

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SHIPS

CONTROL, ELECTRICAL, REFRIGERATION AND FIRE

JULY 2007

PART 6

Lloyd's Register is an exempt charity under the UK Charities Act 1993

Lloyd's Register, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as the 'Lloyd's Register Group'. The Lloyd's Register Group assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register Group entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

PART	1	REGULATIONS
PART	2	RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS
PART	3	SHIP STRUCTURES (GENERAL)
PART	4	SHIP STRUCTURES (SHIP TYPES)
PART	5	MAIN AND AUXILIARY MACHINERY
PART	6	CONTROL, ELECTRICAL, REFRIGERATION AND FIRE
		Chapter 1 Control Engineering Systems
		2 Electrical Engineering
		3 Refrigerated Cargo Installations
		4 Fire Protection, Detection and Extinction Requirements
PART	7	OTHER SHIP TYPES AND SYSTEMS

© Lloyd's Register, 2007. All rights reserved.

Except as permitted under current legislation no part of this work may be photocopied, stored in a retrieval system, published, performed in public, adapted, broadcast, transmitted, recorded or reproduced in any form or by any means, without the prior permission of the copyright owner. Enquiries should be addressed to Lloyd's Register, 71 Fenchurch Street, London, EC3M 4BS.

CHAPTER	1	CONTROL ENGINEERING SYSTEMS
Section	1	General requirements
	1.1	General
	1.2	Plans
	1.3	Control, alarm and safety equipment
	1.4	Alterations and additions
Section	2	Essential features for control, alarm and safety systems
	2.1	General
	2.2	Control stations for machinery
	2.3	Alarm systems, general requirements
	2.4	Safety systems, general requirements
	2.5	Control systems, general requirements
	2.6	Bridge control for main propulsion machinery
	2.7	Valve control systems
	2.8	Fire detection alarm systems
	2.9	Fixed water-based local application fire-fighting systems
	2.10	Programmable electronic systems – General requirements
	2.11	Data communication links
	2.12	Programmable electronic systems – Additional requirements for essential services and safety critical systems
	2.13	Programmable electronic systems – Additional requirements for integrated systems
Section	3	Control and supervision of unattended machinery
	3.1	General
	3.2	Oil engines for propulsion purposes
	3.3	Steam turbine machinery for propulsion purposes
	3.4	Gas turbine machinery
	3.5	Main, auxiliary and other boilers
	3.6	Thermal fluid heaters
	3.7	Inert gas generators
	3.8	Incinerators
	3.9	Auxiliary engines and auxiliary steam turbines
	3.10	Controllable pitch propellers and transverse thrust units
	3.11	Monitoring in cargo pump rooms
	3.12	Electric system
	3.13	Steering gear
	3.14	Waterjets
	3.15	Miscellaneous machinery
Section	4	Unattended machinery space(s) – UMS notation
	4.1	General
	4.2	Alarm system for machinery
	4.3	Bridge control for main propulsion machinery
	4.4	Control stations for machinery
	4.5	Fire detection alarm system
	4.6	Bilge level detection
	4.7	Supply of electric power, general
Section	5	Machinery operated from a centralized control station – CCS notation
	5.1	General requirements
	5.2	Centralized control station for machinery
Section	6	Integrated computer control – ICC notation
	6.1	General
	6.2	General requirements
	6.3	Operator stations
Section	7	Trials
	7.1	General
	7.2	Unattended machinery space operation – UMS notation
	7.3	Operation from a centralized control station – CCS notation
	7.4	Record of trials

CHAPTER	2	ELECTRICAL ENGINEERING
Section	1	General requirements
	1.1	General
	1.2	Plans
	1.3	Surveys
	1.4	Additions or alterations
	1.5	Definitions
	1.6	Design and construction
	1.7	Quality of power supplies
	1.8	Ambient reference and operating conditions
	1.9	Inclination of ship
	1.10	Location and construction
	1.11	Earthing of non-current carrying parts
	1.12	Bonding for the control of static electricity
	1.13	Alarms
	1.14	Operation under fire conditions
	1.15	Protection of electrical equipment against the effects of lightning strikes
Section	2	Main source of electrical power
	2.1	General
	2.2	Number and rating of generators and converting equipment
	2.3	Starting arrangements
	2.4	Prime mover governors
	2.5	Main propulsion driven generators not forming part of the main source of electrical power
Section	3	Emergency source of electrical power
	3.1	General
	3.2	Emergency source of electrical power in passenger ships
	3.3	Emergency source of electrical power in cargo ships
	3.4	Starting arrangements
	3.5	Prime mover governor
	3.6	Radio installation
Section	4	External source of electrical power
	4.1	Temporary external supply
	4.2	Permanent external supply
Section	5	Supply and distribution
	5.1	Systems of supply and distribution
	5.2	Essential services
	5.3	Isolation and switching
	5.4	Insulated distribution systems
	5.5	Earthed distribution systems
	5.6	Diversity factor
	5.7	Lighting circuits
	5.8	Motor circuits
	5.9	Motor control
Section	6	System design – Protection
	6.1	General
	6.2	Protection against short-circuit
	6.3	Protection against overload
	6.4	Protection against earth faults
	6.5	Circuit-breakers
	6.6	Fuses
	6.7	Circuit-breakers requiring back-up by fuse or other device
	6.8	Protection of generators
	6.9	Load management
	6.10	Feeder circuits
	6.11	Motor circuits
	6.12	Protection of transformers

Section	7	Switchgear and control gear assemblies
	7.1	General requirements
	7.2	Busbars
	7.3	Circuit-breakers
	7.4	Contactors
	7.5	Creepage and clearance distances
	7.6	Degree of protection
	7.7	Distribution boards
	7.8	Earthing of high-voltage switchboards
	7.9	Fuses
	7.10	Handrails or handles
	7.11	Instruments for alternating current generators
	7.12	Instrument scales
	7.13	Labels
	7.14	Protection
	7.15	Wiring
	7.16	Position of switchboards
	7.17	Switchboard auxiliary power supplies
	7.18	Testing
	7.19	Disconnectors and switch-disconnectors
Section	8	Rotating machines
	8.1	General requirements
	8.2	Rating
	8.3	Temperature rise
	8.4	Generator control
	8.5	Overloads
	8.6	Machine enclosure
	8.7	Direct current machines
	8.8	Survey and testing
Section	9	Converter equipment
	9.1	Transformers
	9.2	Semiconductor equipment
	9.3	Uninterruptible power systems
Section	10	Electric cables and busbar trunking systems (busways)
	10.1	General
	10.2	Testing
	10.3	Voltage rating
	10.4	Operating temperature
	10.5	Construction
	10.6	Conductor size
	10.7	Correction factors for cable current rating
	10.8	Installation of electric cables
	10.9	Mechanical protection of cables
	10.10	Cable support systems
	10.11	Penetration of bulkheads and decks by cables
	10.12	Installation of electric cables in protective casings
	10.13	Single-core electric cables for alternating current
	10.14	Electric cable ends
	10.15	Joints and branch circuits in cable systems
	10.16	Busbar trunking systems (bustrunks)
Section	11	Batteries
	11.1	General
	11.2	Construction
	11.3	Location
	11.4	Installation
	11.5	Ventilation
	11.6	Charging facilities
	11.7	Recording of batteries for emergency and essential services

Section	12	Equipment – Heating, lighting and accessories
	12.1	Heating and cooking equipment
	12.2	Lighting – General
	12.3	Incandescent lighting
	12.4	Fluorescent lighting
	12.5	Discharge lighting
	12.6	Socket outlets and plugs
	12.7	Enclosures
Section	13	Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts
	13.1	General
	13.2	Selection of equipment
	13.3	Installation of electrical equipment
	13.4	Dangerous zones and spaces
	13.5	Semi-enclosed spaces
	13.6	Ventilation
	13.7	Pressurization
	13.8	Cable and cable installation
	13.9	Requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point not exceeding 60°C (closed-cup test)
	13.10	Requirements for ships for the carriage of liquefied gases in bulk
	13.11	Requirements for ships intended for the carriage in bulk of other flammable liquid cargoes
	13.12	Special requirements for ships with spaces for carrying vehicles with fuel in their tanks, for their own propulsion
	13.13	Special requirements for ships intended for the carriage of dangerous goods
Section	14	Navigation and manoeuvring systems
	14.1	Steering gear
	14.2	Thruster systems for steering
	14.3	Thruster systems for dynamic positioning
	14.4	Thruster systems for manoeuvring
	14.5	Navigation lights
	14.6	Navigational aids
Section	15	Electric propulsion
	15.1	General
	15.2	Power requirements
	15.3	Propulsion control
	15.4	Protection of propulsion system
	15.5	Instruments
Section	16	Fire safety systems
	16.1	Fire detection and alarm systems
	16.2	Automatic sprinkler system
	16.3	Fixed water-based local application fire-fighting systems
	16.4	Fire pumps
	16.5	Refrigerated liquid carbon dioxide systems
	16.6	Fire safety stops
	16.7	Fire doors
	16.8	Fire dampers
	16.9	Fire-extinguishing media release
Section	17	Crew and passenger emergency safety systems
	17.1	Emergency lighting
	17.2	General emergency alarm system
	17.3	Public address system
	17.4	Escape route or low location lighting (LLL)

Section	18	Ship safety systems
	18.1	Watertight doors
	18.2	Stem and side shell doors
	18.3	Bow and inner doors
	18.4	Subdivision doors on vehicle decks
	18.5	Bilge pumps
Section	19	Lightning conductors
	19.1	General
Section	20	Testing and trials
	20.1	Testing
	20.2	Trials
	20.3	High voltage cables
	20.4	Hazardous areas
Section	21	Spare gear
	21.1	General
CHAPTER	3	REFRIGERATED CARGO INSTALLATIONS
Section	1	General requirements
	1.1	Application
	1.2	Plans and particulars
	1.3	Materials
	1.4	Equipment to be constructed under survey
	1.5	Type approved equipment
	1.6	Notation and temperature conditions
	1.7	Novel arrangements and design
	1.8	Heat balance tests
	1.9	Controlled atmosphere (CA) systems
	1.10	Spare gear and refrigerated charge
Section	2	Design criteria
	2.1	General
	2.2	Refrigerants and classes of pipes
	2.3	Refrigeration units
	2.4	Refrigeration capacity
	2.5	Design pressures
	2.6	Insulation
Section	3	Refrigerating machinery and refrigerant storage compartments
	3.1	General
	3.2	Arrangements for compartments housing machinery using ammonia
	3.3	Gas storage compartments
	3.4	Compartments housing carbon dioxide containing equipment
Section	4	Refrigeration plant, pipes, valves and fittings
	4.1	General requirements for refrigerating compressors
	4.2	Reciprocating compressors
	4.3	Screw compressors
	4.4	Pressure vessels and heat exchangers
	4.5	Condensers, oil coolers and evaporators
	4.6	Liquid receivers
	4.7	Oil separators
	4.8	Air coolers and cooling grids
	4.9	Refrigerant pumps
	4.10	Condenser cooling water pumps
	4.11	Piping systems
	4.12	Joints
	4.13	Liquid level indicators
	4.14	Automatic expansion valves
	4.15	Overpressure protection devices

	4.16	Filters, driers and moisture indicators
	4.17	Purging devices
	4.18	Piping in way of refrigerated spaces
	4.19	Drainage from refrigerated spaces
	4.20	Corrosion protection of metal fixtures
	4.21	Pressure testing at manufacturers' works
	4.22	Pressure test after installation on board ship
Section	5	Refrigerant detection systems
	5.1	General
	5.2	Ammonia vapour detection and alarm equipment
Section	6	Electrical installation
	6.1	General
	6.2	Electrical equipment for use in explosive gas atmospheres
Section	7	Instrumentation, control, alarm, safety and monitoring systems
	7.1	Instrumentation
	7.2	Control, alarm and safety systems
	7.3	Temperature monitoring and recording
Section	8	Personnel safety equipment and systems
	8.1	Personnel safety equipment
	8.2	Personnel warning systems
Section	9	Refrigerated cargo spaces
	9.1	Airtightness of refrigerated spaces
	9.2	Insulation systems
	9.3	Access plugs and panels
	9.4	Air circulation and distribution
	9.5	Air refreshing arrangements
	9.6	Heating arrangements for fruit cargoes
Section	10	Container ships fitted with refrigerating plant to supply cooled air to insulated containers in holds
	10.1	General
	10.2	Additional information and plans
	10.3	Air coolers
	10.4	Air duct systems
	10.5	Duct air leakage and distribution tests
	10.6	Cell air conditioning arrangements
Section	11	Acceptance trials
	11.1	Tests after completion
	11.2	Thermographic survey
	11.3	Acceptance tests
	11.4	Sea trials
	11.5	Reporting of tests
CHAPTER	4	FIRE PROTECTION, DETECTION AND EXTINCTION REQUIREMENTS
Section	1	General
	1.1	Application
Section	2	Fire detection, protection and extinction
	2.1	General provisions
	2.2	Definitions
	2.3	Surveys and maintenance
	2.4	Requirements

Control Engineering Systems

Part 6, Chapter 1

Section 1

Section

- 1 **General requirements**
- 2 **Essential features for control, alarm and safety systems**
- 3 **Control and supervision of unattended machinery**
- 4 **Unattended machinery space(s) – UMS notation**
- 5 **Machinery operated from a centralized control station – CCS notation**
- 6 **Integrated computer control – ICC notation**
- 7 **Trials**

■ Section 1 General requirements

1.1 General

1.1.1 This Chapter applies to all ships intended to be classed with Lloyd's Register (hereinafter referred to as 'LR'), and is in addition to other relevant Sections of the Rules.

1.1.2 Whilst these requirements satisfy the regulations of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments, attention should also be given to any relevant statutory requirements of the National Administration of the country in which the ship is to be registered.

1.1.3 Section 2 of this Chapter states requirements for alarm systems, safety systems and automatic or remote controls where fitted.

1.1.4 Section 3 of this Chapter states the essential alarms and safeguards which are required for unattended machinery as defined in 1.2.3, which under normal operating conditions is remotely controlled or is automatic in operation.

1.1.5 Section 4 of this Chapter states requirements which shall apply where it is intended to operate the ship with machinery spaces unattended. In general, ships complying with the requirements of Section 4 will be eligible for the class notation **UMS**, see Pt 1, Ch 2,2.

1.1.6 Section 5 of this Chapter states requirements which shall apply where it is intended to operate the ship with machinery spaces under continuous supervision from a centralized control station. In general, ships complying with the requirements of Section 5 will be eligible for the class notation **CCS**, see Pt 1, Ch 2,2.

1.1.7 Section 6 of this Chapter states requirements which shall apply where it is intended that the control and supervision of ship operational functions are computer based. In general ships complying with the requirements of Section 6 will be eligible for the class notation **ICC**, see Pt 1, Ch 2,2.

1.1.8 LR will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans

1.2.1 Plans required by 1.2.2 to 1.2.7 are to be submitted in triplicate.

1.2.2 Where control, alarm and safety systems are intended for the machinery or equipment as defined in 1.2.3 the following are to be submitted:

- Description of operation with explanatory diagrams.
- Line diagrams of control circuits.
- List of monitored points.
- List of control points.
- List of alarm points.
- Test schedules (for both works testing and sea trials) which should include methods of testing and test facilities provided, see 1.3.1.
- Failure Mode and Effects Analysis (FMEA) where required by other sections of the Rules.
- List of safety functions and details of any overrides, including consequences of use, see 2.4.9 and 2.6.9.

1.2.3 Plans for the control, alarm and safety systems of the following are to be submitted:

- Air compressors.
- Bilge and ballast systems.
- Cargo pumping systems for tankers.
- Cargo and ballast pumps in hazardous areas.
- Controllable pitch propellers.
- Electric generating plant.
- Fixed water based local application fire-fighting systems, see 2.9.
- Incinerators.
- Inert gas generators.
- Main propelling machinery including essential auxiliaries.
- Miscellaneous machinery or equipment (where control, alarm and safety systems are specified by other Sections of the Rules).
- Oil fuel transfer and storage systems.
- Steam raising plant. (Boilers and their ancillary equipment).
- Steering gear.
- Thermal fluid heaters.
- Transverse thrust units.
- Valve position indicating systems.
- Waste-heat boiler.
- Waterjets for propulsion purposes.
- Cargo tank, ballast tank and void space instrumentation where such arrangements are specified by other sections of the Rules (e.g. water ingress detection, gas detection).

1.2.4 **Alarm systems.** Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation are to be submitted.

Control Engineering Systems

Part 6, Chapter 1

Sections 1 & 2

1.2.5 Programmable electronic systems. In addition to the documentation required by 1.2.2 the following is to be submitted:

- System requirements specification.
- System integration plan, see 2.13.2.
- Failure Mode and Effects Analysis (FMEA), see 2.13.5
- Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
- Hardware certification details, see 2.10.5 and 2.12.3.
- Software quality plans, including applicable procedures, see 2.10.21.
- Factory acceptance, integration and sea trial test schedules for hardware and software.

1.2.6 Control station. Location and details of control stations are to be submitted, e.g. control panels and consoles.

1.2.7 Fire detection systems. Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s) are to be submitted. The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

1.2.8 Approved system. Where it is intended to employ a standard system which has been previously approved, plans are not required to be submitted, providing there have been no changes in the applicable Rule requirements. The building port, where applicable, and date of the previous approval is to be advised.

1.2.9 Cables. For details of instrumentation and control system cabling requirements, see Ch 2,10.

1.3 Control, alarm and safety equipment

1.3.1 Major units of equipment associated with control, alarm and safety systems as defined in 1.2.3 are to be surveyed at the manufacturers' works in accordance with the approved test schedule (see 1.2.2), and the inspection and testing are to be to the Surveyor's satisfaction.

1.3.2 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the *List of Type Approved Products* published by LR. A copy of the *Procedure for LR Type Approval System* will be supplied on application. For fire detection alarm systems, see 2.8.8 and for programmable electronic systems, see 2.10.5 and 2.12.3.

1.3.3 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system, see also Table 1.3.12.

1.3.4 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard, e.g. IEC 60051, Direct acting indicating analogue electrical measuring instruments and their accessories..

1.3.5 Special consideration will be given to arrangements that comply with a relevant and acceptable national or international standard, such as IEC 60092-504, *Electrical Installation on Ships – Special Features: Control and Instrumentation*.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Where the modification may affect compliance with these Rules, proposals for verification and validation are also to be submitted.

1.4.3 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

Section 2 Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the equipment defined in 1.2.3 the applicable features contained in this Section are to be incorporated in the system design.

2.1.2 Systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications*, may be accepted as meeting the requirements of this Section, in which case evidence of compliance is to be submitted for consideration.

2.2 Control stations for machinery

2.2.1 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. This may be provided at a main control station or, alternatively at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

2.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

Control Engineering Systems

Part 6, Chapter 1

Section 2

2.2.3 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

2.2.4 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

2.2.5 Control of machinery and associated equipment is to be possible only from one station at a time.

2.2.6 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

2.2.7 For additional requirements where control stations incorporate visual display units and keyboard input facilities, see 2.10.

2.3 Alarm systems, general requirements

2.3.1 Where an alarm system, which will provide warning of faults in the machinery and the safety and control systems, is to be installed, the requirements of 2.3.2 to 2.3.18 are to be satisfied.

2.3.2 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

2.3.3 Alarms associated with machinery, safety and control system faults are to be clearly distinguishable from other alarms (e.g. fire, general alarm).

2.3.4 Where alarms are displayed as group alarms provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.5 All alarms are to be both audible and visual. If arrangements are made to silence audible alarms they are not to extinguish visual alarms.

2.3.6 Acknowledgement of visual alarms is to be clearly indicated.

2.3.7 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible alarm or extinguish the visual alarm in that machinery space.

2.3.8 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible and visual alarms are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm at the main control room alarm display, then the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel, however, the group alarm is to be

re-initiated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.9 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.10 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

2.3.11 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

2.3.12 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.13 The alarm system is to be capable of being tested during normal machinery operation, see 7.1.2.

2.3.14 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

2.3.15 Disconnection or manual overriding of any part of the alarm system should be clearly indicated.

2.3.16 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.3.17 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

2.3.18 Where practicable, alarms displayed on monitors are to be displayed in the order in which they occur. Alarms requiring shutdown or slowdown action are to be given visual prominence.

2.4 Safety systems, general requirements

2.4.1 Where safety systems are provided the requirements of 2.4.2 to 2.4.13 are to be satisfied.

Control Engineering Systems

Part 6, Chapter 1

Section 2

2.4.2 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

- (a) normal operating conditions are restored, e.g. by the starting of standby machinery, or
- (b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g. by reducing the output of the machinery, or
- (c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.3 The safety system required by 2.4.2(c) is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating, see 3.1.4.

2.4.4 For safety systems required by 2.4.2(a) and (b) complete independence from other control systems is not necessary.

2.4.5 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.6 The safety system is to be designed to 'fail-safe'. The characteristics of the 'fail-safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation. Failure of a safety system is to initiate an audible and visual alarm.

2.4.7 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.8 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.9 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. The consequences of overriding a safety system are to be established and documented.

2.4.10 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.11 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.12 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.4.13 As far as practicable, the safety system required by 2.4.2(b) is to be arranged to effect a rapid reduction in speed or power.

2.5 Control systems, general requirements

2.5.1 Where control systems are provided, the requirements of 2.5.2 to 2.5.8 are to be satisfied.

2.5.2 Control systems for machinery operations are to be stable throughout their operating range.

2.5.3 Failure of any power supply to a control system is to operate an audible and visual alarm.

2.5.4 Control systems should be designed to 'fail-safe'. The characteristics of the 'fail-safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.5.5 The control system is to be designed such that normal operation of the controls cannot induce detrimental mechanical or thermal overloads in the machinery.

2.5.6 Remote or automatic controls are to be provided with sufficient instrumentation at the relevant control stations to ensure effective control and indicate that the system is functioning correctly.

2.5.7 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

2.5.8 Failure of a control system is not to result in the loss of ability to provide essential services by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, see also 2.12.2. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery.

2.6 Bridge control for main propulsion machinery

2.6.1 Where a bridge control system for main propulsion machinery is to be fitted, the requirements of 2.6.2 to 2.6.8 are to be satisfied.

2.6.2 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

2.6.3 The following indications are to be provided on the bridge:

- (a) Propeller speed.
- (b) Direction of rotation of propeller for a fixed pitch propeller or pitch position for a controllable pitch propeller, see also 3.10.
- (c) Direction and magnitude of thrust.
- (d) Clutch position, where applicable.
- (e) Shaft brake position, where applicable.

2.6.4 The propeller speed, direction of rotation and, if applicable, the propeller pitch are to be controlled from the bridge under all sea-going and manoeuvring conditions.

Control Engineering Systems

Part 6, Chapter 1

Section 2

2.6.5 Remote control of the propulsion machinery is to be from one control station at any one time, see *also* 2.2.5. Main propulsion control units on the navigating bridge may be interconnected. Means are to be provided at the main machinery control station to ensure smooth transfer of control between the bridge and machinery control stations.

2.6.6 Means of control, independent of the bridge control system, are to be provided on the bridge to enable the watch-keeper to stop the propulsion machinery in an emergency.

2.6.7 Audible and visual alarms are to operate on the bridge and in the alarm system required by 4.2 if any power supply to the bridge control system fails. Where practicable, the preset speed and direction of thrust are to be maintained until corrective action is taken.

2.6.8 Two means of communication are to be provided between the bridge and the main control station in the machinery space. One of these means may be the bridge control system; the other is to be independent of the main electrical power supply, see *also* 2.2.2 and Pt 5, Ch 1,4.

2.6.9 Automation systems are to be designed in a manner such that a 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 are to 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.

2.7 Valve control systems

2.7.1 Where cargo, bilge, ballast, oil fuel transfer and sea valves for engine services are operated by remote or automatic control, the requirements of 2.7.2 to 2.7.5 are to be satisfied.

2.7.2 Failure of control system power or actuator power is not to permit a valve to move to an unsafe condition.

2.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

2.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

2.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

2.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, see Pt 3, Ch 12,4.2. For power supplies on passenger ships, see Ch 2,3.2.

2.8 Fire detection alarm systems

2.8.1 Where an automatic fire detection system is to be fitted in a machinery space the requirements of 2.8.2 to 2.8.14 are to be satisfied. See *also* SOLAS 1974 as amended Reg. II-2/C,7, or Ch 4,4 as applicable.

2.8.2 A fire detection control unit is to be located in the navigating bridge area, the fire-control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

2.8.3 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge.

2.8.4 An audible fire-alarm is to be provided having a characteristic tone which distinguishes it from the alarm system required by 2.3 or any other alarm system. The audible fire-alarm is to be immediately audible on all parts of the navigating bridge, the fire-control station, the crew accommodation areas and the machinery spaces.

2.8.5 Facilities are to be provided in the fire detection system to manually initiate the fire alarm from the following locations:

- (a) Positions adjacent to all exits from machinery spaces.
- (b) Navigating bridge.
- (c) Control station in engine room.
- (d) Fire control station.

2.8.6 The alarm system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm. This alarm may be incorporated in the machinery alarm system as required by 2.3.

2.8.7 For electrical engineering requirements, see Ch 2,16.1.

2.8.8 Fire detection control units (including addressable systems), indicating panels, detector heads, manual call points and short-circuit isolation units are to be Type Approved in accordance with *Test Specification Number 1* given in LR's *Type Approval System* for an environmental category appropriate for the locations in which they are intended to operate. For addressable systems, see *also* 2.10.

2.8.9 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided in order that the system will react to all possible fire characteristics.

2.8.10 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

2.8.11 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

Control Engineering Systems

Part 6, Chapter 1

Section 2

2.8.12 When it is intended that a particular detector(s) is (are) to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

2.8.13 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire-control panel for functional testing and reset of the system.

2.8.14 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective at sea and in port.

2.9 Fixed water-based local application fire-fighting systems

2.9.1 Where fixed water-based local application fire-fighting systems are installed in accordance with SOLAS as amended Ch. II-2/C, Reg. 10.5.6, arrangements are to be in accordance with this sub-Section.

2.9.2 Systems are to be available for immediate use and arranged for manual activation from inside and outside the protected space. *See also* Ch 2,16.3.4.

2.9.3 The activation of a system is not to result in loss of electrical power or reduction of the manoeuvrability of the ship and is not to require confirmation of space evacuation or sealing.

2.9.4 A control panel is to be provided for managing actions such as opening of valves, starting of pumps and sounding of alarms and processing information from detectors.

2.9.5 Alarms are to be initiated upon activation of a system and are to indicate the specific zone activated at the control panel. Alarms are to be provided in each protected space, at an attended machinery control station and in the wheelhouse. The audible alarm is to be distinguishable from other safety system alarms.

2.9.6 Where SOLAS requires the system to, additionally, be capable of automatic release, the arrangements are to be in accordance with 2.9.7 to 2.9.9.

2.9.7 A minimum of two fire detectors is to be provided for each protected area. One is to be a flame detector and the other is to be a smoke or heat detector, as considered appropriate to the nature of the risk and ambient conditions. The system is to be activated upon detection by two of the detectors. A fault in one detector is to initiate an alarm and is not to inhibit activation of the system under the control of the other detector.

2.9.8 A fire detection alarm system panel in accordance with 2.8 may be used for receiving fire detection signals. Separate loops are not required provided that the address of the initiating device can be identified at the control panel. The received signals are then to be sent to the control panel required by 2.9.4 for processing and action.

2.9.9 The system's fire detection systems and control units are to meet the performance criteria of SOLAS Ch II/C, Reg. 7 and satisfy the requirements of LR's *Type Approval System Test Specification Number 1 (2002)*.

2.10 Programmable electronic systems – General requirements

2.10.1 The requirements of this sub-section are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical applications, systems incorporating shared data communication links and systems which are integrated are to comply with the additional requirements of 2.11, 2.12 and 2.13 as applicable. For systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications*, see 2.1.2.

2.10.2 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of 2.10 to 2.13 related to providing those required functions.

2.10.3 Programmable electronic equipment is to revert to a defined safe state on initial start-up or re-start in the event of failure.

2.10.4 In the event of failure of any programmable electronic equipment, the system, and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.10.5 Programmable electronic equipment is to be certified by a recognized authority as suitable for the environmental conditions in which it is intended to operate, *see also* 2.12.3.

2.10.6 Emergency stops are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of 2.12.2 and/or 2.12.8.

2.10.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2. Hardware failure indications are to enable faults to be identifiable at least down to the level of the lowest replaceable unit and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

2.10.8 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply.

2.10.9 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorized alteration.

Control Engineering Systems

Part 6, Chapter 1

Section 2

2.10.10 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilized.

2.10.11 Displays and controls are to be protected against liquid ingress due to spillage.

2.10.12 User interfaces are to be designed in accordance with appropriate ergonomic principles to meet user needs and enable timely access to desired information or control of functions. A system overview is to be readily available.

2.10.13 The keyboard is to be divided logically into functional areas. Alphanumeric, paging and specific system keys are to be grouped separately.

2.10.14 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

2.10.15 The size, colour and density of information displayed to the operator are to be such that information may be easily read from the normal operator position under all operational lighting conditions.

2.10.16 Display units are to comply with the requirements of International Electrotechnical Commission Standard IEC 60950:1991, *Safety of information technology equipment, including electrical business equipment*, in respect of emission of ionising radiation.

2.10.17 Symbols used in mimic diagrams are to be visually representative and are to be consistent throughout the systems' displays.

2.10.18 Where systems detect fault conditions, any affected mimic diagrams are to ensure that the status of unreliable and incorrect data is clearly identified.

2.10.19 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power system (UPS).

2.10.20 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.10.21 Software lifecycle activities, e.g. design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003:2004, *Software engineering – Guidelines for the application of ISO 9001:2000 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.11 Data communication links

2.11.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of 2.11.2 to 2.11.10 are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.11.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.11.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, see also 2.12.2.

2.11.4 The properties of the data communication link (e.g. bandwidth, access control method, etc.) are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.11.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.11.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of 2.3 and, where applicable, 4.2 in the event of a failure of an active or standby component.

2.11.7 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.11.8 Data cables are to comply with the applicable requirements of Pt 6, Ch 2, 10. Other media will be subject to special consideration.

2.11.9 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.11.10 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimized. Duplicated data communication links are to be routed to give as much physical separation as is practical.

Control Engineering Systems

Part 6, Chapter 1

Section 2

2.12 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.12.1 The requirements of 2.12.2 to 2.12.10 are to be complied with where control, alarm or safety systems for essential services, as defined by Pt 6, Ch 2, 1.5, or safety critical systems, incorporate programmable electronic equipment.

- (a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g. fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g. main engine low lubricating oil pressure shutdown).
- (b) Applications that are not essential services may also be considered to be safety critical (e.g. domestic boiler low water level shutdown).

2.12.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be provided by a fully independent hard-wired backup system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*.

2.12.3 Items of programmable electronic equipment used to implement control, alarm and safety functions are to satisfy the requirements of LR's *Type Approval System Test Specification Number 1 (2002)*.

2.12.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.12.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.12.6 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2.

2.12.7 Where it is intended that the programmable electronic system implements emergency stop or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g. fully independent hard-wired backup system, redundancy with design diversity, etc.

2.12.8 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.12.9 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

2.13 Programmable electronic systems – Additional requirements for integrated systems

2.13.1 The requirements of 2.13.2 to 2.13.7 apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or ship safety functions, see Pt 6, Ch 2, 16 to 18.

2.13.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and ship safety.

2.13.3 The system requirements specification, see 1.2.5, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

2.13.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

2.13.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew, and ship safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812, or an equivalent and acceptable national or international standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', see 2.4.6 and 2.5.4, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

2.13.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

2.13.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g. the selection of a particular screen page or mode of operation. See also 2.10.19 to 2.10.20.

■ Section 3 Control and supervision of unattended machinery

3.1 General

3.1.1 Where machinery, as listed in 1.2.3, is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 3.2 to 3.15 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

3.1.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

3.1.3 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

3.1.4 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required in the relevant Tables of this Section, the sensors and circuits utilized for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

3.1.5 Means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

3.1.6 Oil mist monitoring, or engine bearing temperature monitors or alternative methods for crankcase protection are to be provided:

- (a) When arrangements are fitted to override the automatic shutdown for excessive reduction of the lubricating oil supply pressure.
- (b) For engines of 2 250 kW and above or having cylinders of more than 300 mm bore.

NOTES

1. For medium and high speed engines automatic shutdown of the engine is to occur.
2. For slow speed engines, automatic slowdown is to occur.
3. Where arrangements are made to override the automatic slowdown or shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.
4. Where the bearing temperature monitoring method is chosen, all bearings in the crankcase are to be monitored where practicable, e.g. main, crankpin, crosshead.

5. Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist monitoring or engine bearing temperature monitors, see Pt 5, Ch 2,6.9.14.

3.2 Oil engines for propulsion purposes

3.2.1 Alarms and safeguards are indicated in 3.2.2 to 3.2.8 and Tables 1.3.1(a) and (b), *see also* 3.1.5 and 3.1.6.

3.2.2 Alarms are to operate for the fault conditions shown in Table 1.3.1(a). Where applicable, indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be manually reduced or has been reduced automatically.

3.2.3 Alarms are to operate, and automatic shutdown of machinery is to occur for the fault conditions shown in Table 1.3.1(b).

3.2.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s).

- (a) Lubricating oil supply.
- (b) Oil fuel supply, *see also* 3.2.5.
- (c) Piston coolant supply, where applicable.
- (d) Cylinder coolant supply, where applicable.
- (e) Fuel valve coolant supply, where applicable.

3.2.5 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by 3.2.4.

3.2.6 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

3.2.7 The number of automatic consecutive attempts which fail to produce a start is to be limited to three. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see* Pt 5, Ch 2,8.4.

