdot d_b \cdot \sqrt{\frac{n \cdot (b - 0,5 \cdot D_e)}{H_0} \cdot \frac{R_{eb}}{R_{eH}}}$$

where:

D_e : External boss diameter, in mm (average value)

R_{eH} : As defined in [1.4.1]

- in order to ensure the efficient tightening of the coupling around the stock, the two parts of the tiller are to bored together with a shim having a thickness not less than the value j, in mm, calculated from the following formula:

  $j = 0,0015\ d_{se}$

  where:

  d_{se} : Actual diameter, in mm, of the upper part of the rudder stock in way of the tiller

  Special examination for the fitting of such tiller system on hollow section rudder stock is to be carried out

- For such system fitted on composite rudder stocks, examination is to be made by the Society on case by case basis with direct calculation on all component of the system

  As a rule tiller of this type does not required a key they are generally fitted in way of plane area on the rudder stock, coupling is made by the shape of tiller and rudder stock

e) Shrink-fit connections of tiller (or rotor) to stock are to satisfy the following provisions:

- Materials of rudder stock and tiller are to be made of respectively steel and steel or SG cast iron, other material may be accepted by the Society on case by case basis
- the safety factor against slippage is not to be less than:
  - 1 for keyed connections
  - 2 for keyless connections
- the friction coefficient is to be taken equal to:
  - 0,15 for steel and 0,13 for spheroidal graphite cast iron, in the case of hydraulic fit
  - 0,17 in the case of dry shrink fitting
- the combined stress according to the von Mises criterion, due to the maximum pressure induced by the shrink fitting and calculated in way of the most stressed points of the shrunk parts, is not to exceed 80 per cent of the yield stress of the material considered

Note 1: Alternative stress values based on FEM calculations may also be considered by the Society.

- the entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

2.1.5 Piston rods

The scantling of the piston rod is to be determined taking into account the bending moments, if any, in addition to compressive or traction forces and is to satisfy the following provisions:

a) $\sigma_c \leq \sigma_a$

where:

σ_c : Combined stress as per [1.4.1]

σ_a : Permissible stress as per [2.1.3]

b) in respect of the buckling strength:

$$\frac{4}{\pi D_2^2} \cdot \left(\omega F_c + \frac{8M}{D_2}\right) \leq 0,9\sigma_a$$

where:

D_2 : Piston rod diameter, in mm

F_c : Compression force in the rod, in N, when it extends to its maximum stroke

M : Possible bending moment in the piston rod, in N.mm, in way of the fore end of the cylinder rod bearing

ω : $\omega = \beta + (\beta^2 - \alpha)^{0,5}$

with:

$\alpha = 0,0072\ (\ell_s/D_2)^2\ .\ R'_e/235$

$\beta = 0,48 + 0,5\ \alpha + 0,1\ \alpha^{0,5}$

ℓ_s = Length, in mm, of the maximum unsupported reach of the cylinder rod.

2.2 Hydraulic system

2.2.1 General

a) The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure is to be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified in [3], taking into account any pressure which may exist in the low pressure side of the system

b) The power piping for hydraulic steering gear is to be arranged so that transfer between units can be readily effected

c) Arrangements for bleeding air from the hydraulic system are to be provided, where necessary

d) The hydraulic piping system, including joints, valves, flanges and other fittings, is to comply with the requirements of Ch 1, Sec 10 for class I piping systems, and in particular with the requirements of Ch 1, Sec 9, [4], unless otherwise stated.

2.2.2 Materials

a) Ram cylinders, pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings are to be of steel or other approved ductile material

b) In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2

Grey cast iron may be accepted for valve bodies and redundant parts with low stress level, excluding cylinders, subject to special consideration.

2.2.3 Isolating valves

Shut-off valves, non-return valves or other appropriate devices are to be provided:

- to comply with the availability requirements of [3.4]
- to keep the rudder steady in position in case of emergency.

