SECTION 2 PROPELLING AND AUXILIARY MACHINERY

1 General Provisions

1.1 Scope

1.1.1 Application

The following requirements apply to main propulsion and auxiliary machinery for shafts.

1.1.2 Astern power

Any yacht, whose engine is capable of developing a shaft power at the propeller of 5 kW or more is to be provided with astern power adequate for manoeuvrability.

1.1.3 Operating conditions

a) On motor driven yachts, the propulsive engine and all auxiliary equipment must retain their ability to operate satisfactorily in the operating conditions described in Ch 1, Sec 1, [2.4]

b) On sailing yachts, auxiliary engines must operate satisfactorily when and after being heeled to a larger angle, (30°) even for a long time.

1.2 Documents to be submitted

1.2.1 The documents and drawings detailed hereafter are to be submitted to the Society:

- general arrangement showing engines position and seating
- assembly drawing of the reduction gear and detailed drawings of pinions, wheels, coupling and casing indicating the material specificion
- longitudinal section showing stern-tube line of shaft bearing and shaft brackets
- shaftings: general dispositions and details
- propellers
- diagrammatic arrangement of fuel, lubricating, cooling, air, starting, exhaust systems, etc. (see Ch 1, Sec 4 to Ch 1, Sec 9).

1.3 Sea trials

1.3.1 Trials conditions

For trials mentioned in Ch 1, Sec 10, the yacht must be in the completed condition with permanently installed engine(s) - where applicable - and all usual equipment in place. The tests are to be carried out under weather and sea conditions corresponding as far as possible to the conditions for which the yacht is intended to operate, when fitted with an engine of the largest power for which it has been approved and in light weight and fully loaded condition.

1.3.2 Trials contents

The trials are to include evaluation of:

- starting, stopping, reversing characteristics
- turning, maximum speed capabilities
- course stabilities at low and at maximum speed with small rudder and full rudder angles to each side are to be demonstrated to the Surveyor's satisfaction

2 Internal combustion engines

2.1 General

2.1.1 Type approval

The internal combustion engines are to be of a type approved by the Society for marine use having due regard to their intended purpose.

2.1.2 Application

The following requirements apply to internal combustion engines.

2.1.3 Additional requirements

It is reminded that, additionally to the following requirements, internal combustion engines listed below are to be designed, constructed, installed, tested and certified in accordance with the relevant requirement of the Rules for Steel Ship Part C, Chapter 1, Section 2.

- main propulsion engines, when the power exceeds 220 kW per engine
- engines driving electric generators, including emergency generators, when they develop a power of 110 kW and over.

2.2 Installation

2.2.1 Instruction manual

An instruction manual is to be provided with every engine. As a rule, this one is to indicate:

a) the maximum engine power

b) the total dry engine mass, including all standard accessories as described by the manufacturer

c) installation instructions

d) the maximum and minimum allowable rotational speeds at full throttle, the maximum continuous rated speed, and the allowable maximum number of hours overspeed per 24 hours

e) fuel requirements, including the type of fuel

f) lubricating requirements for the engine and transmission including running-in instructions, recommended maximum and minimum oil pressures, capacities of sump and gearbox and recommended types of oil

g) recommended jacket cooling water temperatures for either fresh-water-cooled or salt-water-cooled engines. Flow diagram for the cooling water system. Details on inhibitors to be used in closed-circuit cooling systems

h) starting instructions and trouble shooting guide

i) complete instructions for laying-up the engine, including the location of all drain plugs

j) a wiring diagram of the engine electrical system, including an indication of the ground polarity where the accessories are grounded

k) air compressed or battery requirement for starting

l) a list of recommended emergency spares and tools

m) information for emergency maintenance if the engine becomes submerged (outboard engine).

2.2.2 Engine components and accessories arrangement

a) The arrangement of component parts of the engine is to be in accordance with the installation instructions; the attached equipment is to be accessible, without the use of tools, for normal maintenance of the engine (e.g. oil fills, dip sticks, cooling water fills)

b) Engine accessories and equipment are to be manufactured and installed so that they can be serviced and lubricated as required and recommended.

2.2.3 Lubricating oil

Provision is to be made for removal of substantially all of the oil from the engine sump without spillage of oil into the bilge. Means are to be provided to determine the correct oil level in the engine as it is installed.

2.2.4 Safety devices on moving parts

All exposed belt drives, chain drives and rotating parts, as installed, are to be covered with guards or are to be designed in such a way as to prevent injury during the normal operation of the engine. An engine box shall be accepted for the purpose of this paragraph. Maintenance or engine repairing are not considered normal operation. Belts are to be changeable without dismantling any major part of the engine.

