Part 4 Systems and components
Chapter 1 Machinery systems, General
FOREWORD

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

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CHANGES – CURRENT

This is a new document.
The rules enter into force 1 January 2016.
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SECTION 1 GENERAL REQUIREMENTS

1 Classification

1.1 Application

1.1.1 This chapter contains overall requirements common for machinery, systems and components. Detailed requirements are given in the relevant rule chapters in Pt.4 - Systems and components.

1.1.2 The rules in this chapter apply to machinery, systems and components for ships and barges for the assignment of main class.

1.1.3 For novel design of a component, a system or the complete arrangement of a vessel, and where the existing rules are not suitable for the purpose, the design can be accepted provided that the overall safety and availability level is found to be equivalent or better than that of the rules. The Society withholds the right to request documentation, tests and trials additional to those specified in the rules.

For such designs an engineering analysis shall be prepared and submitted. The analysis shall as a minimum include the following elements:

1) Thorough definition of the ship, ship systems and components subject to the analysis.
2) Identification of requirements with which the ship or design will not comply.
3) Identification of the possible hazards introduced by the design.
4) Identification of failure modes, consequences of failures and system response (e.g. FMEA) and a test program to verify the conclusions.
5) Determination of the required performance, safety and availability criteria addressed by corresponding requirements applicable for traditional design.
6) Design philosophy and detailed description of the novel design, including a list of the assumptions used in the design and any proposed operational restrictions or conditions.
7) Technical justification demonstrating that the alternative design and arrangements meet the required performance criteria in accordance with the above.

Guidance note:

1) For new technology, Recommended Practice DNVGL-RP-A203 can be a suitable basis for such analyses.
2) Refer also to Pt.1 Ch.1 Sec.1 regarding alternatives to detailed requirements in the rules.

1.1.4 Compliance with the rules is required for installations and equipment necessary for performing the main functions given in Pt.1 Ch.1 Sec.1 [1.2].

1.1.5 The rules give system requirements and prescribe minimum requirements for materials, design, manufacture, inspection and testing.

1.1.6 For components to be installed onboard vessels with the class notation Naval, additional requirements given in Pt.5 Ch.13 shall be fulfilled.
## 2 Definitions

### Table 1 Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active components</td>
<td>Active components are components for mechanical transfer of energy, e.g. pumps, fans, electric motors, generators, combustion engines and turbines. Heat exchangers, boilers, transformers, switchgear or cables are not considered to be active components.</td>
</tr>
<tr>
<td>Availability</td>
<td>Availability is the ratio of actual service time to expected service time at sea. Availability may be calculated from the following formula: [ A = \frac{MTTF}{MTTF + MTTR} ]</td>
</tr>
<tr>
<td>Engine room</td>
<td>Engine room is the spaces containing propulsion machinery and machinery for generation of electrical power.</td>
</tr>
<tr>
<td><strong>Guidance note:</strong></td>
<td><em>Rooms within or adjacent to the engine room with visual contact with the machinery should be considered to be part of the engine room.</em></td>
</tr>
<tr>
<td>Failure</td>
<td>Failure in the rule context is a sudden event or deterioration causing loss of function.</td>
</tr>
<tr>
<td>Independently driven</td>
<td>An independently driven component is, when the function of the component and the power supply of the component is independent of the main engine.</td>
</tr>
<tr>
<td>Load reduction</td>
<td>Load reduction, implies that a unit is brought to a safe state under the prevailing conditions, but the reduction shall be limited to a degree where the function the unit serves is not lost, only degraded.</td>
</tr>
</tbody>
</table>
| "Machinery spaces"          | "Machinery spaces are all machinery spaces of category A and all other spaces containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces."
(SOLAS Ch. II-1/3.16) |
| "Machinery spaces of category A" | "Machinery spaces of category A are those spaces and trunks to such spaces which contain:
1) internal combustion machinery used for main propulsion; or
2) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
3) any oil-fired boiler or oil fuel unit."
(SOLAS Ch. II-1/3.17) |
<p>| Mean time to failure (MTTF) | Mean time to failure (MTTF) is the mean value of service time until failure occurs. In the rule context, MTTF shall be considered to be equal to mean time between failures (MTBF). |</p>
<table>
<thead>
<tr>
<th><strong>Mean time to repair (MTTR)</strong></th>
<th>Mean time to repair (MTTR) is the mean value of time from occurrence of failure to re-establishment of lost function.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mutual independence</strong></td>
<td>Mutual independence between components means that the function of the components and their power supply shall not dependent on some common component or system.</td>
</tr>
<tr>
<td><strong>Novel design</strong></td>
<td>Novel design is defined as technology or solutions for which the application of prescriptive requirements in the rules of the Society is not suited.</td>
</tr>
</tbody>
</table>
| **Piping**                    | Piping shall be defined to include the following components:  
|                               | — pipes  
|                               | — flanges with gaskets and bolts and other pipe connections  
|                               | — expansion elements  
|                               | — valves, including hydraulic and pneumatic actuators, and fittings  
|                               | — hangers and supports  
|                               | — flexible hoses  
|                               | — pump housings.  |
| **Piping system**             | A piping system shall be defined to include piping, as well as components in direct connection to the piping such as pumps, heat exchangers, evaporators, independent tanks etc. with the exception of main components such as steam and gas turbines, diesel engines, reduction gears and boilers.  
For components that are subject to internal pressure and are not included in the piping system, the design requirements in Ch.7 apply. |
| **Redundancy**                | Redundancy is the ability to maintain or restore a function when one failure has occurred. Redundancy can be achieved for instance by installation of more than one unit (component redundancy) or by having two or more separate systems capable of performing the same function (system redundancy). |
| **Redundancy types**          | Redundancy types are defined by the time lag accepted upon restoring a lost function, due to failure in a component or system, designed with redundancy.  
|                               | **Redundancy type** | **Time lag in re-establishment of function** |
|                               | 0                  | None (continuously available) |
|                               | 1                  | Up to 30 s |
|                               | 2                  | Up to 10 minutes |
|                               | 3                  | Up to 3 hours |
|                               | not defined        | More than 3 hours |
| **Reliability**               | Reliability is the ability of a component or a system to perform its required function without failure during a specified time interval. |
| **Repairable failure**        | Repairable failure in the machinery is a failure which is possible to be repair on board and for which the following conditions are fulfilled:  
1) the machinery is arranged and designed to allow for repair work at sea  
2) spare parts or complete spare units necessary for permanent or provisional repairs are kept on board  
3) tools, instruction manuals and other necessary facilities to perform the repair work are kept on board. |
| **Shut down**                 | Shut down, implies that a unit is brought to a safe state. The safe state may be stop of a unit or decelerate rotating machinery to idle. |
3 Documentation requirements for builder

3.1 Documentation requirements

3.1.1 Documentation of machinery and systems shall be submitted to the extent specified in the following chapters containing all the data necessary for approval. Where necessary, calculations and descriptions of the plant are to be submitted.