In particular, for all yachts with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

2.2.4 Flexible hoses

a) Flexible hoses may be installed between two points where flexibility is required but are not to be subjected to torsional deflexion (twisting) under normal operation. In general, the hose is to be limited to the length necessary to provide for flexibility and for proper operation of machinery

b) Hoses are to be high pressure hydraulic hoses according to recognised standards and suitable for the fluids, pressures, temperatures and ambient conditions in question

c) They are to be of a type approved by the Society

d) The burst pressure of hoses is to be not less than four times the design pressure.

2.2.5 Relief valves

a) Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure

b) The setting pressure of the relief valves is not to be less than 1,25 times the maximum working pressure

c) The minimum discharge capacity of the relief valve(s) is not to be less than the total capacity of the pumps which can deliver through it (them), increased by 10%. Under such conditions, the rise in pressure is not to exceed 10% of the setting pressure. In this respect, due consideration is to be given to the foreseen extreme ambient conditions in relation to oil viscosity.

2.2.6 Hydraulic oil reservoirs

Hydraulic power-operated steering gear is to be provided with the following:

- a low level alarm for each hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Audible and visual alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed
- where the main steering gear is required to be power operated, a storage mean, as a readily accessible drum, having sufficient capacity to recharge at least one power actuating system if necessary.

2.2.7 Hydraulic pumps

Hydraulic pumps are to be type tested in accordance with the provisions of [7.1.1].

2.2.8 Filters

a) Hydraulic power-operated steering gear are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system

b) Filters of appropriate mesh fineness are to be provided in the piping system, in particular to ensure the protection of the pumps.

2.2.9 Accumulators

a) Accumulators, if fitted, are to be designed in accordance with Ch 1, Sec 9, [4.5.3]

b) The hydraulic side of the accumulators which can be isolated is to be provided with a relief valve or another device offering equivalent protection in case of overpressure.

2.2.10 Rudder actuators

a) Rudder actuators are to be designed in accordance with the relevant requirements of Part C, Chapter 1, Section 3 of the Rules for Steel Ships for class 1 pressure vessels also considering the following provisions

b) Minimum thickness e, in mm, of the cylindrical housings of the actuator is to be determined by the following formula:

$$e = \frac{p \cdot D_i}{2f - p} + 0,75$$

where:

p : Calculation pressure equal to the greatest of the following values (in MPa):
- 1.25 time the maximum working pressure
- the setting pressure of the relief valves

D_i : Internal diameter of housing, in mm,

f : The lowest of Yield stress, in N/mm^2

$$\frac{R}{2,7} \quad \text{or} \quad \frac{R_e}{2,8}$$

c) The minimum thickness e, in mm, of the circular flat bottom plates is to be determined by the following formula:

$$e = 0,5 D_i \sqrt{\frac{p}{f}} + 0,75$$

where the notations are identical to the above

d) Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal or equivalent type

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

f) The strength and connection of the cylinder heads (or, in the case of actuators of the rotary type, the fixed vanes) acting as rudder stops are to comply with the provisions of [6.3.1].

2.3 Electrical systems

2.3.1 General design

The electrical systems of the main steering gear and the auxiliary steering gear are to be so arranged that the failure of one will not render the other inoperative.

2.3.2 Power circuit supply

a) Electric or electrohydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuits fed directly from the main switchboard; however, one of the circuits may be supplied through the emergency switchboard

b) Auxiliary electric or electrohydraulic steering gear, associated with main electric or electrohydraulic steering gear, may be connected to one of the circuits supplying the main steering gear

c) The circuits supplying electric or electrohydraulic steering gear are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

2.3.3 Motors and associated control gear

a) To determine the required characteristics of the electric motors for power units, the breakaway torque and maximum working torque of the steering gear under all operating conditions are to be considered. The ratio of pull-out torque to rated torque is to be at least 1,6

b) Motors for steering gear power units may be rated for intermittent power demand

The rating is to be determined on the basis of the steering gear characteristics of the yacht in question; the rating is always to be at least:

- S3 - 40% for motors of electric steering gear power units
- S6 - 25% for motors of electrohydraulic steering gear power units and for convertors

c) Each electric motor of a main or auxiliary steering gear power unit is to be provided with its own separate motor starter gear, located within the steering gear compartment.