3.2.8 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

3.3 Steam turbine machinery for propulsion purposes

3.3.1 Alarms and safeguards are indicated in 3.3.2 to 3.3.6 and Table 1.3.2.

Control Engineering Systems

Part 6, Chapter 1

Section 3

**Table 1.3.1(a) Oil engines for propulsion purposes:
Alarms and slowdowns**
(see continuation)

Item	Alarm	Note
Lubricating oil sump level	Low	Engines (and gearing if fitted)
Lubricating oil inlet pressure*	1st stage low	Engines (and gearing if fitted). Slowdown
Lubricating oil inlet temperature*	High	Engines (and gearing if fitted)
Lubricating oil filters differential pressure	High	—
Oil mist concentration in crankcase or bearing temperature	High	Automatic slowdown of slow speed engines, see 3.1.6
Cylinder lubricator flow	Low	One sensor per lubricator unit. Slowdown (automatic on medium and high speed engines)
Thrust bearing temperature*	High	Slowdown
Piston coolant inlet pressure	Low	If a separate system. Slowdown
Piston coolant outlet temperature*	High	Per cylinder (if a separate system). Slowdown
Piston coolant outlet flow*	Low	Per cylinder (if a separate system). Slowdown
Cylinder coolant inlet pressure or flow*	Low	Slowdown (automatic on medium and high speed engines)
Cylinder coolant outlet temperature*	1st stage high	Per cylinder (if a separate system). Slowdown (automatic on medium and high speed engines)
Engine cooling water system – oil content	High	Where engine cooling water used in oil/water heat exchangers
Sea water cooling pressure	Low	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Oil fuel pressure from booster pump	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Oil fuel high pressure piping*	Leakage	See 3.1.5
Charge air cooler outlet temperature	High and Low	4-stroke medium and high speed engines
Scavenge air temperature (fire)	High	Per cylinder (2-stroke engines). Slowdown
Scavenge air receiver water level	High	—

**Table 1.3.1(a) Oil engines for propulsion purposes:
Alarms and slowdowns**
(conclusion)

Item	Alarm	Note
Exhaust gas temperature*	High	Per cylinder. Slowdown (automatic on medium and high speed engines) See Note 5
Exhaust gas temperature deviation from average*	High	Per cylinder, See Note 5
Turbocharger exhaust gas inlet temperature	High	Each turbocharger See Note 6
Turbocharger exhaust gas outlet temperature*	High	Each turbocharger
Turbocharger lubricating oil inlet pressure	Low	If system not integral with turbocharger
Turbocharger lubricating oil outlet temperature	High	Each bearing, if system not integral with turbocharger
Starting air pressure*	Low	Before engine manoeuvring valve
Control air pressure	Low	—
Direction of rotation	Wrong way	Reversible engines, see also 3.2.7
Overspeed*	High	See also Pt 5, Ch 2,5
Automatic start of engine	Failure	See 3.2.7
Electrical starting battery charge level	Low	—
NOTES 1. Where 'per cylinder' appears in this Table, suitable sensors may be situated on manifold outlets for medium and high speed engines. 2. For engines and gearing of 1500 kW or less only the items marked* are required. 3. Common sensors are acceptable for alarms and slowdown functions. 4. Except where stated otherwise in the Table, slowdown may be effected by either manual or automatic means, by reduction of speed or power as appropriate. 5. For medium and high speed engine power <500 kW/cylinder, a common sensor for exhaust gas manifold temperature may be fitted. 6. May be combined with exhaust gas outlet temperature high alarm where the turbocharger is mounted directly on the exhaust manifold.		

**Table 1.3.1(b) Oil engines for propulsion purposes:
Alarms and shutdowns**

Item	Alarm	Note
Lubricating oil inlet pressure	2nd stage low	Automatic shutdown of engines (and gearing if fitted), see 3.1.4
Oil mist concentration in crankcase or bearing temperature	High	Automatic shutdown of medium and high speed engines, see 3.1.6
Cylinder coolant outlet temperature	2nd stage high	Automatic shutdown of medium and high speed engines, see 3.1.4

Control Engineering Systems

Part 6, Chapter 1

Section 3

Table 1.3.2 Steam turbine machinery: Alarms and safeguards

Item	Alarm	Note
Lubricating oil pressure for turbines and gearing	1st stage low	—
	2nd stage low	Automatic shutdown, see 3.1.4
Lubricating oil temperature for turbines and gearing	High	—
Lubricating oil sump level	Low	—
Lubricating oil filters differential pressure	High	—
Bearing temperatures or bearing oil outlet temperature of turbines and gearing	High	—
Astern turbine temperature	High	—
Gland steam pressure	High and Low	—
Thrust bearing temperature	High	—
Sea water pressure or flow	Low	—
Turbine vibration	High	Shutdown or speed reduction of turbine(s)
Axial movement of turbine rotor	High	
Main condenser vacuum	Low	
Main condenser condensate level	High	
Overspeed	High	See Pt 5, Ch 3,4

3.3.2 Audible and visual alarms are to operate, and indication is to be given at the relevant control stations to stop or reduce the speed of the turbine(s) for the following fault conditions:

- Excessive turbine vibration.
- Excessive axial movement of turbine rotor.
- Low vacuum in main condenser.
- High condensate level in main condenser.

3.3.3 Reduction of speed may be effected by either manual or automatic control.

3.3.4 Means are to be provided to prevent the risk of thermal distortion of the turbines, by automatic steam spinning, when the shaft is stopped in the manoeuvring mode. An audible and visual alarm is to be provided at the relevant control stations when the shaft has been stopped for a predetermined time.

3.3.5 The following turbine services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the propulsion turbine(s):

- Lubricating oil supply temperature.
- Condenser condensate level.
- Gland steam pressure.

3.3.6 Prolonged running in a restricted speed range is to be prevented automatically, or alternatively, indication of restricted speed ranges is to be provided at each control station.

3.4 Gas turbine machinery

3.4.1 Alarms and safeguards are indicated in 3.4.2 to 3.4.4 and Table 1.3.3.

Table 1.3.3 Gas turbine machinery: Alarms and safeguards

Item	Alarm	Note
Overspeed	High	Automatic shutdown see also Pt 5, Ch 4,8.2
Power turbine inlet temperature	1st stage high	Automatic power reduction
	2nd stage high	Automatic shutdown, see also Pt 5, Ch 4,8.3
Flame failure	Failure	Automatic shutdown, see also Pt 5, Ch 4,8.4
Failure to ignite	Failure	Automatic shutdown, see also Pt 5, Ch 4,8.4
Lubricating oil pressure	1st stage low	—
	2nd stage low	Automatic shutdown, see also Pt 5, Ch 4,8.5
Lubricating oil temperature	High	See also Pt 5, Ch 4,8.5
Lubricating oil filter differential pressure	High	—
Scavenge oil temperature	High	—
Scavenge oil pressure	Low	Automatic shutdown
Bearing temperature	High	—
Turbine vibration	1st stage high	—
	2nd stage high	Automatic shutdown, see also Pt 5, Ch 4,4.2
Oil fuel supply pressure	Low	—
Oil fuel supply temperature	High	—
Oil fuel leakage	High	See also Pt 5, Ch 4,5.2
Automatic starting	Failure	Automatic shutdown
Control system	Failure	Automatic shutdown
Air intake pressure	Low	See also Pt 5, Ch 4,4.4.4

NOTES

- For two-stage alarms, see also 3.1.4.
- For requirements on purging before ignition, see Pt 5, Ch 4,6.2.1.
- Where a requirement for disabling the automatic protection and safety system devices for machinery and engineering systems has been defined by the Owner, the consequences of using the disabling arrangements are to be established and included in the operations procedures and orders provided onboard ship. Details of any disabling arrangements are to be submitted to LR for consideration in each instance.

Control Engineering Systems

Part 6, Chapter 1

Section 3

3.4.2 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine:

- (a) Lubricating oil supply.
- (b) Oil fuel supply, *see also* 3.4.3.
- (c) Exhaust gas.

3.4.3 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by 3.4.2.

3.4.4 A means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station.

3.5 Main, auxiliary and other boilers

3.5.1 Alarms and safeguards are indicated in 3.5.2 to 3.5.9 and Table 1.3.4.

3.5.2 The following boiler services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the boiler:

- (a) Combustion system.
- (b) Oil fuel supply temperature or viscosity, heavy oil only.
- (c) Boiler drum water level.
- (d) De-aerator water level, where applicable.
- (e) Superheated steam pressure, where applicable.
- (f) Superheated steam temperature, where applicable.
- (g) De-superheated steam pressure, where applicable.
- (h) De-superheated steam temperature, where applicable.

3.5.3 Safety systems and overrides are to comply with the requirements of 2.4.9.

3.5.4 Burner controls are to be arranged such that light off is only possible at the minimum firing rate compatible with flame establishment. If ignition is set to occur at a fuel rich condition then the burner is to revert to the correct operating air/fuel ratio on establishment of a stable flame.

3.5.5 Where water level indicators are dependent upon an external power supply, the oil fuel supply to the burners is to be automatically shut-off in the event of power or signal failure.

3.5.6 Arrangements are to be such that burner oil fuel valve(s) do not open:

- (a) prior to completion of required warm up times for residual fuel oil; or
- (b) when the power supply to the igniter has failed, as applicable; or
- (c) until a pilot flame is established, as applicable; or
- (d) prior to the completion of furnace purging, *see* Pt 5, Ch 14,3.1.7.

Table 1.3.4 Main, auxiliary and other boilers: Alarms and safeguards (*see continuation*)

Item	Alarm	Note
Water level*	Low	Two water level sensors are to be provided each to operate independently, and automatically shut-off the oil fuel to the burners and operate alarms, <i>see</i> Notes 1 to 3, and 5
Water level	<div style="display: inline-block; vertical-align: middle;"> <div style="font-size: 3em; vertical-align: middle;">{</div> <div style="display: inline-block; vertical-align: middle;"> 1st stage high* 2nd stage high </div> </div>	— Where applicable automatic closure of turbine steam inlet valves, <i>see</i> 3.1.4
Steam drum or superheater outlet pressure*	High and Low	—
Superheated steam temperature	High	—
De-superheated steam temperature*	High	—
Feed water forced circulation flow (if fitted)	Low	Oil fuel to burners to be shut-off automatically, <i>see</i> Note 5
Feed water pH	Low	When automatic dosing of feed water fitted
Feed water salinity	High	Fitted in boiler feed system
Feed water temperature	Low	When automatic temperature control fitted
Combustion air pressure*	Low	Oil fuel to burners to be shut-off automatically in operation or not released during start up, <i>see</i> Note 5. Purge sequence to be inhibited, <i>see</i> Pt 5, Ch 14,3.1.7
Oil fuel pressure*	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Oil fuel atomizing steam/air pressure	Low	—
Burner flame	Failure	Each burner to be monitored. Oil fuel to burner(s) to be shut-off automatically, <i>see</i> Pt 5, Ch 14,3.1.9, 3.1.10 and Note 5
Flame monitoring device(s)*	Failure	<i>See</i> 3.5.7, and Note 5
Igniter power supply*	Failure	Each igniter to be checked before oil fuel is supplied to burner, <i>see</i> 3.5.6 and Note 5
Forced draft fan*	Power failure	Oil fuel to burners to be shut-off automatically in operation or not released during start up, <i>see</i> Note 5
Air registers and dampers (including those in the uptake)*	Not fully open	Purge sequence to be inhibited, <i>see</i> Pt 5, Ch 14,3.1.7

Control Engineering Systems

Part 6, Chapter 1

Section 3

Table 1.3.4 Main, auxiliary and other boilers: Alarms and safeguards (conclusion)

Item	Alarm	Note
Control system*	Power failure	Oil fuel to burners to be shut-off automatically. Control using alternative arrangements is to remain available, see 2.5.8
Uptake temperature	High	Where economizer and/or gas air heaters are integral with the boiler and also for independent extended surface exhaust gas boilers/economizers, to monitor for soot fires
NOTES 1. For dual-evaporation boilers, the primary circuit is to be fitted with two independent low water level detectors which will operate alarms and shut-off the oil fuel to the burners automatically. The secondary circuit is to be fitted with one low water level detector which will operate alarms and shut-off the oil fuel to the burners automatically. Additionally one high water level alarm is to be fitted on the secondary circuit which may be operated by the same detector as that provided for low water level detection. 2. Only one independent system of low water level detection, alarm and automatic oil fuel shut-off need be fitted in the case of small forced circulation or re-circulation coiled water tube 'package' type boilers when evaporation is less than 2900 kg/hr or the heating surface is less than 100 m ² . 3. Where two level sensors are provided these may be used for other functions, e.g. high level alarm, level control, trip systems, etc.. 4. For boilers not supplying steam for propulsion or for services essential for the safety or the operation of the ship at sea, only the items marked* are required. 5. These safeguards are to remain operative during automatic, manual and emergency operation.		

3.5.7 Arrangements for flame failure detection are to be provided with self-monitoring capabilities which ensure that the flame detector is not erroneously indicating the presence of a flame. In the event of failure being detected by these self-monitoring capabilities:

- an alarm is to be activated.
- In the event of loss of flame detection capability for a burner;
- oil fuel to the burner is to be shut-off automatically; and
 - an alarm is to be activated

3.5.8 Where established as necessary by Pt 5, Ch 14, 3.1.8, means are to be provided to prevent starting of the ignition sequence following multiple flame failures until completion of the identified lock out period.

3.5.9 Following burner shutdown, the furnace is to be purged automatically for at least the required pre-purging time. In event of shutdown due to activation of a required safeguard, this purging is to be manually initiated.

3.6 Thermal fluid heaters

3.6.1 Alarms and safeguards are indicated in 3.6.2 to 3.6.8 and Table 1.3.5.

Table 1.3.5 Thermal fluid heaters: Alarms and safeguards

Item	Alarm	Note
Expansion tank level*	Low	Oil fuel burners to be shut-off automatically
Thermal fluid flow	Low	Oil fuel burners to be shut-off automatically
Thermal fluid pressure	Low	Oil fuel burners to be shut-off automatically
	1st stage high	—
Thermal fluid outlet temperature*	2nd stage high	Oil fuel burners to be shut-off automatically, see 3.1.4
Combustion air pressure*	Low	Oil fuel burners to be shut-off automatically in operation or not released during start up, see Note 3. Purge sequence to be inhibited see Pt 5, Ch 14, 3.1.7
Oil fuel pressure*	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Oil fuel atomizing steam/air pressure	Low	—
Burner flame*	Failure	Each burner to be monitored. Oil fuel to burner to be shut-off automatically, see Pt 5, Ch 14, 3.1.9 and 3.1.10, and Note 3
Flame monitoring device(s)*	Failure	See 3.6.6 and Note 3
Igniter power supply*	Failure	Each igniter to be checked before oil fuel is supplied to burner(s), see 3.6.5 and Note 3
Forced draft fan*	Power failure	Oil fuel to burners to be shut-off automatically in operation or not released during start up, see Note 3
Air register and dampers (including those in the uptake)*	Not fully open	Purge sequence to be inhibited, see Pt 5, Ch 14, 3.1.7
Control system*	Power failure	Oil fuel to burners to be shut-off automatically. Control using alternative arrangements is to remain available, see 2.5.8
Uptake temperature	High	Where applicable, to monitor for soot fires
NOTES 1. Special consideration may be given to the requirements for oil-fired hot water heaters. 2. For heaters not supplying thermal oil for services essential for the safety or the operation of the ship at sea, only the items marked* are required. 3. These safeguards are to remain operative during automatic, manual and emergency operation.		

Control Engineering Systems

Part 6, Chapter 1

Section 3

3.6.2 The standby pumps for oil fuel and thermal fluid circulation are to start automatically when the discharge pressure from the working pump falls below a predetermined value. The standby pumps for thermal fluid circulation are to start before the shut-offs due to low thermal fluid pressure, see Table 1.3.5, are activated

3.6.3 The following heater services are to be fitted with automatic controls so as to maintain steady state conditions throughout the operating range of the heater:

- Combustion system.
- Oil fuel supply temperature or viscosity, heavy oil only.
- Thermal fluid temperature.

3.6.4 Burner controls are to be arranged such that light-off is only possible at the minimum firing rate compatible with flame establishment. If ignition is set to occur at a fuel rich condition then the burner is to revert to the correct operating air/fuel ratio on establishment of a stable flame.

3.6.5 Arrangements are to be such that burner oil fuel valve(s) do not open:

- prior to completion of required warm up times for residual fuel oil; or
- when the power supply to the igniter has failed, as applicable; or
- until a pilot flame is established, as applicable; or
- prior to the completion of furnace purging, see Pt 5, Ch 14,3.1.7.

3.6.6 Arrangements for flame failure detection are to be provided with self-monitoring capabilities which ensure that the flame detector is not erroneously indicating the presence of a flame. In the event of failure being detected by these self-monitoring capabilities:

- an alarm is to be activated.

In the event of loss of flame detection capability for a burner;

- oil fuel to the burner is to be shut-off automatically; and
- an alarm is to be activated.

3.6.7 Where established as necessary by Pt 5, Ch 14,3.1.8, means are to be provided to prevent starting of the ignition sequence following multiple flame failures until completion of the identified lock out period.

3.6.8 Following burner shutdown, the furnace is to be purged automatically for at least the required pre-purging time. In event of shutdown due to activation of a required safeguard, this purging is to be manually initiated.

3.7 Inert gas generators

3.7.1 Alarms and safeguards are indicated in 3.7.2 and Table 1.3.6.

3.7.2 Inert gas generators are to be fitted with an automatic combustion control system so as to maintain steady state conditions throughout the operating range of the generator.

3.7.3 For the requirements of flue gas inert gas systems, see Pt 5, Ch 15,7.

Table 1.3.6 Inert gas generators: Alarms and safeguards

Item	Alarm	Note
Inert gas outlet temperature	High	Oil fuel to burner to be shut-off automatically
Combustion air pressure	Low	Oil fuel to burner to be shut-off automatically
Oil fuel pressure	Low	—
Oil fuel temperature or viscosity	High and Low	Heavy oil only
Burner flame and ignition	Failure	Oil fuel to burner to be shut-off automatically, see Note 1
Cooling water pressure or flow	Low	Oil fuel to burner to be shut-off automatically
Cooling water temperature	High	—
Oil fuel supply	Insufficient	—
Power supply to inert gas generator	Failure	Gas regulating valve is to be shutdown automatically
Automatic control system power supply	Failure	—
NOTES		
1. Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame-out on all burners.		
2. See also Pt 5, Ch 15.		

3.8 Incinerators

3.8.1 Alarms and safeguards are indicated in 3.8.2, 3.8.3 and Table 1.3.7.

Table 1.3.7 Incinerators: Alarms and safeguards

Item	Alarm	Note
Oil fuel temperature or viscosity	High and Low	Heavy oil and sludge
Oil fuel pressure	Low	—
Combustion air pressure	Low	Oil fuel and/or sludge to burners to be shut-off automatically
Burner flame and ignition	Failure	Oil fuel and/or sludge to burners to be shut-off automatically, see Note
Furnace temperature	High	Oil fuel and/or sludge to burners to be shut-off automatically
Furnace temperature	Low	If applicable
Exhaust temperature	High	—
NOTE		
Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame-out on all burners.		

3.8.2 Where arrangements are provided to introduce solid waste into the furnace these are to be such that there is no risk of a fire hazard.

Control Engineering Systems

Part 6, Chapter 1

Section 3

3.8.3 The combustion temperature is to be controlled to ensure that all liquid and solid waste is efficiently burned without exceeding predetermined temperature limits.

3.9 Auxiliary engines and auxiliary steam turbines

3.9.1 Alarms and safeguards are indicated in Table 1.3.8, see also 3.1.5 and 3.1.6.

Table 1.3.8 Auxiliary engines and auxiliary steam turbines: Alarms and safeguards

Item	Alarm	Note
OIL ENGINES		
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage low	—
	2nd stage* low	Automatic shutdown of engine*, see 3.1.4
Oil mist concentration in crankcase or bearing temperature	High	Automatic shutdown of engine, see 3.1.6
Oil fuel high pressure piping*	Leakage	See 3.1.5
Coolant outlet temperature (for engines >220 kW)	1st stage high	—
	2nd stage	Automatic shutdown of engine*, see 3.1.4
Coolant pressure or flow	Low	—
Oil fuel temperature or viscosity	High and Low	Heavy oil only
Overspeed	High	See Pt 5, Ch 2,5
Starting air pressure	Low	—
Electrical starting battery charge level	Low	—
Exhaust gas temperature	High	Per cylinder for engine power <500 kW/cylinder, common sensors for each inlet to the turbo-charger may be accepted
STEAM TURBINES		
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage low	—
	2nd stage low*	Automatic shutdown of turbine*, see 3.1.4
Condenser vacuum	Low	Automatic shutdown of turbine*, see 3.1.4
Axial displacement of rotor	High	
Overspeed	High	See Pt 5, Ch 4,4
NOTES		
1. There are no classification requirements for the items marked * in the case of engines being used for the emergency source of electrical power required by SOLAS.		
2. The arrangements are to comply with the requirements of the National Authority concerned.		

3.9.2 For engines operating on heavy oil fuel, automatic temperature or viscosity controls are to be provided.

3.10 Controllable pitch propellers and transverse thrust units

3.10.1 Alarms and safeguards are indicated in 3.10.2 to 3.10.6 and Table 1.3.9. For azimuth thrusters, see also Pt 5, Ch 20.

Table 1.3.9 Controllable pitch propellers and transverse thrust units: Alarms and safeguards

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic actuator	Failure	See 2.5.3
Propulsion motor	Overload	See Ch 2,15

3.10.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propelling blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

3.10.3 Controllable pitch propellers for main propulsion are to be provided with indications of shaft speed, direction and magnitude of thrust and propeller pitch as a measure of the propeller blade or actuator movement at each station from which it is possible to control shaft speed or propeller pitch.

3.10.4 Where transverse thrust units are remotely controlled means are to be provided at the remote control station to stop the propulsion unit.

3.10.5 Transverse thrust units are to be provided with indications of direction and magnitude of thrust and propeller pitch at each station from which it is possible to control the propeller pitch.

3.10.6 An indication of the angular position of rotatable thrust units is to be provided at each station from which it is possible to control the direction of thrust.

3.11 Monitoring in cargo pump rooms

3.11.1 Alarms and safeguards are indicated in Pt 5, Ch 15.

Control Engineering Systems

Part 6, Chapter 1

Section 3

3.12 Electric system

3.12.1 Alarms and safeguards are indicated in Table 1.3.10.

Table 1.3.10 Electric system: Alarms and safeguards

Item	Alarm	Note
Bus-bar voltage	High and Low	—
Bus-bar frequency	Low	—
Operation of load shedding	Warning	—
Generator cooling air temperature	High	For closed air circuit water cooled machines

3.13 Steering gear

3.13.1 For the requirements of steering gear, see Pt 5, Ch 19.

3.14 Waterjets

3.14.1 Alarms and safeguards are indicated in 3.14.2 to 3.14.4 and Table 1.3.11.

Table 1.3.11 Waterjets: Alarms and safeguards

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Hydraulic system flow	Low	—
Lubricating oil pressure	Low	—
Control system	Fault	—
Control system power supply	Failure	—

3.14.2 For waterjets used as the only means of propulsion, a standby or alternative power source of actuating medium for controlling the angular position and/or the reversing angle is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

3.14.3 An indication of the angular position of waterjets is to be provided at each station from which it is possible to control the angular position.

3.14.4 An indication of the bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

3.15 Miscellaneous machinery

3.15.1 Alarms and safeguards are indicated in 3.15.2 to 3.15.6 and Table 1.3.12.

Table 1.3.12 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Stern tube lubricating oil tank level	Low	—
Stern tube bearing temperature (oil-lubricated)	High	—
Coolant tanks level	Low	—
Oil fuel service tanks level	High and Low	Where a common overflow tank is fitted, a high level alarm in the common overflow tank may be accepted
Oil fuel service tanks temperature	High	Where heating arrangements are fitted
Oil fuel settling tanks temperature	High	Where heating arrangements are fitted
Sludge tanks level	High	—
Feed water tanks level	Low	Service tank only
Purifier water seal broken	Fault	—
Purifier oil inlet temperature	High	—
Air compressor lubricating oil	Failure	Automatic shutdown
Air compressor discharge air temperature	High	—
Hydraulic control system pressure	Low	—
Pneumatic control system pressure	Low	—
Oil heater temperature	High	See also Pt 5, Ch 14
Controlled environmental conditions	Abnormal	See also 1.3.3

3.15.2 **Dual fuel systems.** Oil and gas dual-fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

3.15.3 **Lifts.** For details of alarms and safeguards for lifts classed by LR, reference is to be made to LR's *Code for Lifting Appliances in a Marine Environment*.

Control Engineering Systems

Part 6, Chapter 1

Sections 3 & 4

3.15.4 Oil heaters. Oil fuel or lubricating oil heaters are to be fitted with a high temperature alarm which may be incorporated in the temperature control system. In addition to the temperature control system, an independent sensor, with manual reset, is to be fitted which will automatically cut off the heating supply in the event of excessively high temperatures or loss of flow, except where the maximum temperature of the heating medium remains limited to a value below 220°C.

3.15.5 Oil tank electric heating. Oil fuel and lubricating oil tanks that are provided with electric heating elements are to be fitted with a high temperature alarm, which may be incorporated in the temperature control system, a low level alarm and an additional low level sensor to cut off the power supply at a level above that at which the heating element would be exposed.

3.15.6 Oil fuel tanks. Means are to be provided to eliminate the possibility of overflow from oil fuel service tanks into the machinery space and to safeguard against overflow of oil from oil fuel service tanks through the air pipe. See Pt 5, Ch 13 regarding the termination of air pipes.

■ Section 4 Unattended machinery space(s) – UMS notation

4.1 General

4.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by Section 3, together with those given in 4.2 to 4.7 are to be provided:

- (a) Air compressors.
- (b) Controllable pitch propellers and transverse thrust units.
- (c) Electric generating plant.
- (d) Inert gas generators.
- (e) Incinerators.
- (f) Main propelling machinery including essential auxiliaries.
- (g) Oil fuel transfer and storage systems (purifiers and oil heaters).
- (h) Steam raising plant (boilers and their ancillary equipment).
- (j) Thermal fluid heaters.
- (k) Waste heat boilers.

4.2 Alarm system for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

4.2.2 Audible and visual indication of machinery alarms is to be relayed to the engineers' accommodation so that engineering personnel are made aware that a fault has occurred.

4.2.3 The engineers' alarm required by 2.2.3 is to be activated automatically in the event that a machinery alarm has not been acknowledged in the space within a predetermined time.

4.2.4 Audible and visual indication of machinery alarms is to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:

- (a) a machinery fault has occurred;
- (b) the machinery fault is being attended to; and
- (c) the machinery fault has been rectified.

Alternative means of communication between the bridge area, accommodation for engineering personnel and machinery spaces will be considered.

4.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shut-down of propulsion machinery are to be identified by separate group alarms or by individual alarm parameters.

4.3 Bridge control for main propulsion machinery

4.3.1 A bridge control system for the main propulsion machinery is to be fitted. The system is to satisfy the requirements of 2.6.

4.4 Control stations for machinery

4.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of 2.2.

4.5 Fire detection alarm system

4.5.1 An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of 2.8.

4.6 Bilge level detection

4.6.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with 2.3. This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim. In ships above 2000 gross tons there are to be two independent systems of bilge level detection in the machinery space, arranged such that each branch bilge as required by Pt 5, Ch 13 is provided with a level detector.

4.6.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a bilge injection or a direct bilge system, should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls, see *a/so* 2.7 and Pt 5, Ch 13.2.

Control Engineering Systems

Part 6, Chapter 1

Sections 4, 5 & 6

4.6.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

4.7 Supply of electric power, general

4.7.1 For ships operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For ships operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, see Ch 2,2.2.

■ Section 5 Machinery operated from a centralized control station – CCS notation

5.1 General requirements

5.1.1 Where it is proposed to operate the machinery as listed in 4.1.1 with the continuous supervision from a centralized control station, the control station is to be such that the machinery operation will be as effective as it would be under direct supervision.

5.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g. stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

5.1.3 The controls, alarms and safeguards required by Section 3 and by 4.6 together with a fire detection system satisfying the requirements of 2.8 are to be provided. However, the automatic operation of machinery and certain safeguards required by Section 3 may be omitted.

5.1.4 Additional requirements for controls, alarms and safeguards are given in 5.2.

5.2 Centralized control station for machinery

5.2.1 A centralized control station which satisfies the requirements of 5.2.2 to 5.2.7 is to be provided at a suitable location.

5.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of 2.3 and 2.5, as applicable.

5.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g. temperatures, pressures, tank levels, speeds, powers, etc.

5.2.4 Indication of the operational status of running and standby machinery is to be provided.

5.2.5 At the centralized control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

5.2.6 In addition to the communication required by 5.2.5, a second means of communication is to be provided between the bridge and the centralized control station. One of these means is to be independent of the main electrical power supply, see also Pt 5, Ch 1.

5.2.7 Arrangements are to be provided in the centralized control station so that the normal supply of electrical power may be restored in the event of failure.

■ Section 6 Integrated computer control – ICC notation

6.1 General

6.1.1 Integrated Computer Control class notation **ICC** may be assigned where an integrated computer system in compliance with 6.1 to 6.3 provides fault tolerant control and monitoring functions for one or more of the following services:

- (a) Propulsion;
- (b) Electrical generation and distribution (power management systems);
- (c) Cargo and ballast.

6.1.2 A Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812 and the report and worksheets submitted for consideration. See also 2.13.5. The FMEA is to demonstrate that control and monitoring functions required by 6.2 will remain available at each operator station in the event of a single fault of the integrated computer control system, including input error, without adverse effect on the service(s).

6.1.3 Special consideration will be given to integrated computer control systems for other applications, except where these are addressed by other control engineering class notations. In particular, see Pt 7, Ch 9 for requirements of the optional class notation **IBS** – Integrated Bridge Navigation Systems, and Pt 7, Ch 12 for the requirements of the optional class notation **IFP** – Integrated Fire Protection.

Control Engineering Systems

Part 6, Chapter 1

Sections 6 & 7

6.2 General requirements

6.2.1 The integrated computer control system is to comply with the programmable electronic system requirements of 2.10 to 2.13 and the control and monitoring requirements of the Rules applicable to particular equipment, machinery or systems.

6.2.2 Alarm displays are to be provided, in compliance with the requirements of 2.3, which ensure ready identification of faults in the equipment under control.

6.2.3 Alarm and indication functions required by 2.4 are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system. *See also* 2.12.7.

6.2.4 Controls are to be provided, in compliance with 2.5, to ensure the safe and effective operation of equipment and response to faults, e.g. stopping, starting, adjustment of parameters, etc. Indication of operational status and other such parameters necessary to satisfy this requirement, is to be provided for all equipment under control by the integrated computer control system.

6.3 Operator stations

6.3.1 Each operator station allowing control of equipment is to be provided with a minimum of two multi-function display and control units. The number of units is to be sufficient to allow simultaneous access to control and monitoring functions required by 6.2.2 to 6.2.4. *See also* 2.10.19 to 2.10.20.

6.3.2 Each multi-function display and control unit is to include a monitor, keyboard and tracker ball. Alternative arrangements will be considered where these enable each unit to be configured by the user to provide required control or monitoring functions.

6.3.3 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g. in control, standby, etc.) is to be clearly indicated. *See also* 2.2.

6.3.4 Means of communication are to be provided between operator stations and any other stations from which the equipment may be controlled. The arrangements are to be permanently installed and are to remain operational in the event of failure of the main electrical power supply to the integrated control system.

Section 7 Trials

7.1 General

7.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by 1.2.2. In the case of new construction it will be expected that most of these trials will be carried out before the official sea trials of the ship. During sea trials, system dynamic tests are to be carried out to demonstrate overall satisfactory performance of the control engineering installation.

7.1.2 Means are to be provided to facilitate testing during normal machinery operation, e.g. by the provision of three-way test valves or equivalent.

7.2 Unattended machinery space operation – UMS notation

7.2.1 In addition to the tests required by 7.1 the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials over a four to six hour period observing the following:

- Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.
- Any intervention by personnel in the operation of the machinery.

7.3 Operation from a centralized control station – CCS notation

7.3.1 In addition to the tests required by 7.1, the suitability of the installation for operation from the centralized control station is to be demonstrated during sea trials.

7.4 Record of trials

7.4.1 Two copies of the alarm and control equipment test schedules signed by the Surveyor and builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.

Electrical Engineering

Part 6, Chapter 2

Section 1

Section

- 1 **General requirements**
- 2 **Main source of electrical power**
- 3 **Emergency source of electrical power**
- 4 **External source of electrical power**
- 5 **Supply and distribution**
- 6 **System design – Protection**
- 7 **Switchgear and control gear assemblies**
- 8 **Rotating machines**
- 9 **Converter equipment**
- 10 **Electric cables and busbar trunking systems (busways)**
- 11 **Batteries**
- 12 **Equipment – Heating, lighting and accessories**
- 13 **Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts**
- 14 **Navigation and manoeuvring systems**
- 15 **Electric propulsion**
- 16 **Fire safety systems**
- 17 **Crew and passenger emergency safety systems**
- 18 **Ship safety systems**
- 19 **Lightning conductors**
- 20 **Testing and trials**
- 21 **Spare gear**

■ Section 1 General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to passenger ships and cargo ships except where otherwise stated.

1.1.2 Whilst these requirements are considered to meet those of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments, attention should also be given to any relevant Statutory Regulations of the National Administration of the country in which the ship is to be registered. Compliance with the Statutory Regulations of

the National Administration may be accepted as meeting the requirements of the *International Convention for the Safety of Life at Sea, 1974*, and applicable amendments.

1.1.3 Electrical services required to maintain the ship in a normal sea-going, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power.

1.1.4 Electrical services essential for safety are to be maintained under various emergency conditions.

1.1.5 The safety of passengers, crew and ship from electrical hazards is to be ensured.

1.1.6 Lloyd's Register (hereinafter referred to as 'LR') will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules. Consideration will also be given to electrical arrangements of small ships and ships to be assigned class notation for restricted or special services.

1.2 Plans

1.2.1 At least three copies of the plans and particulars in 1.2.2 to 1.2.13 are to be submitted for consideration. Single copies only are required of plans in 1.2.14 to 1.2.17. Additional copies are to be submitted when requested.