3.1.2 The Builder shall submit the documentation required by Table 2.

Table 2 Documentation requirements for the builder

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propulsion control and monitoring systems</td>
<td>1020 - Control system functional description</td>
<td>Pre-warning and override facility for load reductions and shut-downs.</td>
<td>AP</td>
</tr>
</tbody>
</table>

3.1.3 For general requirements to documentation, including definition of the Info codes, see Pt.1 Ch.3 Sec.2.

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

4 Certification and documentation requirements for Manufacturers

4.1 Certification requirements

4.1.1 Machinery systems and components shall be certified according to the requirements in the relevant rule chapters for the systems and components. Additionally, products shall be certified as required by Table 3.

Table 3 Certification required

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propulsion control and monitoring systems</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Unless otherwise specified the certification standard is the Society's rules

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

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

4.2 Documentation requirements

4.2.1 For products required to be certified, the Manufacturer shall submit the documentation required by Table 4.
Table 4 Documentation requirements - products required to be certified

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propulsion control and monitoring systems</td>
<td>1200 - Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
</tbody>
</table>

AP = For approval

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

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

5 Tests

5.1 Testing of machinery systems and components

5.1.1 Machinery and its component parts shall be subject to constructional and material tests, pressure and leakage tests, and trials.

In the case of parts produced in series, other methods of testing can be agreed instead of the tests prescribed, provided that the former are recognized as equivalent by the Society.

5.1.2 The Society reserves the right, where necessary, to increase the scope of the tests and also to test those parts which are not expressly required to be tested according to the rules.

5.1.3 After installation on board of the main and auxiliary machinery, the installation as well as the operational functioning of the machinery, including the associated ancillary equipment, shall be verified according to rule requirements in the following chapters. Safety functions and safety equipment shall be tested as far as practically feasible. Tests for safety equipment that has formerly been performed and witnessed by the Society need not to be repeated.

In addition, the entire machinery installation is to be tested during sea trials, as far as possible under the intended service conditions.

The tests shall be carried out according to approved test programmes, see Pt.1 Ch.1 Sec.2 [1.6].
SECTION 2 MATERIALS

1 General

1.1 Machinery parts

1.1.1 Requirements for documentation of quality and testing of materials intended for:
— propulsion and auxiliary machinery
— boilers and pressure vessels
— electrical installations
— instrumentation and automation
— fire protection, detection and extinction
— piping systems
are given in the respective chapters of Pt.4.

1.2 Use of asbestos

1.2.1 The use of asbestos is prohibited (Ref. Pt.1 Ch.1 Sec.2 [1.2.4] and Pt.1 Ch.1 Sec.4 [1.2.3]).
SECTION 3 DESIGN PRINCIPLES

1 Arrangement

1.1 General

1.1.1 All machinery, systems and components that are to be operated or subject to inspection and maintenance on board shall be designed and arranged for easy access.

1.1.2 All components in a system shall be satisfactorily matched with regard to function, capacity and strength. Relative motions between parts of the machinery shall be allowed for without inducing detrimental stresses.

1.1.3 All machinery shall be equipped with control and instrumentation considered necessary for safe operation of the machinery.

1.1.4 The following is applicable when local indication of pressure is required in the rules:

— The scales of pressure gauges shall be dimensioned up to the specified test pressure. The maximum permitted operating pressures shall be marked on the pressure gauges for boilers, pressure vessels and in systems protected by safety valves.
— Pressure gauges shall be installed in such a way that they can be isolated.
— Lines leading to pressure gauges shall be installed in such a way that the readings cannot be affected by liquid heads and hydraulic hammer.

1.1.5 All spaces, from which machinery is operated and where flammable or toxic gases or vapours may accumulate, or where a low oxygen atmosphere may occur, shall be provided with adequate ventilation under all conditions.

1.1.6 The capacity and arrangement of machinery spaces and emergency generator room ventilation shall cover demands for operating the machinery, boilers and emergency generator at full power in all weather conditions.

Ventilation inlets and outlets shall be located not less than 4.5 m above freeboard deck. Supply of air to the engine room shall be ensured even in the event of failure of one ventilation fan. As an alternative to the redundancy requirements in [2.3] alternative provision of air by adequate openings may be specially considered.

The air inlets and air outlets on open deck shall be positioned such as to avoid the ingress of exhaust air through the inlet openings into machinery space (short circuiting of air).

Guidance note:
Necessary capacity of ventilation may be calculated according to ISO 8861.

1.1.7 If the pipe tunnels are entered via doors or hatches for operating (e.g. for normal operation of valves or reading of measuring instruments) a mechanical ventilation shall be provided.

If the pipe tunnels are entered from the engine room the engine room ventilation system may be accepted as sufficient means of mechanical ventilation.

1.2 Prevention of inadvertent operations

1.2.1 The machinery shall be so arranged that inadvertent operation, caused by human error, cannot lead to the reduced safety of the ship and personnel.
1.2.2 The machinery and piping systems shall be arranged to prevent sea water, cargo or ballast from reaching dry spaces of the ship or cargo (oils or chemicals) from being discharged overboard as a consequence of inadvertent operations.

1.2.3 Systems and tanks shall be so arranged that leakage or any operation of valves will not directly lead to increased risk of damage to machinery, ship or personnel due to mixing of different fluids.

