INTERNATIONAL ELECTROTECHNICAL COMMISSION

(affiliated to the International Organization for Standardization - I.S.O.)

Publication 92

First Edition

1957

Recommendations for electrical installations in ships

Central Office of the International Electrotechnical Commission

1 rue de Varembé

GENEVA, Switzerland

INTERNATIONAL ELECTROTECHNICAL COMMISSION

(affiliated to the International Organization for Standardization - ISO)

PUBLICATION 92

First edition - 1957

RECOMMENDATIONS FOR ELECTRICAL INSTALLATIONS IN SHIPS

Central Office of the International Electrotechnical Commission

1, rue de Varembé

GENEVA - Switzerland

CONTENTS

TABLES

FOREWORD

(1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

(2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

(3) In order to promote this international unification, the IEC expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the IEC recommendations as the fundamental basis for these rules in so far as national conditions will permit.

(4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The National Committees pledge their influence towards that end.

PREFACE

Delegates from twelve nations with interests in marine applications met at The Hague in June 1935 and decided that an international set of regulations relating to electrical installations in ships would be an advantage to the many interests involved. They fixed on the order of importance of the subjects to be dealt with as :-

(a) Safety

(b) Reliability

(c) Simplicity

(d) Ease of maintenance

The United Kingdom was asked to appoint the Chairman of Technical Committee No. 18 and the Netherlands was entrusted with the Secretariat.

Eight sub-committees were appointed and a further meeting was held in London in June 1936. Some progress had been made in the preparation of draft regulations when the work was interrupted by the Second World War.

At a meeting held in London in July 1948 immediately following the 1948 Convention on Safety of Life at Sea, it was resolved to make a fresh start and ten sub-committees, each based on a National Committee, were appointed to prepare preliminary drafts. These were subsequently combined by a Co-ordinating and Editing Committee into a first comprehensive draft of 25 chapters. Thus no further plenary session was held until the Jubilee IEC meeting at Philadelphia in September 1954, when comments which had been submitted by National Committees on the first comprehensive draft were considered.

It was then resolved that the decisions then taken should be embodied in a second draft and that in view of the length of time which had elapsed it was highly desirable to publish a 1st edition and to continue in the meantime with the consideration of matters still unresolved with a view to a 2nd edition.

The second draft was accordingly circulated to National Committees in August 1955 for approval under the Six Months' Rule. The following 16 countries voted in favour of publication but in every case, except one, comments were submitted.

Australia	Italy	Union of South Africa
Austria	Japan	Union of Soviet Socialist Republics
Belgium	Netherlands	United Kingdom
Denmark	Norway	United States of America
France	Sweden	Yugoslavia
German Federal Republic		

Against approval : Nil

The comments were submitted to the Chairman who recommended the acceptance of those which dealt with technical errors and inconsistencies. In the meantime the Committee had met at The Hague in December 1955 and had agreed certain amendments and had recommended that these be embodied in the 1st edition.

These matters were accordingly submitted to National Committees under the Two Months' Procedure and the following countries voted explicitly in favour of publication.

Austria	German Federal Republic	Sweden
Belgium	Italy	Union of South Africa
Denmark	Netherlands	Union of Soviet Socialist Republics
Finland	Norway	United Kingdom
France	Poland	United States of America
		Yugoslavia

Against approval : Nil

The comments of a purely editorial nature which were submitted with the votes have been accepted. The remainder have, on the Authority of the Chairman of Technical Committee No. 18, been withheld for consideration for the second edition.

INTRODUCTION

The operating conditions in ships sailing the seven seas as far as they affect electrical appliances are the same regardless of where the ship is built. Except for variations in quality the materials used in the construction of electrical appliances are similar and are subject to the same natural laws. The characteristics of electric circuits and the behaviour of appliances are likewise predeterminable and follow the same fundamental laws irrespective of the country of origin. It is accordingly feasible to establish international standards to secure that degree of performance, reliability and safety which are essential for the well-being of crews and passengers alike and for the safe carriage of valuable cargoes.

It is for the fulfilment of these ends that the present recommendations have been formulated. Shipbuilders, electrical contractors and manufacturers engaged in the building of ships for the international market are faced at present with several codes of rules and regulations with which to comply although as already stated the conditions of service are identical. It is recognized that apparatus manufactured in various countries will inevitably differ in appearance and conception but for the same duties similar apparatus and materials will necessarily have to meet the same service conditions. This code has therefore been drafted in the form of "recommendations" thus allowing the fullest possible scope for the manufacturer to use his initiative in the design and development of his product and to use existing tools and patterns so far as they are suitable.

The preparatory work was divided between subcommittees on a National basis with instructions to prepare their drafts as far as practicable on the basis of existing National Standards and the published requirements of Classification Societies.

Complete and progressive cooperation between the naval architect, the shipbuilder, the owner and the designer and installer of the electrical installation are essential from the earliest stages right through to completion to ensure not only that all services required of the electrical appliances are met but that proper and suitable space and accommodation is provided for electric cables and appliances.

It is not intended to exclude new materials, appliances or methods or to discourage invention.

It cannot be too strongly emphasized that good technical design, the correct choice of apparatus, good and suitable materials and, above all, good workmanship are essential for a sound installation. The recommendations are not intended to take the place of a detailed specification or to instruct untrained persons.

NOTE 1:- As some problems could not be resolved satisfactorily without involving considerable delay this first edition has been published embodying the matters on which agreement has been reached.
It is intended to proceed immediately with outstanding items which will be embodied in due course in the second edition.

NOTE 2:- All dimensions in these Recommendations are, in the first place, given in metric units; figures in brackets in British and American units are not exact numerical equivalents of the metric quantities, but are the nearest dimensions in practical use in the respective countries.

CHAPTER 1

DEFINITIONS

NOTE: The following definitions indicate the sense in which the expressions defined are used in this International Code. All other expressions are used in the sense defined in IEC Publication No.50 "International Electrotechnical Vocabulary"

GENERAL

1.01 - Accommodation spaces. Accommodation spaces are those used for public spaces, corridors, lavatories, cabins, offices, crew quarters, barber shops, isolated pantries and lockers, and similar spaces.

1.02 - Appropriate authority. A governmental body or a classification society with whose rules a ship is required to comply.

1.03 - Bond. To connect together non-current-carrying parts such as the armour or lead sheath of consecutive or adjacent lengths of cable or the metal plates, for example, comprising the walls etc. of a radio-receiving room in order to ensure continuity of electrical connection or to equalize the potential between the parts concerned.

1.04 - Cargo spaces. Cargo spaces are all spaces used for cargo (including cargo oil-tanks) and trunks to such spaces.

1.05 - Dangerous spaces in tankers. Dangerous spaces in a tanker are all those where inflammable or explosive vapour or gas may normally be expected to accumulate, such as :-

- cargo oil tanks
- cofferdams
- cargo pump-rooms
- spaces immediately above tank crowns (e.g. between decks)
- spaces adjacent to a tank not extended from a side to the other side of the ship
- zones within 3m (or 10 ft.) of any oil tank outlet or vapour outlet.

1.06 - Degree, electrical. 1/360 of a complete electrical cycle.

NOTE: If P = number of poles of an alternator, the number of electrical cycles in a revolution is P/2, so that 360 mechanical degrees correspond to P/2 x 360 electrical degrees, or one mechanical degree = P/2 electrical degrees.

1.07 - Diversity factor (Demand factor). The ratio of the estimated consumption of a group of power-consuming appliances under their normal working conditions to the sum of their normal ratings.

1.08 - Insulation, double. A portable appliance which is partially or wholly metal-clad is said to have double insulation when every live part, besides being mounted upon or surrounded by a suitable insulation support with adequate creepage path, is so separated from the external casing by means of insulating material or adequate spacing that no live part can be touched,no accessible metal part can become live in the event of failure of the said insulating support.

1.09 - Live conductor or circuit. A conductor or circuit electrically connected to a source of potential difference between it and earth.

1.10 - Machinery spaces. Machinery spaces include all spaces used for propelling, auxiliary or refrigeration machinery, boilers, pumps, workshops, generators, ventilating and air-conditioning machinery, oil-filling stations and similar spaces, and trunks to such spaces.

1.11 - Prospective current. The r.m.s. value of the alternating component of an alternating current, or the value of the direct current which would flow in a circuit, on the occurrence of a short-circuit immediately on the supply side of the fuse or other protective device, under given voltage conditions and supply network conditions.

1.12 - Public spaces. Public spaces are those portions of the accommodation which are used for halls, dining-rooms, lounges, and similar permanently enclosed spaces.

1.13 - Sea-going ship. Any ship not exclusively employed in the navigation of rivers or inland waters.

1.14 - Service spaces. Service spaces are those used for galleys, main pantries, stores (except isolated pantries and lockers), mail and specie rooms, and similar spaces and trunks to such spaces.

1.15 - Services, essential. Services essential to the safety of life, and to the navigation and propulsion of a ship.

1.16 - Tanker. A cargo ship constructed (or adapted) and intended for the carriage in bulk of liquid cargoes having a flash-point (closed test) of 65 °C or less.

1.17 - Voltage, extra low. Applies to systems in which the voltage does not normally exceed 30 volts r.m.s., a.c. or 50 volts d.c.

APPARATUS

1.18 - Accessory. Any device, other than a lighting fitting (see Clause 1.64) associated with the wiring and current-using appliances of an installation; for example, a switch, a fuse, a plug, a socket-outlet, a lampholder, or a ceiling rose.

CABLES

1.19 - Bunched. Cables are said to be bunched when two or more are contained within a single conduit, duct or groove, or, if not enclosed, are not separated from each other.

1.20 - Cable. A length of insulated single conductor (solid or stranded), or of two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

1.21 - Core (of a cable). The conductor with its insulation but not including any mechanical protective covering.

1.22 - Earth-continuity conductor. The wire, cable, or other conductor connecting to each other or to the earthing-lead (see Clause 1.23) those parts which have to be earthed. It may be in whole or in part the metal conduit or the metal sheath of the cables, or the special continuity wire of a cable or flexible cord incorporating such a wire.

1.23 - Earthing-lead. The conductor by which the connection is made to the hull of the ship.

1.24 - Flexible cable. A cable containing one or more cores each formed of a group of wires. The diameters of the cores and of the wires being sufficiently small to afford flexibility.

1.25 - Flexible cord. A flexible cable in which the cross-sectional area of each conductor does not exceed 4 mm^2 (or 0.007 in^2).

1.26 - Length of lay. The axial length of one complete turn of the helix formed by the core, in the case of a cable, or of the wire, in the case of a stranded conductor.

DISTRIBUTION

1.27 - Branch circuit. A branch circuit is that portion of a wiring system extending beyond the final automatic overload protective device of the circuit.

1.28 - Earthed (U.S. Grounded). Connected to the general mass of the hull of the ship in such a manner as will ensure at all times an immediate discharge of electrical energy without danger.

NOTE: A conductor is said to be "solidly-earthed" when it is electrically connected to the hull without a fuse-link, switch, circuit-breaker, resistor, or impedance, in the earth connection.

1.29 - Earth (U.S. Ground). A connection to the general mass of the hull of the ship.

1.30 - Hull return. The use of the hull or other permanently-earthed structure to conduct the current on one pole of the system. (See also 1.32).

1.31 - Point (in wiring). Any termination of the fixed wiring intended for the attachment of a lighting fitting or of a device for connecting to the supply a current-using appliance.

1.32 - Systems of distribution.

(a) Hull-return system. A system in which insulated conductors are provided for connection to one pole of the supply, the hull of the ship or other permanently-earthed structure being used for effecting connections to the other pole.

(b) 2-wire system. A d.c. or single-phase a.c. system comprising two conductors only, between which the load is connected.

(c) <u>3-wire system.</u> A d.c. or single-phase a.c. system comprising two conductors and a middle or neutral wire, the supply being taken from the two outer conductors at full voltage or from the middle wire and either outer conductor, the middle wire carrying only the difference-current and being usually connected to earth.

(d) <u>3-phase 3-wire system.</u> A system comprising three conductors connected to a 3-phase supply.

(e) <u>3-phase 4-wire system.</u> A system comprising four conductors, of which three are connected to a three-phase supply and the fourth to a neutral point in the sources of supply.

ENCLOSURES

<u>1.33 - Drip-proof apparatus.</u> Apparatus which is so constructed that when it is inclined in any direction at an angle not exceeding 15° any drop of liquid or a solid particle falling vertically cannot enter the apparatus either directly or by striking and running along a surface.

<u>1.34 - Flameproof enclosure.</u> An enclosure for electrical apparatus which will withstand an internal explosion of the inflammable gas or vapour which may enter or which may originate inside the enclosure without suffering damage and without communicating the internal flame to the external inflammable gas or vapour for which it is designed, through any joints or structural openings in the enclosure.

<u>NOTE 1:</u> The term "flameproof" is synonymous with the term "explosion-proof" as used in the U.S.A. for the class of apparatus dealt with in this Code.

<u>NOTE 2:</u> A flameproof enclosure in accordance with the foregoing definition will not necessarily or ordinarily be watertight, dust-tight or pressure-tight.

<u>1.35 - Immersible apparatus (submersible apparatus).</u> Apparatus so constructed that it will operate successfully when submerged in water under specified conditions of pressure and time.

<u>1.36 - Watertight apparatus.</u> Apparatus having all live parts enclosed by a cover or covers so constructed as to exclude water under prescribed conditions (see Clause 3.13).

<u>1.37 - Weatherproof apparatus.</u> Apparatus having all live parts enclosed by a cover or covers so constructed as to exclude rain, snow and external splashings.

MACHINES

<u>1.38 - Generator. Stabilized shunt-wound.</u> A d.c. generator in which the field excitation is derived from a winding connected in parallel with the armature circuit and from a series winding of such proportion that equalizers are not required when the generator operates in parallel with similar generators.

<u>1.39 - Generator. Service.</u> A generator, which may be an emergency generator, primarily intended to supply the ship's service system.

MATERIALS

1.40 - Non-inflammable material. Material which, when tested in a prescribed manner, does not glow or carry flame and is neither charred nor scorched in excess of the permitted amount.

1.41 - Flame retarding material. Flame retarding materials and structures have such fire-resisting properties that they will not convey flame or continue to burn for longer times than specified in the appropriate flame test.

1.42 - Incombustible material. Material which neither burns nor gives off inflammable vapours in sufficient quantity to ignite at a pilot flame when heated to approximately 750 °C. Any other material is a "combustible material".

RADIO

1.43 - Radio direction-finding. Radiolocation in which only the direction of a station is determined by means of its emissions.

1.44 - Radio-receiving room. A room in which radio reception is carried out for the purpose of the operation and control of the radio-communication and radionavigation services.

1.45 - Radiolocation. Determination of a position or of a direction by means of the constant-velocity or rectilinear-propagation properties of Hertzian waves.

SWITCHGEAR

1.46 - Distribution board (U.S. Panel Board). An assemblage of parts including one or more fuses (or other overload-protective devices) arranged for the distribution of electrical energy to final sub-circuits rated at not more than 16 amperes.

1.47 - Section board (U.S. Distribution Panel). A switchboard for controlling the supply of electrical energy to other section boards, distribution boards, or devices normally consuming more than 16 amperes. A section board may obtain its supply from a main switchboard, an emergency switchboard, or another section board.

1.48 - Switch-and-fuse. A unit comprising a switch and one or more fuses, the fuses not being carried on the moving part of the switch.

1.49 - Switch. Isolating. A switch for making and breaking, non-automatically, a circuit, when it is not on load.

1.50 - Switchboard. The assembly of switchgear with or without instruments designed to operate and control electrical circuits.

1.51 - Switchboard. Dead-front. A switchboard having no exposed live parts.

1.52 - Switchboard. Open-type. A switchboard in which the current-carrying parts of the switchgear are not provided with protecting covers.

1.53 - Switchgear. A general term applicable to apparatus for the operation, regulation and control of electrical installations.

FUSES

1.54 - Fuse. A device which, by the fusion of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted when the current through it exceeds a certain value for a sufficient time. The fuse comprises all the parts that form the complete device.

1.55 - Fuse. Filled. A fuse in which the arc is extinguished in a powdered, granular or fibrous substance.

1.56 - Fuse. Indicating. A fuse which incorporates a device to indicate that the fuse has opened the circuit.

1.57 - Fuse. Non-interchangeable. A fuse so designed and proportioned as to accept only a fuse-link of a predetermined type of a rated current not exceeding a certain value and provided with a means to make it impossible for the user accidentally to insert a fuse-link of any higher rated current.

1.58 - Fuse with enclosed element. (Commonly known as enclosed fuse). A fuse in which the fuse-element is totally enclosed in such a way that at the time of operation it cannot produce any external effect harmful to persons or objects in the immediate vicinity when it operates within its rated breaking capacity.

1.59 - Fuse with semi-enclosed element. (Commonly known as semi-enclosed fuse).
A fuse in which the development of an arc, the release of gas and the ejection of flame or metal particles caused by the operation, are so controlled as to limit danger to persons.

1.60 - Fuse-link. The part of a fuse which requires replacement after the fuse has operated and before the fuse is put back into service and which comprises the fuse-element and a container, if any, and which is capable of being connected to the fuse-carrier contacts, if any, or otherwise of engaging directly with the fuse-base contacts.

1.61 - Fuse-link. Cartridge. (Abbreviation: Cartridge).
A fuse-link having an insulating enclosure, usually cylindrical, provided at its ends with metal contacts, the shape of which varies according to the type of fuse.

1.62 - Fuse-switch. A switch the moving part of which carries one or more fuse-links. (See also Switch-and-fuse).

LAMPS, LIGHTING

1.63 - Electric discharge lamp. An electric lamp comprising a hermetically sealed bulb or tube containing gas and/or metal intended to be vaporized during operation, and fitted with electrodes between which a discharge of electricity takes place, the useful light being emitted from, and/or excited by, the discharge through the gas or vapour.

1.64 - Fitting. Lighting. A device for supporting or containing a lamp or lamps, together with any holder, shade or reflector.

CHAPTER 2

GRAPHICAL SYMBOLS

2.01 - I.E.C. Publications Nos. 35 and 42. Graphical symbols for the representation of electrical installations on shipboard should be in accordance with those given in I.E.C. Publication No. 35 "Graphical symbols for heavy current systems", and Publication No. 42 "Graphical symbols for weak current systems".

2.02 - Additional graphical symbols. Additional symbols used should be based as far as possible on circuit elements depicted in Publications Nos. 35 and 42. Where doubt may arise, the use of simple circles or squares containing letters or numbers referring to an explanatory table is recommended.

NOTE: "Heavy current systems" refer to power and lighting systems; "weak current systems" refer to telephone and communication systems.

CHAPTER 3

GENERAL REQUIREMENTS AND CONDITIONS

NOTE: This chapter contains conditions and requirements which :

(a) are common to all apparatus and installations, or

(b) are primarily the concern of the shipbuilder or installation contractor.

GENERAL

3.01 - Workmanship. Good workmanship is an essential requirement for compliance with this code.

3.02 - Applicability of the code to a.c. and d.c. Except where a specific statement is made to the contrary, all recommendations made in the present code are equally applicable to a.c. and d.c. installations.

3.03 - Acceptance of substitutes or alternatives. Where in this Code any special type of appliance, construction or arrangement is specified the use of any other appliance, construction or arrangement is admissible provided it is not less effective and reliable.

3.04 - Provision for maximum load. All conductors, switchgear, and accessories, should be of such size as to be capable of carrying, without their respective ratings being exceeded, the maximum current which can normally flow through them.

3.05 - Addition to an installation. An addition, temporary or permanent, should not be made to the authorized load of an existing installation until it has been definitely ascertained that the current-carrying capacity and the condition of the existing accessories, conductors, switchgear, etc., affected, are adequate for the increased load.

3.06 - Ambient-air and cooling-water temperatures. For the purpose of this code the following temperatures are assumed :

(a) For all ocean-going ships a temperature of ambient-air or cooling-water as follows :

1. Primary cooling water supply 30°C.

2. Ambient air temperature of 45°C for all equipment (except machines) located in machinery spaces (engine rooms - boiler rooms), and for all equipment located in galleys, or on weather decks.
   Ambient air temperature of 50°C for machines located in machinery spaces.

3. Ambient air temperature of 40°C for equipment located in all other spaces.

(b) For vessels such as coasters, ferries and harbour craft intended solely for use in Northern or Southern waters outside the tropical belt an ambient air temperature of 40°C and a temperature of primary cooling-water supply of 25°C.

(c) Where adverse and unusual ambients are expected to exist, special consideration should be given.

NOTE: In the above clause the term "ambient air" refers to the air responsible for dissipating the heat losses from the equipment or cables concerned.
This ambient air may be in the case of a ventilated machine the air drawn in by the cooling vent or in the case of cables the comparatively still air surrounding the cables.

DESIGN OF EQUIPMENT

3.07 - Construction. In general all electrical equipment should be constructed of durable, flame-retarding, non-hygroscopic materials which are not subject to deterioration in the atmospheres and at the temperatures to which it is likely to be exposed.

3.08 - Electrical clearances. The distances between live parts of different potential, and between live parts and the case of other earthed metal, whether across surfaces or in air, should be adequate for the working voltage under the conditions of installation, and should be not less than those specified for marine service by an appropriate authority.
Any parts of the case in proximity to the arc from line contactors, circuit-breakers or other contacts liable to arc, or in proximity to re-wirable fuses of non-filled type, should be lined with arc-resisting insulating material.