1.2.2 Single line diagram of main and emergency power and lighting systems which is to include:

- (a) ratings of machines, transformers, batteries and semi-conductor converters;
- (b) all feeders connected to the main and emergency switchboards;
- (c) section boards and distribution boards;
- (d) insulation type, size and current loadings of cables;
- (e) make, type and rating of circuit-breakers and fuses.
- (f) details of harmonic filters (where fitted).

1.2.3 Simplified diagrams of generator circuits, inter-connector circuits and feeder circuits showing:

- (a) protective devices, e.g. short-circuit, overload, reverse power protection;
- (b) instrumentation and synchronizing devices;
- (c) preference tripping;
- (d) remote stops;
- (e) earth fault indication/protection.

1.2.4 Calculations of short-circuit currents at main and emergency switchboards and section boards including those fed from transformers, details of circuit-breaker and fuse operating times and discrimination curves showing compliance with 6.1 and 10.6.2.

1.2.5 For ships in which explosive gas atmospheres and/or combustible dusts occur – a general arrangement of the ship showing hazardous zones and spaces is to be submitted.

Electrical Engineering

Part 6, Chapter 2

Section 1

1.2.6 A schedule of electrical equipment located in hazardous areas giving details of:

- (a) type of equipment;
- (b) type of protection, e.g. Ex 'd';
- (c) apparatus group, e.g. IIB;
- (d) temperature class, e.g. T3;
- (e) enclosure ingress protection, e.g. IP55;
- (f) certifying authority;
- (g) certificate number;
- (h) location of equipment.

1.2.7 Simplified circuit diagram of electrical propulsion system (where fitted) giving details of:

- (a) ratings of electrical machines, transformers, batteries and semiconductor converters;
- (b) insulation type, size and current loadings of cables;
- (c) make, type and rating of circuit-breakers and fuses;
- (d) instrumentation and protective devices;
- (e) earth fault indication/protection;
- (f) explanation of the system with details of the propulsion control systems and the procedures used to ensure that there is satisfactory control of the design in relation to the requirements of Section 15.

1.2.8 Details of electrically-operated fire, ship, crew and passenger emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones and the location of equipment and cable routes to be employed for:

- (a) emergency lighting;
- (b) accommodation fire detection, alarm and extinction systems;
- (c) Fixed water-based local application fire-fighting systems;
- (d) public address system;
- (e) general alarm;
- (f) watertight doors, bow, stern and shell doors and other electrically operated closing appliances.
- (g) low location lighting.

NOTE

A general arrangement plan of the complete ship showing the main vertical fire zones and the location of equipment and cable routes, for the above systems, is to be made available for the use of the Surveyor on board.

1.2.9 A test schedule which is to include the method of testing and the test facilities which are provided for the general emergency alarm system and the public address system.

1.2.10 For battery installations, arrangement plans and calculations are to show compliance with 11.5.

1.2.11 A schedule of batteries fitted for use for emergency and essential services, giving details of:

- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of maintenance and/or replacement; and
- for replacement batteries in storage, the date of manufacture and shelf life; with accompanying battery replacement procedure documentation to show compliance with 11.7.

1.2.12 Plans of propulsion generators, motors, converting equipment, reactors and filters.

1.2.13 For all cables that pass through atria or equivalent spaces, and for vertical runs in trunks or other restricted spaces, the information supplied is to show compliance with 10.8.8.

1.2.14 In order to establish compliance with 1.10.2 and 5.1.4 to 5.1.6, a general arrangement plan of the ship showing the location of major items of electrical equipment, for example:

- main and emergency generators;
- switchboards;
- section boards and distribution boards supplying essential and emergency services;
- emergency batteries;
- motors for emergency services; and
- cable routes between these items of equipment.

1.2.15 Arrangement plans of main and emergency switchboards, and section boards.

1.2.16 Schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected.

1.2.17 In order to establish compliance with the requirements of 1.6.3, evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.3 Surveys

1.3.1 Electrical propelling machinery and associated equipment together with auxiliary services essential for the safety of the ship are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.3.2 The following equipment, where intended for use for essential and emergency services, is to be surveyed by the Surveyors during manufacture and testing:

- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards; and
- UPS units of 50 kVA and over.

1.3.3 For electric propulsion systems, in addition to the equipment listed in 1.3.2, the following equipment is to be surveyed by the Surveyors during manufacture and testing:

- cables;
- exciters;
- filters;
- reactors;
- slip ring assemblies.

1.3.4 For refrigerating cargo installations having an **RMC** notation, motors are to be tested and certificates furnished by the manufacturer. Motors of 100 kW or over are to be surveyed by the Surveyors during manufacture and testing.

1.3.5 All other electrical equipment, not specifically referenced in 1.3.2 to 1.3.4, intended for use for essential or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements of this Chapter.

1.4 Additions or alterations

1.4.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey, and to the satisfaction of the Surveyors.

1.4.3 When it is proposed to replace permanently installed secondary valve-regulated sealed batteries with vented batteries, details are to be submitted for consideration to ensure continued safety in the presence of the products of electrolysis and evaporation being allowed to escape freely from the cells to the atmosphere. These details are to demonstrate that there will be adequate ventilation in accordance with 11.5.9 and that the location and installation requirements of 11.3 and 11.4 are complied with.

1.5 Definitions

1.5.1 Essential services are those necessary for the propulsion and safety of the ship, such as the following:

- air compressors for oil engines;
- air pumps;
- automatic sprinkler systems;
- ballast pumps;
- bilge pumps;
- circulating and cooling water pumps;
- communication systems;
- condenser circulating pumps;
- electric propulsion equipment;
- electric starting systems for oil engines;
- extraction pumps;
- fans for forced draught to boilers;
- feed water pumps;
- fire detection and alarm systems;
- fuel valve cooling pumps;
- hydraulic pumps for controllable pitch propellers and those serving essential services here listed that would otherwise be directly electrically-driven;
- lubricating oil pumps;
- inert gas fans and scrubber and deck seal pumps;
- lighting systems for those parts of the ship normally accessible to and used by personnel and passengers;
- navigational aids where required by Statutory Regulations;
- navigation lights and special purpose lights where required by Statutory Regulations;
- oil fuel pumps and oil fuel burning units;
- oil separators;
- pumps for fire-extinguishing systems;
- scavenge blowers;

- steering gear;
- thrusters for dynamic positioning;
- valves which are required to be remotely operated;
- ventilating fans for engine and boiler rooms;
- watertight doors, shell doors and other electrical operated closing appliances;
- windlasses;
- power sources and supply systems for supplying the above services.

1.5.2 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

1.5.3 Services such as the following, which are additional to those in 1.5.1 and 1.5.2, are considered necessary to maintain the ship in a normal sea-going operational and habitable condition:

- cargo handling and cargo care equipment;
- hotel services, other than those required for habitable conditions;
- thrusters, other than those for dynamic positioning.

1.5.4 A 'high voltage' is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors, see also 5.1.3.

1.5.5 A 'switchboard' is a switchgear and control gear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.5.6 A 'section board' is a switchgear and control gear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.5.7 A 'distribution board' is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.5.8 A 'final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.5.9 'Special category spaces' are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles with fuel, for their own propulsion, in their tanks, into and from which such vehicles can be driven, and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

1.5.10 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

- (a) internal combustion machinery used for main propulsion; or
- (b) 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
- (c) any oil-fired boiler or oil fuel unit.

1.5.11 'Dead ship condition' means that the entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g. compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be available to start the emergency generator at all times, see Pt 5, Ch 2,8.5.

1.5.12 Protected space is a machinery space where a fixed water-based local application fire-fighting system is installed.

1.5.13 Protected areas are areas within a protected space which is required to be protected by a fixed water-based local application fire-fighting system.

1.5.14 Adjacent areas are areas, other than protected areas, exposed to direct spray or other areas where water may extend when a fixed water-based local application fire-fighting system is activated.

1.6 Design and construction

1.6.1 Electrical propelling machinery and associated equipment together with equipment for services essential for the propulsion and safety of the ship are to be constructed in accordance with the relevant requirements of this Chapter.

1.6.2 The design and installation of other equipment is to be such that risk of fire due to its failure is minimized. It is, as a minimum, to comply with a National or International Standard revised where necessary for ambient conditions.

1.6.3 Electrical equipment is to be suitable for its intended purpose and accordingly, whenever practicable, be selected from the *List of Type Approved Products* published by LR. A copy of the Procedure for LR Type Approval System will be supplied on application.

1.7 Quality of power supplies

1.7.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

1.7.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

- (a) voltage:
 - permanent variations +6%, -10%
 - transient variations due to step changes in load ±20%
 - recovery time 1,5 seconds

- (b) frequency:
 - permanent variations ±5%
 - transient variations due to step changes in load ±10%
 - recovery time 5 seconds
 - A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

1.7.3 **Harmonics.** Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any a.c. switchboard or section board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and may be calculated using the expression:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \times 100$$

where

- V_h = rms amplitude of a harmonic voltage of order h
- V_1 = rms amplitude of the fundamental voltage.

1.7.4 Unless specified otherwise, d.c. electrical equipment, is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

- (a) When supplied by d.c. generator(s) or a rectified a.c. supply:
 - Voltage tolerance (continuous) ±10%
 - Voltage cyclic variation deviation 5%
 - Voltage ripple 10% (a.c. rms over steady state d.c. voltage);
- (b) When supplied by batteries:
 - (i) Equipment connected to the batteries during charging: Voltage tolerance +30%, -25%;
 - (ii) Equipment not connected to batteries during charging: Voltage tolerance +20%, -25%.

Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as d.c. power supply systems adequate measures are to be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

1.8 Ambient reference and operating conditions

1.8.1 The rating for classification purposes of essential electrical equipment intended for installation in ships to be classed for unrestricted (geographical) service is to be based on an engine room ambient temperature of 45°C, and a sea-water temperature at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

1.8.2 In the case of a ship to be classed for restricted service, the rating is to be suitable for the ambient conditions associated with the geographical limits of the restricted service, see Pt 1, Ch 2.

Electrical Engineering

Part 6, Chapter 2

Section 1

1.8.3 Main and essential auxiliary machinery and equipment is to operate satisfactorily under the conditions shown in Pt 5, Ch 1.3.6. Electrical equipment satisfying alternative ambient operating condition requirements for installation on ships contained in an acceptable and relevant National or International Standard may be considered to satisfy this requirement.

NOTE

Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements*.

1.8.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not less than 35°C provided:

- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;
- the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than 45°C; and
- alarms are provided, at a continually attended control station, to indicate any malfunction of the cooling units.

See also Pt 6, Ch 1, 1.3.3.

1.8.5 Where equipment is to comply with 1.8.4, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.8.6 Equipment used for cooling and maintaining the lesser ambient temperature in accordance with 1.8.4 are considered essential services and are to satisfy the requirements of 5.2.

1.9 Inclination of ship

1.9.1 Emergency and essential electrical equipment is to operate satisfactorily under the conditions as shown in Table 2.1.1.

1.9.2 In ships for the carriage of liquefied gas and of liquid chemicals the emergency source of electrical power is also to remain operable with the ship flooded to a final athwartships inclination up to a maximum of 30°.

1.9.3 Any proposal to deviate from the angles given in Table 2.1.1 will be specially considered taking into account the type, size and service of the ship.

1.9.4 The dynamic angles of inclination in Table 2.1.1 may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the electrical equipment is capable of operating under these angles of inclination.

Table 2.1.1 Inclination of ship

Installations, components	Angle of inclination, degrees (see Note 2)			
	Athwartships		Fore-and-aft	
	static	dynamic	static	dynamic
Essential electrical equipment	15	22,5	5 (see Note 3)	7,5
Safety systems, e.g. emergency power installations, crew and passenger safety systems	22,5	22,5	10	10
Switchgear, electrical and electronic appliances (see Note 1)				
NOTES 1. Up to an angle of 45° no undesired switching operations or operational changes may occur. 2. Athwartships and fore-and-aft inclinations may occur simultaneously. 3. Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as: $\frac{500}{L} \text{ degrees}$ where L = Rule length, in metres (see Pt 3, Ch 1.6.1).				

1.10 Location and construction

1.10.1 All electrical equipment is to be constructed or selected, and installed such that:

- live parts cannot be inadvertently touched, unless they are supplied at the safety voltage specified in 1.11.2(h);
- it does not cause injury when handled or touched in the normal manner; and
- it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201: *Electrical installations in ships – Part 201: System design – General* for the relevant location will satisfy these requirements.

1.10.2 Switchboards, section boards and distribution boards supplying essential and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

Electrical Engineering

Part 6, Chapter 2

Section 1

1.10.3 Electrical equipment, as far as is practicable, is to be located:

- (a) such that it is accessible for the purpose of maintenance and survey;
- (b) clear of flammable material;
- (c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.8;
- (d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe-type', see Section 13;
- (e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.10.4 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:

- (a) where the electrical energized part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;
- (b) the design, material(s) and construction of the enclosure minimizes, as far as is practicable, any internal ignition causing ignition of adjacent materials; and
- (c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

NOTE:

Compliance with IEC 60695: *Fire hazard testing*, or an alternative and acceptable Standard, will satisfy this requirement.

1.10.5 Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

1.10.6 Studs, screw-type or spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or bus-bar conductors, as appropriate, see also 10.14. There is to be adequate space and access for the terminations.

1.10.7 Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.

1.10.8 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.10.9 All nuts, screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

1.10.10 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

1.10.11 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in 1.9 for essential electrical equipment, see Pt 5, Ch 13.

1.11 Earthing of non-current carrying parts

1.11.1 Except where exempted by 1.11.2, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed for personal protection against electric shock.

1.11.2 The following parts may be exempted from the requirements of 1.11.1:

- (a) lamp-caps, where suitably shrouded;
- (b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
- (c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
- (d) apparatus which is constructed in accordance with the principle of double insulation;
- (e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
- (f) clips for fluorescent lamps;
- (g) cable clips and short lengths of pipes for cable protection;
- (h) apparatus supplied at a safety voltage not exceeding 50 V d.c. or 50 V a.c., between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
- (j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

1.11.3 Armouring, braiding and other metal coverings of cables are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. See 13.8.3 for earthing of cables in dangerous zones or spaces.

1.11.4 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

1.11.5 Metal parts of portable appliances, other than current-carrying parts and parts exempted by 1.11.2 are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket-outlet.

Electrical Engineering

Part 6, Chapter 2

Section 1

1.11.6 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration.

1.11.7 The nominal cross-section areas of copper earthing conductors for electrical equipment are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm², with a minimum of 1,5 mm². Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm².

1.11.8 The nominal cross-section areas of copper earthing conductors for armouring, braiding and other metal coverings of cables are, in general, to be equal to the equivalent cross-section of the armouring, braiding and other metal coverings with a minimum of 1,5 mm².

1.11.9 Earthing conductors of materials other than copper are to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.11.10 The connection of the earthing conductor to the hull of the ship is to be made in an accessible position, and is to be secured by a screw or stud of diameter not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

1.12 Bonding for the control of static electricity

1.12.1 Bonding straps for the control of static electricity are required for cargo tanks, process plant and piping systems, for flammable products and solids liable to release flammable gas and/or combustible dust, which are not permanently connected to the hull of the ship either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1 MΩ.

1.12.2 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of about 10 mm², and are to comply with 1.11.6 and 1.11.8.

1.13 Alarms

1.13.1 Where alarms are required by this Chapter they are to be arranged in accordance with Ch 1,2.3. Sound signal equipment, fire and general alarm bells are not required to be supplemented by visual alarms, except in areas having high levels of background noise, such as machinery spaces.

1.13.2 The alarms in this Chapter are additional to those required by Chapter 1. They may however form part of the alarm system that is required by Chapter 1.

1.13.3 Cables for emergency alarms and their power sources are to be in accordance with 1.14.

1.13.4 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localized fire, collision, flooding or similar damage is minimized, see 1.14.

1.14 Operation under fire conditions

1.14.1 As a minimum, the following emergency services and their emergency power supplies, are required to be capable of being operated under fire conditions:

- Control and power systems to power-operated fire doors and status indication for all fire doors.
- Control and power systems to power-operated watertight doors and their status indication.
- Emergency lighting.
- Fire and general alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Fire safety stops, see *also* 16.6.
- Low location lighting, see *also* 17.4.3.
- Public address systems.
- Emergency fire pump.

1.14.2 Where cables for the emergency services listed in 1.14.1 pass through high fire risk areas, main vertical or horizontal fire zones other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the emergency service in any other area or zone. This may be achieved either by:

- cables being of a fire resistant type complying with 10.5.3, and at least extending from the main control/monitoring panel to the nearest local distribution panel serving the relevant area or zone; or
- there being at least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

1.14.3 Where the cables for the power supplies for the emergency services listed in 1.14.1 pass through high fire risk areas, main vertical or horizontal fire zones other than those which they serve, they are to be of a fire resistant type complying with 10.5.3, extending at least to the local distribution panel serving the relevant area or zone.

1.14.4 Fire resistant electrical cables for the emergency services listed in 1.14.1, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

1.14.5 In addition to 1.10.4, materials used for electrical equipment, cables and accessories within passenger accommodation areas are not to be capable of producing excessive quantities of smoke and toxic products.

NOTE:

Compliance with IEC 60695: Fire hazard testing, or an alternative and acceptable Standard, will satisfy this requirement.

Electrical Engineering

Part 6, Chapter 2

Sections 1 & 2

1.15 Protection of electrical equipment against the effects of lightning strikes

1.15.1 Precautions are to be taken to protect essential electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables. See *also* Section 19.

Section 2 Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to comply with the requirements of this section without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 Under sea-going conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

- (a) to be sufficient to ensure the operation of electrical services for essential equipment, habitable conditions, cargo refrigeration machinery of ships having a **RMC** notation and the container socket outlets and ventilation system of container ships having a **CRC** notation. See 15.2.5 for electric propulsion systems;
- (b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system;
- (c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a dead ship condition. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by Section 3, see *also* 2.3.2.

2.2.2 The arrangement of the ship's main source of power is to be such that the operation of electrical services for essential equipment, habitable conditions and cargo refrigeration machinery of ships having a **RMC** notation can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.2.3 Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator (see 6.9). On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services (see 1.5.1), in as short a time as is practicable.

NOTE

Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The starting arrangements of the generating sets prime movers are to comply with the requirements of Pt 5, Ch 2,8 as applicable.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a 'dead ship condition', the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the 'dead ship condition'. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in Section 3. See Pt 5, Ch 2,8.1.1 for dead ship condition starting arrangements.

2.4 Prime mover governors

2.4.1 The governing accuracy of the generating sets prime movers is to meet the requirements of Pt 5, Ch 2,5.3.

2.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in 1.7.2.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 Generators and generator systems, having the ship's propulsion machinery as their prime mover but not forming part of the ship's main source of electrical power may be used whilst the ship is at sea to supply electrical services required for normal operational and habitable conditions provided that the requirements of 2.5.2 to 2.5.4 are satisfied.

2.5.2 Within the declared operating range of the generators and/or generator system, the specified voltage and frequency variations of the Rules are to be met.

2.5.3 Where there is remote control of the propulsion machinery, arrangements are to ensure that essential machinery power supplies are maintained during manoeuvring conditions in order to prevent a blackout situation.

2.5.4 In addition to the requirements of 2.2.3, arrangements are to be fitted to automatically start one of the generators forming the main source of power should the frequency variations exceed those permitted by the Rules.

■ Section 3 Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to passenger and cargo ships to be classed for unrestricted service. They do not apply to cargo ships of less than 500 tons gross tonnage.

3.1.2 For ships assigned a Service Restriction Notation in accordance with Pt 1, Ch 2, a lesser period than the 36 hour period and 18 hour period specified in 3.2.5 and 3.3.5 respectively may be considered, but not less than 12 hours.

3.1.3 The emergency source of power for cargo ships of less than 500 tons gross tonnage will be the subject of special consideration.

3.2 Emergency source of electrical power in passenger ships

3.2.1 A self-contained emergency source of electrical power is to be provided.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead.

3.2.3 The location of the emergency source of electrical power and associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard is to be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space of Category A will not interfere with the supply, control and distribution of emergency electrical power. The space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard is not to be contiguous to the boundaries of machinery spaces of Category A and those spaces containing the main source of electrical power, associated transforming equipment, if any, or the main switchboard. Where this is not practicable, details of the proposed arrangements are to be submitted.

3.2.4 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

3.2.5 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

- (a) For a period of 36 hours, emergency lighting:
 - (i) at every lifeboat preparation station, muster and embarkation station and oversides;
 - (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
 - (iii) in all service and accommodation alleyways, stairways and exits, personnel lift cars;
 - (iv) in the machinery spaces and main generating stations including their control positions;
 - (v) in all control stations, machinery control rooms, and at each main and emergency switchboard;
 - (vi) at all stowage positions for fireman's outfits;
 - (vii) at the steering gear; and
 - (viii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors;
- (b) For a period of 36 hours:
 - (i) the navigation lights and other lights, as required by the *International Regulations for Preventing Collisions at Sea* in force; and
 - (ii) the radiocommunications, as required by Amendments to SOLAS 1974, Chapter IV.
- (c) For a period of 36 hours:
 - (i) all internal communication equipment required in an emergency;
 - (ii) the navigational aids as required by Amendments to SOLAS 1974 Reg V/19; where such provision is unreasonable or impracticable this requirement may be waived for ships of less than 5000 tons gross;
 - (iii) the fire detection, fire alarm and sample extraction smoke detection systems, and the fire door holding and release system; and
 - (iv) for intermittent operation of the daylight signalling lamp, the ship's whistle, the manually-operated call points and all internal signals that are required in an emergency;

unless such services have an independent supply for the period of 36 hours from an accumulator battery suitably located for use in an emergency.
- (d) For a period of 36 hours:
 - (i) emergency fire pump;
 - (ii) the automatic sprinkler pump, if any; and
 - (iii) the emergency bilge pump and all the equipment essential for the operation of electrically-powered remote controlled bilge valves.
- (e) The steering gear for the period of time required by Pt 5, Ch 19,6.
- (f) For a period of half an hour:
 - (i) any watertight doors if electrically-operated together with their control, indication and alarm circuits;

Electrical Engineering

Part 6, Chapter 2

Section 3

- (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.
- (g) Where applicable, the services required by 2.3.2.

3.2.6 The emergency source of electrical power may be either a generator or an accumulator battery, which are to comply with the following:

- (a) Where the emergency source of electrical power is a generator it is to be:
 - (i) driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed-cup test) of not less than 43°C;
 - (ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in 3.2.5 are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and
 - (iii) provided with a transitional source of emergency electrical power according to 3.2.7.
- (b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:
 - (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
 - (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
 - (iii) immediately supplying at least those services specified in 3.2.7.

3.2.7 The transitional source of emergency electrical power required by 3.2.6 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the following services, if they depend upon an electrical source for their operation:

- (a) For half an hour:
 - (i) the lighting required by 3.2.5(a) and (b);
 - (ii) all services required by 3.2.5(c)(i), (iii) and (iv) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.
- (b) Power to operate the watertight doors at least three times, i.e. closed-open-closed against an adverse list of 15°, but not necessarily all of them simultaneously, together with their control, indication and alarm circuits as required by 3.2.5(f)(i).

3.2.8 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.2.9 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.2.10 No accumulator battery except for engine starting, fitted in accordance with this Section is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged.

3.2.11 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.2.12 In order to ensure the ready availability of the emergency source of electrical power to supply emergency circuits, arrangements are to be made, where necessary, to automatically disconnect non-emergency circuits from the emergency switchboard to ensure that electrical power is available to the emergency circuits. The arrangements are to automatically disconnect sufficient non-emergency loads to ensure continued safe operation of the emergency source of electrical power in the event of overloading.

3.2.13 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.2.14 In addition to the emergency lighting required by 3.2.5(a) passenger ships with roll on-roll off cargo spaces or special category spaces are to be provided with the following:

- (a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service.
- (b) A portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

Electrical Engineering

Part 6, Chapter 2

Section 3

3.3 Emergency source of electrical power in cargo ships

3.3.1 A self-contained emergency source of electrical power is to be provided.

3.3.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead.

3.3.3 The location of the emergency source of electrical power and associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard are to be such as to ensure that a fire or other casualty in the space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard, or in any machinery space of Category A will not interfere with the supply, control and distribution of emergency electrical power. The space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard. Where this is not practicable, details of the proposed arrangements are to be submitted.

3.3.4 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.

3.3.5 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

- (a) For a period of three hours, emergency lighting at every lifeboat preparation station, muster and embarkation station and over the sides.
- (b) For a period of 18 hours, emergency lighting:
 - (i) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;
 - (ii) in the machinery spaces and main generating stations including their control positions;
 - (iii) in all control stations, machinery control rooms, and at each main and emergency switchboard;
 - (iv) at all stowage positions for fireman's outfits;
 - (v) at the steering gear; and

- (vi) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;
- (vii) in all cargo pump rooms of tankers.
- (c) For a period of 18 hours:
 - (i) the navigation lights and other lights, as required by the *International Regulations for Preventing Collisions at Sea* in force; and
 - (ii) the radiocommunications, as required by Amendments to SOLAS 1974, Chapter IV.
- (d) For a period of 18 hours:
 - (i) all internal communication equipment as required in an emergency;
 - (ii) the navigational aids as required by Amendments to SOLAS 1974 Reg V/19; where such provision is unreasonable or impracticable this requirement may be waived for ships of less than 5000 tons gross;
 - (iii) the fire detection and fire-alarm system; and
 - (iv) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency;

unless such services have an independent supply for the period of 18 hours from an accumulator battery suitably located for use in an emergency.
- (e) For a period of 18 hours the emergency fire pump if dependent upon the emergency generator for its source of power.
- (f) The steering gear for the period of time required by Pt 5, Ch 19.6.
- (g) Where applicable, the services required by 2.3.2.

3.3.6 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

- (a) Where the emergency source of electrical power is a generator it is to be:
 - (i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed-cup test) of not less than 43°C;
 - (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with 3.3.7 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.3.7 are to be connected automatically to the emergency generator; and
 - (iii) provided with a transitional source of emergency electrical power as specified in 3.3.7 unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

Electrical Engineering

Part 6, Chapter 2

Section 3

- (b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
- (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
 - (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
 - (iii) immediately supplying at least those services specified in 3.3.7.

3.3.7 The transitional source of emergency electrical power where required by 3.3.6 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

- (a) the lighting required by 3.3.5(a), (b) and (c). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and
- (b) all services required by 3.3.5(d)(i), (iii) and (iv) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

3.3.8 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.3.9 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.3.10 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged.

3.3.11 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.3.12 In order to ensure the ready availability of the emergency source of electrical power to supply emergency circuits, arrangements are to be made, where necessary, to automatically disconnect non-emergency circuits from the emergency switchboard to ensure that electrical power is available to the emergency circuits. The arrangements are to automatically disconnect sufficient non-emergency loads to ensure continued safe operation of the emergency source of electrical power in the event of overloading.

3.3.13 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.4 Starting arrangements

3.4.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in Pt 5, Ch 2,8.5.

3.5 Prime mover governor

3.5.1 Where the emergency source of power is a generator, the governor is to comply with 2.4.

3.6 Radio installation

3.6.1 Every radio installation as required by SOLAS 1974 as amended, Chapter IV, Part C, is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

3.6.2 A reserve source or sources of energy is to be provided on every ship, for the purpose of conducting distress and safety radiocommunications, in the event of failure of the ship's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the ship is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT ship earth station and any of the additional loads mentioned in 3.6.4, 3.6.5 and 3.6.7 for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

3.6.3 The reserve source or sources of energy is to be independent of the propelling power of the ship and the ship's electrical system.

3.6.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in 3.6.2, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by 3.6.2, the VHF radio installation and:

- (a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or

Electrical Engineering

Part 6, Chapter 2

Sections 3, 4 & 5

- (b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

3.6.5 The reserve source or sources of energy may be used to supply the electrical lighting required by 3.6.1.

3.6.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

3.6.7 If an uninterrupted input of information from the ship's navigational or other equipment to a radio installation as referred to in 3.6.1 is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the ship's main or emergency source of electrical power.

Section 4 External source of electrical power

4.1 Temporary external supply

4.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals including one earthed, of ample size and suitable shape to facilitate a satisfactory connection of three-phase external supplies with earthed neutrals.

4.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energized.

4.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

4.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

4.1.5 Alternative arrangements may be submitted for consideration.

4.2 Permanent external supply

4.2.1 Details are to be submitted.

Section 5 Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The following systems of generation and distribution are acceptable, other than for tankers intended for the carriage in bulk of oil, liquefied gases and other hazardous liquids having a flash point not exceeding 60°C (closed-cup test):

- (a) d.c., two-wire;
- (b) a.c., single-phase, two-wire;
- (c) a.c., three-phase:
 - (i) three-wire;
 - (ii) four-wire with neutral solidly earthed but without hull return.

5.1.2 For tankers intended for the carriage in bulk of oil, liquefied gases and other hazardous liquids having a flash point not exceeding 60°C (closed-cup test) only the following systems of generation and distribution are acceptable:

- (a) d.c., two-wire, insulated;
- (b) a.c., single-phase, two-wire, insulated;
- (c) a.c., three-phase, three-wire, insulated;
- (d) earthed systems, a.c. or d.c., limited to areas outside any dangerous space or zone, and arranged so that no current arising from an earth-fault in any part of the system could pass through a dangerous space or zone;
- (e) earthed systems, complying with 5.1.1 and 5.5.7, provided the Government of the flag state permits such an arrangement in accordance with the 'Equivalents' provisions of SOLAS Chapter I, Regulation 5, see Ch 1, 1.4 of the *Rules for Ships for Liquid Chemicals* and/or the *Rules for Ships for Liquefied Gases*, as appropriate, see also 13.1.2.

Earthed intrinsically-safe circuits are permitted to pass into and through dangerous spaces and zones.

5.1.3 System voltages for both alternating current and direct current in general are not to exceed:

- 15 000 V for generation and power distribution;
- 500 V for cooking and heating equipment permanently connected to fixed wiring;
- 250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above.

Voltages above these will be the subject of special consideration.

5.1.4 The arrangement of the main system of supply is to be such that a fire or other casualty in any space containing the main source of electrical power, associated converting equipment, if any, the main switchboard and the main lighting switchboard will not render inoperable any emergency service, other than those located within the space where the fire or casualty has occurred.

5.1.5 The main switchboard is to be so placed relative to the main source of power that, as far as is practicable, the integrity of the main system of supply will be affected only by a fire or other casualty in one space.

5.1.6 The arrangement of the emergency system of supply is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the ship.

5.1.7 Distribution systems required in an emergency are to be so arranged that a fire in any one main fire zone, as defined by SOLAS 1974 as amended Reg II-2/A, 3.32, will not interfere with the emergency distribution in any other such zone.

5.2 Essential services

5.2.1 Essential services that are required by Part 5 to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single fault will not cause the loss of both services.

5.2.2 Where 5.2.1 is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by a multipole linked circuit-breaker, disconnect or switch-disconnector, into at least two independent sections, each supplied by at least one generator, either directly or through a converter. The essential services are to be equally divided, as far as is practicable, between the independent sections.

5.2.3 Where 5.2.2 is applicable provision is to be made to transfer to a temporary circuit those essential services which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section board.

5.3 Isolation and switching

5.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:

- (a) on load;
- (b) for mechanical maintenance;
- (c) in an emergency to prevent or remove danger.

In addition the requirements of 5.3.2 and 5.3.3 are to be complied with.

5.3.2 Isolation and switching is to be by means of a circuit-breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:

- (a) switching off the circuit on load;
- (b) withstanding, without damage, the overcurrents which may arise during overloads and short-circuit.

In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, see 6.5.

5.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energized:

- (a) the circuit-breaker or switch can be withdrawn, or locked in the open position;
- (b) the operating handle of the circuit-breaker or switch can be removed;
- (c) the circuit fuses, where fitted, can be readily removed and retained by authorized personnel.

5.3.4 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit. In addition, the requirements of 5.3.5 and 5.3.6 are to be complied with.

5.3.5 The switching device required by 5.3.4 is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energized.

5.3.6 A notice is to be fixed to any section board, distribution board or item of equipment to which 5.3.4 applies warning personnel before gaining access to live parts of the need to open the appropriate circuit-breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

5.3.7 Tankers designed in accordance with IEC 60092-502: *Electrical Installations in Ships — Tankers — Special Features* (see 13.1.2) are to meet the requirements of 5.3 of that Standard.

5.3.8 Where high voltage equipment is contained in a room or protected area which also forms its enclosure, the access door(s) of the space is to be so interlocked that it cannot be opened until:

- the high voltage supply(ies) to the equipment is switched off;
- the equipment and its cable(s) are earthed down to dissipate stored energy sufficient to ensure personnel safety.

5.3.9 The access to the space(s) described in 5.3.8 are to be suitably marked to indicate the danger of high voltage.

5.4 Insulated distribution systems

5.4.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the event of an abnormally low level of insulation resistance.

5.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

5.4.3 Tankers designed in accordance with IEC 60092-502: *Electrical Installations in Ships — Tankers — Special Features* (see 13.1.2) are to meet the requirements of 5.3 of that Standard.

5.4.4 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

5.5 Earthed distribution systems

5.5.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

5.5.2 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short-circuit current for which the generators are designed.

5.5.3 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage waveform of each generator does not exceed five per cent.

5.5.4 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

5.5.5 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

5.5.6 All earthing impedances are to be connected to the hull. The connections to the hull are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

5.5.7 Tankers designed in accordance with IEC 60092-502: *Electrical Installations in Ships — Tankers — Special Features* (see 13.1.2) are to meet the requirements of 5.3 of that Standard.

5.6 Diversity factor

5.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

5.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

5.6.3 For winches and crane motors the diversity factor is to be calculated and submitted when required.

5.7 Lighting circuits

5.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A.

5.7.2 Lighting for the following spaces is to be supplied from at least two final sub-circuits in such a way that failure of one of the circuits does not leave the space in darkness. One of these circuits may be an emergency circuit provided it is normally energized.

