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NEWBUILDINGS  
SPECIAL EQUIPMENT AND SYSTEMS – ADDITIONAL CLASS

# Redundant Propulsion

JULY 2011

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The Rules lay down technical and procedural requirements related to obtaining and retaining a Class Certificate. It is used as a contractual document and includes both requirements and acceptance criteria.

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## General

The present edition of the rules includes additions and amendments approved by the Executive Committee as of June 2011 and supersedes the January 2011 edition of the same chapter.

The rule changes come into force as indicated below.

Text affected by the main rule changes is highlighted in red colour in the electronic pdf version. However, where the changes involve a whole chapter, section or sub-section, only the title may be in red colour.

This chapter is valid until superseded by a revised chapter.

## Main changes coming into force 1 January 2012

- **General**

- More specific document requirements, e.g. for FMEA, FMEA test program, and documentation regarding fire and flooding separation.
- Clarification on the separation requirements for notation **RPS**.
- Dedicated and separate pneumatic control systems are required for **RP** notation when the redundancy is dependent on these systems.
- Requirements for arrangement of remote control of propulsion and steering on the bridge.

- **Sec.1 General**

Sub-section A has been revised and restructured.

## Corrections and Clarifications

In addition to the above stated rule requirements, a number of corrections and clarifications have been made in the existing rule text.

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## SECTION 1 GENERAL

### A. Introduction

#### A 100 Introduction

**101** This chapter describes standards for a fully redundant propulsion and steering system. Fully redundant, in context of these rules, implies that a required portion of the vessels propulsion power and manoeuvrability is available after a single failure.

**102** For a standard where less than 50% propulsion power is remaining after a failure, refer to Pt.6 Ch.19 Alternative Propulsion.

#### A 200 Scope

**201** This chapter describes additional requirements for the propulsion machinery, the steering system and their auxiliary systems.

**202** For the class notation **RPS**, the scope of this chapter also includes requirements for the separation of installed equipment by specific bulkheads and decks.

#### A 300 Objective

**301** The objective of the class notation **RP** is to ensure the availability of at least 50% of the propulsion power and manoeuvrability after any single failure in the propulsion-, steering- and auxiliary systems.

**302** In addition to the above mentioned single failure in the propulsion and auxiliary system, the class notation **RPS** aims for the 50% minimum also in case of failures caused by fire and flooding incidents.

#### A 400 Application

**401** Vessels built and tested in compliance with the applicable requirements of this chapter may be assigned one of the following additional class notations:

**RP** - Redundant Propulsion

**RPS** - Redundant Propulsion and Separate.

**402** Where a requirement is applicable for one notation only this is indicated in the requirement text.

**403** Section 2 E covering separation requirements is applicable for **RPS** only.

#### A 500 Document structure

**501** This chapter contains two sections in which the first section contains a general description and procedural requirements and the second section contains technical requirements.

**502** The technical requirements of Section 2 are divided along the following sub-sections:

A. Covering: System design describing the redundancy concept and failure modes

B. Covering: System configuration

C. Covering: Auxiliary systems

D. Covering: Propulsion, steering and Auxiliary Control System

E. Covering: Separation requirements.

#### A 600 Relation to other DNV requirements

**601** The requirements of these rules are supplementary to the main class rules.

##### Guidance note:

In particular it is referred to relevant sections of:

Pt.4 Ch.2 Rotating Machinery, General

Pt.4 Ch.6 Piping Systems

Pt.4 Ch.8 Electrical Installations

Pt.4 Ch.9 Instrumentation and Automation

Pt.4 Ch.14 Steering Gear.

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**602** See Pt.3 Ch.1 or Pt.3 Ch.2 for the sub-division requirements connected to the **RPS** notation.

## B. References

### B 100 References

**101** For other relevant international standards see Table B1.

| Table B1 Other references |   |
|---------------------------|---|
| Reference                 | Title   |
| DNV Guideline No. 23      | DNV Guideline for FMEA of Redundant Systems   |
| IEC Publication 60812     | Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA) |
| IMO HSC Code, Annex 4     | Procedures for FMEA   |

### B 200 Definitions

**201** *Active components* are components for mechanical transfer of energy, e.g. pumps, fans, electric motors, generators, combustion engines and turbines.