1.2.4 Open or closed position of valves shall be easily visible.

1.2.5 If a valve's function in the system is not evident, there shall be adequate information on a name plate attached to the valve.

1.2.6 All connections to sea shall be marked:
SEADIRECT.

1.3 Communication and engineers’ alarm

1.3.1 At least two independent means shall be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and direction of thrust of the propellers are normally controlled: one of these shall be an engine-room telegraph which provides visual indication of the orders and responses both in the machinery spaces and on the navigating bridge. Appropriate means of communication shall be provided from the navigating bridge and the engine-room to any other position from which the speed or direction of thrust of the propellers may be controlled.
(SOLAS Ch. II-1/37)

1.3.2 An engineers' alarm capable of being operated from the engine control room or at the manoeuvring platform, as appropriate, to alert personnel in the engineers' accommodation that assistance is needed in the engine room, shall be provided (see SOLAS Ch. II-1/38).

1.4 Fire protection

1.4.1 Where references have been given to SOLAS, this shall be taken as SOLAS 74 including amendments currently in force.

1.4.2 The arrangement of machinery spaces shall be so that safe storage and handling of flammable liquids is ensured. Materials used as flooring, bulkhead lining, ceiling or deck in control rooms, machinery spaces or rooms with oil tanks shall be non-combustible.

Guidance note:
Reference is made to MSC.1/Circ.1321 – Guidelines for measures to prevent fires in engine rooms and cargo pump rooms.

1.4.3 Fuel oil, lubrication oil, hydraulic oil and thermal oil are in this context regarded as “Flammable liquids”.

1.4.4 No tank containing flammable liquid shall be situated where spillage or leakage therefrom can constitute a fire or explosion hazard, by coming into contact with heated surfaces (see SOLAS Ch.II-2/Reg.4.2.2.3.3).

1.4.5 Flammable liquid lines shall not be located immediately above or near units of high temperature, including boilers, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated by [1.4.7]. As far as practicable, flammable liquid lines shall be arranged far apart from hot surfaces, electrical installations or other sources of ignition and shall be screened or otherwise suitable protected to avoid liquid spray or liquid leakage onto the sources of ignition (see SOLAS Ch.II-2/Reg.4.2.2.5.3).
1.4.6 For detailed arrangement of tanks and piping conveying flammable liquids, see Ch.6.

1.4.7 Surfaces with temperatures above 220 °C which may be impinged as a result of a flammable oil system failure shall be properly insulated (see SOLAS Ch.II-2/Reg.4.2.6.1).

1.4.8 Precautions shall be taken to prevent any flammable liquid that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces (see SOLAS Ch.II-2/Reg.4.2.6.2).

1.4.9 The surface of insulation materials shall be impervious to oil or oil vapours (see SOLAS Ch.II-2/Reg.4.4.3).

1.4.10 “The floor plating of normal passageways in machinery spaces of category A shall be made of steel” (SOLAS Ch.II-2/Reg.11.4.2).

1.4.11 Hydraulic power units shall be provided with adequate shielding in order to avoid potential oil leakage, or spray coming into contact with any sources of ignition.

1.4.12 When purifiers for heated fuel oil are not located in a separate room, consideration shall be given with regard to their location, ventilation conditions, containment of possible leakage and shielding from ignition sources.

For machinery spaces of category A above 500 m$^3$, the purifiers shall be protected by a fixed local application fire-extinguishing system.

**Guidance note:**
Reference is made to SOLAS Ch.II-2/Reg.10.5.6 and IMO MSC/Circ.913 for requirements regarding the fixed local application fire-extinguishing system.

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1.5 Requirements dependent upon damage stability calculations
For vessels where damage stability requirements apply, precautions shall be taken to prevent intercommunication through damaged pipe lines between flooded and intact compartments.

For this purpose, where any part of a pipe system is situated within the defined damaged area and the pipe line has an open end in a compartment assumed to be intact, an isolating valve situated outside the damaged area operable from the freeboard deck or from another position, accessible when the ship is in damaged condition shall be fitted. For bilge lines the remotely operated stop valves may be substituted by a non-return valve.

**Guidance note:**
Requirements for damage stability may be found in inter alia SOLAS, the International Convention on Load Lines, MARPOL, IMO Gas and Chemical Codes and for the additional class notations SF and Well Stimulation.

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1.6 Potentially hazardous, non-essential installations

1.6.1 Fixed refrigeration plants shall comply with the requirements in Ch.6 Sec.6.

1.6.2 Ballast water treatment system installations shall comply with safety requirements in Pt.6 Ch.7 Sec.1.
2 Construction and Function

2.1 General

2.1.1 The machinery shall be so designed, installed and protected that risks of fire, explosions, accidental pollution, leakage and accidents thereof will be acceptably low.

2.1.2 Reliability and availability of the machinery shall be adapted according to considerations of the consequences from machinery failures and disturbances.

2.1.3 The design arrangement of machinery foundations, shaft connections, piping and ducting shall take into account the effects of thermal expansion, vibration, misalignment and hull interaction to ensure operation within safe limits.

Bolts and nuts exposed to dynamic forces and vibrations shall be properly secured.

2.2 Environmental conditions

2.2.1 All machinery, components and systems covered by the rules shall be designed to operate under the environmental conditions given in Table 1 to Table 3 if not otherwise specified in the detailed requirements for the machinery, component or system:

Table 1 Water temperature

<table>
<thead>
<tr>
<th>Coolant</th>
<th>Temperature [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seawater</td>
<td>+ 32 ¹)</td>
</tr>
<tr>
<td>Charge air coolant inlet to charge air cooler</td>
<td>+ 32 ¹)</td>
</tr>
</tbody>
</table>

1) The Society may approve other temperatures in the case of ships not intended for unrestricted service.

Table 2 Air temperature

<table>
<thead>
<tr>
<th>Installations, components</th>
<th>Location, arrangement</th>
<th>Temperature range [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machinery and electrical installations ²)</td>
<td>In enclosed spaces</td>
<td>0 to 45 ¹)</td>
</tr>
<tr>
<td></td>
<td>On machinery components, boilers</td>
<td>According to specific local conditions</td>
</tr>
<tr>
<td></td>
<td>In spaces, subject to higher or lower temperatures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>On the open deck</td>
<td>- 25 to + 45 ¹)</td>
</tr>
</tbody>
</table>

1) The Society may approve other temperatures in the case of ships not intended for unrestricted service.