- Spaces that are required to be lit for the safe working of the ship, such as control stations, normal working spaces, etc.
- Spaces where there may be a hazard due to movement of crew, passengers and/or equipment, such as in corridors, working passage ways, stairways leading to boat decks, public rooms, etc.
- Spaces where there may be a hazard due to moving machinery and hot parts, such as in machinery spaces, workshops, large galleys, laundries, etc.

5.7.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other. One of these circuits may be an emergency circuit, provided it is normally energised in which case the arrangements are to comply with Section 3.

5.7.4 Emergency lighting is to be fitted in accordance with Section 3, *see also* Section 17.

5.7.5 Lighting of unattended spaces, such as cargo spaces, is to be controlled by multipole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.7.6 Where lighting circuits in the cargo pump rooms of tankers are also used for emergency lighting, and have been interlocked with the ventilation, the interlocking arrangements are:

- not to cause the lighting to go out following a failure of the ventilation system; and
- not to prevent operation of the emergency lighting following the loss of the main source of electrical power.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.5.1.

5.9 Motor control

5.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in 5.9.2 to 5.9.4.

5.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g. steering gear motor.

5.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, see also 6.10.

5.9.4 Motor control gear is to be suitable for the starting current and for the full load rated current of the motor.

Section 6 System design – Protection

6.1 General

6.1.1 Installations are to be protected against over-currents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:

- (a) availability of essential and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;
- (b) elimination of the fault to reduce damage to the system and hazard of fire.

6.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

6.1.3 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested.

6.1.4 Short circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

6.1.5 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimize the risk of short-circuit.

6.1.6 Except where arrangements comply with 11.3.5, protection for battery circuits is to be provided at a position external and adjacent to the battery compartments.

6.1.7 Protection may be omitted from the following:

- (a) Engine starting battery circuits.
- (b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

6.1.8 Short circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition and where the cabling or wiring is installed in a manner such as to minimize the risk of short-circuit.

6.1.9 Overload protection may be omitted from the following:

- (a) one line of circuits of the insulated type;
- (b) circuits supplying equipment incapable of being overloaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

6.2 Protection against short-circuit

6.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit-breakers and fuses are detailed in 6.5 and 6.6 respectively.

6.2.3 The prospective fault current is to be calculated for the following set of conditions:

- (a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements;
- (b) a fault of negligible impedance close up to the load side of the protective device.

6.2.4 In the absence of precise data, the prospective fault current may be taken to be:

- (a) for alternating current systems at the main switchboard: $10 \times \text{f.l.c.}$ (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, X''_d , of each generator is known, $\frac{\text{f.l.c.}}{X''_d \text{ (p.u.)}}$ for each generator, and $3 \times \text{f.l.c.}$ for motors

simultaneously in service.

The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).

- (b) battery-fed direct current systems at the battery terminals:
 - (i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours, or

- (ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours and,
- (iii) 6 x f.l.c. for motors simultaneously in service (if applicable).

6.3 Protection against overload

6.3.1 The characteristics of protective devices provided for overload protection are to ensure that cabling and electrical machinery is protected against overheating resulting from mechanical or electrical overload.

6.3.2 Fuses of a type intended for short-circuit protection only (e.g. fuse links complying with IEC 60269-1, of type 'a') are not to be used for overload protection.

6.4 Protection against earth faults

6.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3 The rated short-circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in 6.4.2 because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

6.5 Circuit-breakers

6.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

- (a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the instant of contact separation;
- (b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;
- (c) the power factor at which the device short-circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

6.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

6.5.3 The fault ratings considered in 6.5.1 and 6.5.2, are to be assigned on the basis that the device is suitable for further use after fault clearance.

6.6 Fuses

6.6.1 Fuses for a.c. systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

6.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit-breakers are not to be used for this purpose.

6.7.2 The same device may back-up more than one circuit-breaker provided that no essential or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

6.7.3 The combination of back-up device and circuit-breaker is to have a short-circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of 6.5.

6.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

- (a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated short-circuit breaking capacity of the circuit-breaker and;
- (b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded and;
- (c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

6.8 Protection of generators

6.8.1 The protective gear required by 6.8.2 and 6.8.3 is to be provided as a minimum.

6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multipole linked switch with a fuse, complying with 5.3.2, in each insulated pole will be acceptable.

6.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of a short-circuit, an overload or an under-voltage, all insulated poles. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of 2 per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover; a fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

6.8.4 The generator circuit-breaker short-circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

6.8.5 Generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cables between the generator and its circuit breaker, will instantaneously open the circuit breaker and de-excite the generator.

6.8.6 The voltage and time delay settings of the under-voltage release mechanism(s) required by 6.8.2 and 6.8.3 are to be chosen to ensure that the discriminative action required by 6.1.1(a) is maintained.

6.9 Load management

6.9.1 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the following categories, when the generator(s) is/are overloaded; sufficient to ensure the connected generating set(s) is/are not overloaded:

- (a) non-essential circuits;
- (b) circuits feeding services for habitability, see 1.5.2;
- (c) in cargo ships, circuits for cargo refrigeration.

NOTE:

For emergency generators see 3.2.12 and 3.3.12 as applicable.

6.9.2 If required, this load switching may be carried out in one or more stages, in which case the non-essential circuits are to be included in the first group to be disconnected.

6.9.3 The load management of power systems supplying electric propulsion motors is to satisfy the requirements of 15.2.

6.9.4 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

6.10 Feeder circuits

6.10.1 Isolation and protection of each feeder circuit is to be ensured by a multipole circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with 6.2 and 6.3. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

6.11 Motor circuits

6.11.1 Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short-circuit. For motors which for essential services are duplicated, the overload protection may be replaced by an overload alarm; arrangements for steering gear motors are to comply with 14.1.

6.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

6.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short-circuit protection.

6.11.4 For motors for intermittent service, the characteristics of the arrangements for overload protection are to be chosen in relation to the load factor(s) of the motor(s).

6.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

6.12 Protection of transformers

6.12.1 Short circuit protection for transformers is to be provided by circuit-breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

6.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energized from their secondary side when disconnected from their source of supply.

Section 7 Switchgear and control gear assemblies

7.1 General requirements

7.1.1 Switchgear and control gear assemblies and their components are to comply with one of the following standards amended where necessary for ambient temperature and other environmental conditions:

- (a) IEC 60439: *Low voltage switchgear and control gear assemblies*;
- (b) IEC 60298: *AC Metal enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 72.5 kV*;
- (c) IEC 60466: *AC insulated-enclosed switchgear for rated voltages above 1 kV and up to and including 38 kV*;
- (d) IEC 60255: *Electrical relays*;
- (e) acceptable and relevant National Standard.

In addition, the requirements of 7.2 to 7.19 are to be complied with.

7.2 Busbars

7.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/oxidization between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

7.2.2 For bare conductors, where no precautions are taken against surface oxidization, the temperature rise limit at rated normal current is not to exceed 45°C. Where suitable precautions are taken against surface oxidization, e.g. by using silver, nickel or tin coated terminations, a temperature rise limit not exceeding 60°C is permitted. Where the busbar temperature rises are above 45°C it is to be ensured that there is no adverse effect on equipment adjacent to and/or connected to the busbars and that the temperature rise limits of any materials in contact with the busbars are not exceeded. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

7.3 Circuit-breakers

7.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

- (a) IEC 60947-2: *Low voltage switchgear and Control gear Pt 2: Circuit-breakers*;
- (b) IEC 62271-100: *High-voltage switchgear and control gear - Pt 100: High-voltage alternating-current circuit-breakers*;
- (c) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.3.2 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

7.3.3 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.4 Contactors

7.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature.

- (a) IEC 60470: *High-voltage alternating current contactors*.
- (b) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a contactor are to be submitted for consideration when required.

7.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.5 Creepage and clearance distances

7.5.1 The shortest distances between conductive parts and between conductive parts and earth in air or along the surface of an insulating material, are to be suitable for the rated voltage having regard to the nature of the insulating material and the transient over voltages developed by switching and fault conditions. This requirement may be satisfied by subjecting each assembly type to an impulse voltage test in accordance with its constructional Standard or, alternatively, maintaining the minimum distances for bare conductive parts in switchgear and control gear assemblies given in Table 2.7.1.

Table 2.7.1 Minimum clearance distances

Rated Voltage V	Minimum clearance (mm) between phases and earth		Minimum clearance (mm) between phases
	Earthed neutral	Insulated neutral	
≤660	16	19	19
1000	25	25	25
3600	55	55	55
7200	70	100	100
12000	85	140	140
15000	100	165	165

7.5.2 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in Table 2.7.1.

7.5.3 Creepage distances cannot be accurately specified as they depend upon the insulating material, dust deposits, humidity, etc. They are to be not less than the clearance distances given in Table 2.7.1, or less than 16 mm per 1000 V (rated voltage), whichever is the greater.

7.6 Degree of protection

7.6.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

7.6.2 Where switchboards or section boards are required to comply with 5.2.2, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

7.7 Distribution boards

7.7.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorized persons have access in which case the cupboard may serve as an enclosure, see 7.16.4.

7.8 Earthing of high-voltage switchboards

7.8.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

7.9 Fuses

7.9.1 Fuses are to comply with one of the following Standards amended where necessary for ambient temperature:

- (a) IEC 60269: *Low-voltage fuses*;
- (b) IEC 60282-1: *High voltage fuses Pt 1: Current-limiting fuses*;
- (c) acceptable and relevant National Standard for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrails or handles

7.10.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

7.11 Instruments for alternating current generators

7.11.1 For alternating current generators not operated in parallel, each generator is to be provided with at least one voltmeter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

7.11.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

7.11.3 For parallelling purposes, two voltmeters, two frequency meters and two synchronising devices, of which one at least is to be a synchroscope or a set of lamps are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured. Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by two or more generators operating in parallel, the two synchronising devices are to be independent of each other (see also 2.2.1).

7.11.4 Where the indications of voltage, frequency, current and power are displayed digitally, the indications are to be separately displayed.

7.12 Instrument scales

7.12.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

7.12.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

7.12.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

7.12.4 Where the indications provided by the instrumentation required by 7.11 are displayed digitally, nominal voltage, over voltage, over current and reverse power indications are to be indicated by an appropriate means.

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. Section and distribution boards are to be marked with the rated voltage.

7.14 Protection

7.14.1 See Section 6.

7.15 Wiring

7.15.1 Insulated wiring connecting components are to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

7.16 Position of switchboards

7.16.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

7.16.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

7.16.3 The spaces defined in 7.16.1 and 7.16.2 are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

7.16.4 So far as is practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, see Pt 5, Ch 13,2.

7.16.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault.

7.17 Switchboard auxiliary power supplies

7.17.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

7.18 Testing

7.18.1 Tests in accordance with 7.18.2 to 7.18.4 are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer, see also 1.3.2.

7.18.2 A high voltage test, see Section 20.

7.18.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

7.18.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

7.18.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with an appropriate Standard, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3: *Low voltage switchgear and control gear Part 3: switches, disconnectors, switch-disconnectors and fuse combination units*;

(b) IEC 62271-102: *High-voltage switchgear and control gear – Pt 102: High-voltage alternating current disconnectors and earthing switches*;

(c) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

■ Section 8

Rotating machines

8.1 General requirements

8.1.1 Rotating machines are to comply with the relevant part of IEC 60092, or an acceptable and relevant National Standard, and the requirements of this section.

8.1.2 For all the rotating machines a manufacturer's test certificate is to be provided, see also 1.3.2 to 1.3.4.

8.1.3 For rotating machines of 100 kW and over intended for essential services, shaft materials are to comply with LR's *Rules for the Manufacture, Testing and Certification of Materials*.

8.1.4 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalized assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

8.1.5 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034: *Rotating electrical machines Part 14*.

8.1.6 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum ship inclinations defined by 1.9 and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

8.1.7 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

8.1.8 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short-circuit at their terminals without damage.

8.1.9 AC generators and motors for electrical propulsion systems are to have at least one embedded temperature detector (ETD) in each phase of the machine winding in locations which may be subjected to the highest temperature. Where there are two coil sides per slot the ETD's are to be located between the insulated coil sides in the slot, see 15.1.3.

8.2 Rating

8.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 8.3 being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in 8.3.

8.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

8.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

8.3 Temperature rise

8.3.1 The limits of temperature rise specified in Table 2.8.1, are based on the cooling air temperature and cooling water temperature given in 1.8.

8.3.2 If it is known that the temperature of cooling medium exceeds the values given in 1.8 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

8.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.8 the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.8 up to a maximum of 15°C.

8.4 Generator control

8.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distribution system should there be a failure of the voltage regulating system resulting in a high voltage.

8.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within $\pm 2,5$ per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no load voltage.

8.4.3 Generators, and their excitation systems, when operating at rated speed and voltage on no-load are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4 with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds.

8.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off.

8.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short-circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any longer time delay which may be provided by a tripping device for discrimination purposes.

8.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

8.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than five per cent of the rated kVA output of the largest machines.

8.5 Overloads

8.5.1 Machines are to withstand on test, without injury, the following momentary overloads:

- (a) **Generators.** An excess current of 50 per cent for 15 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The foregoing does not apply to the overload torque capacity of the prime mover.
- (b) **Motors.** At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

Table 2.8.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C						
Part of machine	Method of temperature measurement	Insulation class				
		A	E	B	F	H
1. (a) a.c. windings of machines having output of 5000 kVA or more	ETD R	55 50	– –	75 70	95 90	115 110
(b) a.c. windings of machines having output of less than 5000 kVA	ETD R	55 50	– 65	80 70	100 95	115 110
2. Windings of armatures having commutators	R T	50 40	65 55	70 60	95 75	115 95
3. Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	50 40	65 55	70 60	95 75	115 95
4. (a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	–	–	80	100	125
(b) Stationary field windings of d.c. machines having more than one layer	R T	50 40	65 55	70 60	95 75	115 95
(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5. Permanently short-circuited insulated windings	T	50	65	70	90	115
6. Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7. Magnetic cores and other parts not in contact with windings	T					
8. Magnetic cores and other parts in contact with windings	T	50	65	70	90	110
9. Commutators and slip-rings open and enclosed	T	50	60	70	80	90
NOTES 1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in Table 2.8.1 shall be increased by 10°C provided the inlet water temperature does not exceed the values given in 1.8. 2. T = thermometer method R = resistance method ETD = embedded temperature detector 3. Temperature rise measurements are to use the resistance method whenever practicable. 4. The ETD method may only be used when the ETD's are located between coil sides in the slot.						

- d.c. motors 50 per cent for 15 seconds;
 polyphase a.c. synchronous motors 50 per cent for 15 seconds;
 polyphase a.c. synchronous induction motors 35 per cent for 15 seconds;
 polyphase a.c. induction motors 60 per cent for 15 seconds.
- c) **Propulsion machines.** The overload tests for propulsion machines will be specially considered for each installation.
- (d) **Windlasses.** For the design and testing of windlass electric motors, see Pt 3, Ch 13,7.6.

8.6 Machine enclosure

8.6.1 Where water cooled heat exchangers are used in the machine cooling circuit there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the machine.

8.7 Direct current machines

8.7.1 The final running position of brushgear is to be clearly and permanently marked.

8.7.2 Direct current machines are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

8.8 Survey and testing

8.8.1 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded, see also 1.3.2 to 1.3.4.

8.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

8.8.3 A high voltage test, in accordance with Section 20, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately.

8.8.4 An impulse test is to be carried out on the coils of high voltage machines in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges.

The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

$$V_{\text{peak}} = 2,45V$$

where

$$V = \text{rated line voltage r.m.s.}$$

Alternative proposals to demonstrate the withstand level of inter-turn insulation will be considered.

Section 9 Converter equipment

9.1 Transformers

9.1.1 Paragraphs 9.1.2 to 9.1.12 apply to transformers rated for 5 kVA upwards.

9.1.2 Transformers are to comply with the requirements of IEC 60076: *Power transformers*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, see 1.8.

9.1.3 Transformers may be of the dry type, encapsulated or liquid-filled type.

9.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in 1.8, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

- (a) For dry type transformers, air cooled:
 - insulation of Class A – 50°C
 - insulation of Class E – 60°C
 - insulation of Class B – 70°C
 - insulation of Class F – 90°C
 - insulation of Class H – 110°C
- (b) For liquid filled transformers:
 - 50°C – where air provides cooling of the fluid
 - 65°C – where water provides cooling of the fluid.

9.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

9.1.6 The inherent regulation of transformers at their rated output is to be such that the total voltage drop to any point in the installation does not exceed that allowed by 1.7.

9.1.7 Transformers, except those for motor starting, are to be double wound.

9.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief-device with an alarm and there is to be a suitable means provided to contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

9.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

9.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

9.1.11 Where water cooled heat exchangers are used in transformer cooling circuits, there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the transformer.

9.1.12 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests issued by the manufacturer, see also 1.3.2:

- (a) measurement of winding resistances, voltage ratio, impedance voltage, short-circuit impedance, insulation resistance, load loss, no load loss and current;
- (b) dielectric tests;
- (c) temperature rise test on one transformer of each size and type.

9.2 Semiconductor equipment

9.2.1 The requirements of 9.2.2 to 9.2.18 apply to semiconductor equipment rated for 5 kW upwards.

9.2.2 Semiconductor equipment is to comply with the requirements of IEC 60146: *Semiconductor converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, see 1.8.

9.2.3 Semiconductor static power converter equipment is to be rated for the required duty having regard to peak loads, system transients and overvoltage.

9.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively the load may be automatically reduced to a level commensurate with the cooling available.

9.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

9.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shutdown when the temperature exceeds a preset value.

9.2.7 Cooling fluids are to be non-toxic and of low flammability.

9.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

9.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

9.2.10 Protection devices fitted for converter equipment protection are to ensure that, under fault conditions, the protective action of circuit-breakers, fuses or control systems is such that there is no further damage to the converter or the installation.

9.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced in to the ship's electrical system are within the limits of 1.7.3 or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation.

9.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

9.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable throughout the operating range.

9.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

9.2.15 Transformers, reactors, capacitors and other circuit devices associated with converter equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energized.

9.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of 1.7.

9.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

9.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of 20.1, a temperature rise test on one of each size and type of converter equipment, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Details of tests are to be submitted for consideration when required, see also 1.3.2.

9.3 Uninterruptible power systems

9.3.1 Where uninterruptible power systems (UPS) are required to maintain essential services or provide emergency services, the requirements of this sub-Section apply. This sub-Section is in addition to the requirements of 9.1 to 9.2 and Section 11, as applicable.

9.3.2 UPS units are to be constructed in accordance with IEC 62040: *Uninterruptible power systems (UPS)*, or an acceptable and relevant National or International Standard.

9.3.3 The operation of a UPS is not to depend upon external services.

9.3.4 The type of UPS unit employed, whether off-line, line-interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

9.3.5 An external bypass, that is hardwired and manually operated, is to be provided for UPS to allow isolation of UPS for safety during maintenance and maintain continuity of load power.

9.3.6 UPS units are to be monitored and an audible and visual alarm is to be initiated in the navigating bridge or the engine control room, or an equivalent attended location for:

- power supply failure (voltage and frequency) to the connected load;
- earth fault;
- operation of battery protective device;
- battery discharge; and
- bypass in operation for on-line UPS units.

9.3.7 UPS units required to provide emergency services are to be suitably located for use in an emergency.

9.3.8 UPS units utilising valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the arrangements comply with 11.3.5. Ventilation arrangements in accordance with IEC 62040: Uninterruptible power systems (UPS), or an acceptable and relevant National or International Standard, may be considered to satisfy the requirements of 11.5.10.

9.3.9 Output power is to be maintained for the duration required for the connected equipment.

9.3.10 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified. Where it is proposed that additional circuits are connected to the UPS unit, details verifying that the UPS unit has adequate capacity are to be submitted for consideration, see 1.4.

9.3.11 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

9.3.12 Tests at the manufacturer's works are to include such tests necessary to demonstrate the suitability of a UPS unit for its intended duty and location. This is expected to include as a minimum the following tests:

- a temperature rise test and battery capacity test on one of each size and type of UPS;
- the high voltage test of 20.1;
- a ventilation rate test; and
- functional testing, including operation of alarms.

Details of tests are to be submitted for consideration when required, see also 1.3.2.

9.3.13 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical testing.

10.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC Standard stated in Table 2.10.1 or an acceptable and relevant National Standard.

Table 2.10.1 Electric cables

Application	IEC Standard	Title
General constructional and testing requirements	60092-350	Low-voltage shipboard power cables. General construction and test requirements
Fixed power and control circuits	60092-353	Single and multicore non-radial field power cables with extruded solid insulation for rated voltages 1 kV and 3 kV
Fixed power circuits	60092-354	Single and three-core power cables with extruded solid insulation for rated voltages 6 kV, 10 kV and 15 kV
Instrumentation, control and communication circuits up to 60 V	60092-375	Shipboard telecommunication cables and radio frequency cables – General instrumentation, control and communication cables
Control circuits up to 250 V	60092-376	Shipboard multicore cables for control circuits
Mineral insulated	60702	Mineral insulated cables with a rated voltage not exceeding 750 V

10.1.3 Provided that adequate flexibility of the finished cable is assured, conductors of nominal cross-section area 2,5 mm² and less need not be stranded.

10.1.4 Electric cables for non-fixed wiring applications are to comply with an acceptable and relevant Standard.

10.1.5 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereafter referred to under the generic name 'protective casings'.

10.2 Testing

10.2.1 Routine tests, consisting of at least:

- (a) measurement of electrical resistance of conductors;
- (b) high voltage test, see also Section 20;
- (c) insulation resistance measurement;
- (d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of the relevant publication or National Standard referred to in 10.1.2 at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer, see also 1.3.3.

Section 10
Electric cables and busbar
trunking systems (busways)

10.1 General

10.1.1 The requirements of 10.1 to 10.15 apply to all electric cables for fixed wiring unless otherwise exempted. The requirements of 10.16 apply to busbar trunking systems (busways) where they are used in place of electric cables.

10.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in 10.1.2 and a test report issued by the manufacturer.

10.3 Voltage rating

10.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

10.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

10.4 Operating temperature

10.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

10.4.2 The maximum rated conductor temperatures for normal and short-circuit operation, for the insulating materials included within the standards referred to in 10.1.2 is not to exceed the values stated in Table 2.10.2.

Table 2.10.2 Maximum rated conductor temperature

Type of insulating compound	Maximum rated conductor temperature, °C	
	Normal operation	Short-circuit
Thermoplastics:		
–Based upon polyvinyl chloride or co-polymer of vinyl chloride and vinyl acetate	60	150
–Based upon polyethylene	60	130
Elastomeric or thermosettings:		
–Based upon ethylene propylene rubber or similar (EPM or EPDM)	85	250
–Based upon chemically crosslinked polyethylene	85	250
–Based upon silicon rubber	95	To be submitted
Mineral:	95	To be submitted

10.4.3 Electric cables constructed of an insulating material not included in Table 2.10.2 are to be rated in accordance with the National Standard chosen in compliance with 10.1.2.

10.5 Construction

10.5.1 Electric cables are to be at least of a flame-retardant type. IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*, will be acceptable.

10.5.2 Exemption from the requirements of 10.5.1 for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

10.5.3 Where electric cables are required to be of a 'fire resistant type', they are in addition to be easily distinguishable and comply with the performance requirements of the appropriate part of IEC 60331: *Tests for electric cables under fire conditions – Circuit integrity, when tested with a minimum flame application time of 90 minutes*, as follows:

- IEC 60331-21: *Procedures and requirements – Cables of rated voltage up to and including 0.6/1.0 kV*;
- IEC 60331-23: *Procedures and requirements – Electric data cables*;
- IEC 60331-25: *Procedures and requirements – Optical fibre cables*; or
- IEC 60331-31: *Procedures and requirements – Cables of rated voltage up to and including 0.6/1.0 kV*, where the overall diameter of the cable exceeds 20 mm.

10.5.4 Where electric cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour they are to have the conductor insulating materials enclosed in an impervious sheath of material appropriate to the expected ambient conditions.

10.5.5 Electric cables where it is required that their construction includes metallic sheaths, armouring or braids are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion.

10.5.6 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured the armour is to be of a non-magnetic material.

10.5.7 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short-circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short-circuit current. Where electric cables are to be used in circuits with a maximum short-circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short-circuit current.

10.5.8 All high voltage electric cables are to be readily identified by suitable marking.

Electrical Engineering

Part 6, Chapter 2

Section 10

10.6 Conductor size

10.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in 10.7 may be applied as required.

10.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short-circuit conditions, the maximum rated conductor temperature for short-circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short-circuit current.

10.6.3 The cable current ratings given in Tables 2.10.3 and 2.10.4 are based on the maximum rated conductor temperatures given in Table 2.10.2. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table 2.10.4, may be calculated using the method in IEC 60724: *Guide to the short-circuit temperature limits of electric cables* or an acceptable and relevant National Standard.

10.6.4 The cross-sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in 1.7 be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

10.6.5 The size of earth conductors is to comply with 1.11.7.

10.6.6 The cross-sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cables maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service, see 10.7.4.

10.7 Correction factors for cable current rating

10.7.1 The correction factors of 10.7.2 to 10.7.5 provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

Table 2.10.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross section	Continuous r.m.s current rating, in amperes								
	Thermoplastic, PVC, PE			EP rubber and crosslinked PE			Silicon rubber or mineral		
	Single Core	2-core	3- or 4-core	Single Core	2-core	3- or 4-core	Single Core	2-core	3- or 4-core
0,75	6	5	4	13	11	9	17	14	12
1	8	7	6	16	14	11	20	17	14
1,25	10	8	7	18	15	13	23	19	16
1,5	12	10	8	20	17	14	24	20	17
2	13	11	9	25	21	17	31	26	21
2,5	17	14	12	28	24	20	32	27	22
3,5	21	18	14	35	30	24	39	33	27
4	22	19	15	38	32	27	42	36	29
5,5	27	23	19	46	39	32	52	44	36
6	29	26	20	48	41	34	55	47	39
8	35	30	24	59	50	41	66	56	46
10	40	34	28	67	57	47	75	64	53
14	49	42	34	83	71	58	94	80	66
16	54	46	38	90	77	63	100	85	70
22	66	56	46	110	93	77	124	105	87
25	71	60	50	120	102	84	135	115	95
30	80	68	56	135	115	94	151	128	106
35	87	74	61	145	123	102	165	140	116
38	92	78	64	155	132	108	175	149	122
50	105	89	74	185	153	126	200	175	140
60	123	104	86	205	174	143	233	198	163
70	135	115	95	225	191	158	255	217	179
80	147	125	103	245	208	171	278	236	195
95	165	140	116	275	234	193	310	264	217
100	169	144	118	285	242	199	320	272	224
120	190	162	133	320	272	224	360	306	252
125	194	165	134	325	280	230	368	313	258
150	220	187	154	365	310	256	410	349	287
185	250	213	175	415	353	291	470	400	329
200	260	221	182	440	375	305	494	420	346
240	290	247	203	490	417	343	570	485	400
300	335	285	235	560	476	392	660	560	460

Table 2.10.4 Electric cable current ratings, r.m.s. short-circuit current

Nominal cross section	Fault current at 250°C duration			Fault current at 150°C duration			Fault current at 130°C duration		
	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA
1	0,1	0,2	0,5	0,1	0,2	0,4	0,1	0,2	0,3
1,5	0,2	0,3	0,7	0,2	0,3	0,5	0,2	0,3	0,5
2,5	0,4	0,5	1,1	0,3	0,4	0,9	0,3	0,4	0,8
4	0,6	0,8	1,8	0,5	0,7	1,5	0,4	0,6	1,3
6	0,9	1,2	2,8	0,7	1,0	2,2	0,6	0,9	2,0
10	1,5	2,1	4,6	1,2	1,6	3,7	1,0	1,5	3,3
16	2,3	3,3	7,4	1,9	2,6	5,9	1,7	2,4	5,3
25	3,6	5,2	12	2,9	4,1	9,2	2,6	3,7	8,2
35	5,1	7,2	16	4,1	5,8	13	3,6	5,2	12
50	7,3	10	23	5,8	8,2	18	5,2	7,4	16
70	10	14	32	8,2	12	26	7,3	10	23
95	14	20	44	11	16	35	9,9	14	31
120	17	25	55	14	20	44	13	18	40
150	22	31	69	17	25	55	16	22	49
185	27	38	85	22	31	68	19	27	61
240	35	49	110	28	40	89	25	35	79
300	44	62	140	35	50	110	31	44	100

Table 2.10.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
PVC, Polyethylene	1,29	1,15	1,00	0,82	–	–	–	–	–	–	–
EPR, XLPE	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	–	–
Mineral, Silicon rubber	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

10.7.2 Bunching of cables. Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

10.7.3 Ambient temperature. The current ratings of Table 2.10.3 are based on an ambient temperature of 45°C. For other values of ambient temperature the correction factors shown in Table 2.10.5 are to be applied.

10.7.4 Short time duty. When the load is not continuous i.e. operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant, T in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Duty factor} = \sqrt{\frac{1,12}{1 - e^{-\frac{t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-load less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

$$\text{Intermittent factor} = \sqrt{\frac{1 - e^{-\frac{t_p}{T}}}{1 - e^{-\frac{t_s}{T}}}}$$

where

t_p = the intermittent period, in minutes, i.e. the total period of load and no-load before the cycle is repeated

T = $0,245d^{1,35}$ where d is the overall diameter of the cable, in mm

t_s = the service time of the load current in minutes

10.7.5 Diversity. Where cables are used to supply two or more final sub-circuits account may be taken of any diversity factors which may apply, see 5.6.

10.8 Installation of electric cables

10.8.1 Electric cable runs are to be as far as practicable fixed in straight lines and in accessible positions.

10.8.2 The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in Table 2.10.6.

10.8.3 The installation of electric cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

10.8.4 Electric cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and areas of high fire risk except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

10.8.5 Electric cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

10.8.6 Electric cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

10.8.7 Electric cables are to be as far as practicable installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

10.8.8 Where electric cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332: *Tests on electric cables under fire conditions, Part 3-22, Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*, and are installed in the same configuration(s) as are used for the test(s). If the cables are not so installed, information is to be submitted to satisfactorily demonstrate that suitable measures have been taken to ensure that an equivalent limit of fire propagation will be achieved for the configurations to be used. Particular attention is to be given to cables in:

- atria or equivalent spaces; and
 - vertical runs in trunks and other restricted spaces.
- In addition, cables that comply with the requirements of IEC 60332-3-23 are also required to meet the requirements of IEC 60332-1-2.

10.8.9 Electric cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

10.8.10 Where electric cables are installed in refrigerated spaces they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

10.8.11 All metal coverings of electric cables are to be earthed in accordance with 1.11.

- 10.8.12 High voltage cables may be installed as follows:
- in the open, (e.g. on carrier plating), when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;
 - contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

Table 2.10.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Thermoplastic and elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6D
	Other finishes	≤ 25 mm > 25 mm	4D 6D
Mineral	Hard metal sheathed	Any	6D
Thermoplastic and elastomeric above 600/1000 V – single core – multicore	Any	Any	20D
	Any	Any	15D

Electrical Engineering

Part 6, Chapter 2

Section 10

10.8.13 High voltage electric cables are not to be run in the open through accommodation spaces.

10.8.14 High voltage electric cables are to be segregated as far as is practicable from electric cables operating at lower voltages.

10.8.15 Electric cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where necessary the cables are to be protected in accordance with the requirements of 10.9.

10.8.16 Electric cables with the exception of those for portable appliances and those installed in protective casings are to be fixed securely in accordance with the requirements of 10.10.

10.8.17 Where electric cables penetrate bulkheads and decks the requirements of 10.11 are to be complied with.

10.8.18 Where electric cables are installed in protective casings the requirements of 10.12 are to be complied with.

10.8.19 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of 10.13 are to be complied with, see *also* 10.5.6.

10.9 Mechanical protection of cables

10.9.1 Electric cables exposed to risk of mechanical damage are to be protected by suitable protective casings unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible cause of damage.

10.9.2 Electric cables installed in spaces where there is exceptional risk of mechanical damage such as holds, storage spaces, cargo spaces, etc., are to be suitably protected by metallic protective casings, even when armoured, unless the ship's structure affords adequate protection.

10.9.3 Non-metallic protective casings and fixings are to be flame retardant in accordance with the requirements of IEC 60092-101.

10.9.4 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with 1.11.

10.10 Cable support systems

10.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the ship's structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads etc., see 10.8.4.

10.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. Where cable support systems are manufactured of plastics materials, evidence of satisfactory type testing in accordance with an acceptable test procedure is to be submitted for consideration. The cable support system is to be effectively secured to the ship's structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g. where located in areas subject to impact by sea-water.

10.10.3 The distances between the points at which the cable is supported (e.g. distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e. size and rigidity) and the probability of vibration and are to be generally in accordance with those given in Table 2.10.7.

Table 2.10.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
exceeding	not exceeding		
mm	mm	mm	mm
–	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	–	400	450

10.10.4 Where the cables are laid on top of their support system, the spacings of fixings may be increased beyond those given in Table 2.10.7, but should take account of the probability of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g. where they are run on, or above, open deck or in areas subject to impact by sea-water.

10.10.5 Where the cable support system or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided, such that, in the event of a fire or failure, the cable support system and the cables affixed to it are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

10.10.6 Cable support systems manufactured of plastics materials installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

10.10.7 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short-circuit current.

10.11 Penetration of bulkheads and decks by cables

10.11.1 Where electric cables pass through watertight, fire insulated or gastight bulkheads or decks separating dangerous zones or spaces from non-dangerous zones or spaces, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

10.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

10.11.3 Electric cables passing through decks are to be protected by deck tubes or ducts.

10.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

10.12 Installation of electric cables in protective casings

10.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric cables.

10.12.2 When protective casings are secured by means of clips or straps manufactured from a material other than metal the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m.

10.12.3 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

10.12.4 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, see 10.8.2.

10.12.5 The space factor (ratio of the sum of the cross sectional areas corresponding to the external diameters of the cables to the internal cross sectional area of the protective casings) is not to exceed 0.4.