2.3.4 Supply of motor control circuits and steering gear control systems

a) Each control for starting and stopping of motors for power units is to be served by its own control circuits supplied from its respective power circuits

b) Any electrical main and auxiliary steering gear control system operable from the navigating bridge is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit. The power supply systems are to be protected selectively.

2.3.5 Circuit protection

a) Short-circuit protection is to be provided for each control circuit and each power circuit of electric or electrohydraulic main and auxiliary steering gear

b) No protection other than short-circuit protection is to be provided for steering gear control system supply circuits

c) Protection against excess current (e.g. by thermal relays), including starting current, if provided for power circuits, is to be for not less than twice the full load current of the motor or circuit so protected, and is to be arranged to permit the passage of the appropriate starting currents

d) Steering gear motor circuits obtaining their power supply via an electronic converter, e.g. for speed control, and which are limited to full load current are exempt from the requirement to provide protection against excess current, including starting current, of not less than twice the full load current of the motor. The required overload alarm is to be set to a value not greater than the normal load of the electronic converter

Note 1: "Normal load" is the load in normal mode of operation that approximates as close as possible to the most severe conditions of normal use in accordance with the manufacturer's operating instructions.

e) Where fuses are fitted, their current ratings are to be two step higher than the rated current of the motors. However, in the case of intermittent service motors, the fuse rating is not to exceed 160% of the rated motor current

f) The instantaneous short-circuit trip of circuit breakers is to be set to a value not greater than 15 times the rated current of the drive motor

g) The protection of control circuits is to correspond to at least twice the maximum rated current of the circuit, though not, if possible, below 6 A.

2.3.6 Starting and stopping of motors for steering gear power units

a) Motors for power units are to be capable of being started and stopped from a position on the navigation bridge and from a point within the steering gear compartment

b) Means are to be provided at the position of motor starters for isolating any remote control starting and stopping devices (e.g. by removal of the fuse-links or switching off the automatic circuit breakers)

c) Main and auxiliary steering gear power units are to be arranged to restart automatically when power is restored after a power failure.

2.3.7 Separation

a) Where duplicated electric power circuits or steering gear control system are provided, they are to be separated as far as practicable

b) In the case of double follow-up control, the amplifier is to be designed and fed so as to be electrically and mechanically separated. In the case of non-follow-up control and follow-up control, it is to be ensured that the follow-up amplifier is protected selectively

c) Control circuits for additional control systems, e.g. steering lever or autopilot, are to be designed for all-pole disconnection

d) The feedback units and limit switches, if any, for the steering gear control systems are to be separated electrically and mechanically connected to the rudder stock or actuator separately.

2.4 Control, monitoring and alarm systems

2.4.1 Displays and alarms

Displays and alarms are to be provided in the locations indicated in Tab 4.

Table 4 : Location of displays and alarms

Item	Display	Alarms (audible and visible)	Location	
			Navigation Bridge	Steering gear compartment
Indication that electric motor of each power unit is running	X		X	X
Power failure of each power unit		X	G	X
Overload of electric motor of each power unit		X	G	X
Phase failure of electric motor of each power unit **(1)**		X	G	X
Low level of each hydraulic fluid reservoir		X	G	X
Hydraulic lock		X	G	X
Power failure of each control system		X	X	
Rudder angle indicator	X		X	X
(1) Where three-phase supply is used	G: Group alarm			

2.4.2 Remote control system

When steering gear is fitted with a remote control, arrangements is to be made for emergency steering in the event of failure of such control.

2.4.3 Rudder angle indication

The angular position of the rudder is to be indicated on the navigating bridge, if the main steering gear is power operated. The rudder angle indication is to be independent of the steering gear control system and be supplied through the emergency switchboard, or by an alternative and independent source of electrical power.