2) See Ch.9 Sec.5 for electronic appliances.

Table 3 List, rolling, trim and pitch ¹)

<table>
<thead>
<tr>
<th>Installations, components</th>
<th>Angle of inclination (degrees) ²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athwartships</td>
<td>Fore and aft</td>
</tr>
</tbody>
</table>
2.2.2 Where the rules have requirements for capacity or power of machinery, these shall be determined at the ambient reference conditions stated in Table 4. The engine manufacturer is not expected to provide simulated ambient reference conditions at a test bed unless specified in the relevant rule chapters.

**Table 4 Ambient reference conditions for machinery**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total barometric pressure</td>
<td>1 bar</td>
</tr>
<tr>
<td>Ambient air temperature</td>
<td>45°C</td>
</tr>
<tr>
<td>Relative humidity of air</td>
<td>60%</td>
</tr>
<tr>
<td>Sea water temperature</td>
<td>32°C</td>
</tr>
</tbody>
</table>

2.2.3 Machinery, components and systems covered by the rules shall be constructed to withstand, without malfunctioning, the external vibration levels they may be exposed to on board the vessel.

**Guidance note:**
A vibration level defined by a maximum velocity amplitude of 20 mm/s in the frequency range 5 to 50 Hz is considered as a minimum. Higher tolerance levels may be required in the detailed requirements for the machinery, component or system. External vibrations in this context are structure bound vibrations that the machinery, components or systems are exposed to from the vessel structure. Self-induced vibrations are not considered in this respect. This chapter does not set requirements to documentation of vibration tolerance for equipment in general. Where documentation is required, this will be stated in the respective chapter for the equipment. Documentation may also be requested case-by-case for other equipment, e.g. for novel equipment or for equipment not designed for marine applications.

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2.3 Functional capability and redundancy

2.3.1 Components and systems shall be arranged with redundancy so that a single failure of any active component or system (see Sec.1 Table 1 for definition of active components) does not cause loss of any main function for longer periods than specified in [2.3.6]. See Pt.1 Ch.1 Sec.1 Table 2 for definition of the main functions of a vessel.
2.3.2 Redundancy can either be arranged as component redundancy or system redundancy as defined in Sec.1 Table 1.

2.3.3 For main functions served by single systems, redundancy shall be provided on a component level so that no single failure in an active component causes a reduction of output power for the main function.

Guidance note:
For single propulsion systems, this implies that all auxiliaries shall be arranged and dimensioned so that any active component may fail without affecting the propulsion power.

2.3.4 For duplicated systems a single failure of an active component or a system shall not reduce the output power for the main function, served by the duplicated system, to less than 40% of the nominal output rated power. [2.3.1] and [2.3.2] shall be considered as general requirements. For evaluation of deviations or equivalent solutions reference should be made to the relevant rule sections for the component or system in question.

Guidance note:
For single engine propulsion plants all active components should be duplicated to satisfy [2.3.1] and [2.3.4]. Multi engine propulsion plants or propulsion plants with combinations of diesel engines, gas turbines and/or electrical motors are considered to provide redundancy on a system level. For these plants, duplication of the active components is not necessary provided that at least 40% of output rated power for the main function is remaining in case of a single failure. For propulsion plants where less than 40% of output rated power remains, after a single failure, duplication of the active components will be required. "Output rated power" is in this context the total rated propulsion power for the driven unit (e.g. one or several propellers).

All other main functions (see Pt.1 Ch.1 Sec.1 [1.2]) should be treated accordingly.

2.3.5 The following active components are general exceptions to [2.3.1] and are not required as part of the designed redundancy, unless otherwise specified in the rules:

— main engine
— shafting, gear, driven unit (e.g. propeller)
— anchor windlass
— machinery for emergency power supply
— auxiliary thrusters.

2.3.6 Components and systems supporting main functions of the vessel (see definition of main functions in Pt.1 Ch.1 Sec.1 Table 2) shall be arranged as redundancy type 2 (see definition in Sec.1 Table 1). When interruption of a function entails considerable hazard to other components or systems, or to the ship, redundancy type 1 shall be arranged.

Components and systems supporting the propulsion function shall be arranged as redundancy type 1. Where the operational service of the vessel is such that loss of propulsion will not entail considerable hazard to the ship, redundancy type 2 may be accepted upon special consideration.

Components and systems supporting the steering function shall be arranged with redundancy according to the requirements for steering gear in Ch.10.

Guidance note:
Redundancy type 2 for the propulsion function may typically be accepted for vessels not depending on own propulsion for manoeuvring in narrow and congested waters.

2.3.7 A longer restoration time for a function than prescribed in [2.3.6] may be accepted for failures of certain components or systems, where the probability for failure of the component or system is considered to be low. This will be subject to case-by-case acceptance.

Guidance note:
Example of a component or system that may be considered to have a low probability of failure is the bus bars in the main switchboard.

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2.3.8 Active components, arranged as part of the designed redundancy, shall be so dimensioned that in the event of a single failure sufficient capacity remains to cover demands at the maximum continuous load of the component served.

**Guidance note:**

Only relevant for plants where it is required to have redundancy on a component level (e.g. single engine plants, see [2.3.2]).

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2.3.9 When two or more components are performing the same function, these shall be mutually independent and at least one shall be independently driven. Components arranged as part of the designed redundancy, yet only performing auxiliary functions to a main unit, can be directly powered by the main unit through separate power transmissions, on the condition that these components are not necessary for the starting of the main unit.

2.3.10 The machinery shall be so arranged and designed that all functions specified in Pt.1 Ch.1 Sec.1 [1.2] can be maintained simultaneously in normal service at sea.

2.3.11 Maintenance tasks expected to occur regularly, e.g. weekly, shall be carried out without loss of propulsion or steering.

2.3.12 Changeover from one normal operational mode to another normal operational mode of the machinery shall be possible without interruption in propulsion or steering.

2.3.13 Machinery or equipment having remote or automatic control, shall in addition have alternative provisions for attendance and operation.