2.2.5 Hot surfaces protections

Protective guards, jacketing, or engine boxes are to be provided whenever persons or gear might come in contact with the engine or its components as installed in normally occupied spaces, where their temperature exceeds 90°C.

2.2.6 Piping systems

Fuel, lubricating oil, cooling systems are to be in accordance with the relevant provisions of Ch 1, Sec 4 to Ch 1, Sec 9.

2.2.7 Drip tray and gutterways

In wooden yachts, a suitable drip tray wider and longer than the engine and gear box must be fitted to collect leakage of fuel and lubricating oil. Where fitted, it should be of such size and depth as to collect oil which may fall from the engine when the yacht is pitching or heavily heeling.

In yachts built in composite material or metal, a drip tray is not essential provided that the transverse and longitudinal bearers form any oil-tight box section compartment of the above mentioned extent. For yachts built in composite material, care must be taken to ensure that fibres are well covered.

2.3 Engine seating and fixing

2.3.1 Seating and fixing for inboard engine

a) The seatings are to be of robust construction and adequately attached to the hull. They are to be so designed and arranged that they can withstand the various stresses they are subjected to, without detrimental deformations to the machines they are supporting. Provision is to be made, as far as practicable, to ensure continuity between the longitudinal and transverse elements of the seatings and the corresponding elements of the adjacent hull, also to prevent sudden variations of inertia

b) Engine bearers must be of ample size and extend as far forward and aft as is practicable. Where engines are of relatively high power the girders must extend beyond the engine space bulkheads and into the bottom framing system. Built-up engine seatings must be effectively supported both longitudinally and transversely

c) Particular attention is to be paid to the arrangement of thrust-bearing seatings and their attachment to the hull

d) Engines are to be so fixed to their seatings as to prevent any displacement due to the movements of the yacht

e) Where stays are provided for fixing the upper part of engines to the yacht's structure in order, for example, to reduce the amplitude of engine vibrations, such stays are to be so designed as to prevent damage to these engines further to deformation of the shell plating in way of said stays. The stays are to be connected to the hull in such a way as to avoid abnormal local loads on the structure of the yacht

f) Accessories of engines as well as spare parts of large dimensions are to be strongly secured so that they cannot move or become loose under the yacht's movements

g) Where resilient mountings are fitted, the output shaft is to be connected to the propeller shaft through a flexible coupling. Satisfactory arrangements are to be made to transmit thrust, and flexibility is to be provided in all fuel, water, exhaust lines and electrical cables

h) Where resilient mountings are fitted, the permissible radial shaft displacement of the flexible coupling must not be exceeded.

2.3.2 Installation of outboard engines

a) A watertight and self-draining motor well is to be designed into the transom of all outboard engine yachts

b) The strength and rigidity of the transom should be related to the thrust imposed by the propeller and its resultant moment imposed upon the transom under dynamic loads

For yachts built in composite materials and except for engines of very low power, the transom is to be, as a general rule, of sandwich construction having a core of waterproof plywood or of equivalent strength. The internal skin of the sandwich must be of thickness not less than that of the yacht side skin, and the outer skin not less than that of the bottom. The internal skin is to be carried well forward along the sides and bottom of the yacht and gradually tapered in thickness towards its edges

Protective plates should be fitted in way of engine fixing clamps

c) Outboard engines should be capable of being fastened to the hull with through belts, chains or other safety dispositions.

2.4 Starting systems

2.4.1 Compressed air system

Where internal combustion engines are started by means of compressed air, the requirements of Ch 1, Sec 9, [5] regarding the number and position of compressors as well as the arrangement of compressed air systems are to be complied with.

2.4.2 Electric starting system

Where internal combustion engines are fitted with electric starting, the requirements stated in Part C, Chapter 2 are to be complied with.

2.4.3 Emergency system

Where suitable emergency manual starting means are provided, attenuation to these requirements may be considered by the Society.

2.5 Control - safety - monitoring and instrumentation

2.5.1 Control systems

a) Components of the propulsion control system are to be suitably resistant to corrosion, either by virtue of material or coating thereof, and galvanically compatible with each other.

b) On a twin-engine yacht, the throttle controls should be located so that both engines can be throttled with one hand.

c) Where control cables are used, they are to be installed with as few bends as possible. Bends are to have as large a radius as possible and the radius is not to be smaller than the manufacturer's recommended minimum. The route of the cables are to be direct and uncrowded by accessory equipment.

The primary control actuation is to be through a lever and not a knob directly attached to the end of the cable.