**202** *50% propulsion power* is the nominal power consumption of one propeller when operating with all propulsion systems together. I.e. deviations in thrust output caused by changes in vessel speed and propeller r.p.m. at loss of one propulsion system need not to be considered.

**203** *Remaining propulsion power* is the vessels available propulsion power after the occurrence of a failure.

### B 300 Abbreviations

**301** Relevant abbreviations given in Table B2.

| Table B2 Abbreviations |                                   |
|------------------------|-----------------------------------|
| Abbreviation           | In full                           |
| FMEA                   | Failure mode and effects analysis |
| UPS                    | Procedures for FMEA               |

## C. Procedural Requirements

### C 100 Document requirements

**101** The propulsion, power generation and steering systems, with their auxiliaries and remote control shall be documented according to main class. The documentation requirements in Table C1 are additional for **RP/RPS** notation.

| Table C1 Documentation requirements  |   |   |      |                   |
|--|---|---|------|-------------------|
| System   | Documentation type                                | Additional description  | Info | Notation          |
| Propulsion and steering system including necessary auxiliary systems and remote control system | Z071 - Failure mode and effect analysis (FMEA) *) | Including proof that no single failure in required duplicated components and systems will cause loss of more than 50% of propulsion power. See also B200.   | AP   | <b>RP and RPS</b> |
|  | Z140 - Test procedure for quay and sea trial *)   | An FMEA test procedure for failure testing at the sea trial to verify the conclusions in the FMEA. This shall be based upon the failure modes identified, and the vessel system setup as specified in the FMEA. | AP   | <b>RP and RPS</b> |
|  | I260 - Cable routing layout drawing               | All relevant cables.  | AP   | <b>RPS</b>        |
|  | Z030 - System arrangement plan                    | Fire and flooding separation. Also indication of the different fire zones allocated to the installation of the redundant equipment.   | AP   | <b>RPS</b>        |
|  | Z240 - Calculation report                         | Documentation to demonstrate compliance with capacity requirements given in Sec.2 A104.   | AP   | <b>RP and RPS</b> |
|  | Z240 - Calculation report                         | Documentation to demonstrate compliance with capacity requirements given in Sec.2 A107 or Sec.2 A108.   | AP   | <b>RP and RPS</b> |
| Info: AP - For approval*) for a more extensive description on the requirements, see below.     |   |   |      |                   |

**102** A Failure Mode and Effect Analysis, FMEA, for the complete propulsion and steering systems, with their

auxiliaries, shall be submitted for approval. The FMEA shall show that redundancy requirements are fulfilled where relevant.

### **103 Failure mode and effect analysis**

A test procedure for the final sea trial of the complete redundant propulsion and steering systems shall be submitted for approval.

**104** The purpose of the FMEA is to give a description of the different failure modes of the equipment when referred to its functional task. Special attention shall be paid to the analysis of systems that may enter a number of failure modes and thus induce a number of different effects on the propulsion and steering performance. The FMEA shall include at least the information specified in 103 to 109.

**105** The FMEA shall give general vessel information and clearly describe the design intent and the intended overall redundancy and acceptance criteria. The system operational mode(s) shall be described and prerequisites for achieving the required failure tolerance and redundancy shall be specified.

#### **Guidance note:**

Vessel system setup (e.g., but not limited to, setting of any valve cross-over, power feed change-over arrangement condition to be defined - also applies for duty-standby arrangement) for each normal operational mode subject for FMEA shall be specified.

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**106** A breakdown of the systems, into functional blocks shall be made. The functions of each block shall be described. The breakdown shall be performed to such a level of detail that the design intent can be documented.

**107** A description of each functional block shall be made and all associated failure modes with their failure causes shall be identified for normal operational modes.

**108** A description of the effects of each failure mode on the functional block, and on the propulsion and steering function shall be made.

**109** If applicable, a description of the installation of redundant component groups in fire and flooding protected compartments. This also includes cables and communication lines, and associated equipment.