3.09 - Insulation. Insulating materials and insulated windings should be resistant to moisture, sea-air and oil vapour unless special precautions are taken to protect insulants against such agencies.

3.10 - Accessibility. The design of equipment should provide for accessibility to all parts requiring inspection.

3.11 - Enclosures. Enclosing cases for electrical equipment, junction-boxes, joint-boxes, etc. should be of adequate mechanical strength and rigidity to protect the contents and to prevent distortion under all likely conditions of service.

3.12 - Cable entries. Cable glands or bushings, or fittings for screwed conduit, should be provided according to the way in which the cables enter the apparatus. Enclosures of drip-proof apparatus should not have cable-entries on the top, unless the cable-entry plate and/or cable-attachment is so made as to exclude water.

3.13 - Watertight apparatus. Watertight apparatus is totally enclosed apparatus so constructed that leakage to the interior does not occur when a stream of water from a hose not less than 25 mm (or 1 in.) in diameter, under a head of 4 - 10 m (or 13 - 35 ft) is played on the apparatus from any direction for a period of 15 minutes from a distance of 2 m (or 6 ft) for a head of 4 m (or 13 ft), or 3 m (or 10 ft) for a head of 10 m (or 33 ft), or a proportionate distance for intermediate values of head. Nevertheless for rotating machines leakage which may occur round the shaft is considered admissible provided water is prevented from entering the oil reservoir and provision is made for automatic drainage. During the test the hose nozzle should be adjusted to give as far as practicable a solid stream at the enclosure. The apparatus should be provided with a check valve for drainage or a tapped hole at the lowest part of the frame which will serve for the application of a drain pipe or drain plug.

INSTALLATION LOCATION AND PROJECTION OF EQUIPMENT

3.14 - Position in ship. Compartments in which electrical apparatus is placed should be well ventilated. Except where the installation of flameproof apparatus is permitted in this code, electrical apparatus should not be installed where inflammable gases are liable to accumulate.

3.15 - Compartments. Compartments in which engine-driven generating sets are placed should be constructed of metal of other incombustible material. Compartments or cupboards containing switchboards should be constructed of or lined with incombustible material.

3.16 - Mechanical protection. Electrical equipment should be so placed that as far as practicable it is not exposed to risk of mechanical injury.

3.17 - Protection from water, steam and oil. Electrical equipment should be so selected and located that it is unaffected by any water, steam, oil and oil fumes to which it is likely to be exposed.

3.18 - Protection from drip. Where necessary open-type electrical equipment should be provided with a canopy or other suitable means to protect the current-carrying parts and their insulation from drip.

3.19 - Protection against electric shock. Where the voltage to earth exceeds or can exceed under fault conditions 250 V d.c. or 150 V a.c. all electrical equipment should be so enclosed that live parts cannot inadvertently be touched, unless its construction is such as to render this precaution unnecessary.

3.20 - Axes of rotation. Every horizontal rotating machine should preferably be installed with the shaft in the fore-and-aft direction. Where a machine is installed athwartships it should be ensured that the design of the bearings and the arrangements for lubrication are satisfactory to withstand the rolling encountered in heavy weather. The manufacturer should be informed when a machine for installation athwartships is ordered.

3.21 - Precautions against vibration and mechanical shock. Screws and nuts securing current-carrying parts should be effectively locked so that they cannot work loose by vibration. Machines and apparatus should be unaffected by vibration and shock likely to arise under normal service.

3.22 - Space for maintenance. Electrical apparatus should be so installed that sufficient space is available for maintenance; for example, it should be possible to remove the armature or rotor of a rotating machine.

3.23 - Adjacent material. Unprotected woodwork or readily combustible material should not be placed within 30 cm (or 12 in.) measured horizontally, or 120 cm (or 4 ft.) measured vertically, from any open-type electrical apparatus.

3.24 - Handrails. Open-type machines, open-type switchboards or open-type control gear should be provided with handrails where these are necessary to obviate risk of injury to persons.

3.25 - Inclination of ship. Machines and apparatus should operate satisfactorily under all conditions with the ship at the following inclinations from the normal :

Transversely : 15° Rolling: up to 22° 30'

Longitudinally: 10° or for ships of length exceeding 150 m (or 500 ft.) : 5°.

Emergency units should in addition operate satisfactorily with the ship at a permanent list up to 30°.

3.26 - Magnetic compasses. Conductors and equipment should be placed at such a distance from the compass or should be so screened that the interfering external magnetic field is negligible (deviation less than 0.5°), even when circuits are switched on and off.

CHAPTER 4

EARTHING OF NON-CURRENT-CARRYING PARTS

4.01 - Parts for which earthing is recommended. Unless specifically exempted in the following exemptions (i) - (vii) all metal of the electrical installation, other than current-carrying parts, should be earthed.

Exemptions.

(i) Lamp caps.

(ii) Shades, reflectors, and guards, supported on lampholders or lighting fittings of non-conducting material.

(iii) Metal parts on, or screws in or through, non-conducting material, 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.

(iv) Portable appliances having double insulation (see definition, Chapter 1), provided that the appliances conform with recognized safety requirements.

(v) Bearing housings which are insulated in order to prevent circulation of current in the bearings.

(vi) Clips for fluorescent lighting tubes.

(vii) Apparatus supplied at extra low voltage (see 1.17).

4.02 - Earthing connections. All exposed metal of the electrical installation not exempted in Clause 4.01, unless its method of installation ensures positive earthing, should be permanently connected to earth.
Every earthing connection should be of copper or other non-magnetic corrosion-resistant material and should be securely installed and protected against damage. The nominal cross-sectional area of every copper earthing connection should be not less than is recommended in Clauses 4.03 - 4.04 below. Every other earthing connection should have a resistance not greater than that of the corresponding copper conductor.

4.03 - Earthing connections in insulated systems. Every copper earthing connection in a system where the earth connection normally carries no current should be of the minimum cross-sectional area given in (a), (b) or (c) below, as appropriate.

(a) Every bare copper earthing-lead should be of the same cross-sectional area as the associated current-carrying conductors, subject to a minimum of 1.5 mm^2 (or 0.0023 in^2).
Where, however, the cross-sectional area of the associated current-carrying conductors exceeds 6 mm^2 (or 0.01 in^2), the cross-sectional area of the copper earthing-lead need not exceed 4 mm^2 (or 0.007 in^2) per 50 A normal current flowing in the associated current-carrying conductors.
In no circumstances need the size of the copper earthing-lead exceed 64 mm^2 (or 0.1 in^2).

(b) Every insulated copper earth-continuity conductor which forms part of a multi-core cable or is a cable similar to the associated current-carrying cable or cables, should have a nominal cross-sectional area equal to that of the associated current-carrying conductors.

(c) Metal of portable appliances other than current-carrying parts and parts exempted in Clause 4.01 should be earthed by means of an earth-continuity conductor in the flexible cable or cord, which complies with (b) above, and which is earthed through the associated plug and socket-outlet.
Plugs and socket-outlets should be so designed that the earthing-pin of the plug and the earth contact-tube of the socket-outlet make contact before, and break contact after, the associated current-carrying pins and contact-tubes.

4.04 - Earthing connections in earthed distribution systems. The earthing connections in systems where one pole is earthed but in which the earthing connection does not normally carry current, should conform with the recommendations of Clause 4.03, except that no upper limit of 64 mm^2 (or 0.1 in^2) is recommended.

4.05 - Connections to the ship's structure. Every connection to the ship's structure should be made in an accessible position, and should be secured by a brass screw of diameter not less than 6 mm (or 1/4 in.) which should be used for this purpose only. Where a cable socket is not used, the wires should be formed into a hook and placed under a tinned brass washer. In all circumstances care should be taken to ensure bright metallic surfaces at the contact areas immediately before the nut is tightened.

CHAPTER 5

APPLICATION OF DIVERSITY (DEMAND) FACTORS

5.01 - Final sub-circuits. The cables of final sub-circuits should be rated in accordance with the total connected load.

5.02 - Circuits other than final sub-circuits. Circuits supplying two or more final sub-circuits should be rated in accordance with the total connected load subject where justified to the application of a diversity (demand) factor in accordance with Clauses 5.03 - 5.04 below.

Where spare ways are provided on a section or distribution board, an allowance for future increase in load should be added to the total connected load, before the application of any diversity factor. The allowance should be calculated on the assumption that each spare circuit requires not less than 50 % of the average load on each of the active circuits of corresponding rating.

5.03 - Application of diversity (demand) factors. A diversity (demand) factor may be applied to the calculation of the cross-sectional area of conductors and to the rating of switchgear provided that the known or anticipated conditions in a particular part of an installation are suitable for the application of diversity.

5.04 - Motive-power circuits - general. The diversity factor should be determined according to circumstances.

The normal full-load should be determined on the basis of the name-plate ratings of motors; if these ratings are not available the ratings given in the following Table 5.I (page 18) should be assumed.

In the assessment of diversity factors of a.c. motive power circuits account should be taken of the relatively small decrease in current consumption of partially-loaded motors.

Table 5.I

Approximate full-load currents of d.c. and 3-phase a.c. motors

Mechanical output of motors	D.C. Approx. full-load current at 110 volts	D.C. Approx. full-load current at 220 volts	3-phase A.C. Approx. full-load current at line voltage shown at 220 volts	3-phase A.C. at 380 volts	3-phase A.C. at 440 volts
kW	amp.	amp.	amp.	amp.	amp.
¼	4.2	2.1	-	-	-
½	7.6	3.8	2.9	1.7	1.5
1	13	6.7	4.9	2.8	2.5
2	24	12	8.5	4.9	4.2
3	35	18	12	7.0	6.1
4	46	23	16	9.3	8.1
5	56	28	20	12	9.8
7½	81	41	30	17	15
10	108	54	36	21	18
12½	133	67	43	25	22
15	157	79	53	31	27
20	206	103	70	41	35
25	256	128	88	51	44
30	304	152	105	61	53
35	354	177	122	71	61
40	402	201	139	81	70
45	455	228	157	91	79
50	503	252	175	101	88
60	602	301	210	121	105
70	696	348	244	141	122
80	798	399	277	160	139
90	891	446	311	180	155
100	992	496	343	200	172
125	1200	600	424	246	212
150	-	736	503	292	252

Note: It should be understood that the figures in the Table are not necessarily those of particular motors, but are average values and that particular values will be affected by speed, efficiency and power factor, e.g. the efficiencies of slower (and larger) machines are necessarily somewhat less than those of faster (and smaller) models having the same output rating. The figures may, however, be taken as sufficiently near the individual currents for the purpose of these Recommendations.

5.05 - Winch circuits. For winches the diversity factor should be not less than the values in the following Table 5.II.

Table 5.II

DIVERSITY FACTORS FOR WINCH CABLES

Number of motors		Current to be provided for
two	plus	100 % full-load of the larger motor 30 % full-load of the second motor
	or	65 % of the combined full-load if the motors are of equal size
three	plus	100 % full-load of the largest motor 25 % full-load of each of the remaining motors
	or	50 % of the combined full-load, if the motors are of equal size
four	plus	100 % full-load of the largest motor 20 % full-load of each of the remaining motors
	or	40 % of the combined full-load, if the motors are of equal size
five	plus	100 % full-load of the largest motor 20 % full-load of each of the remaining motors
	or	36 % of the combined full-load if the motors are of equal size
six or more		33 % of the combined full-load of the motors

CHAPTER 6

D.C. SHIP'S SERVICE SYSTEM OF SUPPLY

6.01 - Normal distribution systems. The following systems are considered as standard :

(a) 2-wire insulated

(b) Single-wire with hull return

(c) 2-wire with one pole earthed

(d) 3-wire with middle wire earthed but without hull return

(e) 3-wire with middle wire earthed and with hull return.

NOTE: In accordance with Chapter II Regulation 24(a) of the Convention for Safety of Life at Sea, Systems (b) and (e) are not allowed in passenger ships.

6.02 - Voltages. The following schedule gives recommended and maximum system voltages :

Application	Recommended voltages	Maximum voltages
Power	110, 220	500
Cooking	110, 220	250
Heating	110, 220	250
Lighting	24, 110, 220	250
Internal Communications	6, 12, 24, 50, 60, 110, 220	250

For small installations of less than 2 kW, 24 V. is recommended.

For internal communications 24 V. is specially recommended.

NOTE 1: The voltages stated are the mean voltages at the consuming devices.

NOTE 2: For tankers, see Chapter 23

CHAPTER 7

A.C. SHIP'S SERVICE SYSTEM OF SUPPLY

7.01 - Normal distribution systems. The following systems are considered as standard :

Single phase
(a) 2-wire insulated
(b) 2-wire with mid-point earthed for lighting and socket outlets
(c) 2-wire with one pole earthed
(d) 3-wire with mid-wire insulated
(e) 3-wire with mid-wire earthed but without hull return.

Three phase
(f) 3-wire insulated
(g) 3-wire with neutral earthed
(h) 4-wire with neutral earthed but without hull return.

7.02 - Voltages. The following schedule gives recommended and maximum system voltages :

Application	Recommended voltages	Maximum voltages
Power, Cooking and Heating	Single Phase 110 127 220 250 Three Phase 220 380 440	Single Phase 250 Three Phase 500
Lighting	Single Phase 110 127 220* 250*	Single Phase 250*
Socket Outlets	Single Phase 110 127 250*	Single Phase 250*
Internal Communications	Single Phase 12 24 42 48 110 220 250	Single Phase 250

* provided the voltage to earth does not exceed 150

NOTE 1: The voltages stated are the mean voltages at the consuming devices.

NOTE 2: For tankers, see Chapter 23.

7.03 - Frequency. The standard frequency should be 50 or 60 c/s.

CHAPTER 8

SWITCHGEAR, SWITCHBOARDS, SECTION BOARDS AND DISTRIBUTION BOARDS

MAIN AND EMERGENCY SWITCHBOARDS

8.01 - Position of switchboards. An unobstructed space not less than 0.9 m (or 3 ft.) wide should be left in front of switchboards. Pipes should as far as possible not be installed directly above, or in front of or behind switchboards. If such placing is unavoidable the pipes should be without joints on these positions (see also Clause 3.18).

8.02 - Gangways. If fuses or parts which require maintenance are mounted at the rear of a switchboard, a gangway not less than 0.6 m (or 2 ft.) in width should be provided, but where beams or struts occur a width of 0.5 m (or 1 ft. 6 in.) is admissible.

8.03 - Mats. Where there is any risk of accidental contact with live parts during operation, inspection, or maintenance, a rubber insulating-mat or a grating of impregnated wood should be provided.

8.04 - Insulating materials. Insulating material used in the construction of switchboards should be durable and mechanically strong, flame-retarding, non-absorbent, and of satisfactory insulating qualities.

8.05 - Bus-bars, etc. Bus-bars and their connections should be of copper unless otherwise specified. All connections should be so made as to inhibit corrosion as far as possible. Bus-bars should be strengthened to withstand mechanical stresses which may arise from short-circuits. The cross-section of current-carrying parts should be such that the maximum permissible temperature-rise is not exceeded when the parts are carrying their full-load current. The maximum permissible temperature-rise for bare conductors is 40 Centigrade degrees.

8.06 - Rating of equalizer connections. The current rating of each equalizer connector and equalizer switch should be not less than half the rated full-load current of the generator.
The current rating of equalizer bus-bars should be not less than half the rated full-load current of the largest generator in the group.

8.07 - Distinguishing colours for d.c. Bare current-carrying parts of differing polarity should be clearly marked with distinguishing colours. The following colours are recommended for d.c. switchboards:

Red for positive pole
Blue for negative pole
White for middle wire
Black for earth connections.

The equalizer connection should be marked by white bands in addition to the appropriate colour as given above.

8.08 - Distinguishing colours for a.c. Bare current-carrying parts of different phases should be clearly marked with distinguishing colours. The following colours are recommended for a.c. switchboards :

Green	for phase 1
Yellow	for phase 2
Brown or violet	for phase 3
Grey	for insulated neutral
Black	for earth connections.

8.09 - Construction of switchboards. Switchboards should be of solid and durable construction and should be capable of withstanding mechanical stresses which may arise from short-circuits.
For voltages between poles, or to earth, above 150 V. a.c. or 250 V. d.c. dead-front switchboards should always be used.
Live parts should be mounted at such a distance from, or shielded from, parts of opposite polarity and earthed metal, in such a way that an arc cannot be maintained and that the length of creepage path is adequate. Where live parts on a switchboard are adjacent to a gangway, an insulated handrail should be provided to prevent accidental contact with live parts. (See also Clause 3.19). All the parts, including connections, should be readily accessible for inspection, maintenance, or replacement. (See also Clause 3.09).

8.10 - Labels. All apparatus, instruments, and operating handles, should be provided with labels of durable flame-retarding material, bearing clear and indelible indications. The rating of fuses and settings of adjustable protective devices should be indicated.

8.11 - Cable-entries, etc. Cable-entries, ducts and conduits, should comply with the recommendations of Chapter 11. Cable-entries should be suitable for the method of construction of the switchboard etc., to which the cable is connected.

8.12 - Measuring instruments for d.c. generators. For generators not operated in parallel at least one voltmeter and one ammeter should be provided for every generator.
For parallel operation, one ammeter should be provided for each generator and one voltmeter with a changeover switch for measuring the generator and bus-bar voltages.
For compound-wound generators fitted with equalizer connections, the ammeter should be connected to the pole opposite to that connected to the series winding of the generator.
For 3-wire generators, the ammeter should be located between the equalizer connection and the generator.
For 3-wire systems supplied by a 3-wire generator or by a balancing booster an ammeter should be connected to each outer pole of each balancing generator and a voltmeter between each pole of the bus-bars and the middle wire.

8.13 - Measuring instruments for a.c. generators. For generators not operated in parallel each generator should be provided with at least one voltmeter with a changeover switch for measuring the voltage of each phase, one ammeter with an ammeter switch to enable the current in each phase to be read or an ammeter in each phase and for generators above 50 kVA a wattmeter, together with a frequency meter, unless there are other effective means of indicating the revolutions per minute.
For parallel operation there should be provided in addition a synchronizing device with changeover switch for connecting it to any generator. The provision of an ammeter in the exciter circuit of each generator is recommended.

8.14 - Instrument scales. The upper limit of the scale of every voltmeter should be not less than 120 % of the normal voltage of the circuit, and the scale should be provided with a red line to indicate normal voltage.
The upper limit of the scale of every ammeter and wattmeter should be not less than 150 % of the normal rating of the circuit in which it is installed. The scale should be provided with a red line indicating the normal full-load. Ammeters for use with d.c. generators and kW meters for use with a.c. generators which may be operated in parallel should be capable of indicating reverse current or power respectively.

8.15 - Earth indication. For insulated systems, the main switchboard should be provided with means to indicate the state of insulation from earth of the system.

8.16 - Overcurrent protection of a.c. and d.c. generators. All a.c. and d.c. generator circuits should be provided with overcurrent protection in each insulated pole. The following protective gear should be provided as a minimum :

(a) For generators not arranged to operate in parallel:

a circuit-breaker arranged to open simultaneously all insulated poles or a multi-pole linked switch with a fuse in each insulated pole

(b) For generators arranged to operate in parallel :

a circuit-breaker arranged to open simultaneously all insulated poles and, for generators rated above 150 kVA, provided with reverse power protection with a time lag to prevent the tripping of circuit breakers during switching operations and mechanical shocks. The reverse power relays should be adjustable to the circumstances of reverse power between the limits of 3 % and 15 % of full-load that may be expected.
NOTE: The reverse power protection should be adequate to deal effectively with reverse power conditions emanating from the ship's network (e.g. cargo winches).

(c) In place of overcurrent protection to an earthed conductor or middle wire of a 3-wire d.c. system or 4-wire a.c. system :

an alarm relay arranged to operate when the current in the middle wire exceeds the permitted value.

8.17 - Tripping of non-essential load. Where the load includes essential services consideration should be given to an arrangement which will automatically trip sufficient non-essential load when the total load exceeds the connected generator capacity. If required this load shedding may be accomplished in or more stages.

8.18 - Additional requirements for d.c. generators. In addition to the protective gear specified in Clause 8.16 the following should be provided for generators arranged to operate in parallel :

(a) Where an equalizer connection is in use, the reverse current protection should be provided in the pole opposite to that in which the series winding is connected.

(b) For level-compounded generators an equalizer switch for each generator, so interlocked that it closes before, and opens after, the main contacts of the circuit-breaker with which it is associated.

(c) In 3-wire systems a switch in the connection to the middle wire, so interlocked with the generator switch or circuit-breaker connected to the "outers" as to operate simultaneously with them.

8.19 - Protection of outgoing a.c. or d.c. circuits. For all outgoing circuits the following should be provided as a minimum :

(a) Overcurrent and short circuit protection in each insulated pole.

(b) An automatic circuit-breaker so constructed as to open simultaneously all insulated poles or alternatively for currents of 300 A or less, a linked switch with fuses.

Overcurrent protection should be provided in such a manner that effective selectivity or discrimination is achieved as far as is practicable.

8.20 - Protection of meters, pilot-lamps, etc. Protection should be provided where practicable for voltmeters, voltage coils of measuring instruments, earth-indicating lamps and pilot-lamps together with their connecting leads. Fuses used for this purpose should be placed as near as practicable to the tapping from the supply.