10.12.6 Where necessary, ventilation openings are to be provided at the highest and lowest points of protective casings to permit air circulation and to prevent accumulation of water.

10.12.7 Expansion joints are to be provided in protective casings where necessary.

10.12.8 Protective casings containing high voltage electric cables are not to contain other electric cables and are to be clearly identified, defining their function and voltage.

10.13 Single-core electric cables for alternating current

10.13.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

10.13.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

10.13.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

10.13.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

10.13.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

10.13.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

10.14 Electric cable ends

10.14.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections (see 1.10.6), cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent 'whiskering' of the strands.

10.14.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

10.14.3 Soldered sockets may be used in conjunction with non corrosive fluxes provided that the maximum conductor temperature at the joint, under short-circuit conditions, does not exceed 160°C.

10.14.4 High voltage cables of the radial field type (i.e. having a conducting layer to control the electric field within the insulation) are to have terminations which provide electrical stress control.

10.14.5 Electric cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

10.14.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating.

10.14.7 The fixing of conductors in terminals at joints and at tapplings is to be capable of withstanding the thermal and mechanical effects of short-circuit currents.

10.15 Joints and branch circuits in cable systems

10.15.1 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. The flame retardant properties or fire resisting properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current carrying capacity of the cable is not to be impaired.

10.15.2 Tapplings (branch circuits) are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

10.15.3 Cables of a fire resistant type (see 10.5.3) are to be installed so that they are continuous throughout their length without any joints or tapplings.

10.16 Busbar trunking systems (bustrunks)

10.16.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of 10.16.2 to 10.16.6, in addition to the applicable requirements in Section 7.

10.16.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

10.16.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

10.16.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.9 for essential electrical equipment.

10.16.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the ship's structure.

10.16.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

Section 11 Batteries

11.1 General

11.1.1 The requirements of this Section apply to permanently installed secondary batteries of the vented and valve-regulated sealed type.

11.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere.

11.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

11.2 Construction

11.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimize the emission of electrolyte spray.

11.3 Location

11.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

11.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with 11.3.1, or may be installed within a well ventilated machinery or similar space.

11.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

11.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of 11.3.1, 11.3.2 or 11.3.3.

11.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of 11.5.10 and the charging requirements of 11.6.4 and 11.6.5 are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

11.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

11.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects they are to be suitably protected.

11.3.8 Batteries installed in crew and passenger cabins, together with their associated corridors, are to be of the hermetically sealed type.

11.3.9 A permanent notice prohibiting smoking and the use of naked lights or equipment capable of creating a source of ignition is to be prominently displayed adjacent to the entrances of all compartments containing batteries.

11.3.10 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with 11.3.1. Such electrical equipment is to be certified for group IIC gases and temperature Class T1 in accordance with IEC 60079: *Electrical apparatus for explosive gas atmospheres*, or an acceptable and relevant National Standard.

11.4 Installation

11.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are suitably secured to move with the ship's motion.

11.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

11.4.3 Measures are to be taken to minimize the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

11.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

11.5 Ventilation

11.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas. The ventilation openings are to be of a non-closeable type and a permanent notice is to be prominently displayed adjacent to them, stating:

THIS VENTILATOR OPENING IS NOT TO BE CLOSED OR BLOCKED AT ANY TIME – EXPLOSIVE GAS.

11.5.2 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45° from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm² for every 1 m³ of battery compartment or box volume.

11.5.3 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

11.5.4 Mechanical exhaust ventilation complying with 11.5.9 is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW.

11.5.5 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which 11.3.2 and 11.3.3 refer, is to be separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

11.5.6 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

11.5.7 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimize risk of sparking in the event of the impeller touching the casing. Non-metallic-impellers are to be of an anti-static material.

11.5.8 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

11.5.9 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$$Q = 110In$$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr

11.5.10 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in 11.5.9.

11.6 Charging facilities

11.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

11.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

11.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

11.6.4 Where valve-regulated sealed batteries are installed, the charging facilities are to incorporate independent means such as overvoltage protection to prevent gas evolution in excess of the manufacturer's design quantity.

11.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

11.7 Recording of batteries for emergency and essential services

11.7.1 A schedule of batteries fitted for use for essential and emergency services is to be compiled and maintained.

11.7.2 Procedures are to be put in place and documented to ensure that, where batteries are replaced, they are of an equivalent performance type, see also 1.4.3.

11.7.3 When additions or alterations are proposed to the existing batteries for essential and emergency services, the schedule and replacement procedure documentation are to be updated to reflect the proposed installation and submitted in accordance with 1.4.2.

11.7.4 The schedule and replacement procedure documentation are to be made available to the LR Surveyor on request.

Section 12

Equipment – Heating, lighting and accessories

12.1 Heating and cooking equipment

12.1.1 The construction of heaters is to give a degree of protection according to IEC 60529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard, suitable for the intended location.

12.1.2 Heating elements are to be suitably guarded.

12.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

12.2 Lighting – General

12.2.1 Lampholders are to be constructed of flame retarding non-hygroscopic materials.

12.2.2 Lighting fittings are to be so arranged as to prevent temperature rises which overheat or damage surrounding materials. They must not impair the integrity of fire divisions.

12.3 Incandescent lighting

12.3.1 Tungsten filament lamps and lampholders are to be in accordance with Table 2.12.1.

Table 2.12.1 Lamps and lampholders

Designation	Maximum lamp rating		Maximum lampholder current, A
	Voltage, V	Power, W	
Screw cap lamps			
E40	250	3000	16
E27	250	200	4
E14	250	15	2
E10	24	—	2
Bayonet cap lamps			
B22	250	200	4
B15d	250	15	2
B15s	55	15	2
Tubular fluorescent lamps			
G13	250	80	—
G5	250	13	—

12.3.2 Lampholders of type E40 are to be provided with a means of locking the lamp in the lampholder.

12.4 Fluorescent lighting

12.4.1 Fluorescent lamps and lampholders are to be in accordance with Table 2.12.1.

12.4.2 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

12.4.3 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

12.5 Discharge lighting

12.5.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

12.6 Socket outlets and plugs

12.6.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

12.6.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the 'on' position.

12.6.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

12.6.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

12.7 Enclosures

12.7.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame retardant insulating materials.

Section 13

Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts

13.1 General

13.1.1 The installation of electrical equipment in spaces and locations in which flammable mixtures are liable to collect, is to be minimized as far as is consistent with operational necessity and the provision of lighting, monitoring, alarm or control facilities enhancing the overall safety of the ship.

13.1.2 In order to eliminate potential sources of ignition from spaces and locations in which flammable mixtures are liable to collect, in accordance with SOLAS 1974 as amended, Chapter II-1, Regulation 45, such dangerous or hazardous areas are to be identified and electrical equipment within these areas is to be selected and installed in accordance with the requirements of this Section.

13.2 Selection of equipment

13.2.1 When apparatus is to be installed in areas where an explosive gas atmosphere may be present, unless permitted otherwise by 13.2.2, it is to be of a 'safe-type', as listed below, certified or approved by a competent authority for the gases encountered. The construction and type testing is to be in accordance with IEC 60079: *Electrical Equipment for Explosive Gas Atmospheres* or an acceptable and relevant National Standard.

Intrinsically safe	– Ex 'i'
Increased safety	– Ex 'e'
Flameproof	– Ex 'd'
Pressurized enclosure	– Ex 'p'
Powder filled	– Ex 'q'
Encapsulated	– Ex 'm'

13.2.2 Consideration may be given to the use of equipment of the following types:

- equipment such as control panels, protected by purging and pressurization and capable of being verified by inspection as meeting the requirements of IEC 60079-2;
- simple non-energy-storing apparatus having negligible surface temperature rise in normal operation, such as limit switches, strain gauges, etc, incorporated in intrinsically-safe circuits;
- radio aerials having robust construction, meeting the relevant requirements of IEC 60079-15. Additionally, in the case of transmitter aerials, it is to be shown, by detailed study or measurement, or by limiting the peak radiated power and field strength to 1 W and 30 V/m, respectively, that they present negligible risk of inducing incendive sparking in adjacent structures or equipment;
- electrical apparatus with type of protection 'n' or 'N' provided it is in a well ventilated area on open deck and not within 3 m of any flammable gas or vapour outlet.
- electrical apparatus selected in accordance with IEC 60092-502: *Electrical Installations in Ships – Tankers – Special Features*, see 13.9 to 13.11.

Electrical Engineering

Part 6, Chapter 2

Section 13

13.2.3 Where apparatus is to be installed in areas where combustible dusts may be present in quantities sufficient to create an explosive atmosphere, it is, when practicable, to be of a type certified or approved by a competent authority for the dusts and additionally any explosive gases encountered.

13.2.4 Electrical equipment for use in combustible dust atmospheres is to be so designed and installed as to minimize the accumulation of dust which may interfere with the safe dissipation of heat from the enclosure.

13.2.5 Where equipment certified for combustible dusts is not available, consideration will be given to the use of apparatus complying as a minimum, with the following requirements provided no explosive gases will be present:

- (a) the enclosure is to be at least dust protected (IP5X) having, when type tested, an ingress of fine dust within the enclosure not exceeding 10 g per m³ of free air space, and
- (b) the surface temperature of the apparatus, under the most onerous combination of normal operating conditions, but in the absence of a dust layer, is to be at least 10°C below the auto-ignition temperature of the dusts encountered, or
- (c) the equipment is to be certified intrinsically-safe having a temperature classification ensuring compliance with (b), or
- (d) pressurized and operated in accordance with procedures ensuring, prior to its re-energization, the absence of dust within the enclosure following loss of pressurisation and consequent shutdown, and having surface temperature complying with (b), or
- (e) simple apparatus included in intrinsically-safe circuits or radio aerials, complying with 13.2.2(b) or (c) respectively.

13.3 Installation of electrical equipment

13.3.1 The method of installation and application of safe-type equipment is to be in accordance with IEC 60079-14, or the national code of practice relevant to the standard to which the equipment has been certified. Any special requirements laid down by the equipment certification documentation are also to be observed. The ambient temperature range for which the apparatus is certified, is to be taken to be minus 20°C to 40°C, unless otherwise stated, and account is to be taken of this when assessing the suitability of the equipment for the auto-ignition temperature of the gases and dusts encountered.

13.3.2 All switches and protective devices from which equipment located in dangerous zones or spaces is supplied are to interrupt all poles or phases and, where practicable are to be located in a non-hazardous zone or space. Such equipment, switches and protective devices are to be suitably labelled for identification purposes.

13.4 Dangerous zones and spaces

13.4.1 Dangerous zones or spaces and sources of hazard for ships intended for the carriage in bulk of oil, liquefied gases and other hazardous liquids, and the requirements for ships carrying vehicles with fuel in their tanks, are defined in 13.9 to 13.12. The following principles are to apply in general, and where any specific arrangement does not fall into any of the categories covered by 13.9 to 13.12.

13.4.2 A dangerous zone or space may arise from the presence of any of the following:

- (a) spaces or tanks containing either:
 - (i) flammable liquid having a flashpoint (closed-cup test), not exceeding 60°C;
 - (ii) flammable liquid having a flashpoint exceeding 60°C, heated or raised by ambient conditions to a temperature within 15°C of its flashpoint;
 - (iii) flammable gas.
- (b) piping systems or equipment containing fluid defined by (a) and having flanged joints or glands or other openings through which leakage of fluid may occur under normal operating conditions;
- (c) spaces containing solids, such as coal or grain, liable to release flammable gas and/or combustible dust;
- (d) piping systems or equipment associated with processes (such as battery charging or electrochlorination) generating flammable gas as a by-product and having openings from which the gas may escape under normal operating conditions;
- (e) piping systems or equivalent containing flammable liquids not defined by (a), having flanged joints, glands or other openings through which leakage of fluid in the form of a mist or fine spray may occur under normal operating conditions.

13.4.3 The following zones or spaces are regarded as dangerous:

- (a) the interiors of those spaces, tanks, piping systems and equipment defined by 13.4.2(a), (b) and (c);
- (b) spaces separated by a single bulkhead or deck from a cargo defined by 13.4.2(a);
- (c) enclosed or semi-enclosed spaces containing pipework or equipment defined by 13.4.2(b) and (d);
- (d) enclosed or semi-enclosed spaces with direct opening into a dangerous space or zone;
- (e) zones within a 3 m radius of ventilation inlets or outlets, hatches or doorways or other openings into dangerous spaces, or within 3 m of the ventilation outlets of spaces regarded by 13.6 as open areas and which contain the pipework or equipment defined by 13.4.2(b); where the hazard results from flammable gas or vapour having a density relative to that of air of more than 0.75, the dangerous zone is considered to extend vertically downward to solid deck, or for a distance of 9m, whichever is the lesser;
- (f) zones within a 3 m radius of flanged joints, or glands or other openings defined by 13.4.2(b); in the case of gas or vapour having a relative density of more than 0.75, the dangerous zone is considered to extend vertically downwards as described under (e);
- (g) zones within a 1.5 m radius of the ventilation outlets of spaces regarded as open areas containing items defined under 13.4.2(d):

Electrical Engineering

Part 6, Chapter 2

Section 13

- (h) zones within a 1,5 m radius of flanged joints, or glands or other openings defined by 13.4.2(d) and (e);
- (j) zones within a 3 m radius of bunds or barriers intended to contain spillage of liquids defined by 13.4.2(a).

13.5 Semi-enclosed spaces

13.5.1 Semi-enclosed spaces are considered to be spaces limited by decks and/or bulkheads in such a manner that the natural conditions of ventilation are sensibly different from those obtained on open deck.

13.6 Ventilation

13.6.1 Where an enclosed or semi-enclosed space is provided with mechanical ventilation ensuring at least 12 air changes/hour, and leaving no areas of stagnant air, it may be regarded in consideration of dangerous zones as would otherwise be defined by 13.4.3(c) and (d), as an open area.

13.6.2 Where the rate of ventilation air flow, in relation to the maximum rate of release of flammable substances reasonably to be expected under normal conditions, is sufficient to prevent the concentration of flammable substances approaching their lower explosive limit, consideration may be given to regarding as non-dangerous, the space, ventilation and other openings into it, and the zone around the equipment contained within.

13.6.3 An alarm is to be provided on the navigating bridge, engine control room, and where applicable, cargo control room to indicate any loss of the required ventilation capacity.

13.7 Pressurization

13.7.1 A space having access to a dangerous space or zone as defined under 13.4.3(c) to (j) may be regarded as non-dangerous if fulfilling all the following conditions:

- (a) access is by means of an air-lock, having gastight steel doors, the inner of which as a minimum, is self-closing without any hold-back arrangement;
- (b) it is maintained at an overpressure relative to the external hazardous area by ventilation from a non-dangerous area;
- (c) the relative air pressure within the space is continuously monitored and, so arranged, that in the event of loss of overpressure an alarm is given and the electrical supply to all equipment not of a safe-type is automatically disconnected. Where the shutdown of equipment could introduce a hazard, an alarm may be given, in lieu of shutdown, upon loss of overpressure, and a means of disconnection of non-safe-type electrical equipment, capable of being controlled from a manned station, provided in conjunction with an agreed operational procedure; where the means of disconnection is located within the space then it is to be effected by equipment of a safe-type;
- (d) any electrical equipment required to operate upon loss of overpressure, lighting fittings (see 5.7.3) and equipment within the air-lock, is to be of a safe-type;

- (e) means are to be provided to prevent electrical equipment, other than of a safe-type, being energized until the atmosphere within the space is made safe, by air renewal of at least 10 times the capacity of the space.

13.8 Cable and cable installation

13.8.1 Electric cables are not to be installed in dangerous zones or spaces, except where specifically permitted by 13.9 to 13.11 or when associated with intrinsically-safe circuits.

13.8.2 In addition to the requirements of Section 10, cables for circuits that are not intrinsically-safe, which are located in dangerous zones or spaces, or which may be exposed to cargo oil, oil vapour or gas, are to be either:

- (a) mineral insulated with copper sheath, or
- (b) armoured or braided for earth detection.

13.8.3 Armouring, braiding and other metal coverings of cables installed in dangerous zones or spaces are to be effectively earthed at least at both ends.

13.8.4 Where there is risk of intermittent contact between armour and exposed metalwork, non-metallic impervious sheath is to be applied over metallic armour of cables.

13.8.5 Cables associated with intrinsically-safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically-safe circuits, e.g. neither installed in the same protective casing nor secured by the same fixing clip.

13.9 Requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point not exceeding 60°C (closed-cup test)

13.9.1 In order to eliminate potential sources of ignition from hazardous areas onboard tankers in accordance with SOLAS 1974 as amended, Chapter II-1, Regulation 45.11, electrical equipment is to be selected and installed in accordance with IEC 60092: *Electrical installations in ships – Part 502: Tankers – Special features*.

13.10 Requirements for ships for the carriage of liquefied gases in bulk

13.10.1 See Chapter 10 of the *Rules for Ships for Liquefied Gases*.

13.11 Requirements for ships intended for the carriage in bulk of other flammable liquid cargoes

13.11.1 See Chapter 10 of the *Rules for Ships for Liquid Chemicals*.

Electrical Engineering

Part 6, Chapter 2

Sections 13 & 14

13.12 Special requirements for ships with spaces for carrying vehicles with fuel in their tanks, for their own propulsion

13.12.1 Passenger ships with special category spaces above the bulkhead deck for carrying vehicles:

- (a) electrical equipment fitted within a height of 45 cm above the vehicle deck, or any platform on which vehicles are carried, or within the exhaust ventilation trunking for the space, is to be of a safe-type;
- (b) electrical equipment situated elsewhere within the space is to have an enclosure of ingress protection rating of at least IP55, if not of a safe-type, see IEC 60529: *Classification of Degrees of Protection Provided by Enclosures*. Smoke and gas detector heads are exempt from this requirement.

13.12.2 Passenger ships with special category spaces below the bulkhead deck for carrying vehicles: electrical equipment fitted within the space and within the exhaust ventilation trunking for the space, is to be of a safe-type.

13.12.3 Passenger ships with cargo spaces, other than special category spaces, for carrying vehicles:

- (a) electrical equipment within such a cargo space, or within the exhaust ventilation trunking for the space, is to be of a safe-type;
- (b) all electrical circuits terminating in the cargo space are to be provided with multipole linked isolating switches located outside the cargo hold. Provision is to be made for locking in the off position. This does not apply to safety circuits such as those for fire, smoke or gas detection.

13.12.4 Cargo ships with closed ro-ro cargo spaces for carrying vehicles:

- (a) except where exempted by (b) electrical equipment fitted within the space and within the exhaust ventilation trunking for the space is to be of a safe-type;
- (b) where the ventilation system required by SOLAS 1974 as amended, Chapter II-2, Regulation 20.3.1.1.1 is arranged to operate continuously and is sufficient to provide at least ten air changes per hour, whenever vehicles are on board, above a height of 45 cm from the vehicle deck, or any platform on which vehicles are carried, electrical equipment having an enclosure of ingress protection rating of at least IP 55 may be accepted as an alternative to that of a safe-type;
- (c) all electrical circuits terminating in the cargo space are to be provided with multipole linked isolating switches located outside the cargo hold. Provision is to be made for locking in the off position. This does not apply to safety circuits such as those for fire, smoke or gas detection.

13.13 Special requirements for ships intended for the carriage of dangerous goods

13.13.1 In order to eliminate potential sources of ignition in enclosed cargo spaces or vehicle spaces in accordance with SOLAS 1974 as amended, Chapter II-2, Regulation 19.3.2, and from associated hazardous areas (see 13.4.2), electrical equipment is to be selected in accordance with 13.13.2 and 13.13.3 and installed in accordance with 13.3 and 13.13.4 to 13.13.7.

13.13.2 Electrical equipment essential for the safety and operation of the ship is to be of a certified safe type selected in accordance with IEC 60092 *Electrical installations in ships – Part 506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk*.

13.13.3 In addition to the requirements of IEC 60092-506, pipes such as ventilation and bilge pipes, having ends opening into a hazardous area are to be considered a hazardous area. Enclosed spaces such as pipe tunnels and bilge pump rooms containing such pipes and with equipment and components such as pumps, valves and flanges are to be considered as extended hazardous areas unless protected by overpressure.

13.13.4 Electrical equipment not essential for the safety or operation of the ship and which is not of a certified safe type is to be completely disconnected and protected against unauthorised re-connection. Disconnection is to be made outside the hazardous areas and be effected with isolating links or lockable switches.

13.13.5 Electrical equipment and all cables, including through runs and terminating cables, are to be protected against mechanical damage. Cables are to be either enclosed in screwed heavy gauge steel drawn or seam-welded and galvanized conduit, or protected by electrically continuous metal sheathing or metallic wire armour braid or tape.

13.13.6 Cables joints in cargo spaces are to be avoided where possible. Where joints are unavoidable, they are to be enclosed in metal-clad or impact strength plastic junction boxes of certified safe type (see 13.13.2) or heat-shrink or encapsulated crimp sleeve cable joints.

13.13.7 Cable penetrations of decks and bulkheads are to be sealed against the passage of gas or vapour.

Section 14 Navigation and manoeuvring systems

14.1 Steering gear

14.1.1 The requirements of 14.1.2 to 14.1.7 are to be read in conjunction with those in Pt 5, Ch 19.5.

Electrical Engineering

Part 6, Chapter 2

Sections 14 & 15

14.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously are to be provided for each electric or electrohydraulic steering gear arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard, *see also* Pt 5, Ch 19,6.

14.1.3 The main and auxiliary steering gear motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

14.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering gear.

14.1.5 Only short-circuit protection is to be provided for each main and auxiliary steering gear motor circuit.

14.1.6 In ships of less than 1600 gross tonnage, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in 14.1.5 for such a motor primarily intended for other services.

14.1.7 Each main and auxiliary steering gear electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected. Each separate circuit is to be provided with short-circuit protection only.

14.2 Thruster systems for steering

14.2.1 Where azimuth or rotatable thruster units, used as the sole means of steering, are electrically driven the requirements of Pt 5, Ch 20,5.1 are to be complied with.

14.3 Thruster systems for dynamic positioning

14.3.1 For ships having a **DP** notation the requirements of Pt 7, Ch 4 are to be complied with.

14.4 Thruster systems for manoeuvring

14.4.1 Where a thruster unit is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any essential services.

14.4.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the ship, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

14.4.3 The thruster unit electric motor is not to be disconnected as part of a load management switching operation.

14.5 Navigation lights

14.5.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with, for passenger ships, 3.2.5(b) and 3.2.7(a)(i) or, for cargo ships, 3.3.5(c) and 3.3.7(a).

14.5.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

14.5.3 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g. a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to tugs, trawlers and similar small vessels.

14.5.4 Provision is to be made on the navigating bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power.

14.5.5 Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

14.6 Navigational aids

14.6.1 Navigational aids as required by SOLAS are to be fed from the emergency source of electrical power, *see also* 3.2.5(c)(ii) and 3.3.5(d)(ii).

14.6.2 For ships having a notation **NAV 1** navigational aids are to have an alternative supply fed from the main source of electrical power, independent of the emergency switchboard, with automatic changeover facilities.

Section 15 Electric propulsion

15.1 General

15.1.1 Where the arrangements permit a propulsion motor to be connected to a generating plant having a continuous rating greater than the motor rating, means are to be provided to limit the continuous input to the motor to a value not exceeding the continuous full load torque for which the motor and shafts are approved.

Electrical Engineering

Part 6, Chapter 2

Section 15

15.1.2 The ventilation and cooling systems for electrical propulsion equipment are to be provided with monitoring devices arranged to operate an alarm if the temperature of the heated cooling medium exceeds a predetermined safe value.

15.1.3 The embedded temperature detectors required by 8.1.9 are to be arranged to operate an alarm if the temperature exceeds a predetermined safe value.

15.2 Power requirements

15.2.1 The propulsion system is to have sufficient power for manoeuvring the ship and for going astern. With the ship travelling at maximum service speed the propulsion equipment is to be capable of stopping and reversing the ship in an agreed time.

15.2.2 The propulsion system is to have adequate torque and power margins for all operating conditions including manoeuvring and rough weather with due regard to propeller and ship characteristics.

15.2.3 The electric power for the propulsion system may be derived from generating sets dedicated to propulsion duty or from a central power generation plant which serves both propulsion and ship service loads.

15.2.4 Where propulsion power is derived from a central, common, power plant the control system is to ensure a safe distribution of power between propulsion and ship services, with tripping of non-essential loads and/or reduction in propulsion power if necessary.

15.2.5 Where a central power generation system is employed the number and rating of generator sets is to be such that with one set out of action the remaining sets are capable of providing all essential and normal ship service loads whilst maintaining an effective level of propulsion power.

15.2.6 Where, in a central power generation system, the electrical power requirements are normally supplied by two or more generating sets operating in parallel, on sudden loss of power from one set, the rating of the remaining set(s) in service is to be sufficient to ensure uninterrupted operation of essential services and an effective level of propulsion power.

15.3 Propulsion control

15.3.1 Propulsion control systems are to be stable throughout their normal operating range and arranged to attenuate any effects of cyclic propeller load fluctuations caused by wave action.

15.3.2 Step-less control of propeller speed, and/or pitch, from zero to full power ahead or astern is to be provided.

15.3.3 The control system is to ensure that there is no dangerous overspeeding of propulsion motors upon loss of load.

15.3.4 Interlocks are to be provided in the control system to ensure that ahead and astern circuits are not energized simultaneously.

15.3.5 Any single fault in either the propulsion machine excitation or power distribution systems is not to result in a total loss of propulsion power.

15.3.6 Control stations for the propulsion system are to satisfy the requirements of Pt 6, Ch 1.

15.3.7 Each control station is to be provided with emergency stops for propulsion motors. The emergency stop is to be independent of the normal control system.

15.3.8 The control system is to limit the propulsion power if the power available from the generator(s) is not sufficient to supply the demand level of propulsion power. In the event of a power limitation, there is to be a visual indication at the control stations.

15.3.9 Local controls are to be provided, independent of any remote or automatic system, to permit effective control of the propulsion equipment.

15.3.10 The propulsion control may be in analogue or digital form, which is to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements listed above. A quality plan giving evidence of compliance with this requirement is to be submitted when requested.

15.4 Protection of propulsion system

15.4.1 Provision is to be made for protection against severe overloads, and electrical faults likely to result in damage to plant.

15.4.2 The main propulsion circuits are to be provided with means for detecting earth faults. Where the fault current flowing is liable to cause damage to the electrical equipment there are to be arrangements for interrupting the current.

15.4.3 For the protection of electrical equipment and cables against overvoltages means are to be provided for limiting the induced voltage when field windings, and other inductive circuits are opened. Protective resistors and devices are to be sized to cater for the likely extreme operating conditions.

15.4.4 Where, on stopping or reversing the propeller, regenerated energy is produced by the propulsion motor this is not to cause a dangerous increase of speed in the prime mover or a dangerous overvoltage condition on the supply system. Where a central power generation system is used then the voltage and frequency fluctuations are not to exceed the limits given in 1.7.

15.5 Instruments

15.5.1 The main control station is to be provided with the following instruments:

- (a) a.c. systems:
 - (i) an ammeter for each generator and propulsion motor; voltmeter, wattmeter and frequency meter for each generator and ammeter for each excitation circuit;
 - (ii) a temperature indicator for each generator and propulsion motor, the indicator is to read stator winding and cooling system temperature.
- (b) d.c. systems:
 - a voltmeter and ammeter for each generator and propulsion motor;
 - an ammeter for each excitation circuit.

15.5.2 Each control station is to be provided with instruments to indicate:

- (a) propeller speed;
- (b) direction of rotation for a fixed pitch propeller or pitch position for a controllable pitch propeller; and
- (c) visual indication of power limitation.

Section 16 Fire safety systems

16.1 Fire detection and alarm systems

16.1.1 Fire detection and alarm systems are to be provided with an emergency source of electrical power required by 3.2 or 3.3 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main fire control panel are to be provided. Failure of any power supply is to operate an audible and visual alarm. See also 1.13 and 1.14.

16.1.2 For machinery spaces the requirements of Ch 1,2.8 are applicable.

16.1.3 The fire detection system within the accommodation spaces is, in addition to the requirements of Ch 1,2.8.4, 2.8.6, 2.8.8 and 2.8.10 to 2.8.14, to comply with 16.1.4 to 16.1.15.

16.1.4 The fire control panel is to be located on the navigating bridge or in a central fire control station and may form part of that panel specified in Ch 1,2.8.2. For passenger ships carrying more than 36 passengers, the fire control panel is to be located in the continuously manned central control station.

16.1.5 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. This alarm sounder system need not be an integral part of the detection system.

16.1.6 Indicating units are to denote, as a minimum, the section in which a detector or manually operated call point has operated. At least one unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

16.1.7 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section.

16.1.8 Where the fire detection system does not include means of remotely identifying each detector individually no section covering more than one deck within accommodation, service spaces and control stations is normally to be permitted except a section which covers an enclosed stairway. The number of enclosed spaces in each section are to be limited to the minimum considered necessary in order to avoid delay in identifying the source of fire. In no case are more than fifty spaces permitted in any section.

16.1.9 In passenger ships, where the fire detection system does not include means of remotely identifying each detector individually a section of detectors is neither to serve spaces on both sides of the ship nor on more than one deck except when permitted by 16.1.14.

16.1.10 A section of fire detectors which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

16.1.11 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel.

16.1.12 A loop circuit of an addressable fire detection system, capable of remotely identifying from either end of the loop each detector served by the circuit, may serve spaces on both sides of the ship and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers a control station or an accommodation space to include a machinery space of Category A.

16.1.13 A loop circuit of an addressable fire detection system may comprise one or more sections of detectors. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that if a short-circuit occurs anywhere in the loop, only the affected section of detectors will be isolated from the control panel. No section of detectors is in general to include more than 50 detectors.

16.1.14 A section of detectors of an addressable fire detection system is neither to serve spaces on both sides of the ship nor on more than one deck, except that:

- (a) a section of detectors may serve spaces on more than one deck if those spaces are located in either the fore or aft end of the ship, or they constitute common spaces occupying several decks (i.e. public spaces, enclosed stairways, etc.); or
- (b) in ships of less than 20 m in breadth, a section of detectors may serve spaces on both sides of the ship.

16.1.15 The wiring for each section of detectors in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop. Where practicable no loop is to pass through a space twice. When this is not practical, such as in large public spaces, the part of the loop which by necessity passes through the space for a second time is to be installed at the maximum possible distance from other parts of the loop.

16.2 Automatic sprinkler system

16.2.1 Any electrically-driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

16.2.2 For **passenger ships**, electrically-driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic changeover switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

16.2.3 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic changeover facilities located in, or adjacent to, the main alarm and detection panel.

16.2.4 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

16.3 Fixed water-based local application fire-fighting systems

16.3.1 Where fixed water-based local application fire-fighting system pressure sources are reliant on external power they need only be supplied by the main source of electrical power. However, where the system forms a section of the main fixed fire-extinguishing system the power supply arrangements are to be equivalent to those required by 16.2.2.

16.3.2 The fire detection, control and alarm systems are to be provided with an emergency source of electrical power required by 3.2 or 3.3 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main control panel are to be provided.

16.3.3 Failure of any power supply is to operate an audible and visual alarm. See also 1.13 and 1.14.

16.3.4 Means to activate a system are to be located at easily accessible positions inside and outside the protected space. Arrangements inside the space are to be situated such that they will not be cut off by a fire in the protected areas and are suitable for activation in the event of escape. Proposals to install local activation means outside protected spaces are to be submitted for consideration.

16.3.5 For the electrical safety of electrical and electronic equipment in areas protected by fixed water-based local application fire-fighting systems and adjacent areas where water may extend, the requirements of 16.3.6 to 16.3.8 apply.

16.3.6 Unless essential for safety or operational purposes, electrical and electronic equipment is not to be located within protected areas or adjacent areas. The pump, its electrical motor and the sea valve if any, may be in a protected space provided that they are outside areas where water or spray may extend.

16.3.7 Electrical and electronic equipment located within protected areas and those within adjacent areas exposed to direct spray are to have a degree of protection not less than IP44.

16.3.8 Electrical and electronic equipment within adjacent areas not exposed to direct spray may have a lower degree of protection than IP44 provided evidence of suitability for use in these areas is submitted, including details of the design and equipment layout and arrangements to prevent or restrict the ingress of water mist/spray. Cooling airflow for equipment is to be assured.

16.4 Fire pumps

16.4.1 When the emergency fire pump is electrically-driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

16.4.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire resistant type where they pass through other high fire risk areas.

16.5 Refrigerated liquid carbon dioxide systems

16.5.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

16.5.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

16.6 Fire safety stops

16.6.1 In order to limit the fire growth potential in every space of the ship, means for controlling the air supply to the spaces and flammable liquids within the spaces are to be provided.

16.6.2 To control air supply, a means of stopping all forced and induced draught fans, and all ventilation fans serving accommodation spaces, service spaces, control stations and machinery spaces from an easily accessible position outside of the space being served is to be provided. The position is not to be readily cut off in the event of a fire in the spaces served by the fans.

16.6.3 In passenger ships carrying more than 36 passengers, a second means of stopping ventilation fans serving accommodation spaces, service spaces and control stations is to be provided at a position as far apart from the position required by 16.6.2 as is practicable. At both positions, the controls are to be grouped so that all fans can be stopped from either of the two positions.

16.6.4 A second means of stopping ventilation fans serving machinery spaces is to be provided at a position as far apart from the position required by 16.6.2 as is practicable. At both positions the controls are to be grouped so that all fans are operable from either of the two positions. The means for stopping machinery space ventilation fans are to be entirely separate from the means for stopping fans serving all other spaces.

16.6.5 In passenger ships, the means of stopping machinery ventilation fans required by 16.6.2 is to be located at the central control station which is to have safe access from the open deck. The central control station is to be provided with ventilation fan OFF status indications together with a means for restarting the ventilation fans.

16.6.6 To control flammable liquids, a means of stopping all fuel oil, lubricating oil, hydraulic oil, cargo oil and thermal oil pumps, oil purifiers from outside the spaces being served is to be provided. The position is not to be cut off in the event of a fire.