3 Design and construction

3.1 General provisions

3.1.1 Unless expressly provided otherwise, every yacht is to be provided with main steering gear and auxiliary steering gear to the satisfaction of the Society.

3.2 Strength, performance and power operation of the steering gear

3.2.1 Main steering gear

The main steering gear and rudder stock are to be:

a) of adequate strength and capable of steering the yacht at maximum ahead service speed, which is to be demonstrated

b) capable of putting the rudder over from 35° on one side to 35° on the other side with the yacht at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 s

c) operated by power where necessary to fulfil the requirements of b), and

d) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

3.2.2 Auxiliary steering gear

The auxiliary steering gear is to be:

a) of adequate strength and sufficient to steer the yacht at navigable speed and capable of being brought speedily into action in an emergency

b) capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60s with the yacht at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater, and

c) operated by power where necessary to meet the requirements of b).

3.2.3 Hand operation

As a rule, operation of hand operated steering gears should not require an effort exceeding 160 N under normal conditions.

3.3 Control of the steering gear

3.3.1 Control of the main steering gear

a) Control of the main steering gear is to be provided on the navigation bridge

b) Where the main steering gear is arranged in accordance with [3.4.2], two independent control systems are to be provided, both operable from the navigation bridge. This does not require duplication of the steering wheel or steering lever.

3.3.2 Control of the auxiliary steering gear

a) Control of the auxiliary steering gear is to be provided on the navigation bridge, in the steering gear compartment or in another suitable position

b) If the auxiliary steering gear is power operated, its control system is also to be independent of that of the main steering gear.

3.4 Availability

3.4.1 Arrangement of main and auxiliary means for actuating the rudder

The main steering gear and the auxiliary means for actuating the rudder are to be arranged so that a single failure in one will not render the other inoperative.

3.4.2 Omission of the auxiliary steering gear

Where the main steering gear comprises two or more identical power units, auxiliary steering gear need not be fitted, provided that the main steering gear is capable of operating the rudder:

a) as required in [3.2.1], item b), while operating with all power units

b) as required in [3.2.2], item b), while any one of the power units is out of operation.

3.4.3 Hydraulic power supply

Hydraulic power installations supplying steering gear may also supply other equipment at the same time provided that the operation of the steering gear is not affected:

a) by the operation of this equipment, or

b) by any failure of this equipment or of its hydraulic supply piping.

4 Design and construction - Requirements for yachts equipped with several rudders

4.1 Principle

4.1.1 General

In addition to the provisions of [2] and [3], as applicable, yachts equipped with two or more aft rudders are to comply with the provisions of the present Article.

4.1.2 Availability

Where the yacht is fitted with two or more rudders, each having its own actuation system, the latter need not be duplicated.

4.1.3 Equivalent rudder stock diameter

Where the rudders are served by a common actuating system, the diameter of the rudder stock referred to in [3.2.1] is to be replaced by the equivalent diameter d obtained from the following formula:

$$d = \sqrt[3]{\sum_j d_j^3}$$

with:

d_j : Rule diameter of the upper part of the rudder stock of each rudder in way of the tiller.

4.2 Synchronisation

4.2.1 General

Where the yacht has several rudders, a system for synchronising the movement of both rudders is to be fitted, either:

- by a mechanical coupling, or
- by other systems giving automatic synchronising adjustment.

4.2.2 Non-mechanical synchronisation

Where the synchronisation of the rudder motion is not achieved by a mechanical coupling, the following provisions are to be met:

a) the angular position of each rudder is to be indicated on the navigation bridge

b) the rudder angle indicators are to be independent from each other and, in particular, from the synchronising system

c) in case of failure of the synchronising system, means are to be provided for disconnecting this system so that steering capability can be maintained or rapidly regained.