8.21 - Breaking capacity of fuses and circuit-breakers. Circuit-breakers and fuses should be suitable for operation at the maximum short-circuit current which can pass through them.

8.22 - Moving parts of circuit-breakers, etc. Circuit-breakers and contactors in outgoing circuits if practicable should be so installed that their moving parts and corresponding relays are not live when the circuit-breaker etc. is in the "off" position, so that inspection, adjustment, and replacement of parts is facilitated. In essential circuits, the provision of isolating-switches is recommended.

8.23 - Testing. Before installation, switchboards complete with all components should pass the following tests. A high-voltage test should be carried out on all switching and control apparatus for systems of 60 - 500 volts at an alternating voltage of 1000 plus twice the rated voltage at 25 - 60 c/s for one minute applied between current-carrying parts connected together and earth, and between current-carrying parts of opposite polarity. For systems of 60 volts or less the test should be at 500 volts for one minute.
Immediately after the high-voltage tests, the insulation-resistance between current-carrying parts connected together and earth and

between current-carrying parts of opposite polarity should be not less than one megohm when tested with a d.c. voltage of not less than 500 V.

NOTE: Instruments and other ancillary apparatus may be disconnected during the high-voltage test and tested separately in accordance with the requirements of the appropriate standards.

SECTION AND DISTRIBUTION BOARDS

8.24 - Section and distribution boards. Section and distribution boards should comply with the recommendations made for main switchboards in Clauses 8.01 to 8.23 above as far as they apply. Matters particularly applicable to section and distribution boards are dealt with in the following Clauses 8.25 - 8.27.

8.25 - Position of section and distribution boards. Section and distribution boards should be accessible to authorized personnel at all times. They should be suitable enclosed unless they are installed in a cupboard or compartment to which only authorized personnel can have access. Section and distribution boards should be so placed that the maximum permissible temperature is not exceeded.

8.26 - Enclosure of section and distribution boards. The enclosure should be of non-hygroscopic and non-inflammable material, and in accommodation spaces where the enclosure is surrounded by inflammable material a layer of non-hygroscopic non-inflammable material which is also thermal-insulating should be provided. The enclosure should be of adequate mechanical strength and should be so constructed that it can be opened only by authorized personnel. Protection should be provided against accidental contact with live parts.

NOTE: Enclosures should preferably not be placed in contact with or should not be surrounded by inflammable material.

8.27 - Construction of section and distribution boards. All connections should be readily accessible when the protecting covers, if any, are removed. The replacement of parts should not necessitate the removal of the case of the disconnection of cables.
If the bus-bars of any section or distribution board carry "through" load, the size of the bus-bars should be of the same rating as the supply cable.

SWITCHGEAR AND FUSEGEAR

8.28 - Circuit-breakers, fuses and switches - general.

(a) The temperature of current-carrying parts will be dealt with in a later edition when IEC temperature limits have been established.

(b) The temperature limits of release, blowout, contactor-operating and relay coils which are left in circuit continuously at rated voltage and/or current should satisfy the requirements of an appropriate authority.

(c) Where the current to be interrupted by a switch or circuit-breaker is of such magnitude as to cause damage to the contacts, suitable arrangements should be made for the ready renewal of the damaged parts.

(d) The handles and operating mechanism of switches and circuit-breakers should be mechanically strong, and should be so designed and arranged that the hand of the operator, when using the device, cannot accidentally touch live metal or be injured through an arc arising from the switch or circuit-breaker or the blowing of an adjacent fuse. If switches are enclosed, their handles should not operate through unprotected slots.

(e) Metal cases should be well clear of live parts, and where switches are required to operate at voltages exceeding 125 V, and are rated for currents exceeding 6 A, any parts of metal cases which are adjacent to arcing contacts should be lined with incombustible insulating material.

(f) Each circuit-opening device should be so constructed and arranged that when placed in the "off" position it cannot accidentally move sufficiently to close the circuit.

(g) The means of fixing current-carrying parts should be independent from the means of making electrical connections thereto.

(h) Every circuit-breaker and fuse is to have an interrupting capacity not less than the prospective short-circuit current at the point in the circuit at which it is installed unless it is backed up by a fuse of suitable category of duty or by a circuit-breaker with an instantaneous trip-setting of not more than 90 % of the interrupting capacity of the device protected. The back-up protection is to have an interrupting capacity not less than the prospective short-circuit current at the point where it is installed. Reports of tests to establish the maximum interrupting capacity of circuit-breakers are to be submitted for consideration when required.

<u>8.29 - Prospective current.</u> In the absence of precise data, the following values of short circuit contributions may be assumed in estimating the total prospective current :-

D.C. generators	-	10 times rated full load current
D.C. motors	-	6 times " " "
A.C. generators	-	(with amortisseur windings) - 10 times rated full load current
A.C. generators	-	(without amortisseur windings) - 6 times rated full load current
A.C. motors	-	3 times rated full load current.

<u>8.30 - Circuit-breakers.</u>

(a) The over-current releases of circuit-breakers for generators and circuits with "preference" tripping should be adjustable.

(b) Where reverse power or reverse-current protection is provided the device should operate at not more than 15 % of the rated full-load current or nominal rating (kW) of the generator with rated voltage across the voltage coil, at any permissible temperature within the range.
A fall of 50 % in the applied voltage should not render the reverse-current mechanism inoperative, although it may alter the amount of reverse current required to open the breaker.

(c) Every circuit-breaker rated at more than 16 A should be of the free-handle type.

(d) Every circuit-breaker should be so constructed that, irrespective of the method of tripping and the conditions of load, it will when operated break the circuit effectively and without undue arcing.

8.31 - Switches.

(a) Every switch should be capable of breaking a load current 50 % in excess of its rated current at rated voltage, 100 times for switches of rating not exceeding 60 A, and 10 times for larger switches, and be capable of being put into service subsequently without injurious overheating. For d.c. the test load should be resistive and for a.c. it should have a power factor 0.3. The stated number of interruptions should be carried out at equal intervals within one hour.

(b) Every switch should have the contacts and hinges dowelled or otherwise locked to prevent movement out of alignment by rotation on the panel.

8.32 - Fuses.

(a) Every fuse should comply as far as possible with I.E.C. Publication No. 66 : "IEC Specification for fuses for voltages not exceeding 1000 V for a.c. and d.c."

(b) No fuse should be installed in a circuit where the prospective short circuit current is in excess of the rated breaking capacity of the fuse. In determining the prospective short circuit current consideration should be given to the contributions from running motors, which should be added to the short circuit current supplied by the generators.

(c) When fuses are employed to secure overcurrent protection for multiphase motor circuits an overload device should also be fitted for motors over 0.5 kW which will open the circuit if the current in any phase becomes excessive due to the opening of only one phase by the blowing of a fuse.

CHAPTER 9

DISTRIBUTION

Attention is drawn to the requirements of the International Convention for Safety of Life at Sea 1948.

9.01 - Methods of distribution. Current-consuming appliances should be connected to either :

(a) a main switchboard, or

(b) an emergency switchboard, or

(c) a section board, or

(d) a distribution board.

9.02 - Ring-main or looped circuits. One or more section or distribution-boards may be connected together to one cable so that this forms a continuous circuit or a ring-main. Such a cable or ring-main should be formed of conductors having an equal cross-section throughout.
If a cable supplies several section or distribution-boards in such a manner that the cable is looped from board to board, the cable may be interrupted if required at each board without the provision of additional protection. In such a case the bus-bars of the intermediate distribution-boards should be of sufficient cross-section to carry the full cable load.

9.03 - Balance of circuits for 3-wire d.c. systems. Current-consuming appliances connected between an outer conductor and the middle wire should be grouped in such a way that under normal condition the load on the two halves of the system is balanced within as far as possible 15 % at the individual distribution- and section-boards as well as at the main switchboard.

9.04 - Balance of loads on 3- or 4-wire a.c. systems. For a.c. 3- or 4-wire systems the current-consuming appliances should be so grouped in the final sub-circuits that the load on each phase will under normal conditions be balanced as far as possible within 15 % at the individual distribution-and section-boards as well as at the main switchboard.

9.05 - D.C. single-wire systems with hull return. In d.c. single-wire distribution systems with hull return, it is recommended that all final sub-circuits for lighting should consist of 2 insulated wires, the hull return then being achieved by connecting one of the bus-bars of the distribution-board from which they originate with the hull.

9.06 - Final sub-circuits. A final sub-circuit having a current rating not exceeding 16 A may supply any number of lighting points up to the following maxima :
for 24 V and 48 V : 10 points, for 110 V : 14 points,
for 220 V : 18 points.
In cornice-lighting, panel-lighting and electric signs, where lamp-holders are grouped in close proximity to each other and are connected to the circuit without flexible cords, more than the number of holders specified above may, if desired, be connected to a final sub-circuit, provided that the maximum operating current in each sub-circuit does not exceed 10 A.

9.07 - Socket-outlets in lighting systems. Socket-outlets for portable lamps, small domestic appliances and small heaters, may be grouped together as for lighting points (see 9.06). Motors rated at 0.2 kW or less may be connected to a lighting circuit.

9.08 - Precautions against fire. If a ship is divided into fire zones, at least two separate feeders for lighting should be provided in each zone, one of which may be the feeder for the emergency lighting. The feeders for the different zones should be so arranged that in the event of fire in one zone, the supply to the other zone remains as far as possible unimpaired.

9.09 - Lighting circuits in machinery spaces, passengers' accommodations, etc. In machinery spaces and large galleys, and on passenger ships in the following spaces accessible to passengers :

Corridors,
Stairways leading to boat-decks,
Saloons,
Emigrant spaces,

lamps should be supplied from more than one circuit one of which may be the emergency circuit in such a way that failure of any one circuit does not reduce the lighting to an inadequate level.

9.10 - Cargo-space lighting. The lighting of groups of lamps in cargo-spaces should be controlled by multi-pole switches situated outside these spaces and accessible only to authorized personnel.

9.11 - Radio installations, including direction-finding and similar equipment. It is recommended that where practicable radio installations should be supplied from a separate way on the main switchboard or emergency switchboard.

9.12 - Navigation lights. The masthead, side and stern lights should be connected separately to a distribution board which is reserved for this purpose and which is directly connected to the main or emergency switchboard.
The distribution board should be placed in an accessible position under the control of the officer of the watch.
Each navigation light should be protected by a fuse and a double-pole switch, or alternatively by a double-pole circuit-breaker fitted on the distribution-board referred to above.
Each navigation light should be provided with an automatic indicator which gives aural and/or visual warning in the event of extinction of the light. If an aural device is used it should be connected to a separate source of supply, for example a primary or accumulator (storage) battery. If a visual signal is used which is connected in series with the navigation light, means should be provided to prevent the extinction of the navigation light owing to the failure of the visual signal.
Provision should be made on the bridge for the navigation lights to be transferred to an alternative circuit.

9.13 - Final sub-circuits for motors, etc. A separate final sub-circuit should be provided for every motor engaged on an essential service and for every motor rated at 1.25 kW or more.

9.14 - Steering-gear. Where the steering-gear is operated by two independent mechanisms and electric power is used for the operation of both, the power should be supplied by two sets of cables both from the main switchboard.
The feeders should be separated throughout their length as widely as practicable so that in this respect the continuity of operation of the steering-gear is ensured.
Where electric or electro-hydraulic power is employed for the operation of steering-gear, the failure of supply to the steering-gear motor (or motors) should be indicated to the principal propulsion control station and at the main-steering position.
Apart from the alarm, only short-circuit protection should be provided on steering-gear circuits.

9.15 - Ventilation systems. All power ventilation, except for machinery spaces, should be fitted with master controls so that all fans may be stopped from either of two control stations which should be situated as far apart as practicable. It should be possible to operate one of the master controls for power ventilation serving machinery spaces from a position outside the machinery space. The switchboard feeding power to the equipment for these systems may be considered as the second control point.
NOTE: This clause does not apply to small fans connected to lighting circuits (see Clause 9.07).

9.16 - Fuel-oil pumps. Emergency stop-control for motor-driven fuel-oil pumps should be provided at a readily accessible point outside machinery spaces, or means should be provided for the motors to be stopped automatically by the operation of the corresponding fire-extinguishing system.

9.17 - Fire-pump motors. Feeders supplying fire-pump motors should be so arranged that a fire occurring in any one compartment or fire zone will not put out of action all the fire-pumps.

9.18 - Sprinkler fire-extinguisher systems. The supply to sea-water pumps, air compressors and automatic alarms should be fed through the emergency switchboard by a feeder reserved for this purpose. No switch should be installed in the circuit other than that at the switchboard; this switch should be clearly labelled and should be permanently closed in all normal circumstances.

9.19 - Overboard discharges from motor-driven pumps. Motor-driven pumps designed to discharge above the light-load line and in way of life-boat launching should be provided with emergency switches installed in locked boxes having covers of glass or the equivalent, conveniently located outside machinery spaces.

9.20 - Loading- and unloading-equipment. Should it be decided for practical reasons to connect apparatus required when the ship is under way to the same supply as apparatus not so required, means should be provided for the isolation of the latter.

9.21 - Submersible permanently installed bilge-pumps.

(a) The motors of submersible, permanently installed, bilge-pumps should be connected to the emergency switchboard.

(b) Cables and their connections to such pumps should be capable of operating under a head of water equal to their distance below the bulkhead deck. The cables should be lead-sheathed and armoured and should be installed in continuous lengths from above the bulkhead deck to the motor terminals and should enter the air bell from the bottom. Cables of other types but equivalent performance may be used as an alternative to lead-sheathed and armoured cables.

(c) Under all circumstances it should be possible to start the motor of a submersible, permanently installed, bilge-pump from a convenient point above the bulkhead deck. If an additional local starter is provided at the motor, the circuit should be arranged to provide for the disconnection of all control wires therefrom at the starter installed on deck.

9.22 - Heating. Each heater should be connected to a separate final sub-circuit except that up to 10 small heaters of aggregate current rating not exceeding 16 A may be connected to a single final sub-circuit.

9.23 - Heating and cooking appliances. It should be possible to disconnect every fixed heating or cooking appliance by a switch breaking all insulated poles simultaneously.

9.24 - Junction-boxes. Junction-boxes should be easily accessible and if mounted behind panels their position should be indicated by a label on the relevant panel.

9.25 - Overcurrent protection. Except as prohibited in Clause 9.13, overcurrent protection should be provided at section-and distribution-boards for each insulated conductor supplied therefrom, and also where a cable is connected to another cable of lower current rating.
In all circumstances cables should be protected against short-circuit, in such a way that effective discrimination is secured and the damage is restricted as much as possible.
The current setting of the circuit-breaker should be such that the circuit-breaker trips within a safe time, when the current exceeds the current rating of the conductor.
In order to ensure the discrimination of overcurrent protective devices, it is recommended that the number of such devices placed between the bus-bars of the main board and current-using appliances should be limited. The limit should be 4 for motive-power circuits and 5 for lighting or heating circuits.

9.26 - Protective devices. Protection may be provided by fuses of approved construction, by circuit-breakers provided with overcurrent relays or by circuit-breakers backed up by fuses. Circuit-breakers should open all poles of the supply simultaneously.
Every protective device should be rated for the greatest possible short-circuit current which can pass through it. Circuit-breakers and fuses protecting supply cables for motors may be designed to allow excess current to pass during the normal accelerating period of the motor. No protective device rated at less than 5 A need be installed.

NOTE: It is admissible to short-circuit the adjacent overcurrent releases during this accelerating period.

9.27 - Protection of lighting circuits. Each lighting circuit should be protected by an overcurrent device rated at not more than 16 A.

Protective devices of circuits in which socket-outlets are included should not exceed the rating of the connected socket-outlets.

9.28 - Pilot lamps. A pilot lamp installed as an integral part of another item of equipment need not be individually protected, provided that the protective device of the main circuit is rated at not more than 25 A. (See also Clause 8.20).

9.29 - Emergency supply. Where an emergency supply is required, this should comply with the recommendations of the International Convention on Safety of Life at Sea 1948.

An indicator should be provided which indicates when the emergency system is being supplied by the battery. This indicator should preferably be mounted on the main switchboard.

9.30 - Shore connections. Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a suitable connection-box should be installed in a position on the ship convenient for the reception of portable cables from the external source and containing terminals of ample size and suitable shape to facilitate a satisfactory connection.

The circuit should be provided with a multi-pole switch of size appropriate to the current rating of the fixed cable which connects the connection-box to the main switchboard.

Where it is intended to supply electricity through the connection-box to outside loads, a fuse should be fitted on each live pole at the switchboard, or the multi-pole switch specified above may be replaced by a circuit-breaker.

The fixed cable should be provided with an indicator, preferably at the main switchboard, in order to show when the cable is energized.

For three-phase systems with earthed neutral an earth terminal should be provided for connecting the hull to the shore earth.

The connection-box should be provided with means for checking the polarity, if d.c., and the phase sequence, if 3-phase a.c., of the incoming supply in relation to the ship's system.

At the connection-box a notice should be provided giving full information of the system of supply and the normal voltage (and frequency, if a.c.) of the ship's system as well as the requirements for carrying out the connection.

9.31 - Protection of transformers. For transformers above 1 kVA the primary windings should be individually protected in each phase against overcurrents by means of circuit-breakers of fuses.

CHAPTER 10

CABLES, CONSTRUCTION AND TESTS

NOTE : 1 This chapter is not unanimously approved but is published for guidance.
Re-drafting of this chapter is under consideration.

NOTE : 2 The constructions and tests, contained in Chapter 10 are not intended to replace or supplement constructions or tests which are approved by a National Authority for use in ships.

Section 1 - General matters and definitions.

10.01 - Specified values and actual values. In this chapter, the term "specified values" means values which must be met in tests; the term "actual values" is applied to the results of measurements made in accordance with the tests specified.

10.02 - Values specified by these Recommendations and values specified by the Purchaser. When in these Recommendations reference is made to "specified values", it should be understood throughout that these refer to the values specified by the purchaser of the cables (or by the appropriate Authority).

10.03 - Interchangeability of cables.

NOTE: It is under consideration to publish in a later edition a reference table for the choice of interchangeable cables, among those provided for in the most important existing National Standards.

10.04 - Classification of cables.

(a) in relation to voltage rating

The cables dealt with in this chapter are distinguished by the following classes of insulation:

(a1) for a rated voltage of 110 V
(a2) " " " " " 250 V
(a3) " " " " " 660 V
(a4) " " " " " 1100 V
(a5) " " " " " 3300 V
(a6) " " " " " 6600 V

(b) in relation to construction

See Sections 6, 7 and 8 of this chapter.

Section 2 - Conductors

10.05 - Characteristics of the metal. The conductors should be composed of copper of conductivity at least equal to 98% of that of standard annealed copper as defined in Publication No. 28 (1925) of the International Electrotechnical Commission; the resistivity of the copper should thus not be higher than 0.01759 ohm-mm^2/m (6.9252 x 10 $^{-7}$ ohm-in.) at 20°C.
The other properties of the copper should be in conformity with the same publication.

10.06 - Formation of conductors. The conductors should be circular and regular in form. For multi-core cables, shaped conductors are admissible when the insulating material permits, and provided that the cross-section is free from sharp projections and other defects liable to damage the insulation.

For cables intended for fixed wiring, circular conductors other than mineral insulated cables should be composed of strands (all of the same diameter) not less in number than Table 10.V (Page 61) requires.

10.07 - Tinning of copper wires. For rubber-insulated cables, the wires forming the conductor should be coated with pure tin or tin alloy.

10.08 - Cross-sectional area of conductors. The cross-sectional area should be checked by a measurement of electrical resistance, in accordance with Clause 10.51 of these Recommendations.

Section 3 - Insulation

10.09 - Types of insulation. The present chapter applies only to cables using the following types of insulation :

(a) rubber (natural or synthetic)
(b) varnished cambric
(c) mineral

The characteristics which the insulation should possess are indicated in Clauses 10.54, 10.55, 10.56 and 10.57.

NOTE: Other types of insulation which may be used in ships are not dealt with in the present edition of the Recommendations, but may be added in a later edition: for example, asbestos with varnished cambric.

10.10 - Rubber-insulation.

(a) Properties of the rubber
The rubber insulation should be composed of a mix of natural or synthetic rubber satisfying the tests specified in Clause 10.55. Polychloroprene is included in the term "synthetic rubber".

(b) Application of the insulation to the conductor
The insulation may be formed by one or more layers of rubber of equal or different quality (including polychloroprene compound but not pure rubber). The use of a single layer is permissible only when it is applied by extrusion. The layers should be bonded together and the insulation should be close-fitting, but not adherent to the copper conductor.
The manufacturer has the right to apply a rubberized tape to the exterior of the rubber insulation.

(c) Thickness of insulation
The actual mean thickness of insulation (determined in accordance with Clause 10.43) should be not less than the thickness specified by the purchaser, and not less than the values given in the following tables :

Table 10.VI Page 62 - cables for a rated voltage of 250 V.
Table 10.VII Page 63 - " " " " " " 660 V.
Table 10.VIII Page 64 - cables for propulsion and communications.

For twin or multi-core cables, the insulation of the conductors may be completed by a belt of rubber insulation, the mean thickness of which (determined in accordance with Clause 10.43) should be not less than the values given in Table 10.IX Page 65.