**110** A test program to support the conclusions shall be included or referred. The test program shall be based upon the failure modes identified in the FMEA in order to verify the conclusions. References shall be made between the FMEA and the FMEA test program.

**111** Compliance statements referring to the design intent and acceptance criterion shall be made.

**112** The FMEA shall be a self contained document including all necessary descriptions, supporting documents and drawings in order to document the conclusions.

#### **Guidance note:**

Description of FMEA systematic may be found in IEC Publication 60812 and IMO HSC Code, Annex 4.

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#### **Guidance note:**

The above implies that separate FMEAs covering control systems (as supplied by manufacturer) shall be incorporated in the overall system FMEA (as supplied by the yard).

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**113** FMEA(s) and FMEA test program(s) shall be kept on board and at all times be updated to cover alterations to the propulsion and steering systems.

## **C 200 Certification requirements**

**201** Equipment shall be certified according to main class requirements.

## **C 300 Survey and test requirements**

**301** For initial issue of class notation upon completion, the propulsion and steering systems, with their auxiliaries, shall be subjected to final tests during sea trials, in compliance with the requirements for main class.

**302** Additional tests shall be carried out to verify the ability of the system to maintain the required remaining propulsion power after any failure as required in A202 and A203.

**303** Additional tests shall be carried out to verify the redundancy of the propulsion and steering system. The testing shall be done according to the FMEA test program. In case redundancy is based upon restoration of dedicated systems (ref. Sec.2 A107) this includes testing to demonstrate that this process is completed before the vessel has lost steering speed.

**Guidance note:**

For **RPS** this implies that loss of all systems in relevant fire zones should be tested.

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**304** It is not required that the built-in endurance as required by A207 and A208 be demonstrated. However, time-critical resources shall be substantiated by adequate tests of rate of consumption and depletion.



## SECTION 2 TECHNICAL REQUIREMENTS

### A. System design

#### A 100 Redundancy concept

**101** The redundancy concept shall ensure the ability of the system to remain in operation in accordance with the objectives of the specific notation. This covers the following aspects:

- propulsion
- steering
- recovery time
- endurance.

#### 102 Propulsion

For notation **RP** the vessel's propulsion system shall be of a redundant design such that at least 50% of the propulsion power can be restored (if not maintained) after any single failure in the propulsion and auxiliary systems, before the vessel has lost steering speed. For definition of failure modes see 201.

##### Guidance note 1:

The remaining propulsion power after loss of one propulsion line may in practice be less than 50% due to hydrodynamical properties of the vessel when operating at lower speed.

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##### Guidance note 2:

Vessels designed and built with a larger degree of separation than 2 will be subject to special evaluation.

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**103** For notation **RPS** the requirement to ensure at least 50% of the propulsion power as described in 202, also includes single failure caused by fire and flooding incidents. For definition of failure modes see 202.

**104** The propulsion system power capacity shall be such that the required remaining propulsion power, as recovered after failure, will enable the vessel to maintain a speed of not less than 6 knots while heading into BF 8 weather conditions with corresponding wave conditions. The requirement shall be documented by computation where relevant wave spectrum is utilised.

#### 105 Steering

The steering arrangement shall consist of two independent steering systems, each in compliance with the main class rules.

**106** The vessel is to be fully manoeuvrable when operating one (1) propulsion and one (1) steering system.

##### Guidance note:

This implies that each steering system shall comply with main class requirements for rudder (or equivalent means, e.g. thrusters) movement when only one propulsion and one steering system is in operation.

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#### 107 Recovery time

To ensure the required 50% propulsion power, restoration of dedicated systems is allowed as long as the restoration process is completed before the vessel has lost steering speed

##### Guidance note:

The objective of the above stated link between recovery of the propulsion power and steering capability is to allow more time when the vessel is at transit speed in open waters than when the vessel is proceeding at reduced speed in congested waters, in or is in a manoeuvring situation. This implies that systems which are not continually available should be prepared for service before entering critical situations where the recovery time otherwise would be too long in view of external hazards.

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#### 108 Endurance

After any single failure the vessel shall be able to proceed with the required remaining propulsion power for a period of at least 72 hours.