2.5.2 Safety arrangements

a) Except where duly justified, a means for operating the throttle without engaging the gears is to be provided for all yachts exceeding 5 kW in shaft power. To ensure this, it should not be possible to start the motor unless the shift control is in neutral position.

b) Non-propulsion engines intended for automatic operation are to be fitted with an automatic shutdown device actuated by low oil pressure or high cooling fluid temperature.

Engine crankcases are to be sufficiently vented to prevent excessive pressurization.

Each outboard engine is to be provided with a tilt mechanism which shall operate when the driveleg comes into contact with an obstruction. Adequate means are to be provided to adjust the force required to activate the tilt mechanism.

Carburettors are to be fitted with a drainage of fuel leakage in the inlet pipe system and fitted with flame arresting device.

2.5.3 Monitoring - Instrumentation

a) Inboard propulsion engines are to be equipped with instruments at the operator's positions to indicate the following:

- engine rotational speed
- high cooling liquid temperature
- high engine or exhaust temperature in the case of air cooled engines
- low lubricating oil pressure
- failure of the electrical system
- high temperature and/or low oil pressure - for hydraulic transmissions

b) Except specially agreed by the Society, the engines fitted on yachts of 24 m in length and over, are to be fitted with audible alarms for:

- low oil pressure (lubricating and gear box systems)
- high temperature of the jacket cooling water outlet.

3 Reduction gear - transmission

3.1 General

3.1.1 Type approval

Reduction gear and transmissions are to be of marine type and suitably matched to the engine with which they are to be used.

3.1.2 Application

Where the power per shaft line exceeds 220 kW, reduction gear and transmissions are to be in compliance with the relevant requirement of Part C, Chapter 1, Section 6 of the Rules for Steel Ships, with the design factors listed in [3.2.1].

3.2 Design and construction

3.2.1 Design

The reduction gear should normally be designed and built in accordance with the relevant provisions of Chapter 1, Section 6 of the Rules for Steel Ships. However, coefficients SH and SF considered for the determination of respectively the permissible contact stress and the permissible tooth root bending stress are as follows:

SH : Acceptance factor for contact stress. The value of SH is 1.10 for single and duplicate machinery

SF : Acceptance factor for tooth root bending stress. The value of SF is 1.45 for single machinery and 1.40 for duplicate machinery.

3.2.2 Overspeed

As a rule, the reduction gear is to be able to withstand momentary overspeeds of 115% of the maximum rated engine speed in forward and reverse.

3.2.3 Lubricating oil

Reduction gear incorporating an independent oiling system is to include a suitable oil sump, an oil level indicating device, and a vent located to provide adequate breathing, but positioned to prevent oil leakage from the transmission under normal operating conditions.

3.2.4 Cooling

Reduction gear and transmissions are to be provided with a method of cooling so that recommended maximum sump temperatures will not be exceeded under normal operating conditions.

3.2.5 Monitoring

Hydraulically actuated transmissions are to have a provision to monitor oil pressure and/or oil temperature.

4 Shafting

4.1 General

4.1.1 Application

a) Scantling rules mentioned in this section are applicable to propulsion shaft line, whatever the power per shaft may be

b) For shafting components in engines, gears and thrusters, refer to the relevant requirement of Part C, Chapter 1 respectively Sec 2, Sec 6 and Sec 12 of the Rules for Steel Ships.

4.1.2 Materials

Materials used for elements covered by this section should, as a rule, comply with the requirements of the Rule Note NR216 Materials and Welding. Use of other materials are to be subject to special examination.

4.2 Shafting scantling

4.2.1 Propeller shaft diameter

a) The diameter of the shaft going through the stern tube is not to be less than the diameter d, in mm, given by the following formula:

$$d = K (P / N)^{1/3}$$

where:

P : Brake power, in kW

N : Shaft revolutions per minute

K : Coefficient having the values given in Tab 1.

Furthermore, the shaft diameter is not to be less than 25 mm for carbon steel or carbon manganese steel, and 20 mm for the other materials listed in Tab 1.

The use of materials other than those included in Tab 1 is to be subject to special examination.

b) When the propeller shaft is made out of Carbon manganese steel and is protected by a continuous liner or by oil lubrication with approved oil sealing gland, the coefficient K is given by the following formula:

$$K = 126 (560 / (Rm + 160)^{1/3})$$

where:

Rm : Value of the minimum tensile strength of the shaft material, in N/mm². The value of Rm to be introduced in the formula is not to be taken higher than 600 N/mm².