16.6.7 Means of cutting off power to the galley, in the event of a fire, is to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

16.6.8 Following activation of any fire safety stops, a manual reset is to be provided in order to restart the associated equipment.

16.6.9 Fire safety stop systems are to be designed on the fail safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, see 10.5.3. See also 5.2.1.

16.7 Fire doors

16.7.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by 3.2. In passenger ships carrying more than 36 passengers an alternative supply fed from the main source of electrical power, with automatic changeover facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, see also 1.13 and 1.14.

16.7.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

16.8 Fire dampers

16.8.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.

16.8.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

16.9 Fire-extinguishing media release

16.9.1 Where it is required that alarms be provided to warn of the release of a fire-extinguishing medium, and these are electrically-operated, they are to be provided with an emergency source of electrical power, as required by 3.2 or 3.3, and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, see also 1.13. Failure of any power supply is to operate an audible and visual alarm, see also 1.13 and 1.14.

16.9.2 The opening of the fire-extinguishing media control cabinet door, or panel, for any purpose, other than for the release of the fire-extinguishing media, is not to cause the loss of any essential services (see 1.5.1).

■ Section 17

Crew and passenger emergency safety systems

17.1 Emergency lighting

17.1.1 For the purpose of this Section emergency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name 'emergency lighting'.

17.1.2 Emergency lighting provided in compliance with Section 3 is to be arranged so that a fire or other casualty in the spaces containing the emergency source of electrical power, associated transforming equipment and the emergency lighting switchboard does not render the main lighting system inoperative.

17.1.3 The level of illumination provided by the emergency lighting is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke, see 17.4.

17.1.4 The exit(s) from every main compartment occupied by passengers or crew is to be continuously illuminated by an emergency lighting fitting.

17.1.5 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces (i.e. storage rooms, cold rooms, etc.), or they are normally required to be extinguished for operational reasons (i.e. for night visibility from the navigating bridge). Where switches are fitted they are to be accessible only to ships crew with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions.

17.1.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

17.1.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

17.2 General emergency alarm system

17.2.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren, for sounding the general emergency alarm signal is to comply with the *International Life-Saving Appliances (LSA) Code* and with the requirements of this Section, see also 1.13 and 1.14.

17.2.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by 3.2 or 3.3 and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, see also 1.13.

17.2.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS 1974 as amended Reg II-2/A, 3.32, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

17.2.4 There are to be segregated cable routes to public rooms, alleyways, stairways, and control stations, so arranged that any single electrical fault, localized fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any public rooms, alleyways, stairways, and control stations, be it at a reduced capacity.

17.2.5 Where the special alarm fitted to summon the crew, operated from the navigation bridge, or fire-control station, forms part of the ship's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces.

17.2.6 The sound pressure levels are to be measured during a practical test and documented, see 20.2.

17.3 Public address system

17.3.1 Public address systems on passenger ships and public address systems used on cargo ships to sound the general emergency alarm or the fire-alarm, are to comply with the *International Life-Saving Appliances (LSA) Code* and the requirements of this Section.

17.3.2 The public address system is to be provided with an emergency source of electrical power as required by 3.2 or 3.3 and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the public address system. Failure of any power supply is to operate an audible and visual alarm, see also 1.13 and 1.14.

17.3.3 The public address system is to have multiple amplifiers having their power supplies so arranged that a single fault will not cause the loss of the facility to broadcast emergency announcements in public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

17.3.4 The public address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS 1974 as amended Reg II-2/A, 3.32, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

17.3.5 There are to be at least two cable routes, sufficiently separated throughout their length, to public rooms, alleyways, stairways and control stations so arranged that any single electrical fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

17.3.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the public address system, for tone signals.

17.3.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

17.3.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

17.3.9 Where the public address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of 17.2:

- (a) The emergency system is given automatic priority over any other system input.
- (b) More than one device is provided for generating the sound signals for the emergency alarms.

17.3.10 Where more than one alarm is to be sounded through the public address system, they are to have recognizably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

17.3.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals and documented, see 20.2.

17.4 Escape route or low location lighting (LLL)

17.4.1 The escape route or low location lighting (LLL) required by SOLAS 1974 as amended Pt D, Ch II-2, Reg. 13, 3.2.5.1, where satisfied by electric illumination, is to comply with the requirements of this sub-Section.

17.4.2 The LLL system is to be provided with an emergency source of electrical power as required by 3.2 and also be connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, see also 1.14.

17.4.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with 10.5.3, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes, see 11.3.8.

17.4.4 The performance and installation of lights and lighting assemblies are to comply with ISO standard 15370: *Ships and marine technology - Low location lighting on passenger ships*.

■ Section 18

Ship safety systems

18.1 Watertight doors

18.1.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck and for passenger ships be capable of being automatically supplied by the transitional source of emergency electrical power required by 3.2.6 in the event of failure of either the main or emergency source of electrical power.

18.1.2 For passenger ships, where the sources for opening and closing the watertight doors have electric motors, unless an independent temporary source of stored energy is provided, the electric motors are to be capable of being automatically supplied from the transitional source of emergency electrical power.

18.1.3 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

18.1.4 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

18.1.5 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

18.1.6 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529: *Degrees of protection provided by enclosures (IP Code)* or an acceptable and relevant National Standard, as follows:

- (a) Electrical motors, associated circuits and control components, protected to IPX7 standard.
- (b) Door position indicators and associated circuit components protected to IPX8 standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
- (c) Door movement warning signals, protected to IPX6 standard.

Electrical Engineering

Part 6, Chapter 2

Section 18

18.1.7 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the ship may sustain is minimized.

18.1.8 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

18.1.9 Sliding watertight doors on **cargo ships** are to be capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure.

18.1.10 On passenger ships, a central operating console is to be fitted on the navigating bridge and is to be provided with a 'master-mode' switch having:

- (a) a 'local control' mode for normal use which is to allow any door to be locally opened and locally closed after use without automatic closure, and;
- (b) a 'doors closed' mode for emergency use which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

18.1.11 On passenger ships, the 'master mode' switch is to be arranged to be normally in the 'local control' mode position; be clearly marked as to its emergency function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

18.1.12 On passenger ships, the central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

18.1.13 The arrangements are to be such that it is not possible to remotely open any door from the central operating console.

18.2 Stern and side shell doors

18.2.1 A notice is to be displayed at the operating panel stating that the door is to be fully closed, secured and locked preferably before, or immediately the ship leaves the berth and that this operation is to be entered in the ship's log.

18.2.2 Control positions are to be provided with a system of warning indicator lights. The system is to provide positive indication that the door is fully closed, secured and locked. The indication arrangements are to be 'fail-safe' such that in the event of a fault the system cannot incorrectly indicate that the doors are fully closed, secured or locked.

18.2.3 The indication system is to be arranged such that it functions independently of any system for door operation, securing and locking.

18.2.4 The electrical power supply for the indication system is to be independent of any electrical power supply for operating, securing and locking the doors.

18.2.5 The indication system is to be fed from two exclusive circuits, one from the main source of electrical power and one from the emergency source of electrical power with automatic changeover facilities located adjacent to the panel. Loss of either active or standby power supply is to initiate an audible and visual alarm on the navigation bridge.

18.2.6 The indicator panel is to be provided with a lamp test function. It is not to be possible to turn off the indication lights at the panel. Dimming facilities may be provided, but the indications are to remain clearly readable under all operating lighting conditions.

18.2.7 Means are to be provided to prevent unauthorized operation of the doors and associated securing and locking devices.

18.2.8 Detection of door position and securing and locking device status is to be by direct sensing of proximity, contact or equivalent, not inferred from actuator positions. Sensors are to be protected against ice formation, mechanical damage and water ingress to be not less than IPX6 standard as defined in IEC 60529, or an acceptable and relevant National Standard.

18.2.9 Where a strongback or equivalent independent secondary means of securing an inwardly opening door is required, these need not be monitored by the indication system providing their correct positioning can be easily observed from the control position.

18.2.10 Doors with a clear opening area of 12 m² or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m² are to be provided with an arrangement for remote control from a position above the freeboard deck. This remote control is to provide centralised control for:

- (a) The closing and opening of the doors.
- (b) Associated securing and locking devices.

18.2.11 The location of the remote control panel is to be such that door operation can be easily observed by the operator or by other suitable means such as closed circuit television. Where remote control is required, television surveillance or other such means may satisfy this requirement.

Electrical Engineering

Part 6, Chapter 2

Section 18

18.2.12 The additional requirements of 18.2.13 to 18.2.17 apply to doors in the boundaries of special category spaces or ro-ro cargo spaces through which such spaces may be flooded. For cargo ships, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m², then the requirements of 18.2.13 to 18.2.17 need not be applied.

18.2.13 An indicator panel is to be located on the navigating bridge, providing separate visual indications of the position of each door and the status of their associated securing/locking devices.

18.2.14 The indication system is to be provided with a 'harbour/sea voyage' mode selection function, with means of operation located on or adjacent to the navigating bridge indication panel. The selected mode is to be displayed on all indicator panels. An audible alarm is to be initiated on the navigating bridge if the ship leaves the harbour with any door not fully closed or not fully secured. Where practical, the alarm should be initiated immediately the ship leaves the berth. Audible alarms are to be silenced in the 'harbour' mode. Visual indications are to remain operational in either mode.

18.2.15 An audible and visual alarm is to be given on the navigation bridge in the event of any fault within the indication system.

18.2.16 An audible and visual alarm is to be initiated on the navigation bridge and the engine control room, or an equivalent attended position, in the event of leakage through the doors.

18.2.17 For passenger ships, television surveillance arrangements are to be provided to allow leakage through doors below the freeboard deck to be assessed from the navigation bridge and the engine control room, or equivalent attended position.

18.3 Bow and inner doors

18.3.1 Bow doors and inner doors, giving access to vehicle decks, and subdivision doors are to be provided with an arrangement for remote control, from a position above the freeboard deck, providing centralised control for:

- (a) the closing and opening of the doors, and
- (b) associated securing and locking devices.

18.3.2 The location of the remote control panel is to be such that door operation can be easily observed by the operator or by other suitable means such as closed circuit television. Where remote control is required, television surveillance or other such means may satisfy this requirement.

18.3.3 A notice is to be displayed at the control position operating panel stating that the bow and inner doors are to be fully closed, secured and locked immediately before the ship leaves the berth and that this operation is to be entered in the ship's log.

18.3.4 Means are to be provided to prevent unauthorized operation of the doors and associated securing and locking devices.

18.3.5 An indicator panel is to be located on the navigating bridge and at each control position, providing separate visual indications of the position of bow and inner doors and the status of their associated securing/locking devices.

18.3.6 The indication arrangements are to be 'fail-safe' such that in the event of a fault the system cannot incorrectly indicate that the doors are fully closed, secured or locked.

18.3.7 Indicator panels are to be provided with a lamp test function. It is not to be possible to turn off the indication lights at the panel. Dimming facilities may be provided, but the indications are to remain clearly readable under all operating lighting conditions.

18.3.8 The indication system is to be provided with a 'harbour/sea voyage' mode selection function, arranged such that an audible alarm is to be initiated on the navigating bridge if the ship leaves the harbour with any door not fully closed or not fully secured. Where practical, the alarm should be initiated immediately the ship leaves the berth. Audible alarms are to be silenced in the 'harbour' mode. Visual indications are to remain operational in either mode.

18.3.9 An audible and visual alarm is to be given on the navigation bridge in the event of any fault within the indication system.

18.3.10 The indication system is to be arranged such that it functions independently of any system for door operation.

18.3.11 The electrical power supply for the indication system is to be independent of any electrical power supply for operating, securing and locking the doors.

18.3.12 The indication system is to be fed from two exclusive circuits, one from the main source of electrical power and one from the emergency source of electrical power with automatic changeover facilities located adjacent to the panel. Loss of either active or standby power supply is to initiate an audible and visual alarm on the navigation bridge.

18.3.13 Detection of door position and securing and locking device status is to be by direct sensing of proximity, contact or equivalent, not inferred from actuator positions. Sensors are to be protected against ice formation, mechanical damage and water ingress to be not less than IPX6 standard as defined in IEC 60529, or an acceptable and relevant National Standard.

18.3.14 An audible and visual alarm is to be initiated on the navigation bridge and the engine control room, or equivalent attended position, in the event of leakage through the inner door.

18.3.15 Television surveillance arrangements are to be provided that allow the extent of leakage to be readily assessed from the navigation bridge and the engine control room, or equivalent attended position, in the event of leakage through the doors. See also Pt 4, Ch 2, 10.2.

Electrical Engineering

Part 6, Chapter 2

Sections 18, 19 & 20

18.3.16 The electrical power supply for surveillance lighting is to be independent of any electrical power supply for operating, securing and locking the doors.

18.4 Subdivision doors on vehicle decks

18.4.1 Where subdivision doors are provided on passenger ship vehicle decks in accordance with Pt 4, Ch 2,9, the control and monitoring arrangements for these doors are to generally comply with 18.3.

18.5 Bilge pumps

18.5.1 Where the bilge pumps for the holds of open-top container ships are electrically driven one pump is to be supplied from the emergency switchboard, the remaining pumps are to be supplied from the main source of electrical power, independent of the emergency switchboard.

Section 19 Lightning conductors

19.1 General

19.1.1 In order to minimise the risks of damage to the ship and its electrical installation due to lightning, ships having non-metallic masts or topmasts are to be fitted with lightning conductors in accordance with the applicable requirements of IEC 60092-401 *Electrical installations in ships*. Part 401: Installation and test of completed installation or an alternative and relevant National Standard.

Section 20 Testing and trials

20.1 Testing

20.1.1 Tests in accordance with 20.1.2 to 20.1.4 are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

20.1.2 A high voltage at any frequency between 25 and 100Hz is to be applied between:

- (a) all current carrying parts connected together and earth;
- (b) all current carrying parts of opposite polarity or phase.

For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with Table 2.20.1. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test

voltage is then to be maintained for 1 minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

Table 2.20.1 Test voltage

Rated voltage, U_n V	Test voltage a.c. (r.m.s.), V
$U_n \leq 60$	500
$60 < U_n \leq 1000$	$2 \times U_n + 1000$
$1000 < U_n \leq 2500$	6500
$2500 < U_n \leq 3500$	10000
$3500 < U_n \leq 7200$	20000
$7200 < U_n \leq 12000$	28000
$12000 < U_n \leq 15000$	38000

20.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

20.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:

- (a) all current carrying parts connected together and earth;
- (b) all current carrying parts of different polarity or phase.

The minimum values of test voltage and insulation resistance are given in Table 2.20.2.

Table 2.20.2 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

20.1.5 Tests in accordance with the standard with which the equipment complies may be accepted as an alternative to the above.

20.2 Trials

20.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in 20.2.2 to 20.2.7 are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be to the Surveyor's satisfaction.

20.2.2 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:

- (a) all current carrying parts connected together and earth and, so far as is reasonably practicable;
 - (b) all current carrying parts of different polarity or phase;
- The minimum values of test voltage and insulation resistance are given in Table 2.20.2. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

20.2.3 Tests are to be made to verify the effectiveness of:

- (a) earth continuity conductor;
- (b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by 1.11.2;
- (c) bonding for the control of static electricity.

20.2.4 It is to be demonstrated that the Rules have been complied with in respect of:

- (a) satisfactory performance of each generator throughout a run at full rated load;
- (b) temperature of joint, connections, circuit-breakers and fuses;
- (c) the operation of engine governors, synchronizing devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;
- (d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;
- (e) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;
- (f) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory;
- (g) propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction. The equipment is to have sufficient power for going astern to secure proper control of the ship in all normal circumstances. In passenger ships the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed, is to be demonstrated at the sea trial.

20.2.5 Voltage drop is to be measured, where necessary, to verify that this is not in excess of that specified in 1.7.

20.2.6 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew and passenger emergency and ship safety systems.

20.2.7 On completion of the general emergency alarm system and the public address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

20.3 High voltage cables

20.3.1 Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. The test is to be carried out after the insulation resistance test required by 20.2.2 and may use either an a.c. voltage at power frequency or a d.c. voltage.

20.3.2 When an a.c. voltage withstand test is carried out, the voltage is to be not less than the normal operating voltage of the cable and it is to be maintained for a minimum of 24 hours.

20.3.3 When a d.c. voltage withstand test is carried out, the voltage is to be not less than:

- (a) $1,6 (2,5U_o + 2 \text{ kV})$ for cables of rated voltages (U_o) up to and including 3,6 kV, or
- (b) $4,2U_o$ for higher rated voltages

where U_o is the rated power frequency voltage between conductor and earth or metallic screen, for which the cable is designed.

The test voltage is to be maintained for a minimum of 15 minutes. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test in accordance with 20.2.2 is then to be repeated.

20.4 Hazardous areas

20.4.1 All electric equipment located in hazardous areas is to be examined to ensure that it is of a type permitted by the Rules, has been installed in compliance with its certification, and that the integrity of the protection concept has not been impaired.

20.4.2 Alarms and interlocks associated with pressurized equipment and the ventilation of spaces located in hazardous areas are to be tested for correct operation.

Section 21 Spare gear

21.1 General

21.1.1 It is recommended that adequate spares, together with the tools necessary for maintenance, or repair, be carried. The spares are to be determined by the Owner according to the design and intended service. The maintenance of the spares is the responsibility of the Owner.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 1

Sections

- 1 **General requirements**
- 2 **Design criteria**
- 3 **Refrigerating machinery and refrigerant storage compartments**
- 4 **Refrigeration plant, pipes, valves and fittings**
- 5 **Refrigerant detection systems**
- 6 **Electrical installation**
- 7 **Instrumentation, control, alarm, safety and monitoring systems**
- 8 **Personnel safety equipment and systems**
- 9 **Refrigerated cargo spaces**
- 10 **Container ships fitted with refrigerating plant to supply cooled air to insulated containers in holds**
- 11 **Acceptance trials**

■ Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to the refrigerated cargo installations of refrigerated cargo ships, refrigerated container ships, fish factory ships, fishing vessels, fruit juice carriers, and the reliquefaction/refrigerating plant of liquefied gas carriers and chemical carriers or tankers, where an **RMC** notation is requested.

1.1.2 Ships with refrigerated cargo installations which are approved, installed and tested in accordance with these requirements will be eligible for the applicable class notation specified in Pt 1, Ch 2.

1.1.3 The requirements for the classification of ships for the carriage of liquefied gas are given in Lloyd's Register's (hereinafter referred to as 'LR') *Rules for Ships for Liquefied Gases*. Where reliquefaction or refrigeration equipment is fitted for cargo temperature and pressure control, the equipment is to comply with the requirements of Sections 2 to 11, as applicable.

1.2 Plans and particulars

1.2.1 The following plans and particulars, as applicable, and any others which may be specially requested for the **refrigerating plant and systems**, are to be submitted in triplicate for approval, before construction is commenced:

- (a) Schematic plans, including full particulars of piping and instrumentations, for:
 - primary and secondary refrigeration systems;
 - air cooler defrosting arrangements;
 - gas reliquefaction systems; and
 - condenser cooling water systems.
- (b) Detailed dimensioned plans and material specifications for:
 - reciprocating compressor crankshaft and crankcase, where exposed to refrigerant pressure;
 - rotary-type compressor rotors and casing;
 - condensers shell and tube and plate type;
 - evaporators shell and tube and plate type;
 - air coolers;
 - arrangement of air cooling pipe grids and construction method;
 - liquid receivers;
 - oil separators; and
 - any other pressure vessels, see Pt 5, Ch 11,6.1.
- (c) General arrangement of refrigerating machinery compartment in elevation and plan, showing location and arrangement of the plant, ventilation details and location of temperature sensors and vapour detectors.
- (d) Details of automatic controls, alarms and safety systems, see Pt 6, Ch 1,1.
- (e) Details of level indicators.
- (f) Where provision is made for the manufacture and/or storage of inert gas in liquid form, details of the storage vessel insulation arrangements and the reliquefaction equipment and piping system are to be submitted.
- (g) Capacity calculations for pressure relief valves and/or bursting discs, and discharge pipe pressure drop calculations, see 4.15.5 to 4.15.21.
- (h) Programme of tests to be conducted on completion of the installation, see Section 11.

1.2.2 The following plans and particulars, as applicable, and any others which may be specially requested for **refrigerated cargo spaces**, are to be submitted in triplicate for approval, before work is commenced:

- (a) Specification of proposed insulation envelope system, including physical, thermal and fire properties.
- (b) General arrangement of insulated refrigerated spaces in elevation and plan.
 - The plans are to be to a scale adequate for the measurement of the external surfaces and the deck and bulkhead edges.
 - Dimensions and spacing of frames, beams and stiffeners, and details of other steel work intruding into the insulation and within the spaces, are to be shown.
 - Oil fuel and liquid cargo tanks adjacent to or below the refrigerated spaces are to be shown, and whether heating arrangements are provided for such tanks are to be indicated.
 - Ventilating and air conditioning trunks, and ducts passing through refrigerated spaces are to be shown.
 - The plans are to include a diagram showing the position of the spaces in relation to other parts of the ship if this is not otherwise apparent.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 1

- (c) Plans showing:
- the thicknesses and methods of attachment of the insulation and linings on all surfaces including girders, hatch coamings and pillars; and
 - details of prefabricated panels and their fixings, vapour barriers, insulated doors and hatch access, bilge and manhole plugs and their frames.
- (d) Methods of attachment of air cooling grids (if fitted) are to be indicated.
- (e) Size and position of refrigerated space pressure equalizing devices, where fitted, see 9.2.12 and 9.2.13.
- (f) Arrangements of the drainage system, and sounding and air pipes that pass through the refrigerated spaces.
- (g) Arrangements of air ducts and distribution systems within the refrigerated spaces (including method of cooling spaces within hatch coamings), and air cooler spaces showing location of the coolers and their fans and drive motors.
- (h) Details of temperature indicating, and recording and sensing equipment, and arrangement of sensors within the refrigerated spaces.

1.2.3 Single copies of the following plans and particulars are to be submitted:

- LR Data Sheet for refrigerated cargo installations (LR Form 3905).
- Specification of proposed refrigerating system and auxiliary equipment, including the refrigerating capacities of the compressors, condensers, evaporators and air coolers.
- Heat load calculations at all design operating conditions justifying the refrigerating capacity which is to be installed.

1.3 Materials

1.3.1 Steel plating used in ship construction is to be of an appropriate grade corresponding to the proposed temperature notation, see Pt 3, Ch 2,2.2.

1.3.2 Materials used in the construction of the refrigerating equipment and associated systems are to be generally manufactured and tested in accordance with the requirements of the Rules for Materials (Part 2).

1.3.3 Where it is proposed to use materials other than those specified in Rules for Materials (Part 2), details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement with LR.

1.3.4 All materials used in refrigerating equipment and systems are to be suitable for use with the selected refrigerants. This includes joints, sealing materials and lubricants. For example, the following materials and refrigerants are not to be combined:

- Copper with ammonia.
- Magnesium with fluorinated hydrocarbons.
- Zinc with ammonia or fluorinated hydrocarbons.

1.3.5 For ammonia systems, the condensers/evaporators are to be manufactured in titanium or a suitable grade of stainless steel.

1.4 Equipment to be constructed under survey

1.4.1 All major items of equipment are to be surveyed at the manufacturer's works. The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended purpose and duty. Examples of such units are:

- Crankshafts, crankcases, rotor shafts and casings for all compressors.
- Condensers.
- Evaporators (secondary refrigerant coolers).
- Air coolers.
- Pressure vessels (e.g. liquid receivers, surge drums, suction separators, intercoolers, oil separators).
- Cooling water pumps for condensers.
- Valves and other components intended for installation in pressure piping systems having a maximum working pressure greater than 7 bar.
- Thermal insulating panels (factory made).

1.5 Type approved equipment

1.5.1 Where it is proposed to use components (e.g. compressors, condensers, oil separators) which have valid LR Type Approval or General Approval Certificates, the types and model numbers of the components are to be stated. Plans of components that have been so approved need not be re-submitted.

1.6 Notation and temperature conditions

1.6.1 The class notation assigned will state the minimum temperature or a temperature range approved by the Committee for the installation with the maximum sea temperature stated, e.g. '✱ Lloyd's RMC to maintain temperature(s) of minus 29°C to plus 14°C with sea temperature plus 32°C maximum'.

1.6.2 For refrigerated installations aboard container ships with approved refrigerating plant and arrangements to supply refrigerated air through ducting to insulated containers, the class notation assigned will additionally specify the maximum number and characteristics of the containers for which the plant is approved, e.g. 'to supply refrigerated air at temperatures of minus 25°C to plus 14°C to 800 certified insulated containers with an average thermal transmittance per container of 27 W/K with sea temperature plus 32°C maximum'.

1.6.3 For reliquefaction or refrigerating plants aboard liquefied gas carriers, the notation assigned will state the minimum cargo temperature for which the installation is approved, unless otherwise qualified, see LR III.3 of the *Rules for Ships for Liquefied Gases*.

Refrigerated Cargo Installations

Part 6, Chapter 3

Sections 1 & 2

1.6.4 On application from an Owner, consideration will be given by the Committee to an alternative temperature notation being assigned to that appearing in the *Register Book*.

1.7 Novel arrangements and design

1.7.1 Where the proposed construction of the refrigerating plant or refrigerated spaces or chambers is novel in design or involves the use of unusual material, special tests may be required, and a suitable class notation may be assigned when the Committee considers this necessary.

1.8 Heat balance tests

1.8.1 A heat balance test will be required as prescribed in Section 11 on a classed installation, or one being considered for reclassification, when extensive repairs or alterations have been carried out, or when the Surveyors consider that an amended temperature condition should be assigned.

1.9 Controlled atmosphere (CA) systems

1.9.1 Where it is intended to install a CA system on a vessel intended for classification, the requirements of Pt 7, Ch 1 are to be complied with.

1.9.2 Where a **CA** notation is requested by an Owner, it is a prerequisite that the refrigeration installation be assigned an **RMC** notation.

1.10 Spare gear and refrigerant charge

1.10.1 It is recommended that adequate spares, together with the tools necessary for maintenance, or repair, be carried. The spares are to be determined by the Owner according to the design and intended service. The maintenance of the spares is the responsibility of the Owner.

1.10.2 For systems complying with 2.5.6 sufficient carbon dioxide is to be carried on board to allow the refrigeration system to be fully recharged. In addition, adequate reserve supplies of refrigerant are to be carried for maintenance purposes. The replacement refrigerant is to be stored in containers complying with 3.3.5

2.1.2 The properties of steel materials used in refrigerated holds are to be suitable for the proposed notation temperature.

2.2 Refrigerants and classes of pipes

2.2.1 These Rules are applicable to the primary refrigerants in Table 3.2.1.

2.2.2 Attention is to be given to any statutory requirements, regarding the use of refrigerants, of the National Authority of the country in which the ship is to be registered.

2.2.3 Within the parameters of pressures, temperatures, toxic nature and flammability, the class of pipe to be used with various refrigerants is shown in Table 3.2.1.

2.2.4 Design conditions as applicable to the classes of pipes are defined in Pt 5, Ch 12, 1.5.

2.2.5 The materials of Class I and Class II piping systems are to be manufactured at a works approved by LR and tested in accordance with the appropriate requirements of Rules for Materials. Particular attention is drawn to Ch 6.4 of the Rules for Materials, where testing requirements for pipes used for low temperature service are given.

2.2.6 The materials of Class III piping system are to be manufactured and tested in accordance with the requirements of acceptable National Specifications. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of materials.

2.2.7 Particulars of refrigerating systems using refrigerants other than those listed will be given special consideration.

2.3 Refrigeration units

2.3.1 A refrigerating unit is considered to comprise a compressor, its driving motor and one condenser. Where a secondary refrigerant, such as brine, is employed, the unit is also to include an evaporator (secondary refrigerant cooler) and a brine pump.

2.3.2 Two or more compressors driven by a single motor, or having only one condenser or evaporator (secondary refrigerant cooler) are to be regarded as one unit.

2.3.3 The refrigerating units of a classed cargo installation are to be completely independent of any refrigerating machinery associated with air conditioning plant, or any domestic refrigerated installation, or any process plant, unless full details of any proposal have been submitted and approved.

Section 2 Design criteria

2.1 General

2.1.1 The proposed refrigerating plant, insulation and refrigerants are to be suitable for achieving the designed notation temperature. The refrigerating machinery and all components are to operate satisfactorily under the conditions listed in Table 1.3.1 in Pt 5, Ch 1.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 2

Table 3.2.1 Primary refrigerants and their class of pipe

Refrigerant	Type	Composition	Class I	Class of Pipe Class II	Class III
R-717 (Ammonia)	NH ₃	—	✓	—	—
R-22	HCFC	—	—	✓	—
R-290 (Propane)	HC	—	—	✓	—
R-600a (Isobutane)	HC	—	—	✓	—
R-134a	HFC	—	—	—	✓
R-407C	Blend	R-32, R-125, R-134a	—	✓	—
R-410A	Blend	R-32, R-125	—	✓	—
R-507A	Blend	R-125, R-143a	—	✓	—
R-404A	Blend	R-134a, R-125, R-143a	—	✓	—
R-744 (Carbon Dioxide)	CO ₂	—		See 2.5.6	

NOTES

1. HCFC – Hydrochlorofluorocarbon.
2. HFC – Hydrofluorocarbon.s
3. HC – Hydrocarbon.
4. In view of increasing world-wide restrictive legislation and phasing out of the refrigerant R-22, it is recommended that this refrigerant should not be used in any new installation.
5. Although ozone depleting and global warming potentials are not included in these Rules for Classification, these effects are important and need to be considered when selecting the refrigerant for a particular application.

2.4 Refrigeration capacity

2.4.1 The refrigeration capacity provided is to be sufficient to maintain the temperatures specified in the class notation when operating 24 hours per day with one unit on standby. The plant is to be able to cool down a complete cargo to its carrying temperature within the time specified by the manufacturer. The standby unit may be considered as an operating unit during the cooling down period of a non-precooled cargo. In order to compensate for deterioration of machinery and insulation over the life of the installation, the equipment is to be designed to have at least five per cent excess capacity over that required for maximum design output.

2.4.2 The proposals of both machinery and insulating contractors will be evaluated by LR in determining the theoretical capabilities of the equipment to maintain the duty temperatures. LR will advise the contractors after appraisal of the specification and plans if it is considered that additional refrigeration or insulating effect is required, but the temperature assigned on completion of the capacity heat balance test will be determined from the actual results of the test.

2.4.3 Where the units are not connected in common to all refrigerated chambers, the equipment serving each group of chambers is to comply with 2.4.1.

2.4.4 In the case of installations having a large number of small units arranged to serve individual chambers or groups of chambers, the question of standby capacity will be specially considered.

2.4.5 Where only two refrigerating units are fitted, the working parts are to be interchangeable.

2.4.6 Where a refrigerating plant is provided for sub-cooling the liquid refrigerant of other units, but is not arranged for cooling the cargo chambers independently, it will not be regarded as a unit.

2.5 Design pressures

2.5.1 The design pressure of the system is to be regarded as equal to its maximum working pressure.

2.5.2 The maximum working pressure is the maximum permissible pressure within the system (or part system) in operation or at rest. No relief valve is to be set to a pressure higher than the maximum working pressure.

2.5.3 The design pressure of the low pressure side of the system is to be the saturated vapour pressure of the refrigerant at plus 46°C. Due regard is to be taken of defrosting arrangements which may cause a higher pressure to be imposed on the low pressure system.

2.5.4 The minimum design pressure of the high pressure side of the system (P_{dh}), is to be $1,11 \times P_b$, where P_b is an allowance for the compressor high pressure cut-out. P_b is to be at least equal to $1,11 \times P_a$, where P_a is the condenser working pressure, when operating in tropical zones and equates to the saturation pressure at 46°C.

Refrigerated Cargo Installations

Part 6, Chapter 3

Sections 2 & 3

2.5.5 Design pressures (bar g) applicable to refrigerants are to be not less than the values given in Table 3.2.2 when condensers are sea-water cooled. The design pressure for other refrigerants is to be agreed with LR.

Table 3.2.2 Pressure limits

Refrigerant	Pressure (bar g)	
	High	Low
R-717	21,2	17,2
R-22	20,6	16,7
R-290	18,1	14,7
R-600a	6,4	5,2
R-134a	13,4	10,9
R-470C	23,5	19,0
R-410A	34,5	28,0
R-507A	25,3	20,5
R-404A	24,8	20,1
R-744	See 2.5.6	

2.5.6 Due to the low critical temperature of carbon dioxide it is inappropriate to determine the design pressure in accordance with 2.5.3. The proposed design pressure for a carbon dioxide system is to be stated, taking account of the maximum working pressure and the maximum pressure at rest conditions. Where the maximum pressure at rest condition is maintained by the fitting of a supplementary refrigeration unit, condensing the vapour in a holding vessel, supporting calculation is to be provided to show that this can be undertaken with a local ambient temperature of 45°C. The holding vessel is to be thermally insulated to prevent the operation of the relief devices within a 24 hour period after stopping the supplementary refrigeration unit at an ambient temperature of 45°C and an initial pressure equal to the starting pressure of the refrigeration unit.

2.5.7 Where a carbon dioxide system is designed for hot gas defrosting, due regard is to be given to the possibility of a higher pressure being imposed on the low pressure system. The design pressure for this section of the system shall be 10 per cent above the maximum pressure experienced during defrosting.

2.6 Insulation

2.6.1 Properties of materials used for thermal insulation are to be verified against known standards for the following parameters, as applicable, to ensure that they are adequate for the intended service. The following test results are to be made available to LR for approval:

- Closed cell content.
- Density.
- Mechanical properties.
- Thermal expansion.
- Abrasion.
- Cohesion.
- Thermal conductivity.

- Resistance to fire and flame spread.
- Ageing.
- Bonding (adhesive and cohesive strength).

2.6.2 Where the *in situ* foam type of insulation is proposed, full details of the process are to be submitted for approval.

2.6.3 Where applicable, having regard to their location and environmental conditions, insulation materials are to be:

- suitably resistant to fire;
- suitably resistant to the spreading of flame;
- adequately protected against penetration of water vapour; and
- adequately protected against mechanical damage.