2.3.14 The machinery shall be so arranged that it can be brought into operation from the «dead ship» condition within 30 minutes using only the facilities available on board.

«Dead ship» condition is understood to mean that the entire machinery installation, including the power supply, is out of operation and that auxiliary services such as compressed air, starting current from batteries etc., for bringing the main propulsion into operation and for the restoration of the main power supply are not available.

In order to restore operation from the «dead ship» condition, an emergency generator may be used provided that it is ensured that the emergency power supply from it is available at all times. It is assumed that means are available to start the emergency generator at all times.

2.3.15 The performance and capacity of auxiliary systems shall be adapted to the needs of the machinery installations served.

2.4 Failure effects

2.4.1 In the event of failure, components and systems shall enter the least hazardous of the possible failure states with regard to ship machinery, personnel and environment.

2.4.2 The probability that failure in a component causes damage or failure to other components, shall be acceptably low.

2.4.3 Failure of one component in a system arranged as part of the designed redundancy shall not lead to failure or damage to backup or parallel components or systems.
2.5 Component design

2.5.1 Components shall be designed with respect to the loads and ambient conditions which are expected to occur. Accepted safety margins shall be used.

2.5.2 Exceptional conditions shall be considered when justified by the risk of damage or the consequences of damage.

2.5.3 Where no specific requirements are given in the rules regarding dimensioning and choice of materials, recognised standards and engineering principles may be applied.

2.5.4 If acceptable accuracy cannot be obtained by strength calculations, special tests for the determination of the strength of the design may be required.

2.5.5 When it is of essential significance for the safety of the ship that the function of a component is maintained as long as possible in the event of fire, materials with high heat resistance shall be used.

2.5.6 Materials with low heat resistance shall not be used in components where fire may cause outflow of flammable or health hazardous fluids, flooding of any watertight compartment or destruction of watertight integrity.

Guidance note:
Materials with high heat resistance are materials having a melting point greater than 925°C. Materials with low heat resistance are all other materials. Deviations from the above requirement will be subject to special considerations.

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3 Reliability and Availability

3.1 Application

3.1.1 The requirements for reliability and availability apply to machinery for the main functions stated in Pt.1 Ch.1 Sec.1 [1.2] in general and to machinery for which these requirements are made applicable specifically in the rules.

3.2 Reliability and availability analysis

3.2.1 For novel and non-conventional machinery documentation in regard to reliability and availability shall be submitted upon request.

3.2.2 Recognised methods and formulae shall be used in the calculation of reliability, availability and related parameters.

3.2.3 The documentation shall include a failure mode and effect analysis (FMEA) of the component concerned.

3.2.4 When numerical calculations cannot be performed due to insufficient data, approval may be granted on the basis of qualitative failure analyses of the component or system.

3.2.5 Documentation of calculation methods and computer programs shall be submitted upon request.
4 Personnel Protection

4.1 General

4.1.1 Machinery, boilers and associated piping systems shall be so installed and protected as to reduce to a minimum any danger to persons onboard, due regard being paid to moving parts, hot surfaces and other hazards.
SECTION 4 CONTROL OF MACHINERY

1 Control and Monitoring

1.1 General

1.1.1 The requirements in [1.2], [1.3] and [1.4] are additional to those given in Ch.9 and shall be applicable when remote control is installed.

1.1.2 Main and auxiliary machinery essential for the propulsion, control and safety of the ship shall be provided with effective means for its operation and control. All control systems essential for the propulsion, control and safety of the ship shall be independent or designed such that failure of one system does not degrade the performance of another system.

(SOLAS Ch. II-1/31.1 and 31.5.1)

Guidance note:
Compliance with these rules and Ch.9 is regarded as compliance with the above mentioned requirements.

1.1.3 It shall be possible for all machinery, essential for the safe operation of the ship, to be controlled from a local position, even in the case of failure in any part of the automatic or remote control systems.

(SOLAS Ch. II-1/49.4)

Guidance note:
Local position for electrical motors driving pumps, the local position is by the starter.

1.2 Remote control of machinery

1.2.1 The engine room or the engine control room, if provided, is normally the main command location but another permanently attended location may be accepted as a more suitable main command location. It shall be possible at any time to take control of main functions locally at the machinery.

1.2.2 In general, automatic starting, operational and control systems shall include provisions for manually overriding the automatic controls. Failure of any part of such systems shall not prevent the use of the manual override.

(SOLAS Ch. II-1/31.4)

1.2.3 Indicators shall be fitted on the navigation bridge, the main machinery control room and at the manoeuvring platform, for:
— propeller speed and direction of rotation in the case of fixed pitch propellers; and
— propeller speed and pitch position in the case of controllable pitch propellers.

(SOLAS Ch. II-1/31.2.8 and 31.5.6)

1.2.4 Remote starting of the propulsion machinery shall be automatically inhibited if conditions exist which may hazard the machinery, e.g. turning gear engaged.

1.2.5 The design of the remote control system shall be such that in case of its failure an alarm will be given. Unless the Administration considers it impracticable the pre-set speed and direction of thrust of the propeller shall be maintained until local control is in operation.

(SOLAS Ch. II-1/31.2.7)
1.3 Bridge control of machinery

1.3.1 Overload shall be indicated on the bridge if automatic load limitation is not arranged for.

1.3.2 An alarm shall be initiated on the bridge and in the engine room at starting failure.

1.4 Bridge control of propulsion machinery

1.4.1 The speed, direction of thrust and, if applicable, the pitch of the propeller shall be fully controllable from the navigating bridge under all sailing conditions, including manoeuvring.
   (SOLAS Ch. II-1/31.2.1)

1.4.2 The remote control shall be performed, for each independent propeller, by a control device so designed and constructed that its operation does not require particular attention to the operational details of the machinery. Where multiple propellers are designed to operate simultaneously, they may be controlled by one control device.
   (see SOLAS Ch. II-1/31.2.2)

   Guidance note:
   For ships less than 500 gross tonnage, two handle controls may be accepted and some of the normally programmed operations may instead be carried out manually.