10.11 - Varnished-cambric insulation.

(a) Properties of the varnished-cambric

Varnished-cambric insulation should be composed of varnished-cambric tapes satisfying the following requirements :

(i) the textile base of the varnished-cambric should be an even weave of cotton or (if explicitly agreed by manufacturer and cable purchaser) of rayon or silk.

(ii) the tape should be well varnished on both sides with an insulating varnish of such quality that the finished cables satisfy the tests specified in the present chapter;

(iii) the nominal thickness of a varnished-cambric tape should be not more than 0.30 mm (or 0.012 in.); the actual thickness should not differ from the nominal thickness by more than ± 20 %;

(iv) the samples of tape, removed from the cables, should satisfy the physical tests specified in Clause 10.56.

(b) Application of the varnished-cambric insulation to the conductors.

Several varnished-cambric tapes (the nominal thickness of which may be the same or different) should be tightly wound helically round the conductor in such a way as to form a uniform layer of insulation, in which the gaps between tapes should not be greater than the thickness of a single tape.
Each tape should be coated with a viscous insulating compound to serve as a lubricant. This insulating compound should not harden with age and should not exercise any harmful action on the varnished cambric, on the conductors or on the protective sheath.

(c) Separator

The manufacturer may insert a separator either between the conductor and the insulation, or over the insulation, or in both places. The separator should be composed of tapes of cellophane, oiled paper, woven cotton or glass, or a braid.

(d) Thickness of the varnished-cambric insulation

The actual thickness of insulation at any point, determined in accordance with Clause 10.44 should be not less than the thickness specified by the purchaser, and not less than the values given in Table 10.X Page 66.
When a separator is used, its thickness may be taken into account when the actual thickness of the insulation is determined.

10.12 - Mineral insulation.

(a) Properties of mineral insulation

The mineral insulation should be composed of a powdered mineral substance so compressed as to satisfy the tests specified in the present chapter.
The nature of the substance is left to the choice of the manufacturer.

(b) Thickness of mineral insulation

The mean thickness of the insulation, in the case of a magnesium-based insulant, should be not less than the values given in Table 10.XVI Page 72.

Section 4 - Protective coverings

10.13 - Types of constituent elements of protective coverings. The protective sheath of a cable consists of one or more constituent elements, according to the relevant specification given in Sections 6, 7 and 8 of this chapter.
The types of constituent elements provided for in the present edition of these recommendations are:

(a) non-metallic elements
- impregnated textile braid (Clause 10.15)
- bedding for armour and metal braid (Clause 10.16)
- paint for armour (Clause 10.18)
- polychloroprene sheath (Clause 10.21)
- rubber sheath (Clause 10.22)

(b) metallic elements
- lead or lead-alloy sheath (Clause 10.14)
- metal braid (Clause 10.17)
- galvanized-steel-wire armour (Clause 10.19)
- steel tape armour (Clause 10.20)
- copper sheath (Clause 10.23)

NOTE: Other types of constituent element which may be used for the protective coverings of ships' cables are not provided for in the present edition of these recommendations, but may be added in a later edition.

10.14 - Lead or lead-alloy sheath.

(a) Properties of the metal

The sheath should be composed, according to the circumstances (see 10.14 (b)) of lead or of an approved lead-alloy. "Lead" is defined as lead containing not more than 0.1 per cent of other metals, among which the zinc content should not exceed 0.002% and bismuth 0.05%.

"Approved alloys" are those given in the following table. Other types of alloy are admissible only subject to specific agreement between the manufacturer and the purchaser:

Table 10.I

Type of alloy	Composition (percentage by weight)								
	Tin		Antimony		Cadmium		Copper		Pure lead
	min.	max.	min.	max.	min.	max.	min.	max.	
No. 1	1.8	2.2	-	-	-	-	-	-	
No. 2	-	-	0.7	0.95	-	-	-	-	
No. 3	0.35	0.45	0.15	0.25	-	-	-	-	The remainder
No. 4	0.35	0.45	-	-	0.12	0.18	-	-	
No. 5	-	-	-	-	-	-	0.04	0.08	

(b) Application of the sheath to the cables

The use of "lead" as distinct from lead alloy for cable sheaths is admissible only where there is a further protective covering. (See Table 10.XI Page 67). The sheath should remain close-fitting and truly concentric to the cable, and should be free from cracks and other defects.

(c) Thickness of sheath

The mean actual thickness of the sheath, determined in accordance with Clause 10.46, should be not less than the thickness specified by the purchaser and not less than the values given in Tables 10.XI and 10.XII (Pages 67-68).

Table 10.XI Page 67 applies when the lead or lead-alloy sheath has an outer layer of other protective covering (textile braid is not considered to be a protective covering for the purposes of this clause).

Table 10.XII Page 68 applies when the lead-alloy sheath is bare, that is to say without further external protection (textile braid is not considered to be a protective covering for the purposes of this clause).

10.15 - Impregnated textile braid. The textile braid should be of cotton or hemp, or other equivalent textile fibre, and should be of a strength suitable for the size of the cable. It should be effectively impregnated with a compound which is resistant to moisture, flame-retarding and free from deleterious action upon the various materials constituting the cable.

10.16 - Bedding for armour and metal braid.

(a) Bedding for metal braid

(i) A cotton tape wound with an overlap of at least 30 %, or two tapes so wound that the second overlaps by at least 20 % the two edges of the first. The tape may be of glass or other fibre in place of cotton, and should be impregnated or treated with a non-hygroscopic material which is flame-retarding.

(ii) Tapes of polychloroprene may be used in place of textile tapes.

An impregnated textile braid (Clause 10.15) is also a suitable bedding for metal braid.

(iii) When the bedding is applied over a lead sheath, the latter should first be coated with bitumen or other waterproofing material.

(iv) When the metal braid is applied over a protective sheath of polychloroprene (Clause 10.21), no bedding is necessary. A sheath of polychloroprene, even when thinner than that prescribed in Table 10.XI Page 62 may thus be used in place of the above-named covering as a bedding for metal-braid armour.

(b) Bedding for steel wire or tape armour

A wound spiral or braid of jute threads or other textile material (including glass fibre), or a woven tape of the above-mentioned materials, should form a continuous layer of a thickness (measured on the finished cable) equal to at least half the diameter of the steel wires (Table 10.XIV Page 70).

10.17 - Metal braid. The braid should be formed of zinc-coated (galvanized) steel wires of a nominal diameter not less than the value given in Table 10.XIII Page 69.

On special request, the braid may be formed of copper, copper-alloy, or aluminium-alloy wires, whose surface should be protected against corrosion (for example by tinning, galvanizing, or other suitable method). The diameters of such wires should be not less than the values given in Table 10.XIII Page 69.

The braid should be an even weave, free from broken wires and close fitting on the cable. Its density should be such that the weight of the braid is at least 90 per cent of the weight of a tube formed of the same metal, of internal diameter equal to that of the braid, and of thickness equal to the diameter of one of the wires forming the braid.

The metal braid should always be protected externally by a suitable compound (Clause 10.18).

10.18 - Paint for armour and metal braid. The paint should form an effective and durable means of protecting the wires against rust and other chemical corrosion under the conditions of installation normally encountered on shipboard.

10.19 - Galvanized-steel-wire armour. Annealed steel wire should be used and the nominal diameter of the wires should be not less than that specified by the purchaser, and not less than the values given in Table 10.XIV Page 70.

On special request by the purchaser or manufacturer, use may be made of shaped wires in place of circular wires: in that event the mean thickness of the shaped wire should be not less than that specified by the purchaser and not less than the values given in Table 10.XIV Page 70.

On special request, instead of steel wires, wires of the same dimensions but of non-magnetic metal may be used.

The wires should be applied over the bedding so as to form a uniform and substantially uninterrupted cylindrical layer. The lay of the winding formed by each wire should be approximately equal to 10 times the mean pitch circle diameter when the diameter of the wires exceeds 2 mm (or 0.08 in.), or 8 times when it is 2 mm or less.

On request the wire armour should be protected by a suitable compound (Clause 10.18).

10.20 - Steel-tape armour. Annealed steel tape should be used and the mean thickness of the tapes should be not less than that specified by the purchaser and not less than the value given in Table 10.XV Page 71.

On special request, in place of steel tapes, tapes of the same dimensions but of non-magnetic metal may be used.
The armour should be formed of two tapes wound in the same direction over the bedding so that the gap in the first layer is approximately equal to one-third the width of the tape and the second layer covers this gap with an overlap.
For cables whose diameter under the bedding is less than 10 mm (or 0.4 in.) the use of this type of armour is not recommended.

10.21 - Polychloroprene sheath.

(a) Properties of the polychloroprene material
Two types of vulcanized compound based on polychloroprene are provided for in these Recommendations.

Type A - For sheaths having additional external protection;
Type B - For sheaths of all types of cable.

The physical characteristics of both types should satisfy the requirements of the tests specified in Clause 10.60.

(b) Application of sheath
The polychloroprene sheath should be applied to the cables in a manner guaranteeing a high degree of resistance to mechanical damage, close fitting and resistance to moisture, and freedom from air bubbles and other defects.

(c) Thickness of sheath
The mean thickness of the sheath, measured in accordance with Clause 10.48 should be not less than the thickness specified by the purchaser and not less than the values specified in the following tables :

Table 10.XI Page 67 : Polychloroprene sheath combined with other protection for example: direct application over a lead sheath, or protection by external armour (other than textile braid);
Table 10.XII Page 68: Polychloroprene sheath for cables for fixed wiring when this sheath alone (or this sheath combined with a textile braid) forms the protection.

10.22 - Rubber sheath.

(a) Properties of the rubber sheath material
Two types of vulcanized compound based on natural rubber are provided for in these Recommendations.

Type C - For sheaths having further external protection.
Type D - For sheaths for all types of cable.

The physical characteristics of the two types should satisfy the requirements of the tests specified in Clause 10.60.

(b) Application of the sheath
The same requirements apply as for polychloroprene (see Clause 10.21-b)

(c) Thickness of sheath
The same requirements apply as for polychloroprene (see Clause 10.21-c).

NOTE: It is in general preferable to use a polychloroprene sheath rather than a natural-rubber sheath, since it has a stronger resistance to fire, aging and to the action of oils.

10.23 - Copper sheath (for mineral-insulated cables). For mineral insulated cables the sheath over the insulation should be of copper or copper-alloy.
The sheath should be of uniform thickness and free from splits, cracks and other defects. The surface of the metal should be smooth and free from traces of sulphur or foreign matter, particularly chemical substances which may have been used as cleansing agents.
The thickness of the copper sheath should be in accordance with Table 10.XVI, Page 72.

Section 5 - Construction of twin and multi-core cables.

10.24 - Types of twin and multi-core cables. Two types of twin and multi-core cables are provided for in this Code: in the first type, an additional belt of insulation is applied over the insulated and cabled cores; in the other type, the protective covering is applied directly to the insulated and cabled cores. For the first type, the thickness of insulation of each core can be lower than for the second type; see for example Table 10.VII, Page 63.

The thickness of the common belt of insulation should be such that the total thickness of insulation between each conductor and the sheath is equal to or greater than the total thickness of insulation between cores: see for example Table 10.X, Page 66.

10.25 - Cabling of insulated cores.

(a) Cables without common belt of insulation
The insulated cores, with the addition of a tape or separator, if required, (Clauses 10.10-b and 10.11-c) and bearing identification markings (Clause 10.26) should be twisted together so as to form a uniform and flexible cylinder. The spaces between the cores should if necessary be filled with suitable wormings (Clause 10.27).

For cross-sectional areas of conductor not exceeding 2.5 mm^2 (or 0.004 $in.^2$), the construction of twin flat cables is admissible, with or without wormings, and with a flat instead of a round cross-section.

The requirements of this clause do not apply to mineral-insulated cables (for which see Clause 10.29).

(b) Cables with a common belt of insulation.
The same requirements apply as for (a) above, except that the wormings and the common belt must be insulating and the use of a flat cable is not admissible.

10.26 - Identification of insulated cores. Identification may be effected by colouring or by numbering, the insulation or the tape or external separator, if any, or, as a further alternative, by the addition of a coloured binding or braid. The choice of method of identification, (which may also be different from the above systems), is left to the manufacturer, but in any event it should be so carried out that the various cores are readily identifiable, not only in new cables, but also in those which have been in service for some time.

For the choice of colours the following rule is recommended :

- For twin cables : two distinctive colours
- For three-core cables : grey, red, black
- For cables with more than three cores : grey, red, black and another colour (not red or grey) for the other cores.

For multi-core cables in which the cores are cabled in several concentric layers, it is recommended that in each layer there should be at least two adjacent cores coloured differently from all the others.
In telephone cables cabled in pairs, the two cores of each pair should be distinguished from each other, and in addition any particular pair should be identifiable (for example as indicated above for multi-core cables).

10.27 - Wormings.

(a) Cables without common belt of insulation

The wormings may be composed of fibrous materials (for example jute, cotton, fibre glass) or by rubber-like materials (for example rubber or polychloroprene compounds). The wormings should fill all the spaces and should not have any deleterious effect - from either mechanical or chemical point of view - on the cables, at any temperature in the range 0 °C - 75 °C. In particular the wormings should not form a solid mass with the insulation of the cores.

When the protective sheath of the cable is of polychloroprene or rubber, wormings of the same materials can be integral with the sheath or, alternatively, separated by a binding (Clause 10.28).

(b) Cables with common belt of insulation

When the common belt of insulation is of rubber, the wormings should be of rubber and the wormings in the outermost layer should be integral with the sheath. When the common belt of insulation is a layer of varnished-cambric (that is to say for varnished-cambric-insulated cables) the wormings should be of textile material or paper.

10.28 - Covering or binding.

(a) Cables without common belt of insulation

For these cables the application of a wrapping or covering or separator or other suitable binding on the cabled cores before the application of the protective sheath is optional for the manufacturer. Such covering can be formed, for example, by a tape or binding or an impregnated braid.

(b) Cables with common belt of insulation

The nature and construction of the common belt of insulation for the various types of cable provided for in these Recommendations are defined in Clauses 10.24 and 10.27-b.

The thickness of the belt itself (measured opposite the cores, that is to say where the thickness is at a minimum) should be in accordance with the values specified in the clauses regarding insulation of cores (in particular Clause 10.10-c and Table 10.IX, Page 65 for rubber insulation, and Clause 10.11-d and Table 10.X, Page 66 for varnished-cambric insulation).

It is open to the manufacturer to apply a wrapping or separator or other suitable binding between the common belt of insulation and the external protective sheath.

10.29 - Multi-core mineral-insulated cables. The conductors should be parallel and embedded in the insulation so that the thickness of insulation between conductors or between conductors and external copper sheath are in accordance with Table 10.XVI, Page 72.

Section 6 - Specification of rubber-insulated cables.

10.30 - Cables for fixed wiring and for rated voltage not exceeding 250 V.

(a) Conductors

For cables having up to 4 cores the conductor size should not exceed 40 mm^2 (or 0.062 $in.^2$ or 80 000 circ.mil.); for five or more cores the conductor size should not exceed 6.3 mm^2 (or 0.01 $in.^2$ or 12 500 circ.mil.).
The formation of each conductor should be in accordance with Table 10.V, Page 61.

(b) Insulation (Clause 10.10)

Minimum mean thickness should be in accordance with Table 10.VI, Page 62.

(c) Cabling of insulated cores (Clause 10.25-a)

The cores should be identified in accordance with Clause 10.26, the wormings, if any, should be in accordance with Clause 10.27-a, and the wrapping, if any, in accordance with Clause 10.28-a.

(d) Protective coverings

The following types are provided for in the present edition of these Recommendations (the types marked * * are recommended):

(i) Impregnated textile braid with humidity-resistant and flame-retarding compounds (Clause 10.15).

* * (ii) Polychloroprene sheath (Clause 10.21, Grade B), thickness in accordance with Table 10.XII, Page 68.

(iii) Rubber sheath (Clause 10.22, Grade D), only for cross-sectional areas of conductor up to 6.3 mm^2 (or 0.01 $in.^2$, or 12 500 circ. mil.); thickness in accordance with Table 10.XII, Page 68.

(iv) Polychloroprene sheath (Grade B) with impregnated textile braid (Clauses 10.21 and 10.15).

* * (v) Polychloroprene sheath (Grade A or B) with metal braid and overall compound (Clauses 10.21 - 10.17 - 10.18); thickness of sheath in accordance with Table 10.XI, Page 67.

(vi) Lead-alloy sheath (Clause 10.14), thickness in accordance with Table 10.XII, Page 68.

* * (vii) Lead or lead-alloy sheath and metal braid, with bedding under the braid, and overall compound (Clauses 10.14 - 10.16-a - 10.17 - 10.18); thickness of sheath in accordance with Table 10.XI, Page 67.

* * (viii) Lead or lead-alloy sheath with galvanized-steel-wire armour, with bedding under the armour, and if required compound over the armour wires (Clauses 10.14 - 10.16-b - 10.19); thickness of sheath in accordance with Table 10.XI, Page 67.

(ix) As (viii) but with impregnated textile braid (Clause 10.15).

10.31 - Cables for fixed wiring and for rated voltage 660 V.

(a) Conductors (formation in accordance with Table 10.V, Page 61)

A single conductor of cross-sectional area not exceeding approximately 1000 mm^2 (or 1.6 in.^{2} or 2 000 000 circ.mil.) or

Two, three of four conductors of cross-sectional area not exceeding approximately 6.3 mm^2 (or 0.01 in.^{2} or 12 500 circ.mil.).

(b) Insulation (Clause 10.10)

Minimum mean thickness in accordance with Table 10.VII, Page 63 i.e.:
normally in accordance with 10.VII-b, Page 63

in accordance with 10.VII-a, Page 63 only when an additional layer of insulation in accordance with Table 10.IX, Page 65 is applied over the cabled cores.

(c) Cabling of insulated cores (Clause 10.25)

The identification of cores should be in accordance with Clause 10.26, and the wormings in accordance with Clause 10.27. The covering or wrapping should be in accordance with Clause 10.28.

(d) Protective sheath

See under Clause 10.30-d. In addition:

* * (x) Lead or lead-alloy sheath with steel-tape armour, with bedding under the armour, (Clauses 10.14 - 10.16 - 10.20); thickness of sheath in accordance with Table 10.XI, Page 67.

10.32 - Cables for fixed wiring and for rated voltages 3300 V. and 6600 V.

The construction of these cables is similar to that described in Clauses 10.30 and 10.31. The cross-sectional area of conductors is in general greater than 20 mm^2 (or 0.03 in.^{2} or 40 000 circ.mil.). For minimum mean thickness of insulation see Table 10.VIII, Page 64.

The protective sheaths recommended are only of the types (v) - (vii) - (viii) of Clause 10.30-d.

10.33 - Cables for fixed wiring for signalling and control purposes.

(a) for rated voltage of 250 V, or

(b) for rated voltage of 660 V.

For the specification of these cables see Clauses 10.30 and 10.31, bearing in mind that the cross-sectional area of conductors is in general between 1 and 2.5 mm^2 (or 0.0015 in.^{2} and 0.004 in.^{2})

The number of cores normally should not exceed 40. The cabling should normally be carried out by individual cores and not in pairs; the protective sheath of type (i) (impregnated textile braid) is not recognized.

10.34 - Cables for fixed wiring for internal communication circuits (voltage not exceeding 110 V).

(a) Conductors
Cross-sectional area: Between 0.5 mm^2 (0.0008 $in.^2$ or 1000 circ.mil.) and 1.6 mm^2 (or 0.0025 $in.^2$ or 3200 circ.mil.).

Formation : Single wire, 3 or 7 strands;

Number of cores: Normally not exceeding 60

(b) Insulation (Clause 10.10)
Mean thickness not less than 0.8 mm (or 0.03 in.); rubberized tape or coloured braid may be added (at the choice of the manufacturer).

(c) Cabling of insulated cores (Clause 10.10)
This can be carried out either by individual cores (Clause 10.33) or by pairs. In the latter instance two cores are twisted to form a pair and several pairs are cabled (with or without worming), the whole being bound by textile tape. The identification of cores and of pairs should be in accordance with Clause 10.26.

(d) Protective sheath
See Clause 10.30-d, excluding type (i) (textile braid).

Section 7 - Specification of varnished-cambric-insulated cables.

10.35 - Cables for fixed wiring for rated voltage 1100 V.

(a) Conductors (see Clause 10.06, formation in accordance with Table 10.V, Page 61)
A single conductor of cross-sectional area not exceeding approximately 1000 mm^2 (or 1.6 $in.^2$ or 2,000,000 circ. mil.), or

two, three or four cores of round or segmental formation and of cross-sectional area not exceeding approximately 325 mm^2 (0.5 $in.^2$ or 650 000 circ.mil.).

In every instance the cross-sectional area should be not less than 2 mm^2 (or 0.003 $in.^2$ or 4 000 circ.mil.).

(b) Insulation: (Clause 10.11)
Minimum thickness on each conductor.

(b1) in accordance with Table 10.X-a, Page 66 for single-core cables and for multicore cables without common belt of insulation.

(b2) half of the values given in Table X-b, Page 66 for multi-core cables with common belt of insulation.

Minimum thickness of common belt of insulation at least the difference between the values given in Table 10.X-a, Page 66 and half the values given in Table 10.X-b, Page 66.