Section 3 Refrigerating machinery and refrigerant storage compartments

3.1 General

3.1.1 Refrigerating machinery is to be located in a well ventilated compartment. In general, the arrangements are to be such that all components of the refrigerating machinery can be readily opened up for inspection or replacement. Space is to be provided for the withdrawal and renewal of the tubes in 'shell-and-tube' type evaporators (brine coolers) and condensers. Proposals for alternative arrangements are to be submitted for consideration. See 3.2 for refrigerating machinery using ammonia.

3.1.2 Refrigerating machinery using toxic and/or flammable refrigerants is to be located outside the main machinery space in a separate gastight compartment.

3.1.3 Where the refrigerating machinery is located in a separate gastight compartment, outside the main machinery space, this compartment is to be equipped with effective mechanical ventilation to provide 30 air changes per hour based upon the total volume of the space. The mechanical ventilation is to have two main controls, one of which is to be operable from a place outside the compartment.

3.1.4 Refrigerating machinery using non-toxic and non-flammable refrigerants will not, in general, be required to be located in a separate compartment outside the main machinery space.

3.1.5 Openings for pipes, electrical cables and other fittings in the bulkheads and deck are to be fitted with gastight seals.

3.1.6 Ammonia piping is not to pass through accommodation spaces.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 3

3.2 Arrangements for compartments housing machinery using ammonia

3.2.1 Where ammonia refrigerant is used, the refrigerating machinery shall be installed in a dedicated gastight compartment. See also 3.2.9.

3.2.2 The compartment containing ammonia refrigerating machinery and any access ways are to be provided with independent mechanical ventilation capable of:

- removing the heat generated by the equipment installed in the compartment;
- maintaining the atmosphere in the compartment at acceptable vapour threshold levels under normal operating conditions; and
- disposing of ammonia vapour safely and quickly in the event of a major leakage.

3.2.3 The ventilation system is to be of the negative pressure type where abnormal stoppages of the extraction fans activate an audible and visual alarm.

3.2.4 Compartments containing ammonia refrigerating machinery, including process vessels, are to be provided with:

- a negative ventilation system, independent of ventilation systems serving other spaces, having a capacity of not less than 30 air changes per hour based upon the total volume of the space. Other suitable arrangements which ensure an equivalent effectiveness may be considered;
- fresh air inlets, located at a low level in the machinery compartment and arranged so as to provide a supply of fresh air and to minimize the possibility of re-cycling the exhaust air from the outlet;
- exhaust outlets, located at a high level and arranged so as to promote good air distribution throughout the compartment;
- a fixed ammonia detector system with alarms inside and outside the compartment;
- water screens above all access doors, operable manually from outside the compartment in all ambient conditions;
- an independent bilge system;
- where the charge is greater than 50 kg, emergency body shower and eye wash facilities shall be installed locally outside the compartment. The water for the shower is to be thermostatically controlled so as to avoid low temperature shock.

3.2.5 Compartments are to have at least two access doors, opening outwards, one of which is to be an emergency exit giving direct access to the open deck. The doors are to be fitted with an easily operated opening mechanism to facilitate rapid escape in an emergency. In the case of small compartments where more than one door would be impractical, the emergency exit only is to be provided.

3.2.6 At least two sets of self-contained breathing apparatus and protective clothing are to be provided, readily available in the vicinity of the compartment but external to the area of risk. See 8.1.4.

3.2.7 The location of the exhaust duct, from the compartment or area, is to be free from obstruction and be such as not to cause danger. Where practicable, they are to be 10 m, in the horizontal direction from other ventilation intakes and openings to accommodation and other enclosed areas, and at least 2 m above the surrounding deck.

3.2.8 Ventilation fans are not to produce a source of vapour ignition in either the ventilated compartment/area or ventilation system. Ventilation fans and fan ducts, in way of fans only, are to be of non-sparking construction.

3.2.9 In the case of ammonia plants on fishing ships under 55 m overall length, or ammonia plants with a charge of ammonia not greater than 25 kg, the refrigerating machinery may be located in the main machinery space provided it complies with the following requirements:

- The entrance to the machinery space is properly illuminated and marked and has warning signs permanently posted.
- The area where the ammonia machinery is installed is served by a hood with a negative ventilation system, so as not to permit any leakage of ammonia dissipating into other areas.
- A water spray system is provided for the area.
- Coamings, of not less than 150 mm in height, are installed around the ammonia machinery area.
- A fixed ammonia detector system with alarms inside and outside the main machinery space is provided.
- Means are provided for stopping the ammonia compressor prime movers from a position outside the machinery space.
- At least two sets of self-contained breathing apparatus and protective clothing are to be provided readily available in the vicinity of the compartment but external to the area of risk. See 8.1.4.
- Air intakes of other machinery are located away from the ammonia machinery area as far as is practicable.

3.3 Gas storage compartments

3.3.1 Portable steel cylinders containing reserve supplies of refrigerant are to be stored in a well ventilated compartment reserved solely for this purpose.

3.3.2 The compartment is to be provided with a mechanical ventilation system providing 10 air changes per hour and is to have at least one door opening outwards giving direct access to open deck.

3.3.3 Bulk storage tanks holding more than 150 kg of replacement carbon dioxide are to be located in a separate compartment. The compartment is to be provided with a mechanical ventilation system having a minimum capacity of 6 air changes per hour. The ventilation system exhaust ducting is to remove air from the base of the compartment. The compartment is to be fitted with a gas tight access door opening outward.

3.3.4 The compartment is to be provided with a vapour detection system.

Refrigerated Cargo Installations

Part 6, Chapter 3

Sections 3 & 4

3.3.5 The compartment is to be provided with suitable water drainage arrangements not connected with the main machinery spaces.

3.3.6 Steel storage cylinders are to be of an approved type, supplied by the refrigerant manufacturer and are to be filled to a level suitable for an ambient temperature of plus 46°C.

3.3.7 The compartment is to be provided with racks to facilitate secure stowage of the cylinders.

3.4 Compartments housing carbon dioxide containing equipment

3.4.1 Self closing gas tight access doors are to be provided between each compartment and the dedicated escape routes. See 5.1.5.

3.4.2 In compartments which are normally occupied and where the volume of ventilation required by 3.1.3 is not desirable, such as production areas on fishing vessels, a negative pressure ventilation system, capable of 10 air changes per hour, is required to be fitted. This ventilation system is to be automatically activated when, in the event of a leak the concentration of carbon dioxide reaches a predetermined level but in no case higher than the threshold limit value of 5,000 ppm.

4.1.6 A pressure relief valve and/or safety disc is to be fitted between each compressor and its gas delivery stop valve in accordance with 4.15.5 and 4.15.6.

4.1.7 Stop valves are to be provided on compressor suctions and discharges.

4.1.8 Suction strainers and lubricating oil filters are to be provided and so arranged that they are easily accessible for cleaning or renewal of the filter elements, without substantial loss of refrigerant or lubricating oil.

4.1.9 The correct direction of rotation is to be permanently indicated.

4.1.10 Where any hermetic or semi-hermetic compressor has the electric motor cooled by the circulating refrigerant, the following arrangements are to be provided:

- (a) Refrigeration circuits are to contain no more than one hermetic or semi-hermetic compressor.
- (b) Every compressor motor is to be fitted with a thermal cut-out device to protect the motor against overheating.
- (c) In each refrigeration circuit containing a hermetic or semi-hermetic compressor, suitable arrangements shall be provided to remove debris and contaminants resulting from a motor failure. See 4.16.1.
- (d) The pressure envelope of any hermetic or semi-hermetic compressor exposed to the refrigerant pressure is to be designed and constructed in accordance with the requirements of Pt 5, Ch 11 and Ch 17 as applicable. Plans are to be submitted for consideration as required by Pt 5, Ch 11,1.6.

Section 4 Refrigeration plant, pipes, valves and fittings

4.1 General requirements for refrigerating compressors

4.1.1 New compressor types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation.

4.1.2 Where it is proposed to treat the bearing surfaces either by local hardening or by chromium plating, then these processes are to be confined to the bearing area and not extended to the fillets. Particulars of the process are to be submitted.

4.1.3 Where ball or roller bearings are incorporated, they are to have a minimum life expectancy of 25 000 running hours, for the application in question.

4.1.4 A check valve is to be fitted to each compressor discharge.

4.1.5 Where off-loading devices are incorporated, arrangements are to be provided which indicate the extent of the off-loading being effected.

4.2 Reciprocating compressors

4.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

- (a) Carbon and carbon-manganese steel castings – 400 to 550 N/mm².
- (b) Carbon and carbon-manganese steel forgings (normalized and tempered) – 400 to 600 N/mm².
- (c) Carbon and carbon-manganese steel forgings (quenched and tempered) – not exceeding 700 N/mm².
- (d) Alloy steel castings – not exceeding 700 N/mm².
- (e) Alloy steel forgings – not exceeding 1000 N/mm².
- (f) Spheroidal or nodular graphite iron castings – 370 to 800 N/mm².
- (g) Grey iron castings – not less than 300 N/mm².

4.2.2 Where it is proposed to use materials outside the ranges specified in 4.2.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 4

4.2.3 Materials for components of reciprocating compressors such as crankshafts, pistons, piston rods, crank cases, etc., are to be produced at a works approved by LR and in general to be tested in accordance with the Rules for Materials (Part 2).

4.2.4 A fully documented fatigue strength analysis is to be submitted indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue strength criteria. Alternatively, the requirements of 4.2.5 to 4.2.9 may be used.

4.2.5 The diameter, d , of a compressor crankshaft using one of the refrigerants detailed in 2.5, is to be not less than that determined by the following formula, when all cranks are located between two main bearings:

$$d = V_c \left(\frac{D^2 p Z}{78,5} \left(\frac{S}{16} + \frac{ab}{a+b} \right) \right)^{1/3} \text{ mm}$$

where

- a = distance between inner edge of one main bearing and the centreline of the crankpin nearest the centre of the span, in mm
- b = distance from the centreline of the same crankpin to the inner edge of the adjacent main bearing, in mm
- $a + b$ = span between inner edges of main bearings, in mm
- d_p = proposed minimum diameter of crankshaft, in mm
- p = design pressure, in bar g, as defined in 2.5
- D = diameter of cylinder, in mm
- S = length of stroke, in mm
- V_c = 1,0 for shafts having one cylinder per crank, or

$\left. \begin{array}{l} = 1,05 \text{ for } 90^\circ \\ = 1,18 \text{ for } 60^\circ \\ = 1,25 \text{ for } 45^\circ \end{array} \right\}$	between adjacent cylinders on the same crankpin
---	---

 for the shaft and cylinder arrangements as detailed in Table 3.4.1

$$Z = \frac{560}{\sigma_u + 160} \text{ for steel}$$

$$Z = \frac{700}{\sigma_u + 260 - 0,059d_p} \text{ for spheroidal or nodular graphite cast iron}$$

$$Z = \frac{700}{\sigma_u + 260 - 0,069d_p} \text{ for grey cast iron}$$

σ_u = specified minimum tensile strength of crankshaft material, in N/mm².

Table 3.4.1 Angle between cylinders

Number of crankpins	Number of cylinders per crank	Angle between cylinders, in degrees		
1 or 2	2	45	60	90
3	2	45	60	—
4	2	45	60	—
1	3	45	60	90
2	3	45	60	—
3	3	45	—	—
1	4	45	60	—
2	4	45	—	—

4.2.6 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by six per cent for the full length shaft diameter.

4.2.7 The dimensions of crankwebs are to be such that Bt^2 is to be not less than given by the following formulae:

0,4 d^3 , for the web adjacent to the bearing

0,75 d^3 , for intermediate webs

where

B = breadth of web, in mm

d = minimum diameter of crankshaft as required by 4.2.5, in mm

t = axial thickness of web which is to be not less than 0,45 d for the web adjacent to the bearing, or 0,60 d for intermediate webs, in mm.

4.2.8 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius not less than 0,05 d . Smaller fillets, but of a radius not less than 0,025 d , may be used provided the diameter of the crankpin or journal is not less than cd ,

where

$$c = 1,1 - 2 \frac{r}{d} \text{ but to be taken as not less than } 1,0$$

d = minimum diameter of crankshaft as required by 4.2.5, in mm

r = fillet radius, in mm.

4.2.9 Fillets and oil holes are to be rounded to an even contour and smooth finish.

4.2.10 An oil level sight glass is to be fitted to the crankcase.

4.2.11 Compressors with cylinder bores in excess of 50 mm diameter are to be provided with arrangements to relieve high cylinder pressures such as would result from 'hydraulic lock' (i.e. liquid refrigerant in the cylinders). Alternatively the provision of positive means to prevent liquid refrigerant reaching the compressor may be accepted.

4.2.12 The crankcases of trunk piston compressors are to be designed to withstand a pressure equal to the maximum working pressure of the system. The crankcases of compressors of the crosshead type which are substantially isolated from the refrigerant circuit may be designed for lower pressures but are to be provided with relief valves adjusted to lift at a pressure not exceeding the design pressure, and discharging to a safe place.

4.2.13 A crankcase heater, arranged to be energized when the compressor is stopped, is to be provided.

4.3 Screw compressors

4.3.1 For screw-type compressors, the materials of the rotors and casings are to be produced, and the manufacture is to be carried out, at a works approved by LR, and in general, they are to be tested in accordance with the Rules for general machinery forgings.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 4

4.3.2 The rotor casing is to be designed for the maximum pressure to which it may be subjected, see 2.5.

4.3.3 Where gearing is fitted to increase the rotor speed and also to locate the rotors, the gearing is to comply with Pt 5, Ch 5. The manufacturer's maximum allowable tolerances for clearances and backlash between mating rotors are to be stated.

4.4 Pressure vessels and heat exchangers

4.4.1 The term 'pressure vessel' will normally apply to receivers and heat exchangers, and does not include any of the following:

- Compressors.
- Liquid refrigerant pumps.
- Pipes and their fittings.

The use of plate heat exchangers will be specially considered on submission of plans, and special tests may be required.

4.4.2 Fusion welded steel pressure vessels exposed to the pressure of the refrigerants are to be constructed in accordance with the requirements of Pt 5, Ch 11 and Ch 17. Plans are to be submitted for consideration if required by Pt 5, Ch 11,1.6.

4.4.3 Where ammonia is the refrigerant, the pressure vessels are to be constructed to at least Class 2/1 requirements.

4.4.4 Pressure vessels for the containment of primary refrigerants for use in conventional refrigeration circuits where the pressure/saturation temperature relationship applies are not required to be low temperature impact tested unless the design temperature is lower than minus 40°C.

4.4.5 Pressure vessels are to be thermally insulated to an extent which will minimize condensation of moisture from the surrounding atmosphere. The insulation is to be provided with an efficient vapour barrier and adequately protected from mechanical damage. Prior to applying the insulation, the steel surfaces are to be suitably protected against corrosion.

4.4.6 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated is to be protected with overpressure relief devices, see 4.15.

4.5 Condensers, oil coolers and evaporators

4.5.1 In order to minimize the risk of corrosion, where the refrigerant is ammonia, the material interface between the primary refrigerant and cooling water or secondary refrigerant is to be of a suitable grade of stainless steel. Carbon-manganese steel with a suitable inhibitor would also be acceptable.

4.5.2 Space is to be provided for the withdrawal and replacement of condenser and evaporator tubes, see 3.1.1.

4.5.3 Where ammonia is used as the refrigerant, the refrigerating plant is to comply with the following additional requirements:

- (a) Automatic air purgers are to be provided, with their discharges being led through water before venting to atmosphere.
- (b) The cooling water returns from sea-water cooled condensers are not to be led into the main machinery spaces.
- (c) Fresh water condenser cooling systems are to be provided with pH meters to activate audible and visual alarms in the event of an ammonia leak.

4.6 Liquid receivers

4.6.1 Primary refrigerating systems are to be provided with liquid receivers with sufficient capacity to hold the complete refrigerant charge to prevent emission of the refrigerant to the atmosphere during servicing or repairs.

4.6.2 Alternatively, in systems using a secondary refrigerant, with a number of units, smaller receivers may be used provided the system includes a common storage receiver with sufficient capacity to hold at least the primary refrigerant charge from two units. The common receiver is to be provided with the necessary crossover connections to facilitate transfer of refrigerant to and from each unit in the system.

4.7 Oil separators

4.7.1 Oil separators are to be provided at compressor discharges and are to be fitted with a control arrangement to enable the separated oil to be returned to the compressor crankcase. Wire gauze used in separators is to be sufficiently robust and well supported.

4.8 Air coolers and cooling grids

4.8.1 Refrigerated spaces may be cooled by air coolers or cooling grids on the ceiling, bulkheads and sides. In order to minimize the dehydration of the cargo and the frosting of the air coolers or cooling grids, the installation is to be designed to maintain the required notation temperatures with a minimum of difference between the refrigerant and space temperatures.

4.8.2 Individual spaces are to have a minimum of two independent air coolers, each comprising one or more fans and one or more refrigerant circuits in a single casing and with isolating valves. Alternatively, multiple circuits each with their own fan(s), in a single cooler casing may each be regarded as a separate cooler, provided stop valves are fitted so that each circuit may be isolated.

4.8.3 For refrigerated spaces having a net volume of 300 m³ or less, a single cooler with one circuit will be accepted.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 4

4.8.4 The refrigeration capacity of the air cooler arrangement is to be such that the notation temperature conditions can be maintained with any one independent cooler or circuit out of action. The capacities of the fans are also to be such that they can maintain the required air flow rates (see also 9.4) and uniform air temperature throughout the refrigerated spaces, when part or fully loaded with cargo, with any one cooler or fan out of action.

4.8.5 Air cooler fan motors are to be suitably enclosed to withstand the effects of moisture.

4.8.6 Means are to be provided for effectively defrosting air coolers. Air coolers are to be provided with trays of suitable depth arranged to collect all condensate. The trays are to be provided with drains at their lowest points to enable the condensate to be drained away when the refrigerated spaces are in service. Provision is to be made for the prevention of freezing of the condensate.

4.8.7 Air coolers are to be located such that when the refrigerated spaces are loaded with cargo, adequate space is provided for the inspection, servicing and renewal of controls, valves, fans and fan motors.

4.8.8 The cooling grids in each refrigerated space are to be arranged in not less than two sections, and each section is to be fitted with valves so that it can be shut off. The notation temperature conditions are to be capable of being maintained with any one section isolated. For spaces having a net volume of 300 m³ or less, a single section will be acceptable.

4.8.9 Steel air cooler circuits and cooling grids are to be suitably protected against external corrosion.

4.9 Refrigerant pumps

4.9.1 Pumped primary and/or secondary refrigerant systems are to have a minimum of two pumps. Each pump is to be capable of operating on all cargo chambers and maintaining full duty with any one pump out of operation.

4.9.2 Primary and, where appropriate, secondary refrigerant pumps are to be provided with pressure relief valves, see 4.15.13.

4.10 Condenser cooling water pumps

4.10.1 At least two separate condenser cooling water pumps are to be installed. One of the pumps may be considered as a standby pump and may be used for other purposes, provided that it is of adequate capacity and its use on other services does not interfere with the supply of cooling water to the condensers.

4.10.2 Not less than two sea inlets are to be provided supplying sea-water to the pumps for condenser cooling. It is recommended that one of the sea inlets be provided on the port side and the other on the starboard side. The sea inlets are to be fitted in accordance with Pt 5, Ch 13,2.6.

4.10.3 The cooling water pumps and sea inlets are to be suitably valved and cross-connected with each condenser.

4.10.4 Suitable spring-loaded safety valves are to be provided in each cooling water circuit, see 4.15.13.

4.11 Piping systems

4.11.1 All piping, valves and fittings are to be suitable for the maximum pressure to which the system can be subjected and are to comply with the requirements of Pt 5, Ch 12.

4.11.2 Pipework for ammonia (R-717) is to comply with Class I requirements.

4.11.3 In addition to visual examination of pipe welds, non-destructive examination of pipe welds is to be carried out in accordance with the requirements of Pt 5, Ch 17,10.2, to the satisfaction of the Surveyors.

4.11.4 All steel pipework on the low temperature part of the system is to be protected against external corrosion. Protective coatings are to be removed from pipe surfaces to a distance of not less than 50 mm either side of the joint weld preparations prior to welding. On completion of welding and testing a protective coating is to be applied.

4.11.5 Where brine is the secondary refrigerant, piping and tanks should not be galvanized on the brine side. If any parts of the brine system have been galvanized, the brine cooling and return tanks are to be provided with a ventilating pipe or pipes led to the atmosphere in a location where no damage will arise from the gas discharged. The ventilation pipes are to be fitted with wire gauze diaphragms which can be readily renewed.

4.11.6 Copper piping is to be manufactured in accordance with Pt 5, Ch 12,3 except in the case of small air coolers having finned pipes of sizes not greater than 19 mm outside diameter, and which have been fabricated under workshop conditions. The finned pipes may have a minimum wall thickness of 0,5 mm when used with R-22 and R-134a refrigerants.

4.11.7 Where the use of plastics pipe is proposed in a secondary refrigerant system (e.g. brine), it is to be in accordance with Pt 5, Ch 12,5.

4.11.8 Pipelines are to have ample provision for expansion and contraction in service conditions. In general, expansion bends are to be used for this purpose. However, the use of metallic expansion bellows will be accepted provided test data is produced showing satisfactory strength and fatigue properties under the appropriate conditions.

4.11.9 All pipelines are to be fully supported and secured so as to prevent vibration. Flexible hoses may be used, where necessary, to prevent transmission of vibration provided the documentation in 4.11.8 is provided. Flexible hoses are to be of a type which has been approved by LR, see Pt 5, Ch 12,6.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 4

4.11.10 Pipework, which may contain low temperature refrigerant, except within secondary refrigerant cooler rooms, is to be thermally insulated to an extent which will minimize condensation of moisture. Insulation in pre-formed sections is recommended. If *in situ* foamed insulation is employed, pre-production testing on site is to be carried out to the satisfaction of the Surveyor, using a 'mock-up' representative of the system to be employed.

4.11.11 All pipe insulation is to be provided with an efficient vapour barrier, care being taken to ensure that it is not interrupted in way of supports, valves, etc. Also adequate protection of insulation surfaces from mechanical damage is to be provided.

4.11.12 Where refrigerating piping is embedded in the cargo chamber insulation, the locations of the pipe joints are to be marked on the outside of the insulation lining.

4.12 Joints

4.12.1 Butt welded pipe joints are to be employed as far as practicable. Socket welded pipe joints are acceptable up to 25 mm diameter. Flanged or other joints are to be kept to a minimum and, in general, are to be restricted to connections with items of machinery or components which may have to be removed for maintenance purposes. Connections to valves are normally to be welded unless they are of a type, or in a position, which precludes *in situ* maintenance.

4.12.2 Pipe connections to fittings (e.g. gauge lines, level controls) which are likely to be subjected to heavy corrosion, are to be of heavy gauge construction, or be made from suitable corrosion resistant materials.

4.13 Liquid level indicators

4.13.1 Where liquid level indicators of the 'see-through' variety are used they are to be of the flat plate type incorporating glass (or equivalent material) of heat resistant grade.

4.13.2 All level indicators are to be provided with automatic shut-off devices and isolating valves. Plate-type sight glasses which form an integral part of the component in which they are mounted (e.g. compressor crankcases, pressure vessels) are exempt from this requirement.

4.13.3 All level indicators are to be suitable for the system maximum working pressure and tested accordingly.

4.14 Automatic expansion valves

4.14.1 Refrigerating systems with automatic expansion valves are also to be provided with efficient hand expansion valves and the arrangement is to be such that the automatic expansion valves can be by-passed and isolated.

4.14.2 As an alternative, duplicate automatic expansion valves may be fitted, each valve to be capable of the required duty and operable with the other out of action.

4.15 Overpressure protection devices

4.15.1 Refrigeration systems are to be provided with relief devices, but it is important to avoid circumstances which would bring about an inadvertent discharge of refrigerant to the atmosphere. The system is to be so designed that pressure due to fire conditions will be safely relieved.

4.15.2 Pressure relief devices are to be mounted in such a way that it is not possible to isolate them from the part of the system which they are protecting except that, where duplicated, a changeover valve may be fitted which will allow either device to be isolated for maintenance purposes without it being possible to shut off the other device at the same time.

4.15.3 Relief discharge is to be led to a safe place above deck away from personnel accesses and air intakes. Discharge piping should be designed to preclude ingress of water, dirt or debris which may cause the equipment to malfunction.

4.15.4 For ammonia systems, discharge from relief valves is to be led through water before venting to the atmosphere. Vapour detectors are to be provided in the discharge pipes to activate audible and visual alarms in the event of a leakage of ammonia.

4.15.5 A pressure relief valve and/or bursting disc is to be fitted between each positive displacement compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. The flow capacity of the valve or disc is to exceed the full load compressor capacity on the particular refrigerant at the maximum potential suction pressure. For these internal relief valves, servo-operated valves will be accepted. Where the motive power for the compressor does not exceed 10 kW, the pressure relief valve and/or bursting disc may be omitted.

4.15.6 Compressors protected by bursting discs are to be provided with automatic shutdown in the event of high discharge temperatures.

4.15.7 Each compressor is to be provided with automatic shutdown in the event of high discharge pressure. For refrigeration systems where the maximum working pressure is less than or equal to 40 bar g the automatic shutdown is to operate at a pressure in excess of normal operating pressure but no greater than 0,9 of the maximum working pressure. For refrigeration systems where the maximum working pressure is greater than 40 bar g the automatic shutdown is to operate at a pressure in excess of normal operating pressure but no greater than 0,95 of the maximum working pressure.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 4

4.15.8 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated by means of stop or automatic control or check valves is to be protected by two pressure relief valves or two bursting discs, or one of each, controlled by a changeover device.

4.15.9 Pressure vessels which are interconnected by pipework without valves, so that they cannot be isolated from each other, may be regarded as a single pressure vessel for this purpose, provided that the interconnecting pipework does not prevent effective venting of any vessel.

4.15.10 Omission of one of the specified relief devices and the changeover device, as required by 4.15.8, will be allowed where:

- vessels are of less than 300 litres internal gross volume; or
- vessels discharge into the low pressure side by means of a relief valve.; or
- vessels operating using only cargo gas and, which can be independently isolated and gas freed during normal cargo operations provided that a shelf spare is carried.

4.15.11 Sections of systems and components which could become full of liquid between closed valves are to be provided with pressure relief devices relieving to a suitable point in the refrigerant circuit.

4.15.12 Refrigerant pumps are to be provided with pressure relief valves on the discharge side, which may relieve to the suction side, or to another suitable location.

4.15.13 Suitable spring-loaded safety valves are to be provided on the cooling liquid side of condensers and the brine side of evaporators where the pressure from any pump or expansion of the liquid in the circuit could exceed the design pressure of the system or any component forming part of the cooling system.

4.15.14 Relief valves are to be adjusted and bursting discs so selected that they relieve at a pressure not greater than the design pressure of the system, as defined in 2.5.

4.15.15 When satisfactorily adjusted, relief valves are to be protected against tampering or interference by a wire with a lead seal or similar arrangement.

4.15.16 Valves which are arranged to discharge to the low pressure side of the system are to be substantially independent of back pressure and are to be of a type which has been approved by LR.

4.15.17 The minimum required discharge capacity related to air of the pressure relief device for each pressure vessel is to be determined as follows:

$$C = D L f$$

where

- C = minimum required discharge capacity related to air of each relief device, in kg/s
- D = outside diameter of the vessel, in metres
- L = length of the vessel, in metres

f = factor which is dependent on the refrigerant:

R-717 (Ammonia)	0,041
R-22, R-134a, R-407C	0,131
R290 (Propane), R-600a (Isobutane)	0,082
R-410A, R-404A, R-507A	0,203
R-744 (Carbon dioxide)	
(when used on the low side of a cascade system)	0,082

4.15.18 The rated discharge capacity of the pressure relief valves expressed in kg/s of air may also be determined in accordance with an appropriate recognised National or International Standard such as *ISO 5149 Mechanical Refrigeration Systems used for Cooling and Heating – Safety Requirements*.

4.15.19 The rated discharge capacity of a bursting disc discharging to atmosphere under critical flow conditions is to be determined by the following formula:

$$d = 857,5 \sqrt{\frac{C}{P}} \text{ mm}$$

where

- d = minimum diameter of free aperture of bursting disc, in mm
- C = minimum required air equivalent discharge capacity, in kg/s, see 4.15.17
- P = 1,1 x maximum working pressure, see 2.5.

4.15.20 The bore of the discharge pipe shall be at least the same bore as the relieving device outlet. The size of a common discharge line serving two or more pressure relieving devices which may discharge simultaneously shall be based on the sum of their outlet areas. Where discharge lines are long or where the outlets of two or more pressure relieving devices are connected into a common line, the discharge piping shall be sized such that the back pressure at full relief rate does not exceed 10 per cent of the relief valve set pressure.

4.15.21 Due account is to be taken of the reaction force on a relief valve or on discharge piping during discharge and adequate support provided.

4.15.22 As carbon dioxide can form a solid powder at atmospheric pressure, there is a possibility that relief devices will choke if vented directly to atmosphere. The method used to guard against the formation of powder is to be submitted for consideration.

4.15.23 In carbon dioxide systems, overpressure protection is to be fitted to pipelines or components which can be isolated in a liquid full condition. Pressure relief devices are to be arranged such as to vent vapour at all times.

4.15.24 In cascade systems where carbon dioxide is used in combination with ammonia, the effects of carbon dioxide leaking into the ammonia side are to be considered. It may be desirable to design the ammonia system to either withstand the design pressure on the carbon dioxide side or have relief arrangements to safely deal with the additional vapour produced if a leak occurs.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 4

4.16 Filters, driers and moisture indicators

4.16.1 Suitable filters are to be provided in the refrigerant gas lines to compressors and in the liquid lines to refrigerant flow controls. Wire gauze used in filters is to be sufficiently robust and well-supported. A filter may be combined with the oil separator required by 4.7.1. Stop valves are to be provided to allow for servicing of filters. After first commissioning of the system, the filters should be examined to confirm that elements remain intact and not collapsed.

4.16.2 Refrigerant filters, driers and moisture indicators are to be fitted in halocarbon refrigerant systems, and the arrangement is to be such that filters and driers can be bypassed, isolated and opened up without interrupting plant operations.

4.17 Purging devices

4.17.1 Where the operating pressure of the low pressure system may be below atmospheric, a purging device is to be provided, the discharge from which is to be led to a safe place above deck.

4.18 Piping in way of refrigerated spaces

4.18.1 All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C or below, are to be not less than 65 mm bore. The pipework is to be in accordance with the requirements of Pt 5, Ch 12 and Pt 5, Ch 13,2.9.

4.18.2 Sounding pipes to oil compartments are not to terminate within refrigerated spaces or in their air cooler spaces, nor are these pipes to terminate in enclosed spaces from which access is provided to refrigerated spaces or their air cooler spaces.

4.18.3 All pipes, including scupper pipes, air pipes and sounding pipes that pass through refrigerated spaces are to be insulated.

4.18.4 Where the pipes referred to in 4.18.3 pass through chambers intended for temperatures of 0°C or below, they are also to be insulated from the steel structure, except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deck plate within the ship side insulation, where the deck is fully insulated below and has an insulation ribband on top, are to be attached to the deck plating. In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be avoided so far as practicable.

4.18.5 The air refreshing pipes to and from refrigerated spaces need not, however, be insulated from the steelwork.

4.19 Drainage from refrigerated spaces

4.19.1 Provision is to be made for the continuous drainage of the inside of all refrigerated spaces and cooler trays. The pipework is to be in accordance with the requirements of Pt 5, Ch 12 and Pt 5, Ch 13,3.2.

4.19.2 All drain pipes from the refrigerated spaces and cooler trays are to be fitted with liquid sealed traps, which are to be of adequate depth and readily accessible for cleaning and refilling with brine. The pipes from lower spaces situated on the tank tops are also to be fitted with bilge non-return valves.

4.19.3 Where drains from separate refrigerated spaces join a common main, the branch pipes are each to be provided with a liquid sealed trap.

4.19.4 Sluices, scuppers or drain pipes which would permit drainage from compartments outside the refrigerated spaces into the bilges of the latter, are not to be fitted.

4.19.5 Screwed plugs or other means for blanking off scuppers, draining chambers and cooler trays are not to be fitted. If, however, it is specially desired to provide means for temporarily closing these scuppers, they may be fitted with shut-off valves.

4.20 Corrosion protection of metal fixtures

4.20.1 All steel bolts, nuts, hangers, brackets and fixtures which support or secure cooling appliances, piping insulation, meat rails, linings and prefabricated insulated panels, etc., are to be suitably protected against corrosion.

4.21 Pressure testing at manufacturers' works

4.21.1 Components intended for use with a primary refrigerant are to be subject to strength and leak pressure tests as detailed in Table 3.4.2.

Table 3.4.2 Test pressure

Component	Test pressure, bar g	
	Strength test	Leakage test
1. Pressure vessels	See Pt 5, Ch 11	1,0p
2. Compressor cylinders/ crankcase/casing	1,5p	1,0p
3. Valves and fittings	2,0p	1,0p
4. Pressure piping, fabricated headers, air coolers, etc.	1,5p	1,0p
NOTE p is the design pressure as defined in 2.5.		

4.21.2 Component strength pressure tests are to be hydraulic or where suitable safety measures are taken, may be pneumatic. The latter is to be carried out with a suitable dry inert gas.

Refrigerated Cargo Installations

Part 6, Chapter 3

Sections 4, 5 & 6

4.21.3 Component leakage pressure tests are to be carried out only after completion of satisfactory strength pressure tests. Pneumatic pressure is to be applied using a suitable dry inert gas.

4.21.4 Components for use with a secondary refrigerant or cooling water are to be hydraulically tested to 1,5 times the design pressure, but in no case less than 3,5 bar g.

4.22 Pressure test after installation on board ship

4.22.1 For primary refrigerant piping welded in place, strength pressure tests of the welds are to be carried out at a test pressure of 1,5p. This will normally take the form of a pneumatic test since hydraulic testing media such as water are not acceptable due to their incompatibility with the primary refrigerants and the difficulty of removing all traces from a completed system.