**109** For vessels built for a specific service where the duration of a sea voyage is less than 72 hours, the built-in endurance at the required remaining propulsion power may be limited to the duration of the maximum crossing time but not less than 12 hours.

## A 200 Failure modes

**201** For the **RP** notation, the defined failure modes include component breakdown and malfunctions, but exclude the effects of fire and flooding. Thus, it is acceptable that redundant components are installed in a common area or compartment.

**202** In addition to active components, the component breakdown as stated above shall include the failure of the following components:

- coolers and heat exchangers
- filters
- motorised valves
- boilers
- transformers
- switchgear
- cables.

See sub-section C for more specific requirement.

**203** For the **RPS** notation, the failure modes include all those defined for **RP**, in addition to any failure in the propulsion and steering systems that will result from incidents of fire and flooding. Hence, redundant components and systems shall be located in different fire sub-divisions. The sub-divisions are to be watertight below the damage waterline, (see Pt.3 Ch.1 or Pt.3 Ch.2). Reference is also made to the separation requirements given in E.

**Guidance note:**

Loss of stability (e.g. as a result of flooded compartments) is not a relevant failure mode.

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## B. System Configuration

### B 100 General

**101** The basic requirement of maintaining at least 50% of propulsion power may typically be realised by installation of two mutually independent propulsion systems of equal capacity.

**Guidance note:**

The minimum of 50% propulsion power is to be understood as the nominal power consumption of one propeller when operating with all propulsion systems together. I.e. the deviations in thrust output caused by changes in vessel speed and propeller r.p.m. at loss of one propulsion system need not to be considered.

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**102** Typical configuration will consist of two propulsion lines, alternatively two azimuth thrusters. Two independent engine systems geared onto one propeller are not considered equivalent.

**103** The redundancy in steering function shall be realised by the installation of two (or more) mutually independent steering systems, e.g. two rudders or two azimuth thrusters. Each steering system, with steering controls and actuators, shall comply with the main class rules. This implies that each steering system shall be provided with a main and an auxiliary steering gear.

**Guidance note:**

Vessels designed and built with a larger degree of separation than 2 will be subject to special evaluation.

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**104** After failure of one propulsion system, the steering capability, as required for main steering gear, shall be available at the maximum achievable speed.

### B 200 Electrical power generation

**201** The electrical power required for propulsion, steering and auxiliary systems shall be generated by a power plant complying with main class requirements of Pt.4 and the redundancy, capacity and separation requirements as specified in A100.

**202** The vessel shall be capable of operating with the emergency switchboard out of operation.

### B 300 Electrical power distribution

**301** When power for propulsion, steering and their auxiliaries is supplied from one switchboard, the bus-bars of the switchboard shall be arranged for automatic separation into at least 2 sections, with the circuits for propulsion and steering units and auxiliaries distributed between the sections. Automatic separation shall take

place when short circuit currents are detected on the main bus-bars. The bus-tie breaker(s) or inter-connector breaker(s), shall be capable of breaking the maximum short circuit current in the system, and shall provide discrimination towards the generator breakers for short circuit. In addition bus-tie breaker(s) or inter-connector breaker(s), shall be provided with under voltage trip. Alternatively the redundancy may be provided by two separate switchboards.

**302** Power supply to control and auxiliary systems shall be arranged so that at least one of the propulsion and steering systems are capable of being operated after failure of any one switchboard section. The remaining capacity shall be so that the requirements in A100 are fulfilled. This applies for all electrical (AC and DC) distribution systems.

**303** For **RPS** notation, the switchboard sections as described in 301 shall be separated by bulkheads and decks, fire-insulated by A-60 class division, and in addition, watertight if below the damage water line. These sections may be connected by 2 bus-tie breakers, which shall be installed at each side of the A-60 partition. Power distribution must also be arranged in compliance with the separation requirements given in E. below.

**304** The power distribution system shall be arranged so that the power supply can be maintained or automatically restored, such that the power supply to the switchboard(s) is restored within 45 s and power to the auxiliary services in compliance with A100.

#### **B 400 Electrical power plant control**

**401** The power plant control system shall be arranged so that a single failure therein will not jeopardise the propulsion redundancy concept.