(c) Cabling of cores (Clauses 10.24 and 10.25).
Identification of cores in accordance with Clause 10.26; worming in accordance with Clause 10.27; belt of insulation or wrapping (with or without separator at the choice of the manufacturer) in accordance with Clause 10.28.

(d) Protective sheath.
The following types are provided for in the present edition of these Recommendations (the types shown ж ж are recommended):

ж ж (ii) - (iv) - ж ж (v) - (vi) - ж ж (vii) - ж ж (viii) - (ix) of Clause 10.30-d.

10.36 - Cables for fixed wiring and for rated voltages of 3300 V. and 6600 V.

The design of these cables should be similar to that described in Clause 10.35 for cables either with or without common belt of insulation (at the choice of the manufacturer). For minimum thickness of insulation see Tables 10.X-c and 10.X-d, Page 66.

Section 8 - Specification for mineral-insulated cables.

10.37 - Cables for fixed wiring for operating voltage up to 660 V.

(a) Single-core cables.
These cables should be composed of a single copper wire, a layer of mineral insulation and a protective sheath of copper or copper-alloy provided with additional protection, if necessary. For standard dimensions see Table 10.XVI, Page 72.

(b) Multi-core cables.
These cables consist of 2, 3 or more copper wires of equal cross-sectional areas, which are straight and parallel, embedded in mineral insulation and forming a cylindrical whole within a protective sheath, of copper or copper-alloy, with additional protection, if necessary. For standard dimensions see Table 10.XVI, Page 72.

Section 9 - General recommendations for tests.

10.38 - Object and place of test. The tests specified in the present Chapter should be carried out solely on the finished cables, that is to say, they are tests on complete lengths ready for dispatch or, alternatively, tests on samples removed from lengths selected at random.
In general, the tests should be carried out at the manufacturer's works and the manufacturer should make available the necessary equipment.

10.39 - Batches. It is assumed in this Chapter that the cables forming a consignment are divided into batches of not more than 50 lengths. Each batch should consist solely of cables of the same cross-sectional area and the same type. Nevertheless, when a consignment includes several batches containing less than 10 lengths, the inspecting engineer can include in the same batch cables of different cross-sectional areas.

The number of tests which are recommended for each batch is shown in the following sections of this chapter.

10.40 - Repetition of tests. When the result of a recommended test for a batch is unsatisfactory, the same test should be repeated on twice the number of lengths tested previously, the lengths now tested being different from those first chosen. If a single result is then not satisfactory, the complete batch should be declared not in conformity with these Recommendations.

Section 10 - Manufacturing control and check of dimensions.

10.41 - General. A general examination for the conformity of the cables with the manufacturing requirements given in Sections 2 - 8 of this chapter should be carried out on a certain number of lengths as determined by the inspecting engineer. In addition, the dimensions of two lengths at least from each batch should be checked in accordance with the requirements of the present section.

As the ends of the lengths may sustain damage, it is admissible to cut off a portion of the cable end before taking samples for tests.

10.42 - Conductors. The actual cross-sectional areas of the conductors should be checked by a measurement of electrical resistance (see Clause 10.51).
The number of wires and the regularity of the stranding should also be checked.

10.43 - Rubber insulation. The thickness of the rubber insulation should be determined as the mean of 12 measurements carried out on two samples selected at least 0.3 m or 1 ft. from each other. On each sample 6 measurements should be carried out at points spaced 60° apart, including the point where the thickness appears to be the least.
The mean thickness thus determined should be not less than the specified thickness. In addition, the least thickness measured at any point should not fall below the specified thickness by more than 10 per cent plus 0.1 mm (or 0.0039 in.).
The measurements should be carried out by a measuring microscope or other equivalent optical means.
NOTE: For further details see C.E.E. Publication No. 2 (Clause 7).

10.44 - Varnished-cambric insulation. The thickness of the varnished-cambric layer should be determined in at least two different positions at least 0.3 m (or 1 ft.) apart.

In each position a sample of conductor about 12 cm (or 5 in.) long should be taken. The varnished-cambric tapes (with the exception of the separator, if any) should be removed and the thickness of each layer should be measured by micrometer. The thickness of the layers applied to each sample should be added so that two values of thickness of insulation are obtained. The lower value should be not less than that specified in Table 10.X, Page 66.

Alternatively the thickness of insulation may be determined by bunching together individual strips of varnished-cambric tape removed from the finished cable and measuring the total thickness with a micrometer having the characteristics defined below. All the varnished-cambric tapes comprising the insulation should be included in the measurement. The faces of the micrometer should be cleaned between successive measurements.

The micrometer may be any form of precision dead-weight micrometer capable of gauging the thickness of a number of impregnated tapes up to a possible total thickness of 6.35 mm (or 0.25 in.) with an instrument error not exceeding ± 0.005 mm (or 0.0002 in.). The micrometer should be provided with two parallel plane faces between which the tapes may be placed for measurement. One of the faces should be able to move in a direction perpendicular to the other, which is fixed. The movable face of the pressure foot should be circular, and have a diameter of 6.35 mm ± 0.25 mm (or 0.25 in. ± 0.01 in.). The area of contact between the fixed face and the pressure foot should be equal to the area of the pressure foot. The faces should be concentric and parallel to within 0.0025 mm (or 0.0001 in.) over the range of travel. The pressure foot should exert a steady pressure of 3.5 ± 0.18 kg/cm² or 50 ± 2.5 lb/in².

For multi-core cables two values are found for each core and two values for the common belt of insulation, if any. The sum of these minimum values appropriately combined should satisfy the minimum limits given in Table 10.X, Page 66.

10.45 - Mineral insulation. The thickness of the mineral insulation should be determined as the mean of at least 6 measurements carried out on two samples taken from two parts of the coil under test spaced at least 30 cm (12 in.) apart. The selected samples should be of suitable length and one of the ends should be carefully smoothed in a plane at right angles to the cable. The thickness of insulation should be measured by means of an optical micrometer, measuring microscope, or other equivalent optical means.

For single-core cables, the thickness of each sample, across the smoothed cross-section, should be measured radially at the point where it is smallest, and in addition, two other radial measurements should be made at 120° on either side.

For twin and multi-core cables the shortest distance between two adjacent conductors should be measured.

The mean thickness should be not less than the specified value and the thickness at any point should not fall below the specified value by more than 10 %.

10.46 - Lead or lead-alloy sheath. The actual mean thickness of the sheath should be determined as the mean of 8 measurements carried out on two samples taken from points at least 0.3 m (or 1 ft.) apart. Four measurements should be carried out on each sample at equidistant points, including the point where the thickness appears to be least.

The mean thickness thus determined should be not less than the specified thickness. In addition, the least thickness measured should not fall below the specified thickness by more than 10 % + 0.125 mm (or 0.005 in.).

10.47 - Polychloroprene, rubber. Two samples of the sheath should be taken from two points at least 30 cm (or 1 ft.) apart, and should be cut perpendicularly to the axis of the sheath after the removal of the cores. By means of a measuring microscope the radial thickness in the directions where the sheath is thinnest are determined (corresponding to the points where the insulated core is embedded in the sheath).

The number of measurements should thus be equal to the number of cores, subject to a maximum of six measurements. When the sheath is applied over a single core or over a lead sheath, six measurements should be made.

The mean of the results of the measurements should be taken as the actual mean thickness of the sheath and should be not less than the specified thickness. In addition, the smallest thickness measured at any point should not fall below the specified thickness by more than 15 % plus 0.1 mm (or 0.0039 in.).

The method indicated above is also valid for the measurement of thickness of the insulating belt (Table 10.IX, Page 65).

10.48 - Copper sheath. The thickness of the copper or copper-alloy sheath should be determined in the manner indicated in Clause 10.45 for the thickness of mineral insulation of single-core cables.

The mean thickness thus determined should comply with the specified mean thickness (Table 10.XVI, Page 72) within the tolerances given. In addition, the least thickness measured should not fall below the thickness specified by more than 10 %.

10.49 - External diameter of cable. The actual diameter should be measured by micrometer or calculated from measurements of the external circumference of the cable carried out at three different points, 1 m (or 3 ft.) from one another. The mean of the three results should not differ from the specified diameter by more than 5 % + 0.5 mm (or 0.02 in.). For armoured cables, however, the tolerance is 5 % + 1.0 mm (or 0.039 in.). The dimensions of mineral insulated cables should be not less than those specified in the appropriate tables.

Section 11 - Electrical tests.

10.50 - General. The electrical tests specified in Clauses 10.51 to 10.53 should be carried out on all complete lengths of finished cables. (Tests applicable to unfinished cables, for example, on insulated cores before they are cabled, are not specified in these Recommendations).

10.51 - Measurements of resistance of conductors.

(a) The resistance of each conductor should be measured on all complete lengths. The values obtained corrected to 20 °C should be not greater than the specified resistance of the conductor concerned.

If R_T ohms is the resistance of a copper conductor (tinned or plain) at a temperature of T °C, the resistance R_{20} of the same conductor at 20 °C is obtained by applying the formula :

$$R_{20} / R_T = 254.45 / (234.45 + T).$$

(b) When the cross-sectional area of the conductor is specified instead of its electrical resistance, the specified resistance should be calculated by dividing the following standard resistivities by the cross-sectional area specified. When the formation of the conductor (number and diameter of wires) is specified instead of the cross-sectional area the specified cross-sectional area should be considered as the sum of the calculated cross-sectional areas of the wires forming the conductors.

To determine the specified resistance (expressed in ohms per kilometre of the finished cable and corrected to 20 °C) the following coefficients should be divided by the actual cross-sectional area (expressed in mm²) ;

Standard resistivities of copper conductors
(see 10.52(b))

Type of conductor	Type of cable	Copper (Tinned or plain)
Conductors for fixed wiring (Table 10.V)	single-core	17.86
	multi-core	18.18

10.52 - High-voltage tests.

(a) General

(i) The dielectric tests specified in this clause should be carried out on complete lengths. A single-phase alternating voltage of virtually sinusoidal waveform (of frequency between 25 and 60 cycles per second) should be used or, alternatively, a d.c. voltage. The power available in the test equipment should be sufficient to maintain constantly in the cable the specified value of test voltage and the corresponding charging current.

(ii) The values of voltage indicated in this clause are r.m.s. values on a.c.: if the tests are carried out with d.c., the stated values should be doubled.

(iii) The voltage test may be made without immersion in water on twin and multi-core cables of all types and on single-core lead-sheathed cables. For this test the voltage should be maintained for 15 minutes and should be applied between conductors, and for metal-sheathed cables between conductor(s) and earth. Where specially required, tough-rubber-sheathed cables, polychloroprene-sheathed cables and mineral-insulated copper-sheathed cables may be tested in water after at least 6 hours immersion, when a test should be made between each conductor and the water, to which the other conductors and metal parts of the cable should be bonded.

(b) Test voltages and time of application.

Each insulated core should sustain for 15 minutes the following values of test voltage (r.m.s. values expressed in volts):

Table 10.II

Rated voltage of cable	Type of insulation		
	Rubber (Table 10.VI Page 62) (" 10.VII " 63) (" 10.VIII " 64) (" 10.IX " 65)	Varnished cambric (Table 10.X, Page 66)	Mineral (Table XVI, Page 72)
(volts)	(volts)	(volts)	(volts)
110	1,000*	-	1,500
250	1,500	-	2,500
660	2,500	-	-
1,100	3,500	3,500	-
3,300	10,000	10,000	-
6,600	16,000	16,000	

* for 5 minutes only

For rated insulation voltages different from the values indicated in the first column of the table, test voltages should be calculated by direct interpolation.

10.53 - Measurement of insulation resistance. Insulation resistance should be measured on complete lengths immediately after the high-voltage test specified in Clause 10.52. The measurement should be carried out between each conductor and the others, which should be bonded to the metallic sheath (if any) or to the water (if the high voltage test has been made in water), after a d.c. voltage between 400 and 600 volts has been applied for one minute.

The values obtained, corrected to a temperature of 20 °C and a length of one km (or 5/8 mile) should be not less than the values specified in the Table given below.

To correct the values of insulation resistance measured at another temperature to 20 °C, use should be made of an appropriate coefficient chosen by agreement between the manufacturer and the inspecting engineer.

Section 12 - Tests of physical characteristics of insulation.

10.54 - General. The samples for these tests should be removed from a single length of finished cable for each batch (unless Clause 10.40 applies). The length of the samples should be sufficient for test pieces to be made in accordance with the following clauses.

10.55 - Rubber insulation.

(a) Selection of samples

The mechanical properties of the insulation should be determined with and without accelerated aging in accordance with paragraphs (d) and (e) below.

The tests should be carried out on samples from which the sheath, if any, has been removed. The samples should be at least 10 cm long and should be taken in at least three places, a, b and c, at least 0.3 m (or 1 ft.) from one another.

The number of samples removed at each place should be six for cables of cross-sectional area not exceeding 25 mm^2, or three for cables of cross-sectional area exceeding 25 mm^2 (or 0.038 in^2).

The samples should be marked in the order in which they have been taken, as follows :

a1	a2	a3	a4	a5	a6)		(a1	a2	a3
b1	b2	b3	b4	b5	b6)	or	(b1	b2	b3
c1	c2	c3	c4	c5	c6)		(c1	c2	c3

T a b l e 10.III

Insulation resistance
of rubber-insulated cables

Cross-sectional area of conductor						Minimum insulation resistance at 20 °C		
exceeding			not exceeding					
mm²	in.²	circ. mil	mm²	in.²	circ. mil	megohm per km	megohm per 1000 yds.	megohn per 1000 ft.
250 V-grade cables								
1	0.0016	2.000	3	0.0046	6.000	560	620	1850
3	0.0046	6.000	9	0.014	18.000	380	420	1250
9	0.014	18.000	20	0.031	40.000	340	370	1100
20	0.031	40.000	40	0.062	80.000	310	340	1000
660 V-grade cables								
1	0.0016	2.000	4	0.0062	8.000	750	800	2500
4	0.0062	8.000	20	0.031	40.000	420	450	1350
20	0.031	40.000	40	0.062	80.000	350	380	1150
40	0.062	80.000	70	0.11	140.000	300	330	1000
70	0.11	140.000	160	0.25	320.000	250	280	830
160	0.25	320.000	315	0.49	630.000	230	250	750
315	0.49	630.000	480	0.74	960.000	215	230	700
480	0.74	960.000	800	1.24	1600.000	185	200	610
Internal communication cables whose operating voltage does not exceed 110 V. to earth								
0.5	0.00078	1.000	1.7	0.0026	3.5	700	760	2300
3300 V-grade propulsion cables								
25	0.039	50.000	50	0.0078	100.000	580	620	1900
50	0.078	100.000	120	0.19	240.000	420	460	1380
120	0.19	240.000	255	0.40	510.000	300	330	980
255	0.40	510.000	480	0.75	960.000	260	280	850
480	0.75	960.000	650	1.00	1300.000	230	240	750
6600 V-grade propulsion cables								
25	0.039	50.000	50	0.078	100.000	750	820	2460
50	0.078	100.000	120	0.19	240.000	550	600	1800
120	0.19	240.000	255	0.40	510.000	400	440	1310
255	0.40	510.000	450	0.70	900.000	320	350	1050

T a b l e 10.IV

Insulation resistance
of varnished-cambric-insulated cables

Cross-sectional area of conductor						Minimum insulation resistance at 20 °C		
exceeding			not exceeding					
mm²	in.²	circ. mil	mm²	in.²	circ. mil	megohm per km	megohm per 1000 yds.	megohm per 1000 ft.
for 1100 V-grade cables								
-	-	-	10	0.016	20.000	115	126	380
10	0.016	20.000	40	0.062	80.000	65	71	214
40	0.062	80.000	125	0.19	250.000	40	43	130
125	0.19	250.000	200	0.31	400.000	35	37	110
200	0.31	400.000	630	0.98	1250.000	30	33	100
for 3300 V-grade cables								
10	0.016	20.000	40	0.062	80.000	130	140	425
40	0.062	80.000	100	0.16	200.000	90	100	295
100	0.16	200.000	200	0.31	400.000	65	70	215
200	0.31	400.000	400	0.62	800.000	50	55	165
400	0.62	800.000	630	0.98	1260.000	40	45	130
for 6600 V-grade cables								
20	0.031	40.000	40	0.062	80.000	165	180	540
40	0.062	80.000	100	0.16	200.000	120	130	400
100	0.16	200.000	200	0.31	400.000	90	100	295
200	0.31	400.000	400	0.62	800.000	65	70	215
400	0.62	800.000	630	0.98	1260.000	55	60	180

The samples numbered 2 and 5 should be subject to the tension test in accordance with c, those numbered 1 and 4 to the tests in accordance with d, and those numbered 3 and 6 to the tests in accordance with e.

10.55 - Rubber insulation.

(b) Preparation of test pieces and determination of their cross-sectional area.

For the purpose of the tensile test the conductor and any intermediate covering should be withdrawn from the sample without damage to the insulation.

If the removal of the conductor is difficult, the conductor should be stretched in a tensile test machine, or the sample should be immersed in mercury until the insulation becomes loose.

The cross-sectional area of the samples should be determined as follows.

1. For conductors of cross-sectional area not exceeding 25 mm^2, the cross-sectional area Q of the rubber insulation should be determined from the formula :

$$Q = \pi (d + i)i$$

where
i represents the mean thickness of the insulation measured as shown in Clause 10.43 in the test pieces submitted to the tensile tests.

d is the diameter of the conductor measured by micrometer dial indicator, or measuring microscope. Where the conductor is stranded, d is the overall diameter. If there is an intermediate covering (separator) between the conductor and rubber insulation, d is the diameter measured over the intermediate covering.

For a solid conductor the cross-sectional area Q can be determined by immersing the sample in a measuring flask at 20 °C, containing alcohol of 96 %.

2. For cables of cross-sectional area exceeding 25 mm^2, a test strip should be cut from each sample, following the lay of the cores, in the shape of a Figure 3 of CEE-Publication No. 2.
The cross-sectional area of these test strips should be calculated from the smallest width and from the mean value of the thickness obtained from the test strips submitted to the tension test.

(c) Tensile test and limiting values without aging.
The tensile test should be carried out, if possible, at 20 ± 2 °C, the test strips being kept at this temperature for at least one hour before the test.

In the middle of the samples two gauge marks should be made 20 mm apart. The test pieces should be placed in the tensile test machine so that the length left free is at least 50 mm.

The speed of the tensile test machine should be approximately 30 cm/min. (or 1 ft/min).

The elongation should be determined by a measurement of the distance between the two gauge marks at rupture. The mean of the values obtained should be not less than :

70 kg/cm^2 (1000 lb/in.^{2}) for the tensile strength
250 % for the elongation.

(d) Aging in air.
A test of accelerated aging should be carried out in an atmosphere having the composition and pressure of the ambient air. The test pieces with their conductors should be suspended freely in a hot-air oven ventilated by convection.

The test pieces should be kept at a temperature of 80 ± 2 °C for 7 x 24 hours. Immediately after these 168 hours they should be withdrawn and left at ambient air temperature for 16 hours at least. Then the test pieces should be prepared and submitted to the measurements of cross-sectional area and to the tension tests described in (c).

The mean of the values obtained should be not less than

70 kg/cm^2 (1000 lb/in.^{2}) for the tension strength
250 % for the elongation.

In addition, the difference between the mean values of tensile strength and elongation obtained before and after accelerated aging should not differ by more than :-

± 30% of the mean value before aging for stranded cables

± 25% for other cables.

If a tension test is not carried out at an ambient temperature of 20 ± 2 °C, and if one of the deviations of ± 25% or ± 30% shown above is exceeded, the tensile test without aging should be repeated at exactly the same ambient temperature as that carried out with accelerated aging.

It is recommended that an electrically heated oven should be used. The measurement of the temperature can be made by thermometer. The ventilation by natural convection can be obtained by means of holes in the walls of the oven.

(e) Aging in oxygen.

A test of accelerated aging should be carried out in an atmosphere of oxygen under pressure.

The samples, complete with conductors, should be suspended freely in an oxygen bomb, so that they are not in contact with each other and so that one group of samples is not affected by the emanations of another group during heating.

The total space occupied by the samples should not exceed 1/10 of the effective volume of the bomb. The bomb should be filled with commercial oxygen with a purity of not less than 97 %, to a pressure of 21 ± 0.7 kg/cm^2 (or 300 ± 10 lb/in.^{2}).

The samples should be kept in the bomb at a temperature of 70° ± 1 °C for 4 x 24 hours and immediately afterwards they should be left at ambient temperature, avoiding direct light, for at least 16 hours. The samples should then be subjected to the preparation, the cross-section measurement and the tensile test as described under (c). The mean of the values so found shall be not less than :

70 kg/cm^2 (1000 lb/in.^{2}) for the tension strength,
250 % for the elongation.

In addition the difference between the mean values of tensile strength and elongation obtained before and after accelerated aging should not differ by more than :

± 30 % of the mean value before aging, for stranded cables

± 25 % for other cables.

If a tensile test is not carried out at an ambient temperature of 20 ± 2°C and if the above mentioned limit of 30 or 25 % is exceeded, the tensile test without accelerated aging should be repeated at exactly the same temperature as the tensile test with aging.