1.4.3 The main propulsion machinery shall be provided with an emergency stopping device on the navigating bridge which shall be independent of the navigating bridge control system.
   (SOLAS Ch. II-1/31.2.3)

   Guidance note:
   If means are provided to stop the propulsion without stopping the main engine(s) (e.g. clutch arrangement) then this will be accepted.

1.4.4 Propulsion machinery orders from the navigation bridge shall be indicated in the main machinery control room and at the manoeuvring platform.
   (SOLAS Ch. II-1/31.2.4)

1.4.5 Remote control of the propulsion machinery shall be possible only from one location at a time, at such locations interconnected control positions are permitted. At each location there shall be an indicator showing which location is in control of the propulsion machinery. The transfer of control between the navigating bridge and machinery spaces shall be possible only in the main machinery space or the main machinery control room. This system shall include means to prevent the propelling thrust from altering significantly when transferring control from one location to another.
   (SOLAS Ch. II-1/31.2.5)

   Guidance note:
   The space where propulsion thrusters are located may in this context be regarded as the machinery space.

1.4.6 It shall be possible to control the propulsion machinery locally, even in the case of failure in any part of the remote control system. It shall also be possible to control the auxiliary machinery, essential for the propulsion and safety of the ship, at or near the machinery concerned.
   (SOLAS Ch. II-1/31.2.6)
1.4.7 An alarm shall be provided on the navigating bridge and in the machinery space to indicate low starting air pressure which shall be set at a level to permit further main engine starting operations. If the remote control system of the propulsion machinery is designed for automatic starting, the number of automatic consecutive attempts which fail to produce a start shall be limited in order to safeguard sufficient starting air pressure for starting locally.
(SOLAS Ch. II-1/31.2.9)

1.4.8 Automation systems shall be designed in a manner which ensures that threshold warning of impending or imminent slowdown or shutdown of the propulsion system is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems shall control, monitor, report, alert and take safety action to slow down or stop propulsion while providing the officer in charge of the navigational watch an opportunity to manually intervene, except for those cases where manual intervention will result in total failure of the engine and/or propulsion equipment within a short time, for example in the case of overspeed.
(SOLAS Ch. II-1/31.2.10)

 Guidance note:
The above is regarded to be fulfilled when:
1) All parameters initiating slowdown and shutdown shall initiate an alarm at a set-point different from the slowdown/shutdown set-point. These alarms shall be individually or in groups indicated on the navigating bridge whenever the propulsion machinery is controlled from this position.
Exempted from the requirement to give a pre-warning are the following parameters:
— overspeed on rotating machinery
— crankcase explosive condition using oil mist detection on diesel engines
— short-circuit in electrical propulsion plants.
2) An override facility to manually intervene on all slowdowns and shutdowns shall be available for all parameters except those which will result in total failure of the engine and/or propulsion equipment within a short time.
Note: examples of such parameters:
— lubricating oil pressure for rotating machinery
— overspeed for rotating machinery for fluid film bearings
— crankcase explosive condition on diesel engines
— short-circuit conditions in electrical installation
— high vibration for gas turbines.
3) For multi-engine propulsion plants, overriding of safety shutdowns is not required if manoeuvrability of the vessel is maintained.

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1.5 Supervision from a control room

1.5.1 Where the main propulsion and associated machinery, including sources of main electrical supply, are provided with various degrees of automatic or remote control and are under continuous manual supervision from a control room the arrangements and controls shall be so designed, equipped and installed that the machinery operation will be as safe and effective as if it were under direct supervision; for this purpose Regulations 46 to 50 shall apply as appropriate. Particular consideration shall be given to protect such spaces against fire and flooding.
(SOLAS Ch. II-1/31.3)

1.5.2 Ships intended to operate as described in [1.5.1] shall satisfy the requirements given in Pt.6 Ch.2 Sec.2 [4].
1.6 Operation with periodically unattended machinery spaces

1.6.1 Ships intended to operate with periodically unattended machinery spaces shall be arranged and tested as required in Pt. 6 Ch. 2 Sec. 2.

Guidance note:
Pt. 6 Ch. 2 Sec. 2 is considered to meet the regulations of SOLAS Chapter II-1 Part E, Additional Requirements for Periodically Unattended Machinery Spaces.

---end of guidance note---
SECTION 5 SPARE PARTS

1 General

1.1 Machinery installations

1.1.1 Spare parts in general are not mandatory for retention of class. It is, however, assumed that an inventory of spare parts sufficient to meet the needs posed by the ship’s plans of operation is maintained on board. Its content should be decided taking into consideration:
— the probability of need as a consequence of likely failures
— the likely failures and effect on the main functions
— the possibility of the ship’s staff effecting the necessary repairs.

Further guidance for spare parts is given in the relevant rule chapters in Pt.4.

1.1.2 For general guidance purposes, machinery and electrical installations in vessels intended for common world wide trading are recommended to be provided with inventory of spare parts as listed in the Table 1 to Table 6, including the necessary tools and instructions for replacement.

1.1.3 For systems and components related to main functions the recommendations of the manufacturer shall be taken into account.

1.1.4 Any applicable statutory requirement of the country of registration of the vessel is also to be considered.

1.1.5 The Society may require specific spare parts to be carried, if deemed necessary (mandatory requirement). The extent and amount shall be decided on a case by case basis.

Guidance note:
The Society may require spare parts in cases where it is planned to do repairs on board instead of having redundancy on a component or system level. This should only be considered for “repairable failures” and normally only for redundancy type 3.

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1.2 Tables of recommended spare parts

1.2.1 Spare parts for internal combustion engines for propulsion, see Table 1.

1.2.2 Spare parts for internal combustion engines driving electric generators, see Table 2.

1.2.3 Spare parts for main steam turbines, and auxiliary steam turbines driving electric generators, see Table 3.

1.2.4 Vessels with boilers supplying steam necessary for performing the main functions of a vessel are recommended to be provided with spare parts in accordance with Table 4. See Pt.1 Ch.1 Sec.1 Table 2 for definition of the main functions of a vessel.