**402** Battery and UPS power sources shall be arranged in accordance with D300.

### **C. Auxiliary Systems**

#### **C 100 General**

**101** Active components in auxiliary systems shall be arranged with redundancy in order that any one component may be taken out of service for maintenance purposes without having to reduce the normal full propulsion power.

##### **Guidance note:**

Active components in this context are components for mechanical transfer of energy, e.g. pumps, fans, electric motors. The intention is to achieve a similar availability of the normal propulsion power as for a single engine propulsion plant.

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**102** Fixed piping may be shared by redundant components for the **RP** notation, except as given in 201, 402 and 600.

**103** For the **RPS** notation, separate piping systems shall be arranged for redundant systems. These systems shall be separated by A-60 class fire division as required in E. below. Cross-over pipes are accepted provided these can be closed from both sides of separating bulkheads, with one valve on each side of the bulkhead(s) fitted directly or as close as possible to it. Crossover valves shall be easy to reach and clearly marked. Ventilation ducts shall not have cross-over facilities.

**104** Auxiliary system shall be so arranged that they after failure are able to support the required remaining propulsion capacity in accordance with A107 or A108.

##### **Guidance note:**

Typical systems included:

- ventilation systems
- cooling systems
- fuel oil transfer system
- fuel pre-treatment systems, i.e. all equipment for purification, filtering, heating, and measuring fuel oil
- lubrication oil systems
- other systems when relevant.

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**105** If equipment is dependent upon cooling, i.e. air ventilation or another cooling media, in order to avoid excessive heat increase, the cooling system shall be designed with redundancy, and in addition separation as applicable for the **RPS** notation.

**106** For **RPS**, the capacity of the bilge system in each engine room shall be in accordance with the main class rules.

**107 Main and emergency fire fighting systems shall be arranged in accordance with SOLAS requirements.**

#### **C 200 Fuel oil**

**201** There shall be at least two service tanks, which shall serve dedicated sub-systems. Cross-over facilities may be arranged, but shall be kept closed in normal operation.

**202** For **RPS**, the service tanks shall be installed one in each of the separate engine rooms.

**203** If the fuel system requires heating, also the heating system shall comply with the redundancy requirements and in addition the separation requirements as applicable for the **RPS** notation.

**204** If the fuel system requires heating, the heating system shall comply with redundancy requirements

#### **C 300 Lubrication oil system**

**301** Each propulsion system shall have an independent lubrication oil circulation system. The system shall comply with the redundancy requirements and in addition the separation requirements as applicable for the **RPS** notation.

#### **C 400 Cooling water**

**401** Cooling water systems for **RP** and **RPS** notations shall comply with main class rules, while also taking into consideration the requirements for component redundancy and separation as given in A200 and E. below. For vessels with class notation **Passenger ship** or **Ferry** notation, sea water suction shall be arranged from separate sea chests located in the bottom of the ship, in addition to a high sea chest located at one side. The two low sea chests shall have separate ventilation arrangements.

**402** Fresh water cooling systems shall be arranged as fully separated systems also for the **RP** notation, in view of the risk of severe loss of water or accumulation of gas due to leakage, so that the redundancy and capacity requirements in Sec.1 A200 are fulfilled after failure of any one fresh water cooling system.

##### **Guidance note:**

Redundant systems for air conditioning and control of ambient temperature, e.g. air condition units, chillers and HVAC, may share common piping for notation **RP**.

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#### **C 500 Compressed air system**

**501** The starting air system shall comply with main class for **RP**. For **RPS**, an equivalent system will be accepted when the compressors and air receivers are adequately distributed on both sides of fire and or flooding partitions.

**502** The control air system shall be considered in view of the actual use of compressed air for control functions. If control air is found necessary for essential functions in the propulsion and steering system separated systems shall be arranged also for the **RP** notation, so that the redundancy and capacity requirements in Sec.1 A200 are fulfilled after failure of any one control air system.

#### **C 600 Ventilation systems**

**601** Ventilation systems shall not have any common units or cross-over pipes, when supplying different fire-division areas, which are required in order to comply with the **RPS**.