The manipulation of the oxygen bomb presents a certain danger. Every precaution should be taken to avoid the risk of explosion due to sudden oxidation.

10.56 - Varnished-cambric insulation.

(a) Bending test and checking of thickness of tapes.

After the varnished cambric has been carefully removed from the cable, it should be capable of being bent back through 180° without splits becoming visible to the naked eye. In order to test this, the tape should be placed on a plane surface and bent; a strip of metal 30 mm wide and 2 mm thick, long enough to cover the fold completely and loaded with a weight of 50 grammes, should be placed over the fold.

The metal should be left for 5 minutes in this position and then removed, when the tape should be straightened and examined. In addition, the constancy of the thickness of the tape should be verified on samples of adequate length (Clause 10.11-d).

(b) Test of heat resistance.

The check is carried out on samples of varnished-cambric tape carefully removed from a portion of cable.

The pieces of tape should be placed for 150 hours in a hot-air oven ventilated by natural convection, and in which the temperature of the working portion is 120 + 2 °C.

The pieces of tape should then be withdrawn from the oven and left at ambient temperature for at least 2 hours. They should then be bent at 180° round a mandrel formed by a shaped metal band 3.2 mm (or 0.125 in.) thick, with rounded corners, the sample being sharply bent, one half longitudinally, the other half transversely.

The varnish should not be detached or show splits visible to the naked eye.

(c) Flow test.

A sample of finished cable about 0.3 m (or 1 ft.) in length should be suspended vertically in an oven and kept at a temperature of 80 °C for 18 hours.
The viscous compound should not drip from the insulation.

10.57 - Characteristics of mineral-insulated cables.

(a) Bending test.

Two samples removed from two places at least 0.3 metre (or 1 ft.) apart should be bent alternately in one direction and in the other and this cycle carried out twice, so as to form on each occasion a semi-circle extended by two straight portions; the diameter of the mandrel should be 20 times the nominal external diameter of the cable for single-core cables, and 25 times the diameter for multi-core cables.

The samples should then be submitted to a dielectric test in accordance with Clause 10.53, the time of application of the voltage being limited to five minutes, and the test voltage to 2000 V.

The protective sheath should reveal no split, crack, flaw or abnormal deformation. During the application of the voltage, no flash-over should be observed between conductors or between conductors and sheath.

10.57 (b) Flattening test.

Two samples approximately 20 cm (or 8 in.) in length, removed from two places at least 0.3 metre (or 1 ft.) apart, should be flattened by being hammered on an anvil until the thickness of the hammered portion is 2/3 of the external diameter of the cable before the test. The steel anvil should be flat and the hammer should have rounded edges and should be of a weight of about 2 kg (or 4.1/2 lb.).

The samples should then be submitted to a dielectric test in accordance with Clause 10.52, the time of application of the voltage being limited to five minutes, and the test voltage to 1000 V.

(c) Test for fittings for mineral insulated cables.

The special fittings which should be provided for mineral-insulated cables at both ends should satisfy the following test :

A sample of cable should be provided with a fitting at each end. One of the ends should be left at atmospheric pressure, the other immersed in a closed container filled with water whose pressure at the fitting should be maintained at 1 kg-weight per cm^2 (or 14 $lb/in.^2$) above atmosphere for 15 minutes. After being wiped, the sample should be submitted to a measurement of insulating resistance in accordance with Clause 10.53, and to dielectric test in accordance with Clause 10.52, the time of application of the voltage being limited to five minutes, and the test voltage to 1500 V.

During the dielectric test no flash-over should be observed between the conductors or between conductors and sheath.

Section 13 - Tests of physical characteristics of protective sheath.

10.58 - General. The samples for these tests should be removed from a single length of finished cable for each batch (unless Clause 10.40 is applicable). The length of the samples should be sufficient to enable test pieces to be taken in accordance with the following clauses.

10.59 - Rubber sheaths.

NOTE: The provisions of Clause 10 of C.E.E. Publication No. 2 are applicable with modifications as follows:

(a) Removal of samples.

The tests should be carried out on samples 20 cm (or 8 in.) long, removed from three places, a, b, c, spaced at least 0.3 m (or 1 ft.) apart. Three samples should be taken at each place. The samples should be marked

a1	a2	a3
b1	b2	b3
c1	c2	c3

The samples numbered 2 should be submitted to the tension test in accordance with (c), those numbered 1 should be submitted to the test in accordance with (d), and those numbered 3 should be submitted to the test in accordance with (e).

When the sheath is composed of a single layer, the samples should be cut parallel to the lay of one of the cores. If the sheath is composed of two layers, the outer layer should be cut parallel to the webs, and the internal layer should be detached; the latter should be cut parallel to the lay of one of the cores. The cores should be withdrawn from the sheath. If necessary, the samples should be ground with a suitable machine so that two plane parallel surfaces are obtained.

It is recommended that the grinding should be carried out with carborundum of hardness between those denoted by the letters M and P in the Norton scale. The peripheral speed should be 25 m/sec. approximately (or 80 ft./sec.), the pressure being regulated so that undue heating of the test piece is avoided.

(b) Preparation of test pieces and measurement of cross-sectional area.

From each end of the samples removed, two test pieces are punched in the form of a band in the shape of figure 3 of C.E.E. Publication No. 2 (or, if this is not possible, the figure 2). In the case of a sheath with two layers, test pieces should be prepared for the two layers.

The thickness of the samples should be measured by means of a micrometer or the equivalent at a pressure between layers between 60 and 100 g/cm^2 (or 0.85 and 1.4 lb/in.^{2}).

(c) Tensile test and limiting values without aging.

The tensile test should be carried out in accordance with 10.56(c). If the test piece in the form of Figure 2 of C.E.E. Publication No. 2 is used, the gauge marks should be made 10 mm (or 0.4 in.) apart and the length of the test piece left free in the machine should be 25 mm (or 1 in.).

The mean of the values obtained should be not less than :

150 kg/cm^2 (2140 lb./in.^{2})	for the tensile strength of type D compound;
70 kg/cm^2 (1000 lb./in.^{2})	for the tensile strength of type C compound;
250 %	for the elongation.

(d) Aging in air.

The test of accelerated aging in air should be carried out in accordance with Clause 10.55-d. The test pieces should then be submitted to the tensile test described in Clause 10.55-c.

The variation of tensile strength and elongation in relation to the values obtained on the samples not submitted to accelerated aging should not exceed ± 30 % of those values. In addition, the elongation after aging should be not less than 200 %.

(e) Aging in oxygen.

Aging should be carried out in accordance with Clause 10.55(e), following by the tensile test in accordance with Clause 10.55(c).
The results should be in accordance with the provision of (d) above.

10.60 - Polychloroprene sheath.

(a) Tensile test with and without aging in air or oxygen.

All the provisions of Clause 10.59 apply equally to polychloroprene sheaths, with the exception of the following :

limiting values of tensile strength :

70 kg/cm^2 (or 1000 lb./in.^{2}) for type A compound
125 kg/cm^2 (or 1800 lb./in.^{2}) for type B compound

limiting values of elongation, type A or type B compound

250 % before aging and 200 % after aging;

maximum variation permissible after aging :

± 30 % in every instance.

Table 10.V

Dimensions of conductors for fixed wiring

Nominal cross-sectional area						Minimum number of wires +
exceeding			not exceeding			
mm^2 1	in^2 2	cir.mil 3	mm^2 4	in^2 5	cir.mil 6	7
*	*	*	2	0.0031	4.000	1
2	0.0031	4.000	16	0.025	32.000	7
16	0.025	32.000	63	0.10	133.000	19
63	0.10	133.000	200	0.31	400.000	37
200	0.31	400.000	315	0.50	630.000	61
315	0.50	630.000	500	0.78	1000.000	91
500	0.78	1000.000	1000	1.55	2000.000	127

* Minimum cross-section admissible: 1 mm^2 or 0.0016 in^2 or 2000 circular mils.

\+ Conductors of mineral-insulated cables manufactured by extrusion may be formed by a single wire irrespective of cross-section.

Table 10.VI

Thickness of rubber insulation for cables rated at 250 V.

Nominal cross-sectional area of conductor						Minimum average thickness of insulation		
exceeding			not exceeding					
mm^2	in^2	cir.mil	mm^2	in^2	cir.mil	mm	mils	64ths in.
1	2	3	4	5	6	7	8	9
(10.VIa) - for lead-sheathed cables when the insulation is not taped.								
1	0.0016	2.000	9	0.014	18.000	1.0	39.4	2.5
9	0.014	18.000	20	0.031	40.000	1.2	47.2	3.0
20	0.031	40.000	40	0.062	80.000	1.4	55.1	3.5
40	0.062	80.000	-	-	-	* *	* *	* *
(10.VIb) - for lead-sheathed cables when the insulation is taped.								
1	0.0016	2.000	3	0.0046	6.000	0.8	31.5	2.0
3	0.0046	6.000	9	0.014	18.000	0.9	35.4	2.2
9	0.014	18.000	16	0.025	32.000	1.0	39.4	2.5
16	0.025	32.000	20	0.031	40.000	1.1	43.3	2.8
20	0.031	40.000	40	0.062	80.000	1.4	55.1	3.5
40	0.062	80.000	-	-	-	* *	* *	* *
(10.VIc) - for cables with non-metallic sheath.								
1	0.0016	2.000	3	0.0046	6.000	0.8	31.5	2.0
3	0.0046	6.000	9	0.014	18.000	0.9	35.4	2.2
9	0.014	18.000	16	0.025	32.000	1.0	39.4	2.5
16	0.025	32.000	20	0.031	40.000	1.1	43.4	2.8
20	0.031	40.000	40	0.062	80.000	1.4	55.1	3.5
40	0.062	80.000	-	-	-	* *	* *	* *

* * For conductors of cross-sectional areas exceeding 40 mm^2 or 0.062 in^2 or 80000 cir.mils, 660 V-grade cables should be used (Table 10.VII, Page 63).

NOTE: Cables protected by a metal braid or armour should be considered as metallic-sheathed cables unless the braid or armour is over a non-metallic sheath.
Textile braid or bedding cannot be considered as a non-metallic sheath for the purpose of Table 10.VIc, Page 62.

T a b l e 10.VII

Thickness of rubber insulation for cables rated at 660 V.

(10.VIIa) - for conductors having additional insulation inside the sheath +

Nominal cross-sectional area of conductor: exceeding mm² (1)	exceeding in² (2)	exceeding cir.mil (3)	not exceeding mm² (4)	not exceeding in² (5)	not exceeding cir.mil (6)	Minimum average thickness of insulation mm (7)	mils (8)	64ths in. (9)
1	0.0016	2.000	3	0.0046	6.000	0.8	31.5	2.0
3	0.0046	6.000	9	0.014	18.000	1.0	39.4	2.5
9	0.014	18.000	20	0.031	40.000	1.2	47.2	3.0
20	0.031	40.000	40	0.062	80.000	1.4	55.1	3.5
40	0.062	80.000	95	0.147	190.000	1.6	63.0	4.0
95	0.147	190.000	150	0.232	300.000	1.8	70.9	4.5
150	0.232	300.000	185	0.287	365.000	2.0	78.7	5.0
185	0.287	365.000	240	0.372	475.000	2.2	86.6	5.5
240	0.372	475.000	300	0.465	600.000	2.4	94.5	6.0
300	0.465	600.000	400	0.620	800.000	2.6	102	6.5
400	0.620	800.000	-	-	-	2.8	110	7.0

(10.VIIb) - for all types of 660 V-grade cable except the above type

Nominal cross-sectional area of conductor: exceeding mm² (1)	exceeding in² (2)	exceeding cir.mil (3)	not exceeding mm² (4)	not exceeding in² (5)	not exceeding cir.mil (6)	Minimum average thickness of insulation mm (7)	mils (8)	64ths in. (9)
1	0.0016	2.000	20	0.031	40.000	1.4	55.1	3.5
20	0.031	40.000	40	0.062	80.000	1.6	63.0	4.0
40	0.062	80.000	70	0.11	140.000	1.8	70.9	4.5
70	0.11	140.000	120	0.19	240.000	2.0	78.7	5.0
120	0.19	240.000	160	0.25	320.000	2.2	86.6	5.5
160	0.25	320.000	255	0.40	510.000	2.5	98.4	6.3
255	0.40	510.000	315	0.49	630.000	2.8	110	7.1
315	0.49	630.000	480	0.74	960.000	3.1	122	7.8
480	0.74	960.000	800	1.24	1600.000	3.4	134	8.6

+ The thickness of the insulating belt should be in accordance with Table 10.IX, Page 65.

<u>NOTE:</u> The thicknesses given in Table 10.VII, Page 63, are valid for insulation with or without tape and whatever type of protective sheath is used.

T a b l e 10.VIII

Thickness of rubber insulation for Cables for Propulsion and for Communications

Nominal cross-sectional area of conductor						Minimum average thickness of insulation		
exceeding			not exceeding					
mm^2 1	in^2 2	circ.mil 3	mm^2 4	in^2 5	circ.mil 6	mm 7	mils 8	64ths in. 9
(10.VIIIa) - cables for internal communication operating at voltages not exceeding 110 V. to earth								
0.5	0.00078	1.000	1.7	0.0026	3.500	0.8	31.5	2.0
(10.VIIIb) - propulsion cables rated at 3300 V. (systems with neutral insulated)								
25	0.039	50.000	255	0.40	510.000	3.5	138	8.8
255	0.40	510.000	650	1.0	1300.000	4.0	157	10.1
(10.VIIIc) - propulsion cables rated at 6600 V. (systems with neutral insulated)								
25	0.039	50.000	450	0.70	900.000	5.0	197	12.6

NOTE: The thicknesses given in Table 10.VIII, Page 64 are valid for insulation with or without tape, and whatever type of protective sheath is used.

T a b l e 10.IX

Thickness of additional belt of insulation for 660-V cables having reduced thickness of insulation on individual cores.

(Table 10.VIIa, Page 63, and Clause 10.10).

Diameter below insulating rubber sheath				Minimum average thickness of insulating belt		
exceeding		not exceeding				
mm 1	in 2	mm 3	in 4	mm 5	mils 6	64ths in 7
-	-	17	0.67	0.8	31.5	2.0
17	0.67	21	0.83	0.9	35.4	2.2
21	0.83	35	1.34	1.0	39.4	2.5
35	1.34	45	1.77	1.4	55.1	3.5
45	1.77	60	2.36	1.8	70.9	4.5

T a b l e 10.X

Thickness of varnished cambric insulation

Nominal cross-sectional area of conductor						Thickness		
exceeding			not exceeding					
mm^2	in^2	cir.mil	mm^2	in^2	cir.mil	mm	mils	64ths in.
1	2	3	4	5	6	7	8	9
(10.Xa) - 1100 V-grade cables (neutral insulated) : minimum thicknesses between conductor and sheath (earth)								
4	0.0062	8.000	125	0.19	250.000	1,4	55.1	3.5
125	0.19	250.000	200	0.31	400.000	1,5	59.1	3.8
200	0.31	400.000	325	0.50	650.000	1,75	68.9	4.4
325	0.50	650.000	500	0.77	800.000	2,0	78.7	5.0
500	0.77	800.000	630	0.98	1250.000	2,3	90.6	5.8
(10.Xb) - 1100 V-grade cables (neutral insulated) : minimum thickness between conductors								
4	0.0062	8.000	125	0.19	250.000	1,75	68.9	4.4
125	0.19	250.000	200	0.31	400.000	2,0	78.7	5.0
200	0.31	400.000	325	0.50	650.000	2,3	90.6	5.8
325	0.50	650.000	500	0.77	800.000	2,3	90.6	5.8
500	0.77	800.000	630	0.98	1250.000	2,5	98.4	6.3
(10.Xc) - 3300 V-grade cables (neutral insulated)*								
10	0,016	20.000	630	0.98	1250.000	3,3	130	8,3
(10.Xd) - 6600 V-grade cables (neutral insulated)*								
20	0.031	40.000	630	0.98	1250.000	4,6	181	11.6

* Minimum thicknesses between conductors and between conductors and earth.

T a b l e 10.XI

Thickness of sheath for lead-, lead-alloy, polychloroprene- or rubber sheathed cable for fixed wiring, having composite sheath.*

Calculated internal diameter of sheath				Minimum average thickness		
exceeding		not exceeding				
mm 1	in 2	mm 3	in 4	mm 5	mils 6	64ths in. 7
-	-	6	0.24	1.0	39.4	2.5
6	0.24	10	0.39	1.1	43.3	2.8
10	0.39	15	0.59	1.2	47.2	3.0
15	0.59	20	0.79	1.3	51.2	3.3
20	0.79	25	0.98	1.4	55.1	3.5
25	0.98	30	1.2	1.5	59.1	3.8
30	1.2	35	1.4	1.6	63.0	4.0
35	1.4	40	1.6	1.7	66.9	4.3
40	1.6	45	1.8	1.9	74.8	4.8
45	1.8	50	2.0	2.0	78.7	5.0
50	2.0	55	2.2	2.2	86.6	5.5
55	2.2	60	2.4	2.3	90.6	5.8
60	2.4	65	2.6	2.4	94.5	6.0
65	2.6	70	2.8	2.5	98.4	6.3

* NOTE: The thicknesses specified in the table apply to all types of conductors for fixed wiring when the sheath is a constituent element of a composite protective sheath (for example: "sheath plus armour", but not "sheath plus textile braid").
The thicknesses given are valid as "minimum average values", according to the tests and tolerances indicated in :

Clause 10.46 for lead or lead-alloy sheath
Clause 10.47 for polychloroprene or rubber sheath.

T a b l e 10.XII

Thickness of lead-alloy, polychloroprene or rubber sheath for cables for fixed wiring, having a single sheath.

Calculated internal diameter of sheath				Thickness of sheath		
exceeding		not exceeding				
mm 1	in 2	mm 3	in 4	mm 5	mils 6	64ths in. 7
-	-	6	0.24	1.0	39.4	2.5
6	0.24	12	0.47	1.2	47.2	3.0
12	0.47	20	0.79	1.4	55.1	3.5
20	0.79	25	0.98	1.9	74.8	4.8
25	0.98	32	1.3	2.3	90.6	5.8
32	1.3	38	1.5	2.5	98.4	6.3
38	1.5	44	1.7	2.8	110	7.1
44	1.7	57	2.2	3.0	118	7.6
57	2.2	70	2.8	3.3*	130	8.3
70	2.8	85	3.3	3.5*	138	8.8

NOTE: The thicknesses specified in the table apply to all types of cables for fixed wiring when the sheath is the sole protection of the cable. (The sheath is also considered to be the sole protection when accompanied by a textile braid).

The thicknesses given in the table are valid as minimum average values according to the tests and tolerances indicated in :

Clause 10.46 for lead or lead-alloy sheath
Clause 10.47 for polychloroprene or rubber sheath.

* For varnished-cambric-insulated cables these thicknesses are valid as "minimum values" without tolerances.

Table 10.XIII

Diameter of wires forming protective metal braid

Calculated diameter under braid				Nominal diameter of wire *	
exceeding		not exceeding			
mm 1	in 2	mm 3	in 4	mm 5	mils 6
-	-	10	0.39	0.2	7.9
10	0.39	25	0.98	0.3	11.8
25	0.98	-	-	0.4	15.7

* Tolerance: ± 10 %.

T a b l e 10.XIV

Diameter of steel wires for armour

Calculated diameter of cable excluding bedding				Minimum diameter of steel wires (round wires)		Minimum thickness of steel wires (flattened wires)	
exceeding		not exceeding					
mm 1	in 2	mm 3	in 4	mm 5	in 6	mm 7	in 8
-	-	12.5	0.49	1.2	0.047	1.0	0.039
12.5	0.49	20	0.79	1.5	0.059	1.2	0.047
20	0.79	30	1.2	2.0	0.079	1.4	0.055
30	1.2	57	2.25	2.5	0.098	1.8	0.071
57	2.25	-	-	3.2	0.126	1.8	0.071

T a b l e 10.XV

Thickness of steel tape for armour

Calculated diameter of cable excluding bedding				Nominal thickness of each tape *	
exceeding		not exceeding			
mm 1	in 2	mm 3	in 4	mm 5	mils 6
30	1.2	45	1.8	0.5	19.7
45	1.8	70	2.8	0.8	31.5

* Tolerance ± 20%

Table 10.XVI

Mineral-insulated cables for fixed wiring for power and lighting

Conductor: Nominal cross-section	Conductor: Actual cross-section	Conductor: Nominal diameter	Nominal thickness of insulant	Sheath: Mean thickness	Sheath: Tolerance on mean thickness	External diameter of cable	Tolerance on external diameter
1	2	3	4	5	6	7	8
mm²	mm²	mm	mm	mm	mm	mm	mm
Single-core cables							
1	1,13	1,2	1,45	0,6		5,3	
2	2,01	1,6	1,45	0,65		5,8	
3,2	3,14	2	1,45	0,65		6,2	
5	4,91	2,5	1,45	0,7	−0	6,8	+ 0,3
8	7,79	3,15	1,45	0,7	−0,15	7,4	+ 0
10	9,89	3,55	1,45	0,75		7,9	
12,5	12,57	4	1,45	0,75		8,4	
16	15,90	4,5	1,45	0,75		8,9	
20	19,63	5	1,45	0,75		9,4	
25	24,63	5,6	1,55	0,85		10,4	
32	31,17	6,3	1,6	0,9		11,3	
40	39,59	7,1	1,6	0,95	−0	12,2	+ 0,4
50	50,27	8	1,7	1	−0,2	13,4	+ 0
63	63,62	9	1,7	1,05		14,5	
80	78,54	10	1,8	1,15		15,9	
100	98,52	11,2	1,9	1,15	−0	17,3	+ 0,5
125	122,72	12,5	1,9	1,2	−0,25	18,7	+ 0
150	153,94	14	2	1,25		20,5	
Twin-core cables							
1	1,13	1,2	1,45	0,8		8,3	
2	2,01	1,6	1,45	0,85	−0	9,2	+ 0,4
3,2	3,14	2	1,45	0,9		10,1	
5	4,91	2,5	1,45	0,95	−0,2	11,2	+ 0
8	7,79	3,15	1,5	1,1		13,1	
3-core cables							
1	1,13	1,2	1,45	0,8		8,7	
2	2,01	1,6	1,45	0,85		9,6	
3,2	3,14	2	1,45	0,9	−0	10,6	+ 0,4
5	4,91	2,5	1,45	1	−0,2	11,8	+ 0
8	7,79	3,15	1,5	1,15		13,9	
4-core cables							
1	1,13	1,2	1,45	0,85		9,5	
2	2,01	1,6	1,45	0,9	−0	10,6	+ 0,4
3,2	3,14	2	1,5	1	−0,2	12,1	+ 0
5	4,91	2,5	1,5	1,1		13,5	
7-core cables							
1	1,13	1,2	1,45	0,95	−0	11,3	+ 0,4
2	2,01	1,6	1,45	1,05	−0,2	12,7	+ 0

CHAPTER 11

THE INSTALLING OF CABLES

NOTE: This chapter is not unanimously approved, but is published for guidance.
Redrafting of this chapter is under consideration.