Table 1 : Values of coefficient K

Material	R_{eH} mini N/mm²	R_m mini N/mm²	K
Carbon and carbon manganese steel	200	400	126
Austenitic stainless steel (type 316)	175	470	91
Manganese bronze	245	510	92
Martensitic stainless steel (type 431)	675	850	88
Ni-Al bronze	390	740	85
Nickel-copper alloy (Monel 400)	350	550	85
Nickel-copper alloy (Monel K 500)	690	960	71
Duplex stainless steel (Type S31803)	450	650	63

4.2.2 Intermediate shaft diameter

The diameter, in mm, of the intermediate shafts is not to be less than:

$$d' = 0{,}8\ K (P / N)^{1/3}$$

where P, N and K are defined in [4.2.1].

4.2.3 Hollow shaft

Where hollow shafts are used the required diameter determined according to the formulas given in [4.2.1] and [4.2.2] are to be multiplied by the factor Kd as indicated in Tab 2, where:

Q : Ratio of the internal diameter to the outer shaft diameter

A central hole of diameter less than 1/2,5 of the shaft diameter may be accepted without increase in shaft size.

Table 2 : Values of coefficient Kd

Q	0.4	0.5	0.6	0.7
Kd	1.01	1.02	1.05	1.10

4.2.4 Cardan shaft

Characteristics of the cardan shaft and justification of the cardan shaft life duration are to be submitted for information.

4.2.5 Propeller shaft overhang

The overhang of the propeller shaft between the forward face of the propeller boss and the aft face of the adjoining shaft bearing is not to exceed the actual propeller shaft diameter. However, an overhang greater than this amount may be permitted provided that the bending stress due to the additional overhang is considered in the calculation of the shaft diameter and in whirling calculations in this case justifications are to be submitted.

4.2.6 Alignment

Shaft alignment should be carried out with the boat floating and should be checked occasionally or if unusual vibration is evident.

4.3 Shafting accessories

4.3.1 Coupling flanges

a) The thickness of inboard coupling flanges, at the pitch circle of the bolt holes, is not to be less than the required diameter of the corresponding bolts determined as indicated in 14, paying due regard to the specified minimum tensile strength of the material of said flanges. Besides, the thickness of the propeller shaft coupling flange is not to be less than 0,20 times the required diameter of the intermediate shaft, calculated paying due regard to the specified minimum tensile strength of the material of said flange.

   The fillets of coupling flanges at their junction with the shafts are to have a radius at least equal to 8% of the diameter of the corresponding shaft.

b) Outboard coupling flanges are to have a thickness not less than 0,25 times the required diameter of the corresponding shaft. The fillet radius at the junction with the shaft is not to be less than half the required thickness of the flange.

c) The fillets are to be carefully machined and, as a rule, recesses are to be avoided as far as possible in way of bolt heads and nuts.

4.3.2 Coupling bolts

a) The diameter of coupling bolts at the joining faces of the couplings is to be not less than the diameter D_b given, in mm, by the following formula, for intermediate, propeller and thrust shafts:

$$D_b = 11,10^3\left(\frac{P}{n \cdot r \cdot Rb \cdot N}\right)^{1/2}$$

   where:

   n : Number of bolts in the coupling

   r : Radius of the pitch circle of the bolts, in mm

   Rb : Ultimate tensile strength of the bolt metal, in N/mm².

   P : As defined in [4.2.1]

   N : As defined in [4.2.1]

b) For the bolts of coupling flanges for crankshaft parts as well as of coupling flanges between crankshafts and thrust and flywheel-shafts, the above formula is to be applied but the factor 11.10^3 is to be superseded by 14.10^3

c) Where the pieces of the shafting are not joined by means of forged coupling flanges, the arrangement will be given special consideration by the Society; in this case, provision is to be made for the coupling to resist the rated astern pull

d) Where the shafts have peculiar machining such as grooves, longitudinal slots or transverse holes the design is to be such as to reduce stress concentrations. A local increase of the shaft diameter may be required by the Society.

4.3.3 Shaft liners

a) Propeller shafts of carbon steel are to be protected by a continuous salt water resistant liner where exposed to sea water. Alternatively, the liner may be omitted provided the shaft runs in an oil lubricated stern tube with an approved sealing gland at the after end. Length of shafting between stern tube and propeller bracket may be protected by suitable coatings

b) The thickness of bronze shaft liners in way of the bushes and sterngland is to be not less than the thickness e, in mm, given by the following formula:

$$e = \frac{d + 230}{32}$$

   where:

   d : Actual diameter of the propeller shaft, in mm

c) The thickness of the continuous liner between the bushes is to be not less, as a rule, than 0,75 e

   The liners are considered as continuous when they are:

   - either cast in one piece
   - or made of two or more lengths assembled by joints of an approved type

d) Where parts of liners are assembled by welding, arrangements are to be made to protect the surface of the shaft during welding and to allow the free contraction of the joint after welding

e) The joints between liner parts are not to be located in way of the bushes or sterngland

f) Each continuous liner or length of liner is to be tested by hydraulic pressure to 2 bars after rough machining

g) Liners are to be carefully shrunk on the shafts either whilst hot, or by hydraulic press, or by any other approved process. Pins or other similar devices are not to be used to secure the liners on the shafts

h) Where ways are provided between liner and propeller shaft outside the bearings, these ways are to be filled with a material insoluble in water and non-corrosive

i) Means are to be provided, particularly at the junction of liner and propeller boss, to prevent any entry of sea water under the liner and on the propeller boss.