### **D. Propulsion, Steering and Auxiliary Control System**

#### **D 100 Propulsion control system**

**101** Independent control systems for each propulsion line shall be arranged according to main class and consistent with the failure concept given in A200. Each line shall include a main control station and an emergency control station.

**102** Reliable means of communication, also operable during black-out, between the navigating bridge and the alternative or emergency control stations shall be arranged. The systems shall be so arranged that at least one means of communication is available also after any relevant single failure.

##### **Guidance note:**

For notation **RPS**: This requirement is not relevant for failure modes which makes the bridge unavailable, e.g. fire.

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**103** The bridge propulsion control system shall be independent for each propulsion line; so that any single failure will only affect one of them, and that operation of the remaining system can continue on the normal means of operation (e.g. levers). Alternatively a system arranged with redundancy can be accepted if in addition

independent back-up control system for each propulsion system is arranged. The redundant system must be so arranged that any single failure will not prevent continued normal control of the complete propulsion system. The independent back-up control system shall be based upon similar input devices as the normal means of operation (e.g. levers).

**104** For both propulsion systems local control shall be available after any single failure of cabling or equipment on the bridge or between the bridge and the location where the local control is installed. For **RPS** notation this also includes incidents of fire, and associated cabling and equipment installed outside of the bridge shall follow the requirements in E. below.

**105** Both normal and any possible back-up bridge control system shall be arranged so that the operator can control the systems from (or adjacent to) the main navigation stand, in order to maintain the normal view to the outside and to the required feedback and heading indicators. Back-up control shall be based upon similar input devices as the normal means of operation (e.g. levers).

**Guidance note:**

Mechanical levers are not required to be duplicated.

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**106** At failure of control of one propulsion unit, this unit may be stopped, as an alternative to remain in operation at fixed thrust.

**D 200 Control system for auxiliary services**

**201** Control systems for auxiliary systems shall be arranged in accordance with the redundancy concept for the propulsion and steering, so that a single failure within any control system does not affect the required remaining propulsion and steering capabilities.

**D 300 Battery and UPS systems**

**301** Uninterruptible power supplies (UPSes) shall, where fitted, be arranged so that they comply with the capacity, redundancy and separation concept for propulsion and steering as applicable for the relevant notation. In addition, each UPS shall be arranged with a by-pass, which may be used when an UPS fails. If the control system is powered by batteries, the batteries shall be built with redundancy in technical design and physical separation in accordance with A100, and in addition, be arranged with cross-over facilities, which may be used when a battery fails.

**302** Control power sources shall be arranged so that all equipment under control which has not lost its power source due to a partial black-out can still be operated.

**D 400 Steering Control System**

**401** The requirements in 104 and 105 also apply to the bridge steering gear systems.

**E. Separation Requirements for RPS**

**E 100 General**

**101** Systems, include single components, cabling, and piping, that form part of the designed redundancy, shall be separated by bulkheads and decks, which shall be fire insulated A-60 class division, and in addition shall be watertight if below the damage water line. Watertight bulkheads shall be strong enough to withstand one sided flooding, and if doors are fitted in such bulkheads, they shall comply with SOLAS Ch. II-1/25-9.

**Guidance note 1:**

If two A-0 bulkheads are arranged in areas with low fire risk, this may be accepted based on case-by-case approval.

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**Guidance note 2:**

When it is practically unfeasible to comply with the above requirement, cables running together within an A-60 cable duct or equivalent fire-protection can be accepted. This alternative is not accepted in high fire risk areas, e.g. engine rooms and fuel treatment rooms. Cable connection boxes are not allowed in such ducts. If cables are located in A-60 cable ducts, means should be provided to keep the temperature inside the duct within the specified temperature for the cables. This, as far as practicable, also applies to piping.

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**Guidance note 3:**

Definition of high fire risk areas: Reference to be made to SOLAS Chapter II-2 Reg. 3.31 Machinery spaces of category A.

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**102** The remote control panels and cabling on the bridge are accepted as a non-separable and does not need to be separated by A-60 partitions provided alternative control stands are arranged.

**103** Local control of propulsion and steering shall be possible according to main class requirements. Such means shall be operable after total failure of the central bridge installation by reliable means of separation of remote and local control.