4.22.2 Pneumatic pressure tests are to be carried out using a suitable inert gas. All pneumatic tests are potentially dangerous and due precautions are to be observed.

4.22.3 Where pneumatic tests are prohibited by relevant authorities, the tests required by 4.22.2 may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out with satisfactory results on the entire circumference of all butt welds not tested in accordance with 4.11.3. Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the service performance of the piping.

4.22.4 After completion of the test required by 4.22.1, 4.22.2 or 4.22.3, a leak pressure test is to be carried out using a suitable inert gas at a pressure equal to the design pressure, in the presence of the Surveyor.

4.22.5 Secondary refrigerant piping welded in place is to be hydraulically tested to 1,5 times the design pressure, but in no case less than 3,5 bar g.

5.1.3 Detection equipment is to be so designed that it may be readily tested and calibrated, and failure of the equipment is to initiate an alarm.

5.1.4 The location of the detectors is to be determined relative to the layouts of the individual compartments and machinery spaces and are to be indicated on the plan submission.

5.1.5 For carbon dioxide systems, spaces such as machinery rooms, storage compartments, production areas on fishing vessels and valve stations, where leakage may occur, are to be fitted with detectors. Welded pipelines passing through passageways or access ducts are not considered possible leakage areas.

5.1.6 Audible and visual alarms are to be activated, located both inside and outside the affected space. The alarms are to be readily identifiable and be visible and audible in all locations within the space housing the refrigeration equipment.

5.2 Ammonia vapour detection and alarm equipment

5.2.1 A fixed detector system for ammonia is to comply with the requirements contained in 5.1.2.

5.2.2 The location of the detectors is to be determined relative to the layouts of the individual spaces and are to be indicated on the plan submission required by 1.2.

5.2.3 Ammonia vapour detectors are to be provided in the refrigeration machinery compartment, associated access ways, the exhaust ducts, the ammonia store room and the discharge pipes from pressure relief valves.

5.2.4 Sufficient detectors are to be provided to monitor the total areas of the above spaces.

5.2.5 For vapour detection in relief valve discharge pipes, see 4.15.4.

5.2.6 Details of the refrigerant detector set points and operational philosophy are to be submitted for consideration.

Section 5 Refrigerant detection systems

5.1 General

5.1.1 A fixed refrigerant detection system is to be provided in the refrigerating machinery compartment or space, the discharge pipes from pressure relief valves, ventilation outlet ducts, and the cargo chambers, where appropriate.

5.1.2 The alarm system is to comply with the requirements of Chapter 1 and, as a minimum requirement, the system is to activate at a low-level concentration to give warning of refrigerant leaks, and a high-level concentration corresponding to the refrigerant's safe occupational level.

Section 6 Electrical installation

6.1 General

6.1.1 Where the refrigerating machinery is to be electrically driven, the requirements of Ch 2,2 are to be complied with, as applicable.

Refrigerated Cargo Installations

Part 6, Chapter 3

Sections 6 & 7

6.1.2 The generating capacity available for the refrigerated installation is to be sufficient to supply power to the installation during cooling down of a complete cargo to, and maintenance of, the notation temperature conditions in all refrigerated spaces at the Rule maximum ambient and sea-water temperatures.

6.1.3 Electrical equipment is not to be installed in spaces in which ammonia refrigerant is used or stored unless it is essential for operational purposes. Where electrical equipment is installed in such spaces the requirements of 6.2 are to be complied with.

6.2 Electrical equipment for use in explosive gas atmospheres

6.2.1 Lighting fittings are to be of a certified safe-type and be arranged on at least two independent final branch circuits. Switches and protective devices are to interrupt all lines or phases and are to be located outside the space.

6.2.2 Where electric motors driving ventilation fans are located within the spaces, within ventilation ducts, or within three metres of ventilation openings, they are to be of a certified safe-type.

6.2.3 Monitoring control and alarm systems which are required to operate under conditions of ammonia leakage are to be of a certified safe-type.

6.2.4 Electrical equipment which is not of a certified safe-type is to de-energize automatically if the ammonia concentration within the space exceeds 1,0 per cent by volume.

■ Section 7 Instrumentation, control, alarm, safety and monitoring systems

7.1 Instrumentation

7.1.1 All compressors are to be provided with the following instrumentation and automatic shutdowns:

- Indication of suction pressure (saturated temperature), including intermediate stage, when applicable.
- Indication of discharge pressure (saturated temperature), including intermediate stage, when applicable.
- Indication of lubricating oil pressure.
- Indication of cumulative running hours (screw compressors).
- Automatic shutdown in the event of low lubricating oil pressure.
- Automatic shutdown in the event of high discharge pressure, see also 4.15.7.
- Automatic shutdown in the event of low suction pressure.

7.1.2 The automatic safety equipment is to be designed to fail safe and the arrangements are to be such that the compressors can be operated manually with the equipment out of action, in accordance with the relevant requirements of Chapter 1.

7.1.3 For installations greater than 25 kW the following instrumentation, additional to that required by 7.1.1, is to be provided:

- Indication of lubricating oil temperature.
- Indication of cooling water outlet temperature.
- Indication of cumulative running hours (reciprocating compressors).
- Indication of suction and discharge temperatures.

7.2 Control, alarm and safety systems

7.2.1 Where the refrigerating system is fitted with automatic or remote controls, so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms required by 7.2.2 and 7.2.3 in accordance with the relevant requirements of Chapter 1.

7.2.2 Alarms are to be initiated in the event of the following compressor fault conditions:

- High discharge pressure.
- Low suction pressure.
- Low oil pressure.
- High discharge temperature.
- High oil temperature.
- Motor shutdown.

7.2.3 Alarms are also to be initiated in the event of the following fault conditions:

- Failure of condenser cooling water pumps.
- High condenser cooling water outlet temperature.
- Failure of air cooler fans.
- High and low refrigerated air delivery temperatures.
- High secondary refrigerant temperatures.
- Failure of secondary refrigerant pump.
- Failure of air refreshing fans.
- Low level in secondary refrigerant header tank.

7.3 Temperature monitoring and recording

7.3.1 Temperature sensors are to be of a type which has been approved by LR. The number of sensors and their locations are to be such as to give a true measurement of the temperatures within the refrigerated spaces and of the cooler delivery and return air temperatures.

7.3.2 At least one automatic recorder is to be provided for the remote monitoring and continuous recording of air temperatures within the refrigerated spaces, and delivery and return air temperatures of individual air coolers. Where only one recorder is installed, at least one sensor in each refrigerated space or in its air distribution system is to be connected to a separate remote temperature indicating instrument.

Refrigerated Cargo Installations

Part 6, Chapter 3

Sections 7 & 8

7.3.3 Where the equipment controlling the temperature of the air delivered from the air coolers is equipped with a temperature indicator, this indicator will be given consideration as a standby instrument.

7.3.4 In the case of freezer fishing vessels, where the catch is frozen on board and stored in a refrigerated space, thermometer(s) hung within each space(s) will be accepted as the standby temperature indicator, provided the space is accessible at all times.

7.3.5 Automatic temperature recorders and temperature indicators are to be of a type which has been approved by LR and, where appropriate, are to be in accordance with the requirements of Pt 6, Ch 1. Approval will be granted on the basis of compliance with 7.3.6 and 7.3.7, together with satisfactory environmental testing in accordance with the requirements of LR's Type Approval System. This is to include low temperature testing at the class notation minimum temperatures for any components which may be installed in environments subject to temperatures below ambient.

7.3.6 All temperature instrumentation is to be accurate to within $\pm 0,15^{\circ}\text{C}$ of the true temperature in the range minus 3°C to plus 15°C , and to $\pm 0,3^{\circ}\text{C}$ in other parts of the range and is to register to 0,1 of a degree Celsius.

7.3.7 Where the installation is intended for the carriage of frozen cargo only, the readings need only be accurate to within $\pm 0,5^{\circ}\text{C}$ of the true temperature, throughout the range.

7.3.8 A spirit-in-glass thermometer is to be carried on board for checking purposes, which is to be calibrated to a recognized National Standard.

7.3.9 Thermometer tubes with their flanges and covers are to be insulated from the deck plating, and on weather decks they are to be so arranged that water will not run down the tubes when temperatures are being taken.

7.3.10 The inside diameter of thermometer tubes is to be not less than 50 mm, and the tubes are not to be in contact with cold decks.

7.3.11 Where thermometer tubes pass through compartments other than those which they serve, they are to be efficiently insulated.

Section 8 Personnel safety equipment and systems

8.1 Personnel safety equipment

8.1.1 Access doors and hatches to the refrigerated spaces and air cooler spaces are to be provided with an external locking arrangement.

8.1.2 Access ways to the refrigerated space are to be designed to facilitate escape in emergencies, and the removal of stretcher-borne personnel.

8.1.3 Access ways and air cooler spaces are to be provided with an independent lighting system in accordance with the requirements of Ch 2,5.7.2 and Ch 2,5.7.4, with the means of locking the switches in the 'on' position.

8.1.4 Where ammonia is used in refrigerating systems, the following items of safety equipment are to be provided as a minimum, and positioned in accessible protected storage (e.g. locked glass fronted cabinets) located outside the machinery compartment:

- Two sets of ammonia protective clothing (including helmet, boots and gloves).
- Two portable battery powered hand lamps (to be of certified safe-type).
- Two sets of self-contained breathing apparatus (compressed air).
- Two full face mask respirators.
- Two fire-resistant life-lines.
- Two firemen's axes.
- Two heavy duty adjustable spanners.
- Two wheel wrenches.
- Irrigation facilities or eye wash bottles containing an eye wash solution, distilled water or non-carbonated mineral water.
- Hand or foot-operated douches providing a copious supply of clean water, located outside the compartment's doors. See 3.2.4.

8.2 Personnel warning systems

8.2.1 A system to monitor the well-being of crew members entering refrigerated spaces is to be provided.

8.2.2 The system is to be such that at a predetermined time, after initiation, the crew member(s) receives warning that the Surveyors must indicate their well-being by accepting the warning.

8.2.3 The system is to be designed and arranged such that only an authorized person has access for enabling and disabling it and setting the appropriate intervals, and such that it cannot be operated in an unauthorized manner.

8.2.4 It is to be possible to acknowledge the warning by means of illuminated switches situated near the access doors or hatches of each refrigerated space or chambers within the space.

8.2.5 In the event that the crew member(s) fail(s) to respond and accept the warning within an agreed specified time, the system is to immediately initiate an alarm on the bridge and in the engineers' accommodation. Manual initiation of the alarm system from the refrigerated spaces is to be possible at any time.

8.2.6 The system is to comply with the relevant requirements of Chapter 1.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 9

■ Section 9 Refrigerated cargo spaces

9.1 Airtightness of refrigerated spaces

9.1.1 The envelopes of individual refrigerated spaces, enclosing each temperature zone, are to be sufficiently airtight to prevent infiltration of water vapour and cross-contaminating odours. Each envelope is to be hose-tested for tightness before the insulation is installed. Alternative proposals to test with gas or air under pressure will be considered.

9.1.2 Hatch closing appliances, access doors, side loading doors, bilge and manhole plugs forming part of an insulated envelope are to be made airtight and, where exposed to ambient conditions, are to be provided with a double seal.

9.1.3 Ventilators, ducts or pipes passing through refrigerated spaces to other compartments are to be made airtight and efficiently insulated. Particular attention is to be given to insulation linings forming surfaces of air ducts. Ventilators to refrigerated spaces, if fitted, are to be provided with airtight closing appliances.

9.1.4 Refrigeration pipes passing through bulkheads or decks of refrigerated chambers or spaces are not to be in direct contact with the steelwork. The temperature of the ship's steelwork close to low temperature refrigeration piping must not be lower than that acceptable for the steel grade, see also Pt 3, Ch 2.2.2. The airtightness of the bulkheads and decks is to be maintained and, where the pipes pass through watertight decks and bulkheads, the fittings and packing of the glands are to be both fire resisting and watertight.

9.2 Insulation systems

9.2.1 Steelwork and fittings are to be clean and dry, and suitably coated to prevent corrosion, before insulation is applied.

9.2.2 *In situ* insulation and insulating panels are to be of a type that has been approved by LR and accordingly, whenever practicable, be selected from the *List of Type Approved Products* published by LR. A copy of the *Procedure for LR Type Approval System* will be supplied on application. Prefabricated panels, with an organic foam core and metal or similar cladding both sides, are also to be manufactured under survey at a works approved by LR. Organic foam materials are to be certified as self-extinguishing. All materials are to be free from odour likely to cause taint.

9.2.3 The thickness of insulation over all surfaces and the manner in which it is supported are to be in accordance with the approved specification and plan.

9.2.4 The insulation is to be efficiently packed and, where it is of slab form, the joints are to be butted closely together and staggered. Where it is intended to use a foamed *in situ* type of insulation, full details of the process are to be submitted for approval before the work commences and pre-production testing on site is to be carried out to the satisfaction of the Surveyor, using a 'mock-up' representative of the system to be employed. Prefabricated panels are to be of a design such that, when erected, continuity of the insulation envelope is maintained without any gaps. Gaps between panels or insulation slabs are to be filled with insulating material to the satisfaction of the Surveyor.

9.2.5 The inner surfaces of insulation envelopes are to be clad with a suitable lining, such as marine grade aluminium or plywood, or equivalent material which is:

- impermeable;
- able to withstand wear and tear and the flexing of the ship's structure without fracture at the notation temperatures;
- non-corrosive, non-rotting; and
- free from odour likely to cause taint.

Where prefabricated panels are employed the outer surfaces are also to be clad with a suitable lining.

9.2.6 Insulation linings are to be constructed and fitted so that they are airtight and provide an effective vapour barrier. The means of joining prefabricated panels are to have sufficient mechanical strength to maintain a vapour barrier on the inner and outer faces. All joints, including corner, deck, deckhead and tank top intersections are to be sealed with a suitable flexible, water vapour resistant sealant or gasket. Special care is necessary where air ducts are embedded in the insulation, and where refrigeration pipes, air refreshing ducts, fan supports, fixtures, etc., protrude through the linings.

9.2.7 Hatch covers and plugs, access doors, manhole plugs, bilge limbers and plugs forming part of the insulated envelope are to be constructed of, or covered with, a suitable lining material.

9.2.8 Insulation linings and air screens, together with supports, are to be strong enough to withstand the loads imposed by either refrigerated or general cargo.

9.2.9 Successive coatings impervious to oil are to be applied before insulating the exposed plating of tank tops and bulkheads protecting tanks containing oil. The total thickness of the required coating will depend on the construction of the tank, the composition of the coating used and the method of application.

9.2.10 If the cargo to be loaded on the tank top insulation could cause damage to the lining, then additional protection is to be provided in way of the hatch and 0,6 m beyond. The protection may be of either a permanent or temporary nature.

Refrigerated Cargo Installations

Part 6, Chapter 3

Sections 9 & 10

9.2.11 Where the insulation is to support fork lift trucks, the strength of the lining and its supports is to be demonstrated. A sample of the insulation, approximately 4 m x 4 m, is to be prepared and tested by a fully loaded fork lift truck with a gross weight of 6,5 tons on one axle with a wheel pitch of 1450 mm, having single wheeled pneumatic tyres. The truck is to be driven and manoeuvred over the sample to the satisfaction of the Surveyors.

9.2.12 Prefabricated panel systems are to be fitted with suitable pressure equalizing devices to prevent damage which may be caused by under or over pressure resulting from the defrosting of coolers, rapid changes in pressure on the inner and outer faces of the panels or rapid cooling of the chamber.

9.2.13 The pressure equalizing devices are to be so designed as to allow the passage of air in either direction, but remain effectively closed until the pressure differential reaches a value of 10 mm water column. Heating is to be provided to protect the mechanism from freezing.

9.3 Access plugs and panels

9.3.1 Insulated plugs are to be provided in the insulation where required for easy access to the bilges, bilge suction strum boxes, cooler and chamber drains and tank manhole lids. Removable panels are to be provided for access to tank air and sounding pipes and drains.

9.3.2 Tank top insulation in way of manholes and bilge hats is to be provided with a liquid-tight steel coaming to prevent seepage into the insulation.

9.3.3 Manholes are not permitted in the bulkheads of fuel oil tanks which form part of the cargo space envelope.

9.4 Air circulation and distribution

9.4.1 When frozen cargo is carried, provision is to be made for the adequate circulation of air between the frozen cargo and all the insulation lining surfaces.

9.4.2 When cooled cargo is carried, of a type which may generate heat or emit gas, provision is to be made for the adequate circulation of air through all the stow.

9.4.3 There is to be adequate air flow between cargo and cooling grids, where fitted.

9.4.4 The air distribution arrangements are to be such that the required circulation rate and uniform distribution can be achieved when the space is part or fully loaded with cargo. The arrangement is also to be capable of maintaining uniform air temperature throughout the space with any one fan, or air cooler, or cooling grid circuit out of action, see 4.8.

9.5 Air refreshing arrangements

9.5.1 Where spaces are intended for the carriage of refrigerated cargoes requiring controlled ventilation, means are to be provided for air refreshing. The positions of the air inlets are to be carefully selected to minimize the possibility of contaminated air entering the spaces. Chambers or spaces are to be provided with separate inlet and discharge vents. Each vent is to have a positive airtight valve capable of closing onto a seat. It is recommended that a distance of at least 3 m is maintained between inlet and exhaust vents.

9.6 Heating arrangements for fruit cargoes

9.6.1 Where the class notation includes the symbol ‡ for the carriage of fruit cargoes, facilities for heating the refrigerated spaces are to be provided to maintain the carrying temperatures when the temperatures outside the spaces are lower.



Section 10

Container ships fitted with refrigerating plant to supply cooled air to insulated containers in holds

10.1 General

10.1.1 Classed installations designed to supply refrigerated air to insulated 'porthole' containers in holds aboard container ships are to comply with the requirements of Sections 1 to 9 and 11, so far as they are applicable, and the special requirements of this Section.

10.1.2 The classed refrigerating installation is to include the refrigerating machinery, air coolers, supply and return air ducting, and the flexible couplings between containers and the duct system. Where the arrangements are such that cell air conditioning is essential to the carriage of the containers, the air conditioning equipment and (if fitted) the insulation of the hold, deckheads, sides and tank tops are to be included in the classification.

10.2 Additional information and plans

10.2.1 In addition to those requirements detailed in Section 1 which are also applicable to refrigerated container ships, the following information is to be submitted before the work commences:

- Details of air coolers.
- Details of the design of ducting proposed, including joints, connections, insulation, vapour sealing and linings.
- Details of cell air conditioning arrangements and components.
- Details of couplings between ducting and containers, including operating arrangements.

Refrigerated Cargo Installations

Part 6, Chapter 3

Sections 10 & 11

10.3 Air coolers

10.3.1 Air ducts supplying more than ten standard 20 ft containers or five standard 40 ft containers are to have a single air cooler with multiple circuits or two independent coolers. The individual circuits or coolers are to be provided with stop valves so that each circuit or cooler may be readily isolated.

10.3.2 The refrigeration capacity of the air cooler arrangement is to be such that the temperature conditions can be maintained with any one circuit or independent cooler out of action.

10.3.3 For air ducts supplying ten standard 20 ft containers or five standard 40 ft containers or less, a single cooler with one circuit will be acceptable.

10.4 Air duct systems

10.4.1 The air ducts, together with all branches and couplings, supplying refrigerated air to insulated containers in holds, are to be made airtight. For design purposes, however, an air leakage rate of 0,5 per cent of total volume flow at the design pressure for each duct is to be taken.

10.4.2 Where air ducting is insulated on the internal surfaces, provision is to be made to prevent retention of odour which may taint subsequent cargo.

10.4.3 Couplings are to be of a type that has been approved by LR. Prototypes are to be tested under all operating conditions, witnessed by the Surveyors, to demonstrate that they extend, retract and separate satisfactorily from a 'container end wall' at the minimum temperature condition. When operated by means of air pressure they are to be supplied with air sufficiently dry to avoid ice formation. The air supply lines are to be strength pressure tested to 1,5 x design pressure.

10.5 Duct air leakage and distribution tests

10.5.1 Air leakage tests on at least 10 per cent of ducting, selected at random, are to be carried out to the satisfaction of the Surveyors before the insulation is applied. The Surveyors may require further testing to demonstrate airtightness of ducting. The air leakage from each duct will depend on several factors and, while complete airtightness should be the objective, the air leakage rate for design purposes is not to exceed 0,5 per cent of total volume flow at the design pressure of 250 Pa.

10.5.2 In the case of prefabricated ducts, the prototype is to be subjected to air distribution, heat leakage and air leakage tests. Each production duct is to be tested for air leakage and is not to exceed the prototype test results by more than five per cent. Additionally, one duct in 50 or part thereof is to be tested for heat leakage and the results are not to exceed the prototype test results by more than 10 per cent.

10.5.3 In all cases when prefabricated sections are assembled on board, the tests as detailed in 10.5.2, are to be carried out aboard the ship.

10.5.4 On application from the Owner, the air leakage tests on air ducts installed aboard the ship, as detailed in 10.5.1 to 10.5.3, may be omitted provided that:

- the installation is designed with at least 20 per cent surplus refrigerating capacity, or
- assignment of a temperature notation for the installation be deferred until verified by a thermal balance test to the Surveyor's satisfaction.

10.5.5 All ducts are to be tested for air distribution to the containers, at the manufacturer's works, by measuring the flow of air from the supply couplings while the fan is operated at full speed against the designed pressure. The air flow at each coupling is to meet the specified figure within ± 5 per cent.

10.5.6 Systems comprising rigid prefabricated ducts complete with coolers and fans are to be tested for air distribution at the place of manufacture. The remaining tests are to be carried out aboard the ship.

10.6 Cell air conditioning arrangements

10.6.1 The cell air conditioning equipment and ducting, and/or insulation of the holds, deckheads, sides and tank tops, is to be such as to maintain a uniform temperature throughout the cell and to ensure the ship's steelwork is maintained above the minimum temperature acceptable for the steel grade, see also Pt 3, Ch 2,2.2.

Section 11 Acceptance trials

11.1 Tests after completion

11.1.1 On completion of construction, the acceptance tests prescribed in 11.3.1 are to be carried out to verify the correct functioning of the installation and its ability to maintain the lowest notation temperature conditions required for the assignment of the intended class notation. The proposed test schedules, which should include methods of testing and test facilities provided, are to be submitted for approval before these acceptance tests are started.

11.2 Thermographic survey

11.2.1 The insulated envelope of refrigerated cargo ships and, where applicable, fish factory ships, fishing vessels, fruit juice carriers and container ships is to be scanned using a thermal imaging camera. The main purpose of carrying out the infra-red scan is to verify the efficiency of the insulation system.

Refrigerated Cargo Installations

Part 6, Chapter 3

Section 11

11.2.2 During the course of, or prior to, the acceptance trials all inner insulated surfaces, including tank tops, bulkheads, 'tween decks, insulated hatches, coamings and weather decks are to be subject to an infra-red scan.

11.2.3 Where internal obstructions preclude an internal scan, it is to be carried out externally.

11.2.4 The scan is to be conducted with the 'tween deck and main holds in total darkness and with air coolers/cooling grids isolated and all heat sources disconnected. The temperature difference, cargo hold to ambient air or sea-water temperature, is to be 15 K or more.

11.2.5 Any deficiencies or abnormalities revealed are to be investigated and repaired to the extent considered necessary by the Surveyor.

11.3 Acceptance tests

11.3.1 The acceptance tests (see also 11.3.2 and 11.3.3) are to comprise the following:

- (a) Verification of control, alarm, safety and refrigerant detection systems.
- (b) Test simulating failure of selected components such as compressors, fans and pumps, to verify correct functioning of alarm and systems in service.
- (c) Verification of accuracy, calibration and functioning of temperature control, monitoring and recording instrumentation.
- (d) Verification of air cooler fan outputs running at maximum speed, and air circulation rates and distribution arrangements in individual refrigerated spaces or chambers. The latter is to be undertaken firstly with all coolers in operation and secondly with any one cooler or fan out of action.
- (e) Verification of air refreshing and heating arrangements.
- (f) Verification of personnel safety devices and warning systems in refrigerated spaces.
- (g) Refrigeration and thermal balance tests to demonstrate the capability of the combined refrigerating plant and insulation envelope to maintain the lowest notation temperature to be assigned.
- (h) Refrigeration tests for refrigerated container ships carrying 'porthole' type insulated containers. If the prescribed thermal balance tests cannot be carried out due to the number of insulated containers available in the shipyard being inadequate, then, alternatively, the following separate tests will be accepted:
 - (i) Compressor capacity test.
 - (ii) Duct heat leakage test on at least 20 per cent of the insulated ducting selected at random.
 - (iii) Cell heat leakage test.
- (j) Thermographic scan to be carried out as required by 11.2.

11.3.2 Where a number of identical installations are constructed for the same Owner and by the same shipyard, the refrigeration and thermal balance tests required in 11.3.1(g), need only be carried out on two of the series, provided the results are satisfactory.

11.3.3 Where the cells of 'porthole' type insulated containers are not insulated, a heat leakage test will be required on the first ship of the series only.

11.4 Sea trials

11.4.1 Where the class notation includes the symbol ‡ for the carriage of fruit, or the symbol ‡ is to be assigned to a fishing vessel the following records are to be kept during the first loaded voyage:

(a) Refrigerated cargo or container ships:

Refrigerating machinery logs and temperature records for the refrigerated cargo spaces or containers, demonstrating the installation's capability to cool down the full cargo of fruit and maintain the notation temperature conditions.

(b) Fishing vessels:

Refrigerating machinery and freezing equipment logs and temperature records for the refrigerated cargo spaces, demonstrating the installation's capability to freeze the catch and maintain the notation temperature conditions.

11.5 Reporting of tests

11.5.1 On completion of the tests prescribed in 11.1, two copies of the test schedule for the refrigerated cargo installation, giving details of all recorded data and thermal heat balance results, signed by the Surveyor and Builder are to be provided. One copy is to be placed on board the ship and the other submitted to LR.

11.5.2 At the end of the first loaded voyage a copy of the logs and temperature records requested in 11.4.1(a) and (b), as applicable, signed by the ship's Chief Engineer, are to be submitted to LR.

Fire Protection, Detection and Extinction Requirements

Part 6, Chapter 4

Sections 1 & 2

Section

1 General

2 Fire detection, protection and extinction

■ Section 1 General

1.1 Application

1.1.1 Cargo ships of 500 gross tons or more, all passenger ships and gas and chemical tankers on international voyages, where provision is made within International Conventions are to be provided with the fire safety measures required by the *International Convention for the Safety of Life at Sea*, 1974, as amended (SOLAS 74). Fishing vessels of 45 m freeboard length and over are to be provided with the fire safety measures required by the Torremolinos Protocol of 1993 relating to the *Torremolinos International Convention for the Safety of Fishing Vessels*, 1977 (Torremolinos Protocol).

1.1.2 Cargo ships of 500 gross tons or more, all passenger ships, and gas and chemical tankers, employed on national voyages are to comply with the fire safety measures prescribed and approved by the Government of the flag state.

1.1.3 It is the responsibility of the Government of the flag state to give effect to the fire protection, detection and extinction requirements of 1.1.1 and 1.1.2. However Lloyd's Register (hereinafter referred to as 'LR') will undertake to do this in cases where:

- (a) contracting Governments have authorized LR to apply the requirements of SOLAS 74 or the Torremolinos Protocol and issue the appropriate certification on their behalf; or
 - (b) the Government of the flag state is not a signatory to SOLAS 74 or the Torremolinos Protocol; or
 - (c) the ship or fishing vessel is to be classed for restricted or special service in national waters for which the Government of the flag state has no national requirements. In such cases, LR will apply the fire safety measures required by SOLAS 74 or the Torremolinos Protocol, as appropriate.
- However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognizance of the circumstances of the restricted or special service.

1.1.4 Section 2 of this Chapter, which is within the spirit of the International Convention and Protocol requirements for ships of Convention size, is applicable to cargo ships of less than 500 gross tons (where not covered by International Conventions), fishing vessels of 12 m registered length and over but less than 45 m freeboard length, and ships not fitted with propelling machinery.

1.1.5 Consideration will be given to the acceptance of fire safety measures prescribed and approved by the Government of the flag state in lieu of 1.1.4.

1.1.6 Special consideration, consistent with the fire hazard involved, will be given to construction or arrangement features not covered by this Chapter.

1.1.7 Cargo ships of less than 500 gross tons intended for the carriage of dangerous goods are to comply with SOLAS 1974 as amended II-2/G.19.

■ Section 2 Fire detection, protection and extinction

2.1 General provisions

2.1.1 The provisions of these requirements, are intended to apply to new and, as far as reasonable and practicable, or as found necessary by the relevant Administration, to existing cargo ships of less than 500 GT.

2.1.2 It should be remembered that the *International Codes for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk and Liquefied Gases in Bulk* are applicable to such ships regardless of size including those of less than 500 GT.

2.2 Definitions

2.2.1 The terms, used in these requirements are as defined in SOLAS 1974 (as amended).

2.2.2 The term Gross Tonnage (GT) is as defined in IMO Resolutions A.493 (XII), calculated in accordance with the 1969 Tonnage Convention and the interim scheme applicable to ships with keels laid up to 18 July 1994 in accordance with IMO Resolution A.494 (XII).

2.2.3 Service area definitions

- (a) 'Unrestricted service' means a ship engaged on international voyages.
- (b) 'Restricted service' is broken down into two broad categories: (a) ships operating coastal or specified operating areas (b) ships operating within protected or extended protected waters.

- (i) **Specified coastal service.** Service along a coast, the geographical limits of which are to be defined and for a distance out to sea generally not exceeding 20 nautical miles, unless some other distance is specified for 'coastal service' by the Administration with which the ship is registered, or by the Administration of the coast off which it is operating. A typical example might be 'Indonesian coastal service'.

Specified operating or service areas may be service between two or more ports or other geographical features, or service within a defined geographical area such as 'Red Sea Service', 'Piraeus to Thessaloniki and Islands within the Aegean Sea'.

- (ii) **Protected water service.** Service in sheltered water adjacent to sand banks, reefs, breakwaters to other coastal features, and in sheltered water between islands.
Extended protected water service. Service in protected waters and also short distances (generally less than 15 nautical miles) beyond protected waters in 'reasonable weather'.

2.3 Surveys and maintenance

2.3.1 The hull, machinery and all equipment required for safety aspects of every ship should be constructed and installed so as to be capable of being regularly maintained to ensure that they are at all times, in all respects, satisfactory for the ship's intended service.

2.3.2 A competent authority should arrange for appropriate surveys of the required equipment relating to fire safety aspects during construction and, at regular intervals after completion, generally as prescribed within Chapter I of SOLAS 1974 (as amended). Such surveys should be carried out by the Society classing the ship or the Flag State.

2.3.3 The condition of the structural fire protection and fire safety related equipment shall be maintained to conform with the provisions of the requirements to ensure that the ship in these respects, will remain fit to proceed to sea without danger to the ship or persons on board. The hull structure and machinery do not form part of these requirements but should be similarly surveyed and maintained.

2.4 Requirements

2.4.1 Table 4.2.1 details the various minimum fire protection, detection and extinction arrangements that are required depending on the vessel's intended service area.

Fire Protection, Detection and Extinction Requirements**Part 6, Chapter 4**

Section 2

Table 4.2.1 General fire detection, protection and extinction requirements

Fire-fighting	Unrestricted	Restricted	Protected
1. FIRE PUMPS Ships greater than 150 GT Independently driven power pumps Power pumps Hand pumps Ships less than 150 GT Independently driven power pumps Power pumps Hand pumps	 1 1 — — 1 1 1	 1 1 — — 1 1 1	 1 — 1 — 1 —
2. FIRE HYDRANTS Sufficient number and so located that at least one powerful water jet can reach any normally accessible part of ship	X	X	X
3. FIRE HOSES (Length >15 m) With couplings and nozzles	≥ 3	≥ 3	≥ 2
4. FIRE NOZZLES Dual purpose (spray/jet) with 12 mm jet and integral shut-off Jet may be reduced to 10 mm and shut-off omitted for hand pump hoses	X	X	X
5. PORTABLE FIRE EXTINGUISHERS Accommodation and service spaces Boiler rooms, etc. Machinery spaces (one extinguisher per 375 kw of internal combustion engine power) Cargo pump rooms (capacity 9 l. fluid or equivalent)	≥ 3 ≥ 2 ≥ 2 ≤ 6 ≥ 2	≥ 3 ≥ 2 ≥ 2 ≤ 6 ≥ 2	≥ 2 ≥ 2 ≥ 2 ≤ 6 ≥ 2
6. NON-PORTABLE FIRE EXTINGUISHERS IN MACHINERY SPACES Ships greater than 150 GT Ships greater than 350 GT (capacity 45 l. fluid or equivalent)	1 —	1 —	— 1
7. FIXED FIRE EXTINGUISHING SYSTEMS SHIPS GREATER THAN 350 GT Category A machinery spaces Cargo pump rooms	 X X	 X X	 — —
8. CARGO TANK PROTECTION Mobile foam appliances	X	X	X
9. FIREMAN'S OUTFIT Ships greater than 150 GT complete outfit Ships less than 150 GT complete outfit Fireman's axe	≥ 2 ≥ 1 —	≥ 2 ≥ 1 —	≥ 2 — 1
10. MEANS OF ESCAPE Accommodation and service spaces Machinery spaces Cargo pump rooms	2 ≥ 1 1	2 ≥ 1 1	2 ≥ 1 1
11. STRUCTURAL FIRE PROTECTION WHEEL HOUSE AND MACHINERY SPACES Separation from adjacent spaces of negligible fire risk Separation from other adjacent spaces Escape routes	A-0 A-60 B-0	A-0 A-30 B-0	A-0 A-0 B-0

© Lloyd's Register, 2007
Published by Lloyd's Register
Registered office
71 Fenchurch Street, London, EC3M 4BS
United Kingdom

Printed by Butler and Tanner,
Frome, Somerset