5 Design and construction - Requirements for yachts equipped with thrusters as steering means

5.1 Principle

5.1.1 General

The main and auxiliary steering gear referred to in [3] may consist of thrusters of the following types:

- azimuth thrusters
- water-jets
- cycloidal propellers

complying with the provisions of Part C, Ch 1, Sec 12 as far as applicable of the Rules for Steel Ships.

5.1.2 Actuation system

Thrusters used as steering means are to be fitted with a main actuation system and an auxiliary actuation system.

5.1.3 Control system

Where the steering means of the yacht consists of two or more thrusters, their control system is to include a device ensuring an automatic synchronisation of the thruster rotation, unless each thruster is so designed as to withstand any additional forces resulting from the thrust exerted by the other thrusters.

5.2 Use of azimuth thrusters

5.2.1 Azimuth thrusters used as sole steering means

Where the yacht is fitted with one azimuth thruster used as the sole steering means, this thruster is to comply with [3.3.1] or [3.2.1], as applicable, except that:

a) the main actuation system is required to be capable of a rotational speed of at least 0,4 RPM and to be operated by power where the expected steering torque exceeds 1,5 kN·m

b) the auxiliary actuation system is required to be capable of a rotational speed of at least 0,1 RPM and to be operated by power where the expected steering torque exceeds 3 kN·m.

5.2.2 Azimuth thrusters used as auxiliary steering gear

Where the auxiliary steering gear referred to in [3.3.1] or [3.1.1] consists of one or more azimuth thrusters, at least one such thruster is to capable of:

- steering the yacht at maximum ahead service speed
- being brought speedily into action in case of emergency
- a rotational speed of at least 0,4 RPM.

The auxiliary actuation system referred to in [5.1.2] need not be fitted.

5.2.3 Omission of the auxiliary actuation system

Where the steering means of the yacht consists of two independent azimuth thrusters or more, the auxiliary actuation system referred to in [5.1.2] need not be fitted provided that:

- the thrusters are so designed that the yacht can be steered with any one out of operation
- the actuation system of each thruster complies with [5.2.1], item b).

5.3 Use of water-jets

5.3.1 The use of water-jets as steering means are to be given special consideration by the Society.

6 Arrangement and installation

6.1 Steering gear room arrangement

6.1.1 The steering gear compartment is to be:

a) readily accessible and, as far as practicable, separated from machinery spaces, and

b) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

6.2 Rudder actuator installation

6.2.1 Rudder actuators are to be installed on foundations of strong construction so designed as to allow the transmission to the yacht structure of the forces resulting from the torque applied by the rudder and/or by the actuator, considering the strength criteria defined in [2.1.3] and [6.3.1]. The structure of the yacht in way of the foundations is to be suitably strengthened.

Where the rudder actuators are bolted to the hull, the grade of the bolts used is not to be less than 8.8. Unless the bolts are adjusted and fitted with a controlled tightening, strong shocks are to be fitted in order to prevent any lateral displacement of the rudder actuator.

The fixation of actuators on yacht's structure built in composite materials is to be designed to prevent their loss.

6.3 Overload protections

6.3.1 Mechanical rudder stops

a) The steering gear is to be provided with strong rudder stops capable of mechanically stopping the rotation of the rudder at an angle slightly greater than its maximum working angle. Alternatively, these stops may be fitted on the yacht to act on another point of the mechanical transmission system between the rudder actuator and the rudder blade. These stops may be built in with the actuator design

b) The scantlings of the rudder stops and of the components transmitting to the yacht's structure the forces applied on these stops are to be determined for the greater value of the torques T_R or T_G (where T_R and T_G are defined in [1.4.1]

Where $T_G \geq 1,5T_R$, the rudder stops are to be fitted between the rudder actuator and the rudder stock, unless the rudder stock as well as all the components transmitting mechanical forces between the rudder actuator and the rudder blade are suitably strengthened.

6.3.2 Rudder angle limiters

a) Power-operated steering gear is to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear itself and not with the steering gear control

b) For power-operated steering gears and where the rudder may be oriented to more than 35° at very reduced speed, it is recommended to fit a limit system 35° for full speed. A notice is to be displayed at all steering wheel stations indicating that rudder angles of more than 35° are to be used only at very reduced speed.