11.01 - Choice of type of cable.

(a) The cables for fixed installations for power and lighting should be chosen from those described in Clauses 10.30, 10.31, 10.35 and 10.37.

(b) Cables for telecommunication and internal communication should be selected from those described in Clause 10.18.

(c) Rubber-insulated cables should not be adopted where it is anticipated that the cooling-air temperature may exceed 50 °C.

(d) Cables placed on decks exposed to the weather, in damp situations, refrigerated spaces, generating compartments or motor compartments, or in any position where harmful gas or vapour may be present, and cables for circuits operating at voltages above 250 V, irrespective of installation conditions, should be of the following types :

- lead- or lead-alloy-sheathed
- polychloroprene-sheathed
- mineral-insulated-metal-sheathed.

(e) Cables which may be liable to mechanical damage should be metal-armoured (see Clause 10.14) or protected by metal casing.

11.02 - Current ratings for continuous service.

The current ratings for continuous service for the different types of cable permitted in the present Recommendations are indicated in appended Tables 11.IV, Page 81, 11.VI, Page 83.

Continuous service should be taken to mean any service carried on for a length of time greater than :

15 minutes for cables of nominal cross-section less than 20 mm^2 (or 0.03 in^2 or 38250 circ.mils).

1 hour for cables of nominal cross-section not less than 20 mm^2 (or 0.03 in^2) but less than 80 mm^2 (or 0.124 in^2 or 158000 circ.mils).

2 hours for cables of nominal cross-section not less than 80 mm^2 (or 0.124 in^2 or 158000 circ.mils).

11.03 - Correction factors for current ratings at different cooling-air temperatures.

The current ratings given in Tables 11.IV, Page 81, 11.VI, Page 83 are laid down for a cooling-air temperature of 45 °C and apply to electric cables for ships for navigation on the high seas or in tropical climates.

For ships intended for certain special purposes (temperate zones) or certain particular applications (coasters, ferries and harbour craft, etc.), cooling-air temperatures other than 45 °C +) may be permitted.

+) See Clause 3.05

In such cases the values of current ratings will be obtained by multiplying those given in Tables 11.IV, Page 81, 11.VI, Page 83.

T a b l e 11.I

Correction factors for cable ratings

Cables	Correction factors for cooling-air temperatures of:		
	35 °C	40 °C	45 °C
1	2	3	4
Rubber-insulated (Table 11.IV, Page 81)	1,33	1,17	1
Varnished-cambric-insulated (Table 11.V, Page 82)	1,25	1,13	1
Mineral-insulated (Table 11.VI, Page 83)	1,15	1,09	1

11.04 - Short-time current ratings. For cables intended to supply equipment or installations operating for periods less than the limit defined by continuous service, the values of current ratings are shown in the appended Tables 11.IV, Page 81, 11.VI, Page 83.

11.05 - Voltage drop. The sizes of conductors should be so selected that the drop in voltage from the main switchboard bus-bars to any and every point on the installation when the conductors are carrying the maximum current under normal conditions of service does not exceed for heating and lighting circuits, 5 % of the nominal voltage and for power 7 % of the nominal voltage.

These values are applicable under normal steady conditions. During current surges of short duration the voltage drop may be 8 % and 11 % respectively.

11.06 - Estimation of lighting load. In the assessment of the current rating of lighting points for the purpose of determining sizes of conductors, every lampholder should be deemed to require a current equivalent to the maximum load likely to be connected to it, and this should be assumed to be at least 60 watts, provided that where the lighting fitting is so constructed as to take only a lamp rated at less than 60 watts the current rating may be assessed accordingly.

In circuits by which inductor-operated discharge lamps are exclusively supplied, the total steady current multiplied by 1,25 should not exceed the rating of the conductors. Where inductor-operated discharge lamps and incandescent lamps are both supplied by a single circuit the sum of the total steady current taken by the discharge lamps should not exceed the rating of the conductors.

11.07 - Equalizer connections. The conductor of a cable connecting the equalizer terminal of a generator to a switchboard should be of cross-sectional area not less than half that of the negative conductor from the generator to the switchboard, and should preferably be of such size that its resistance is not more than half the sum of the resistances of the series field of the generator and of its connection to the switchboard.

11.08 - Cable-ends.

(a) Where mechanical clamps are not used the ends of all cable conductors having a sectional area greater than 6,6 mm^2 (0.01 in^2) should be provided with clamping sockets or soldering-sockets of sufficient size to contain all the strands of the conductor. Where soldering is adopted, corrosive solid or liquid fluxes should not be used.

(b) The insulation should be removed from the cable ends in a suitable manner. All protective sheaths should be removed for at least 10 mm (0.4 in.) from the end of the insulation.

(c) When required, the watertightness of the cable ends situated below the bulkhead deck should be ensured by appropriate means at the time of installation.

(d) Cable-sockets and connecting terminals should be of such dimensions that the maximum current likely to flow through them will not produce heat which would be injurious to the insulation.

11.09 - Joints and branch circuits.

(a) Normally cable runs should not include joints. If a joint is absolutely necessary or desirable, it should be carried out in a suitable box of such design that the conductors remain properly insulated and protected from atmospheric action, and fitted with terminals and bus-bars of dimensions proportionate to the current rating.

(b) In certain exceptional cases it may be permissible to use soldered joints in conductors and to re-constitute the insulation and protective sheath of the cable.

(c) Tappings should be made in suitable boxes, of such design that the conductors remain suitably insulated and protected from atmospheric action, and fitted with terminals and bus-bars of dimensions appropriate to the current rating. In the sole case of final sub-circuits in accommodation spaces it is permissible to use suitable non-hose-proof junction-boxes for cables of small cross-section.

(d) For cable joints as in the case of tappings, the cable-ends should be connected as described in Clause 11.08.

11.10 - Cable runs.

(a) Cable runs should be selected so as to be as far as possible straight and accessible.

(b) They should be selected so as to avoid as far as possible action from condensed moisture or drip. Cables should be as remote as possible from sources of heat such as hot pipes, resistors, etc. and protected from risk of mechanical damage.

(c) In lavatories as far as possible only cables absolutely necessary for the supply of equipment used in these spaces should be permitted.

(d) The installation of cables across expansion joints should be avoided unless this is absolutely necessary when a loop of radius equal to 13 times the cable diameter should be provided so as to afford the necessary flexibility.

(e) In the choice of cable runs account should be taken of the need for protection against rats.

(f) For cable runs in the vicinity of a radio-receiving room etc., the recommendations of Clauses 21.11 - 21.14 should be observed.

11.11 - Mechanical protection.

(a) Cables exposed to risk of mechanical damage, if not armoured or enclosed in steel conduit should be protected by metallic casing.
Mineral insulated metal sheathed cables are for the purpose of this Clause deemed to be armoured cables.

(b) Cables exposed to exceptional risk of mechanical damage, for example in holds, storage-spaces, cargo spaces, etc. should be protected by suitable casing even where they are armoured.

11.12 - Earthing of metallic sheaths and coverings. (see also Chapter 4).

(a) All metallic coverings of cables (lead sheath, armour, etc.) should be electrically connected to the metallic hull of the ship at both ends except in final sub-circuits where they may be connected only at the supply end. Particular attention and care should be given to this recommendation when earth-return systems or single-core cables on a.c. supply are in use.

(b) Earthing connections should be carried out with conductors having cross-sectional areas related to the current ratings of the cables (see Chapter 4), or with metallic clamps gripping the metal sheath of the cable and connected to the metallic hull of the ship. If cables are taken into metallic boxes it may be sufficient for the metallic coverings to make contact by means of special devices with the cable-entries of the boxes which in turn should be connected to the metallic hull of the ship.

(c) For cables of considerable length the external metallic sheath should be earthed at appropriate intermediate points according to the type of cable.

(d) The electrical continuity of all metallic coverings of cables throughout the length of the cables, particularly at joints and tappings, should be ensured.

11.13 - Radius of bends. The internal radius of bends should be not less than the values set out in the following Table 11.II, Page 77.

Table 11.II

Radius of bends

Type	External diameter d	Minimum internal radius of bend
1	2	3
Rubber-insulated	any	4d
Rubber-insulated and lead-sheathed or armoured	any	6d
Varnished cambric-insulated	under 30 mm (or 1,2 in.)	6d
	30 - 40 mm (or 1,2 - 1,6 in.)	8d
	above 40 mm (or 1,6 in.)	10d
Mineral-insulated	under 7 mm (or 0,28 in.)	2d
	7 - 12 mm (or 0,28 - 0,47 in.)	3d
	above 12 mm (or 0,47 in.)	4d

11.14 - Fixing.

(a) With the exception of cables for portable appliances and those installed in conduits or wood casings, cables should be fixed by means of clips or saddles made of metal or other non-hygroscopic incombustible material, if necessary suitably treated, having a large surface area and smooth edges and so rounded that the cables remain tight without their covering being damaged.

(b) The distances between supports should be suitably chosen according to the type of cable and the probability of vibration. The following Table 11.III indicates the order of magnitudes.

Table 11.III

Spacing of cable supports

External diameter d of the cable	Distance between supports			
	Non-armoured cables		Armoured cables	
1	2		3	
	cm	in.	cm	in.
under 13 mm (or 0,5 in.)	25	10	30	12
13 mm - 20 mm (or 0,5 - 0,75 in.)	30	12	35	14
20 mm - 30 mm (or 0,75 - 1,2 in.)	35	14	40	16
over 30 mm (or 1,2 in.)	40	16	45	18

(c) The supports and the corresponding accessories, should be of corrosion-resistant material or should be suitably treated to resist corrosion.

11.15 - Cables penetrating bulkheads and decks.

(a) Penetrations of watertight decks and bulkheads should be effected in a watertight manner. Either individual stuffed glands or boxes containing several cables and filled with a fire-retarding packing may be used for this purpose.

(b) Cables passing through watertight or non-watertight decks should be protected to a suitable height above the deck (at least 200 mm (8.0 in.)).

11.16 - Installation in pipes or conduits. Armoured cables should in general be used in preference to unarmoured cables run in metallic tubes or metallic conduits +). When this method is nevertheless adopted, the following precautions should be observed :

(a) The pipes should be perfectly smooth on the interior and not subject to deterioration from the effects of moisture.

(b) The pipes or conduits should have their ends shaped or bushed in such a way as not to damage the cable covering.

(c) The pipes and conduits should have such internal dimensions and radius of bends as will permit the easy drawing-in and -out of the cables which they are to contain; the internal radius of bends should be not less than those permitted for cables (see Clause 11.13) and for pipes, not less than twice the external diameter of the pipe.

(d) Pipes and conduits should be so arranged that water cannot accumulate inside them (account being taken of possible condensation).

(e) Pipes and conduits should be mechanically and electrically continuous and effectively earthed.

(f) Terminating boxes should be mechanically and electrically connected to the pipes and conduits.

(g) The drawing-in 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 pipe or conduit) should not be greater than 0.4.

(h) If necessary ventilating openings should be provided, preferably at the highest and lowest points, so as to permit air circulation and to obviate the possibility of water accumulating at any part of the pipe or conduit run.

(j) The drawing of cables with lead sheath but without further covering into conduits or pipes is deprecated.

11.17 - Installation in non-metallic ducting, casing or capping.
The only cables which may be installed in ducting, capping or casing are those having a waterproof flame-retarding covering. The ducting, capping or casing should be fireproofed wood or other fire-retarding material.
The following precautions should be observed:

+) Non-metallic tubes or conduits should not be used without special authorization.

(a) The cables should be visible when the covers of the capping or casing are removed.

(b) The fixing of the casings or covers should be effected by means of screws of brass or other non-rusting metal arranged so as not to damage the cables. The covers should be readily accessible and in full view.

(c) The cables should be of cross-sectional area not exceeding 16 mm^2 and the voltage should not exceed 250 V.

(d) Cables in casing should be fixed with clips as described in Clause 11.14.

11.18 - Protection of cables in stores containing low-flash-point hydrocarbon products.

Where it is necessary to install cables in such spaces, for example, where the lighting cannot be effected using cables fitted externally, the cables in the space should be protected by substantial watertight sheet-iron covers or by tubing with watertight joints, from the bulkhead or deckhead of the compartment to the apparatus supplied.
Mineral-insulated cables only may be run open in such spaces.

11.19 - Installation in refrigeration spaces.

(a) Cables installed in refrigeration spaces should be lead-sheathed or polychloroprene sheathed (or have equivalent protection). They should not be covered by the thermal insulation.
Alternatively cables may be attached to galvanized perforated tray plate with a space left between the back of the tray plate and the lining of the space. The casual use of the cables as a means of suspension should be obviated by the provision of guards surrounding the cables.

(b) If the cables must pass through the thermal insulation of the compartments, they should do so at right angles, in tubes provided with glands.

11.20 - Tensile stress. Cables should be so installed that the tensile stress applied to them either by reason of their own weight or for any other reason, is minimized.

These precautions are particularly important for cables of small cross-section and for cables on vertical runs, which should be suitably fixed.

11.21 - Electrodynamic forces. In order to guard against the effects of electrodynamic forces developing on the occurrence of a short circuit, single-core cables must be firmly fixed.

11.22 - Special precautions for a.c. wiring. A.C. wiring should be carried out as far as possible in twin or multi-core cables.

In certain cases, it may be necessary to use single-core cables; it is then necessary to observe the following precautions:

(a) The cables should not include any magnetic armour.

(b) Conductors belonging to the same circuit should be contained within the same pipe or conduit.

(c) In the installing of 2, 3 or 4 single-core cables forming respectively single-phase circuits, three-phase circuits, or three-phase and neutral circuits, the cables should as far as possible be in contact with one another. In every case, the distance measured between the external covering of two adjacent cables should not be greater than one diameter.

(d) When single-core cables having a nominal cross-sectional area greater than 200 mm^2 (or 0.3 in^2) must be installed against a steel bulkhead, the distance between the cables and bulkhead should be at least 50 mm (or 2 in.).

(e) Glands for the passage of cables through bulkheads and decks should be of non-magnetic metal. In addition it is advantageous to use non-magnetic plates of sufficient size of obviate heating of the steel plating.

(f) In ascertaining the cross-sectional area of cables it is necessary for account to be taken of induced currents in the sheaths and the effect of bulkheads, when cable runs pass along metallic plates or pass through bulkheads of magnetic metal.

(g) In order to equalize to some degree the impedances of circuits of considerable length consisting of single-core cables or large cross-section, recourse should be had to a transposition of the phases at intervals not exceeding 15 metres or other appropriate means; this precaution will not, however, be necessary when the length of the run is less than 30 metres (or 100 ft).

(h) In the case of circuits involving several cables in parallel per phase, the cables of the same phase should be as far as possible alternated with those of other phases.

Table 11.IV

Current ratings ** for rubber-insulated cables

Cooling-air temperature : 45 °C
Maximum temperature of conductor : 60 °C

Nominal cross-sectional area	Single-core cables *	
	Continuous rating	1-hour rating
1	2	3
mm²	amp.	amp.
1	9	9
1.2	9	9
1.6	11	11
2	13	13
2.5	16	16
3.2	20	20
4	23	23
5	27	27
6.3	30	30
8	34	34
10	41	41
12.5	45	45
16	50	50
20	62	63
25	69	70
32	76	77
40	89	91
50	103	106
63	120	125
80	138	145
100	160	168
125	186	199
160	219	237
200	247	270
250	289	318
315	336	372
400	406	455
500	489	532
630	538	616

* For twin, three-core or four-core cables with nominal cross-sectional area exceeding 6 mm², the values shown in Cols. 2 and 3 should be multiplied by the following correction factors:
twin-core 0.85 3- or 4-core 0.70

** The values shown are applicable to a.c. and d.c. circuits, when the nominal cross-sectional area of the cables does not exceed 315 mm². For cables of nominal cross-sectional area exceeding 315 mm² account should be taken on a.c. circuits of a correction factor which should be determined for each particular case.
The current ratings apply subject to the maximum permissible voltage-drop not being exceeded.

T a b l e 11.V

Current ratings * * for varnished-cambric-insulated cables

Cooling-air temperature : 45 °C
Maximum temperature of conductor : 75 °C

Nominal cross-sectional area	Single-core cables *	
	Continuous rating	1-hour rating
1	2	3
mm	amp.	amp.
1	13	13
1,2	13	13
1,6	16	16
2	19	19
2,5	23	23
3,2	28	28
4	33	33
5	38	38
6,3	42	42
8	47	47
10	58	58
12,5	63	63
16	70	70
20	87	89
25	97	100
32	108	112
40	128	136
50	148	161
63	170	187
80	198	219
100	227	258
125	267	310
160	316	373
200	360	422
250	420	526
315	480	600
400	582	732
500	678	872
630	767	1005

* For twin, three-core or four-core cables with nominal cross-sectional area exceeding 6 mm^2, the values shown in Cols. 2 and 3 should be multiplied by the following correction factors :
twin-core 0,85   3- or 4-core 0,70

* * The values shown are applicable to a.c. and d.c. circuits, when the nominal cross-sectional area of the cables does not exceed 315 mm^2. For cables of nominal cross-sectional area exceeding 315 mm^2 account should be taken on a.c. circuits of a correction factor which should be determined for each particular case.
The current ratings apply subject to the maximum permissible voltage-drop not being exceeded.

T a b l e 11.VI

Current ratings ** for mineral-insulated cables

Cooling-air temperature : 45 °C
Maximum temperature of conductor : 85 °C

Nominal cross-sectional area	Single-core cables * in a.c. or d.c. circuits	
	Continuous rating	1-hour rating
1	2	3
mm^2	amp.	amp.
1	19	19
2	25	25
3.2	33	33
5	42	42
8	57	57
10	67	67
12.5	77	79
16	89	93
20	100	105
25	112	121
32	127	140
40	148	170
50	171	205
63	198	248
80	225	306
100	257	360
125	293	410
150	335	

* For twin, three-core or four-core cables with nominal cross-sectional area exceeding 6 mm^2, the values shown in Cols 2 and 3 should be multiplied by the following correction factors :

twin-core 0.85 3- or 4-core 0.70

** The current ratings apply subject to the maximum permissible voltage-drop not being exceeded.

CHAPTER 12

TRANSFORMERS FOR POWER AND LIGHTING

12.01 - Scope. This chapter * applies to all transformers for power and lighting installed on shipboard, rated at 1 kVA or more for single-phase or at 5 kVA or more for 3 -phase and where appropriate to static balancers.

12.02 - General. Transformers except those used for motor starting should be double-wound (two separate windings) and preferably of the dry, air-cooled type.

12.03 - Position. Transformers should be installed in well-ventilated compartments, accessible only to authorized personnel except that air-cooled transformers provided with means of protection against accidental contact with live parts need not be installed in special compartments.
Oil-cooled transformers should be housed in a metallic compartment having adequate means for the drainage of leakage oil.

Transformers and their connections should be protected against such mechanical damage, condensation and corrosion as may reasonably be expected.

12.04 - Terminals. Suitable terminals, clearly marked, should be provided in an accessible position, convenient for external connections. The terminals should be effectually secured and should be so spaced and/or shielded that they cannot be accidentally earthed, short-circuited or touched.

12.05 - Construction. The degree of protection required for transformers and their terminals should be related to their position on board; transformers should have protection of at least the drip-proof type.

12.06 - Liquid-cooling. Liquid-cooled transformers should be preferably of the conservator type, and should be so designed that, under all conditions with the ship inclined from the normal at any angle up to 15 degrees transversely and 10 degrees longitudinally, and with rolling up to 22.1/2 degrees from the vertical, they operate without risk of spilling liquid. Transformers for emergency supplies should in addition operate satisfactorily during permanent list of 22.1/2°. If provision is made for breathing, a suitable dehydrator should be provided.