1.2.5 Spare parts for various machinery equipment, see Table 5.

1.2.6 Spare parts for electrical installations, see Table 6.
### Table 1 Recommended spare parts for internal combustion engines for propulsion of ships for unrestricted service

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
<th>Number recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main bearings</td>
<td>Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts</td>
<td>1</td>
</tr>
<tr>
<td>Main thrust block</td>
<td>Pads for one face of tilting type thrust block, or Complete with metal thrust shoe of solid ring type, or Inner and outer race with rollers, where roller thrust bearings are fitted</td>
<td>1</td>
</tr>
<tr>
<td>Cylinder liner</td>
<td>Cylinder cover, complete with valves, joint rings, gaskets and rocker arms with brackets. For engines without covers, the respective valves for one cylinder unit</td>
<td>1</td>
</tr>
<tr>
<td>Cylinder cover</td>
<td>Cylinder cover bolts and nuts, for one cylinder</td>
<td>1/2 set</td>
</tr>
<tr>
<td>Cylinder valves</td>
<td>Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder</td>
<td>2 sets</td>
</tr>
<tr>
<td></td>
<td>Air inlet valve, complete with casings, seats, springs and other fittings for one cylinder</td>
<td>1 set</td>
</tr>
<tr>
<td></td>
<td>Starting air valve, complete with casing, seat, spring and other fittings</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cylinder overpressure sentinel valve, complete</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Fuel valves of each size and type fitted, complete with all fittings, for one engine</td>
<td>1 set 2)</td>
</tr>
<tr>
<td>Connecting rod bearings</td>
<td>Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder</td>
<td>1 set</td>
</tr>
<tr>
<td>Pistons</td>
<td>Crosshead type: Piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Trunk piston type: Piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod</td>
<td>1</td>
</tr>
<tr>
<td>Piston rings</td>
<td>Piston rings, for one cylinder</td>
<td>1 set</td>
</tr>
<tr>
<td>Piston cooling</td>
<td>Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit</td>
<td>1 set</td>
</tr>
<tr>
<td>Cylinder lubricators</td>
<td>Lubricator, complete, of the largest size, with its chain drive or gear wheels</td>
<td>1</td>
</tr>
<tr>
<td>Fuel injection pumps</td>
<td>Fuel pump complete or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.)</td>
<td>1</td>
</tr>
<tr>
<td>Fuel injection piping</td>
<td>High pressure fuel pipe of each size and shape fitted, complete with couplings</td>
<td>1</td>
</tr>
<tr>
<td>Scavenging system (including turbo-chargers)</td>
<td>Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if other types</td>
<td>1 set 3)</td>
</tr>
<tr>
<td>Scavenging system</td>
<td>Suction and delivery valves for one pump of each type fitted</td>
<td>1 set</td>
</tr>
</tbody>
</table>
Machinery systems, general

**Guidance note:**
The availability of other spare parts, such as gears and chains for camshaft drive, should be especially considered and decided upon by the customer.

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**Table 2 Recommended spare parts for internal combustion engines driving electric generators of ships with unrestricted service**

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
<th>Number recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main bearings</td>
<td>Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts</td>
<td>1</td>
</tr>
<tr>
<td>Cylinder valves</td>
<td>Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder</td>
<td>2 sets</td>
</tr>
<tr>
<td></td>
<td>Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder</td>
<td>1 set</td>
</tr>
<tr>
<td></td>
<td>Starting air valve, complete with casing, seat, springs and other fittings</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cylinder overpressure sentinel valve, complete</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Fuel valves of each size and type fitted, complete, with all fittings, for one engine</td>
<td>1/2 set</td>
</tr>
<tr>
<td>Connecting rod bearings</td>
<td>Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder</td>
<td>1 set</td>
</tr>
<tr>
<td></td>
<td>Top end bearings or shells of each type fitted, complete with shims, bolts and nuts, for one cylinder</td>
<td>1 set</td>
</tr>
<tr>
<td></td>
<td>Trunk piston type: Gudgeon pin with bushing for one cylinder</td>
<td>1 set</td>
</tr>
<tr>
<td>Piston rings</td>
<td>Piston rings, for one cylinder</td>
<td>1 set</td>
</tr>
<tr>
<td>Piston cooling</td>
<td>Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit</td>
<td>1 set</td>
</tr>
</tbody>
</table>

1) In case of multi-engine installations, the minimum recommended spares are only necessary for one engine.
   a) Engines with one or two fuel valves pr. cylinder: one set of fuel valves, complete
   b) Engines with three or more fuel valves pr. cylinder: two fuel valves complete per cylinder and sufficient number of valve parts, excluding the body, to form with, those fitted in the complete valves, a full engine set.

2) The spare parts may be omitted where it has been demonstrated, at the builders test bench for one engine of the type concerned, that the engine can be manoeuvred satisfactorily with one blower out of action.

3) The requisite blanking and blocking arrangements for running with one blower out of action shall be available on board.
Fuel injection pumps | Fuel pump complete or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.) | 1
Fuel injection piping | High pressure fuel pipe of each size and type fitted, complete with couplings | 1
Gaskets and packings | Special gaskets and packings of each and type fitted, for cylinder covers and cylinder liners for one cylinder | 1 set

1) Where the number of generators of adequate capacity fitted for essential service exceed the required number, no spare are required for the auxiliary engines.

### Table 3 Recommended spare parts for main steam turbines and auxiliary steam turbines driving electric generators of ships with unrestricted service 1) 2) 3)

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
<th>Number recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main bearings</td>
<td>Bearing bushes or roller bearings of each size and type fitted, the rotor, pinion and gear wheel shafts, for one turbine</td>
<td>1</td>
</tr>
<tr>
<td>Turbine thrust</td>
<td>Pads of each size for one face of tilting type thrust, with liners, or rings for turbine adjusting block, of each size fitted with assorted liners, for one turbine</td>
<td>1 set</td>
</tr>
</tbody>
</table>
| Main thrust block | Tilting type: Pads for one face 4)  
Roller type: Inner and outer race with rollers | 1 set |
| Turbine shaft sealing rings | Carbon sealing rings, where fitted, with springs, for each size and type of gland | 1 set |
| Oil filters | Strainer baskets or inserts, for filters of special design, of each type and size | 1 set |

1) In case of multi-turbine installations, the minimum required spare parts are only necessary for on turbine of each type.
2) The list covers auxiliary turbines as far as applicable.
3) Where the number of generators of adequate capacity fitted for essential service exceed the required number, no spare are required for the auxiliary engines.
4) When the pads of one face differ from those of the other, a complete set of pads shall be provided.