4.3.4 Shaft bearing

a) Any unsupported length of shafting is not to exceed, as a rule, that determined by the following formula:

$$L = 108a\sqrt{\frac{d}{N}}$$

where:

L : Maximum unsupported length, in mm

d : Shaft diameter, in mm

N : Shaft rotational speed, in rpm

a : Coefficient depending on the material:

a = 84 for naval brass

a = 96 for nickel copper

a = 100 for stainless steel

b) The forward most bearing should be preferably at least 12 shaft diameters from the engine gear box or thrust block flange

c) The shaft bearings are to be readily accessible.

4.3.5 Stern tube

a) Oil lubricated bearings of white metal

The length of white metal lined bearings is to be not less than 2,0 times the rule diameter of the shaft in way of the bearing

b) Oil lubricated bearings of synthetic rubber, reinforced resin or plastic materials

For bearings of synthetic rubber, reinforced resin or plastic materials which are approved for use as oil lubricated stern bush bearings, the length of the bearing is to be not less than 2,0 times the rule diameter of the shaft in way of the bearing

c) Water lubricated bearings of synthetic material

- Where the bearing is constructed of synthetic material which are approved for use as water lubricated stern bush bearings such as rubber or plastics the length of the bearing is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing
- For a bearing design substantiated by experiments to the satisfaction of the Society consideration may be given to a bearing length not less than 2,0 times the rule diameter of the shaft in way of the bearing

d) Other arrangements

The other arrangements beside those defined in items a) and b) are to be given special consideration. The length of the after bearing of the propeller shaft is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing

e) Where the bearings are lubricated by water, arrangements are to be made for an adequate supply of water

A forced water lubrication is to be provided, if necessary, namely for bearings lined with lignum vitae, rubber or plastic materials

f) For oil lubricated bearings and where the lubrication is made by gravity, the lubricating oil tank is to be located above the load centre water line. In this case, a low level indication or preferably an alarm is to be given at the operator's position.

4.3.6 Sealing glands

a) The sealing glands must be readily accessible, for inspection or replacement

b) The sealing glands are to be periodically inspected

c) It is to be mentioned in the Owner's manual, all necessary measures to be taken in case of accidental breaking of a main element, as well as the periodicity of inspections and replacement of elements subject to deterioration or wearing

d) The wear strength of non-metallic parts is to be established, either by satisfactory operations, or by relevant tests

An easy to fit emergency device may be accepted.

5 Propeller

5.1 Scantling

5.1.1 When the diameter of the propeller exceeds 1 meter, the propeller materials are, as a rule, to comply with the Rule Note NR216 Materials and Welding, and the scantling with the requirements of Part C, Chapter 1, Section 8 of the Rules for Steel Ships.

5.1.2 The Society may agree, for propellers, scantling either justified by adequate calculations or satisfactory experience in service.

6 Shaft Vibrations

6.1 General

6.1.1 Application

A torsional vibration calculation is to be submitted for review for the shafting of the following installation in compliance with the relevant requirement of Part C, Chapter 1, Section 9 of the Rules for Steel Ships.

- propulsion systems with prime movers developing 220 kW or more
- other systems with internal combustion engines developping 110 kW or more and driving auxiliary machinery intended for essential services.

7 Shaft Alignment

7.1 General

7.1.1 Application

In the case of propulsion shafting with direct coupled engines or bearings with offsets from a reference line, the relevant shaft alignment calculation is to be submitted for approval.

The Society may also require the above calculation in the case of special arrangements.

7.1.2 Shaft alignment calculation

The alignment of the propulsion machinery and shafting and the spacing and location of the bearings are to be such as to ensure that the loads are compatible with the material used and the limits prescribed by the Manufacturer.

The calculation is to take into account thermal, static and dynamic effects; the results are to include the reaction forces of bearings, bending moments, shear stresses and other parameters (such as gap and sag of each flanged coupling or jacking loads) and instructions for the alignment procedure.

The alignment is to be checked on board by the Shipyard by a suitable measurement method.