6.3.3 Relief valves

Relief valves are to be fitted in accordance with [2.2.5].

6.3.4 Buffers

Buffers are to be provided on all yachts fitted with mechanical steering gear. They may be omitted on hydraulic gear equipped with relief valves or with calibrated bypasses.

6.4 Means of communication

6.4.1 When applicable, a means of communication is to be provided between the navigation bridge and the steering gear compartment.

If electrical, it is to be fed through the emergency switchboard or to be sound powered.

6.5 Operating instructions

6.5.1 For steering gear comprising two identical power units intended for simultaneous operation, both normally provided with their own (partly or mutually) separate control systems, the following standard notice is either to be placed on a signboard fitted at a suitable place on the steering control post on the bridge or incorporated into the operation manual:

CAUTION

IN SOME CIRCUMSTANCES WHEN 2 POWER UNITS ARE RUNNING SIMULTANEOUSLY, THE RUDDER MAY NOT RESPOND TO THE HELM. IF THIS HAPPENS STOP EACH PUMP IN TURN UNTIL CONTROL IS REGAINED.

7 Certification, inspection and testing

7.1 Type tests of hydraulic pumps

7.1.1 Each type of power unit pump is to be subjected in the workshop to a type test of not less than 100 hours' duration.

The test arrangements are to be such that the pump may run both:

- in idling conditions, and
- at maximum delivery capacity at maximum working pressure.

During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board.

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

After the test, the pump is to be disassembled and inspected.

Note 1: Type tests may be waived for a power unit which has been proven to be reliable in marine service.

7.2 Testing of materials

7.2.1 Components subject to pressure or transmitting mechanical forces

a) Materials of components subject to pressure or transmitting mechanical forces, specifically:
   - cylindrical shells of hydraulic cylinders, rams and piston rods
   - tillers, quadrants
   - rotors and rotor housings for rotary vane steering gear
   - hydraulic pump casings
   - and hydraulic accumulators, if any

   are to be duly tested, including examination for internal defects, in accordance with the requirements of the Rule Note NR216 Materials and Welding

b) A works' certificate may be accepted for low stressed parts, provided that all characteristics for which verification is required are guaranteed by such certificate.

7.2.2 Hydraulic piping, valves and accessories

Tests for materials of hydraulic piping, valves and accessories are to comply with the provisions of Ch 1, Sec 4, [10.3].

7.3 Inspection and tests during manufacturing

7.3.1 Components subject to pressure or transmitting mechanical forces

The mechanical components referred to in [7.2.1] are to be subjected to appropriate non-destructive tests. For hydraulic cylinder shells, pump casings and accumulators, refer to Part C, Chapter 1, Section 3 of the Rules for Steel Ships.

Defects may be repaired by welding only on forged parts or steel castings of weldable quality. Such repairs are to be conducted under the supervision of the Surveyor in accordance with the applicable requirements of the Rule Note NR216 Materials and Welding.

7.3.2 Hydraulic piping, valves and accessories

Hydraulic piping, valves and accessories are to be inspected and tested during manufacturing in accordance with Ch 1, Sec 4, [10], for a class I piping system.

7.4 Inspection and tests after completion

7.4.1 Hydrostatic tests

Hydraulic cylinder shells and accumulators are to be subjected to hydrostatic tests according to the relevant provisions of Part C, Chapter 1, Section 3 of the Rules for Steel Ships

Hydraulic piping, valves and accessories and hydraulic pumps are to be subjected to hydrostatic tests according to the relevant provisions of Ch 1, Sec 4, [10.4].

7.4.2 Shipboard tests

After installation on board the yacht, the steering gear is to be subjected to the tests detailed in Ch 1, Sec 10, [3.8].

7.4.3 Sea trials

For the requirements of sea trials, refer to Ch 1, Sec 10.