### Table 4 Recommended spare parts for boilers and steam-heated steam generators of ships with unrestricted service

<table>
<thead>
<tr>
<th>Specification</th>
<th>Number recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety valves: springs of each size</td>
<td>1</td>
</tr>
<tr>
<td>Water gauge glasses of round type with packings</td>
<td>3 sets</td>
</tr>
<tr>
<td>Water gauge glasses of flat type with packings</td>
<td>1 set</td>
</tr>
<tr>
<td>Strainers: strainer basket of each size for fuel oil system</td>
<td>1</td>
</tr>
<tr>
<td>Fuel oil burner: parts subjected to wear, for each burner</td>
<td>1 set</td>
</tr>
<tr>
<td>Pressure gauge for steam drum</td>
<td>1</td>
</tr>
<tr>
<td>Tube stoppers or plugs of each size for boilers, superheater and economiser</td>
<td>2%</td>
</tr>
</tbody>
</table>
### Table 5 Recommended spare parts for various machinery equipment of ships with unrestricted service

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
<th>Number recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pumps</strong>&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— fuel oil transfer</td>
<td>Valve with seats and springs each size fitted</td>
<td>1 set</td>
</tr>
<tr>
<td>— feed water</td>
<td>Piston rings each type and size for one piston</td>
<td>1 set</td>
</tr>
<tr>
<td>— cooling water</td>
<td>Centrifugal pumps:</td>
<td></td>
</tr>
<tr>
<td>— bilge water</td>
<td>Bearings of each type and size</td>
<td>1</td>
</tr>
<tr>
<td>— lubrication oil</td>
<td>Rotor sealings of each type and size</td>
<td>1</td>
</tr>
<tr>
<td><strong>Gear type pumps:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bearings of each type and size</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Rotor sealings of each type and size</td>
<td>1</td>
</tr>
<tr>
<td><strong>Air compressors for essential service</strong></td>
<td>Suction and delivery valves complete for each size fitted in one unit</td>
<td>1/2 set</td>
</tr>
<tr>
<td></td>
<td>Piston rings for each type and size fitted for one piston</td>
<td>1 set</td>
</tr>
</tbody>
</table>

<sup>1</sup> When a sufficiently rated standby pump is available, the spare parts may be dispensed with.

### Table 6 Recommended spare parts for electrical installations of ships with unrestricted service

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
<th>Number recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generators</strong></td>
<td>The spare parts shall be supplied for each size and type of generator required according to Ch.8.</td>
<td>1 complete brush holder, 1 set of brushes, 1 set of any special tools required, 1 set of necessary spare parts for excitation and automatic voltage regulation equipment.</td>
</tr>
<tr>
<td></td>
<td>For generators having excitation and voltage regulation equipment with semiconductors, the following is recommended.</td>
<td>1/3 of the number of main diodes for excitation, 1 complete set of all other semiconductor components, or alternatively 1 complete specimen of each assembled unit of such components, if the units are such that it is impracticable to carry out repairs on board.</td>
</tr>
<tr>
<td><strong>Switchboards</strong></td>
<td>For each repairable circuit-breaker on each pole:</td>
<td>1 set of contacts, subject to wear, 1 set of other parts, subject to wear, 1 set of springs, 1 coil of each type used, 1 resistance element of each type used. For 6 or less circuits-breakers of same type, 1 set of such spare parts.</td>
</tr>
<tr>
<td></td>
<td>For each type of non-repairable circuit-breaker (e.g. “miniature” circuit-breakers):</td>
<td>5% of each size with a minimum of 2 of each size used.</td>
</tr>
<tr>
<td><strong>Cables</strong></td>
<td></td>
<td></td>
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<tr>
<td>---</td>
<td></td>
<td></td>
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<tr>
<td>For each type of fuses:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% of each size with a minimum of 12 of each size used, 3 fuse-bases of each size used.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 set of any special tools and equipment for repairing mineral-insulated cables, where such cables are installed.</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Motors</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>For each essential and important D.C. and A.C. motor with commutator or slipring:</td>
</tr>
<tr>
<td>1 complete brush holder,</td>
</tr>
<tr>
<td>1 set of brushes,</td>
</tr>
<tr>
<td>1 set of any special tools.</td>
</tr>
<tr>
<td>For 6 or less motors of the same size and type, 1 set of such spare parts.</td>
</tr>
<tr>
<td>D.C. machinery: 1 armature of each size fitted, complete with shaft and halyard coupling, 1 field coil of each type fitted,</td>
</tr>
<tr>
<td>A.C. machinery: 1 stator complete of each size fitted.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Control gear</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>For each repairable control gear of motors and other consumers, intended for essential and important services:</td>
</tr>
<tr>
<td>1 set of the contacts which are subject to wear,</td>
</tr>
<tr>
<td>1 set of springs,</td>
</tr>
<tr>
<td>10% of each different resistance element, with at least 1 of each,</td>
</tr>
<tr>
<td>1 of each type coil used.</td>
</tr>
<tr>
<td>When 6 or less motors or other consumers are fitted with control gear having interchangeable parts, it is normal to provide one set of spares for the control gear which is provided with the greatest number of parts.</td>
</tr>
<tr>
<td>For each type of non-repairable control gear of motors and other consumers intended for essential and important services (e.g. some types of small motor starters):</td>
</tr>
<tr>
<td>5% of each size with a minimum of 2 of each size used.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Portable insulation-resistance measuring instrument</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ships with electrical installation of 100 kW and above are recommended to carry insulation-resistance measuring instrument, having a D.C. test voltage of not less than the installation's voltage.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Miscellaneous</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>For navigation lights with their pilot lamps:</td>
</tr>
<tr>
<td>1 complete set of lamps.</td>
</tr>
<tr>
<td>Where the emergency lighting voltage is different from the main lighting voltage:</td>
</tr>
<tr>
<td>10% of the emergency lamps, with a minimum of 10.</td>
</tr>
</tbody>
</table>
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