12.07 - Rating.

(i) Rated primary voltage. The rated primary voltage is the voltage of the principal primary tapping under the usual operating conditions. It should be specified by the purchaser and marked on the rating plate.

(ii) Rated secondary voltage. The rated secondary voltage is the voltage of the principal secondary tapping at no-load when applying rated primary voltage to the principal primary tapping and should be as specified by the purchaser and marked on the rating plate.

---

* Attention is drawn to the relevant recommendations of Chapter 3, which are not repeated here.

(iii) Rating. The rating is expressed in kVA and should be specified by the purchaser and marked on the rating plate. The rating is a continuous rating and is such that the transformer at rated primary voltage can deliver its rated secondary current (see definition below) for an unlimited period without the limits of temperature rise given in Clause 12.10 being exceeded.

NOTE: If the transformer has to work the constant primary voltage, the apparent power at the secondary terminals in loaded conditions differs from the rating by a quantity corresponding to the voltage drop and is the product of the actual secondary voltage the rated secondary current and the appropriate phase factor.

(iv) Rated secondary current. The rated secondary current is the current derived by dividing the rating by the rated secondary voltage and, in the case of polyphase transformers, by the appropriate phase factor.

(v) Impedance voltage. Impedance voltage is the voltage, expressed as a percentage of the rated primary voltage, required to be applied to the primary winding when the secondary winding is short-circuited and the rated primary current is flowing in the primary winding; or vice versa, in which latter case it is expressed as a percentage of the rated secondary no-load voltage. The associated tapping should be the principal tapping unless otherwise stated. The impedance voltage may be measured at a current less than the rated current and the value corrected in proportion to the current and to a temperature of 75 °C.

12.08 - Regulation. The voltage variations between no load and full load, with non-inductive loading should not exceed 5% for transformers rated at up to 5 kVA per phase and 2.1/2 % for transformers rated at more than 5 kVA per phase.
The voltage ratio should be within 0.5% of the declared ratio, or a percentage equal to 1/10 of the percentage impedance voltage at rated load, whichever is the smaller.

12.09 - Parallel operation. When transformers are so arranged that their secondary windings may be connected in parallel, the voltage regulation and short-circuit potential of the transformers should be such that the actual current of each parallel-operating unit does not deviate more than 10 % from the correct value of the full load current of that unit.
When transformers are intended for operation in parallel, the rated output of the smallest transformer in the group should be not less than one-third of the rated output of the largest transformer in the group.

12.10 - Limits of temperature-rise. The temperature-rise, measured during continuous operation at the maximum rating should not exceed the limits given in Table 12.I, Page 86.

For a dry or liquid-cooled transformer where the cooling depends upon natural air circulation or forced draught, the limits of temperature-rise should be specified as the temperature-rise above the cooling-air temperature. For a transformer cooled by circulating water, the temperature-rise should be measured with respect to the temperature of the water at the point of entry.

Table 12.I, below is based on temperatures of cooling fluid equal to 30 °C for water and 45 °C for air.
Where the reference temperatures for fluids are 25 °C for water and 40 °C for air the values shown in Table 12.I, below may be increased by 5 °C. (See Clause 3.06).

T a b l e 12.I.

Limits of temperature-rise on transformers

Average temperature-rise of winding as measured by increase in resistance of the winding connected between the terminals (Centigrade degrees)

Type	Circulation	Cooling	Insulation Class A	Insulation Class B
1	2	3	4	5
Dry	-	Air	50	70
Liquid-immersed	Natural thermal head only	Air	55	-
	Forced circulation by external pumps	Air	60	-
		Water	65	-

Liquid -	(For all liquid-immersed types) temperature-rise (by thermometer) - 45 Centigrade degrees
Cores -	(For all types) the temperature-rise when measured by thermometer on the external surface of the core should not exceed that permitted for the adjacent windings.

12.11 - Short-circuit. Transformers should be capable of withstanding short-circuits on any secondary winding or windings without injury for the time periods given in Table 12.II, Page 87, with the rated line voltages maintained on all windings intended for connection to external sources of power. Allowance may be included for the impedance of the system feeding the transformer by agreement between the purchaser and the manufacturer. (See IEC-Publication No. 76 IEC Recommendations for power transformers).

The initial current is assumed to be completely displaced from zero in so far as determining the mechanical stresses.

If a short-circuit test is made, it should be a type test.

Table 12.II

Short-circuit currents and their duration

Transformer Impedance voltage	Duration of short-circuit in seconds	R.M.S. symmetrical short-circuit current to be withstood
4 % or lower	2	25 times rated current
higher than 4 %	3	Rated current times $\frac{100}{\%\ \text{impedance voltage}}$

For transformers having 3 or more windings, the time for which the transformer should be capable of withstanding a short circuit is dependent upon the maximum current which can flow in any short-circuited winding with rated voltage maintained on all other windings intended for connections to an external source of power.

Each winding should be considered separately and the ratio of maximum short-circuit current in a winding to its rated current should be used in the table to obtain the permissible duration of short-circuit for that winding.

12.12 - High-voltage test. An applied high-voltage test should be carried out on every transformer at the manufacturer's works, preferably with the transformer hot immediately after the temperature test, if any. The test should be applied between the winding under test and the remaining windings, frame and tank of the transformer all connected to earth.

The test should be made with a.c. at 1 kV plus twice the highest r.m.s. voltage sustained between lines subject to a minimum voltage of 2.5 kV. at any convenient frequency between 25 c/s and twice the rated frequency of the transformer, but preferably at the rated frequency. The full test-voltage should be maintained for one minute.

Single-phase transformers for use in a polyphase group should be tested in accordance with the requirements for the transformers as connected together on the system.

RATING-PLATE

12.13 - Information required. The rating plate of every transformer should show the I.E.C. rating in accordance with the relevant I.E.C. Recommendations for power transformers No. 76.

12.14 - Where parallel operation is intended all necessary information needed to ensure satisfactory parallel operation or banking should be shown either on the rating plate or on a diagram.

CHAPTER 13

GENERATORS (with associated prime movers) AND MOTORS

13.01 - Scope. This chapter applies to all generators (with the associated prime movers) and motors installed on the shipboard, rated at 750 W or more; with the exception of alternators of the non-salient-pole steam-turbine-driven type.

For electric propelling machines, see Chapter 24.

PRIME MOVERS

13.02 - General. Engines for driving electrical generators intended for supplying essential services should comply with the following Clauses 13.03 - 13.10, and should be rated for continuous running.

13.03 - Ships for unrestricted service. In ocean-going ships and ships operating in tropical waters, i.e. between latitudes 35°N and 20°S, they should be rated for the following conditions unless otherwise specified.

(a) An air temperature of 50 °C, combined with 70 % relative humidity.

(b) A primary cooling-water supply at 30 °C.

13.04 - Restricted-service craft outside tropics. In ships such as coasters, ferries and harbour craft, intended solely for restricted service in Northern and Southern waters outside the tropical belt defined in Clause 13.03 above, the engines should be rated for the following conditions unless otherwise specified:

(a) An air temperature of 40 °C combined with 40 % relative humidity.

(b) A primary cooling-water supply at 25 °C.

13.05 - Governing characteristics.

(a) General. Governors on prime movers should be such that they will automatically maintain the speed within a momentary variation of 10 % and a permanent variation not exceeding 5 % when full load is suddenly thrown on or off. Every turbine should be fitted with an emergency overspeed device which will operate at a speed not more than 15 % above rated speed and has provision for tripping by hand.

(b) A.C. generating sets. For a.c. generating sets operating in parallel, the governing characteristics of the prime movers should be such that within the limits of 20 % and 100 % total load, the load on any generating set does not normally differ from its proportionate share of the total load by more than 15 % of the rated full-load output of the largest machine.

The facilities for adjusting the governor at normal frequency should be sufficiently fine to permit a minimum adjustment of load on the engine not exceeding 5 % of full load.

(c) D.C. generating sets. See Clause 13.22

13.06 - Turbine-driven d.c. generating sets in parallel. Where a turbine-driven direct-current generator is arranged to run in parallel with other generators, a switch should be fitted on each turbine emergency governor for the purpose of opening the generator circuit-breaker when the emergency governor functions.
The contacts of the overspeed switch should be normally closed.

13.07 - Lubrication. Prime movers should be efficiently and continuously lubricated at all running speeds and at all working oil temperatures without the spilling of oil with the ship at the following inclinations from normal :

Transversely	15°
Longitudinally	10°
or for ships of length exceeding 150 m (or 500 ft.)...	5°
Rolling : up to	22° 30'
Emergency sets should in addition operate satisfactorily with the ship at a permanent list of	30°

Turbine-driven generating sets dependent on forced lubrication should be arranged to shut down automatically on failure of lubrication.

13.08 - Running speed. The normal running speed of a combined generating set should not be in the vicinity of a critical speed.

13.09 - Cyclic irregularity. The maximum permissible cyclic irregularity in a reciprocating engine throughout one engine cycle should conform to the following :

(a) For an engine having one or two cylinders the cyclic irregularity should not be worse than 1/75 unless a closer limit is specified.

(b) For an engine having more than two cylinders the cyclic irregularity should not be worse than the values given in the following Table 13.I.

T a b l e 13.I

Limits of cyclic irregularity

Number of engine impulses per second	Cyclic irregularity to be not worse than
less than 10	1/150
10 to 20	$\frac{\text{No. of impulses per second}}{1\,500}$
more than 20	1/75

NOTE: (See page 90)

NOTE: Cyclic irregularity is defined as the ratio of the maximum variation in angular velocity at the fly-wheel during one engine cycle to the mean angular velocity when the engine is running at any load up to and including rated load and at rated speed. This is conveniently expressed as follows :

$$\frac{\text{max. speed} - \text{min. speed}}{\text{mean speed}}$$

13.10 - Flywheel effect for a.c. generating sets in parallel. For a.c. generators operating in parallel, the combined flywheel effect of the flywheel and alternator should be such that the angular deviation in either direction from the position of uniform rotation should not at any time exceed 3.1/2 electrical degrees, in addition to complying with the limit of cyclic irregularity given in Clause 13.09.

The engine maker should inform the supplier of the alternator regarding the total flywheel effect he intends shall be provided to ensure that the maximum calculated angular deviation of 3.1/2 electrical degrees is not exceeded. He should also state the frequencies of such engine-disturbing forces as are of significant magnitude and the supplier of the alternator should then specify to the engine maker what additional flywheel effect (if any) is necessary for the avoidance of the effects of resonance due to alternator-swing.

The generator manufacturer should provide all necessary information to the engine manufacturer who will be responsible for checking the whole system for critical speeds and for calculating the torsional rigidity and torsional strength of the complete shaft system. The engine manufacturer should state what reasonable changes, if any, in the generator shafting are necessary to avoid the occurrence of excessive stresses and such changes should be undertaken by the generator manufacturer.

NOTE 1 : The angular deviation specified is that calculated on the assumption that the torque of the alternator, i.e. the torque opposing the motion of the engine, is uniform throughout the engine cycle.

NOTE 2 : The angular deviation specified applies to alternators on ordinary regulation. Alternators designed for special regulation may require still closer uniformity of rotation.

NOTE 3 : Avoidance of the effects of resonance means that the natural frequency of oscillation of the alternator with its flywheel, when connected to the electrical system with which it is to work in parallel, should not approach the frequency of any engine impulses of significant magnitude.

MATTERS COMMON TO A.C. and D.C. GENERATORS and MOTORS

13.11 - Types of rating. Ship's service generators, including the prime movers, should be suitable for continuous duty at their full rated load for an unlimited period, without the limits of temperature-rise given in Clause 13.12 being exceeded.

Generators (including exciters) other than ship's service generators, and motors, should be rated in accordance with the duty which they are required to perform.

13.12 - Permissible limits of temperature-rise. The limits of temperature-rise given in Table 13.II, Page 92 should be adopted for machines which are insulated with materials of Class A or Class B, as defined in Appendix I, Page 152 to these Recommendations. For ventilated or enclosed machines a temperature of cooling air not exceeding 50 °C is assumed, and for water-cooled machines, a temperature of cooling water not exceeding 30 °C. For water-cooled machines, the temperature-rise is measured in relation to the temperature of the cooling water, measured at the inlet.

An increase in limits of temperature-rise up to not more than 10 Centigrade degrees may be made if the temperature of the cooling medium is less than the values stated above. If the temperature of the cooling medium exceeds the values stated, the permissible temperature-rise is reduced by an amount equal to the excess temperature of the cooling medium.

Temperature is measured as described in Appendix II, Page 154 to these Recommendations.

T a b l e 13.II

Permissible limits of temperature-rise (centigrade degrees)

for an ambient air temperature of 50 °C and a primary cooling water supply of 30 °C

Machine Parts	Method of temp. measurement	Water-cooled machines Class A	Water-cooled machines Class B	Enclosed machines Class A	Enclosed machines Class B	Ventilated machines Class A	Ventilated machines Class B
Windings (other than single-layer field windings with exposed surface) and cores with which they are in contact	thermometer ø	60	75	45	60	40	55
	Resistance ø	70	90	50	70	50	70
Single-layer field windings with exposed surface	thermometer or resistance	75	95	55	75	55	75
Commutators and sliprings ++	thermometer	70+	80*+	55	65*	55	65*
Permanently short-circuited uninsulated windings, iron cores and other parts not in contact with windings	thermometer	This temperature-rise should in no case reach such a value that there is a risk of injury to any insulating or other material on adjacent parts					

NOTES TO TABLE 13.II.

* NOTE 1: The limits of temperature-rise applicable to Class B insulation do not apply to commutators or sliprings insulated with Class B materials, unless the insulation of the armature or rotor is also Class B.

++ NOTE 2: The temperature rise of commutators and slip rings may exceed the value given provided that the three following conditions are fulfilled:-

(a) The temperature rises of the insulating materials on the adjoining windings do not exceed those allowed for the insulating materials of those parts.

(b) The Manufacturer guarantees that the higher temperature attained will not impair the commutation.

(c) The temperature is not so high as to affect the quality of the soldered joints and connections.

\+ NOTE 3: Where commutators or sliprings of water-cooled machines are not in the enclosed air-circuit, the temperature conditions should be in accordance with the requirements for ventilated machines.

ø NOTE 4: It is not intended that measurements by both the thermometer and the resistance method shall be required, and the figures of temperature-rise given in the table 13.II, above, for the thermometer method and the resistance method are not to be used as a check against one another.

13.13 - Mechanical balance. Machines should be so constructed that when running at any and every working speed all revolving parts are well balanced.

13.14 - Entry of water. Where water-cooling is used, the cooler should be so arranged as to prevent any entry of water into the machine, whether by leakage or condensation in the heat-exchanger.

13.15 - Shaft currents. Measures should be if necessary taken to prevent the circulation of current between the shaft and the bearings.

13.16 - Lubrication.

(a) Generators and motors should be efficiently and continuously lubricated automatically at all running speeds and all normal working bearing temperatures, with the following inclinations from normal :

Transversely	15°
Longitudinally	10°
or for ships of length exceeding 150 m (or 500 ft.)	5°
Rolling: up to	22° 30'
Emergency generators and motors required to operate under emergency conditions should in addition operate satisfactorily with the ship at a permanent list of	30°

Means should be provided to prevent the lubricant from creeping along the shaft or otherwise gaining access to the insulation of the machine or any live part thereof.

(b) Every oil-lubricated bearing should be provided with a suitable overflow which, while permitting efficient lubrication when the machine is running, prevents the bearing from containing an excess of oil.

(c) Where ring lubrication is employed, the rings should be so constrained that they cannot leave the shaft.

(d) Every self-lubricated sleeve bearing should be fitted with an inspection lid and means for visual indication of oil level.

NOTE: For turbine-driven generating sets, see 13.07.

13.17 - Terminals. Suitable terminals, clearly marked should be provided in an accessible position, convenient for external connections. The terminals should be effectually secured and should be so spaced and/or shielded that they cannot be accidentally earthed, short-circuited, or touched.

13.18 - Rating plate. The rating plate of every machine should give the following information, the values of output, voltage, current and speed being those pertaining to rated full load.

(a) General

(i) The specification to which the machine conforms.
(ii) The name of the maker.
(iii) The maker's machine number.
(iv) The class of rating or the necessary information if the machine is intended to operate under more than one class of rating.
(v) The additional information detailed in (b), (c), (d), (e), (f) or (g) below, as appropriate.

(b) D.C. Generator

(vi) Generator.
(vii) Direct current (d.c.) and whether shunt, series, compound or separately excited.
(viii) Electrical output in kW.
(ix) Voltage between terminals and at rated output.
(x) Current in amperes.
(xi) Speed, in revolutions per minute.
(xii) Excitation voltage and current, if excited from a separate source.

(c) D.C. Motor

(vi) Motor.
(vii) Direct-current (d.c.), and whether shunt, series, compound or separately excited.
(viii) Mechanical output.
(ix) Voltage between terminals.
(x) Current, approximate, in amperes.
(xi) Speed, in revolutions per minute, at rated output.
(xii) Excitation voltage and current, if excited from a separate source.

(d) A.C. Generator

(vi) Alternator.
(vii) Frequency, in cycles per second.
(viii) Number of phases and method of connection.
(ix) Electrical output, in kVA.
(x) Voltage between terminals at rated output.
(xi) Current, in amperes.
(xii) Power factor.
(xiii) Speed, in revolutions per minute.
(xiv) Excitation voltage.
(xv) Exciting current, in amperes, at rated output.

(e) Synchronous motor

(vi) Synchronous motor.
(vii) Frequency, in cycles per second.
(viii) Number of phases.
(ix) Mechanical output.
(x) Voltage between terminals.
(xi) Current, approximate, in amperes.
(xii) Speed, in revolutions per minute.
(xiii) Excitation voltage.
(xiv) Maximum exciting current, in amperes.

(xv) Power factor at rated load, whether unity or otherwise.

(xvi) For a synchronous motor intended to be started as an induction motor, the maximum voltage which can exist between the slip-rings at starting should be stated.

(f) Induction motor

(vi) Motor.
(vii) Frequency, in cycles per second.
(viii) Number of phases.
(ix) Mechanical output.
(x) Voltage between terminals.
(xi) Current, approximate, in amperes.
(xii) Speed, in revolutions per minute, at rated output.
(xiii) For slip-ring motors the voltage on open circuit between slip-rings.
(xiv) Rotor current in amperes.

(g) A.C. commutator motor

(vi) A.C. commutator motor.
(vii) Frequency in cycles per second.
(viii) Number of phases.
(ix) Mechanical output.
(x) Voltage between terminals.
(xi) Current, approximate, in amperes.
(xii) Speed range, in revolutions per minute, at rated outputs.

SHIP's SERVICE D.C. GENERATORS

13.19 - Number and size of ship's service d.c. generators. When the number and ratings of generating sets to be provided is determined, careful consideration should be given to the normal and maximum demands as well as the safe and efficient operation of the ship when at sea and in port. The number and ratings of generating sets and converting sets should be sufficient to ensure the operation of the auxiliary services indispensable for the propulsion and safety of the ship even when one generating set or converting set is out of service. The combined normal capacity of the sets should be at least equal to the maximum peak load sustained at sea, unless the peak load and its duration fall within the limits of the specified overload capacity of the sets.

13.20 - Automatic voltage-regulation for d.c. generators. When lighting circuits are to be supplied direct from ship's service generators of the shunt-wound type, an automatic voltage-regulator should be provided.

13.21 - 3-wire generators. Unless otherwise specified all 3-wire direct-current generators should be designed for a current unbalance of 25%.

13.22 - Inherent voltage-regulation of d.c. generators. The inherent voltage-regulation of ship's service generators should be designed in relation to the speed regulation and governing of the prime movers, as follows :

(a) Shunt- or stabilized shunt-wound generators rated at 50 kW and above should satisfy the following tests:

(i) When the voltage has been set at full load, the steady voltage at no load should be between 12.1/2 % and 15 % higher than the full-load voltage.

(ii) When the voltage has been set at no load the application of full load should not cause a drop in steady voltage of more than 17 %.

(iii) When the voltage has been set either at full load or at no load, the voltage obtained at any value of load should not exceed the no-load voltage.

(b) Compound-wound generators rated at 50 kW and above should be so designed in relation to the governing characteristics of the prime mover, that with the generator at full-load operating temperature, and starting at 20 % load with voltage within 1 % of rated voltage, it should give at full load a voltage within 1.1/2 % of rated voltage. The average of the ascending and descending voltage regulation curves between 20 % load and full load should not vary more than 3 % from rated voltage.

(c) Generators falling below the limits given in (a) and (b) above should be the subject of special consideration.

<u>13.23 - Field regulation of d.c. generators.</u> Means should be provided at the switchboard to enable the voltage of each generator to be adjusted separately. The equipment provided should be capable of adjusting the voltage of the d.c. generator to within 0.5 % of the rated voltage for machines above 100 kW and 1 % of the rated voltage for smaller machines, at all loads between no load and full load, with the d.c. generator coupled to its prime mover, at any permissible temperature within the working range. The regulator should be capable of reducing the no-load voltage to 10 % below the rated voltage with the generator cold.

<u>13.24 - Stability of d.c. generators.</u> Generators which are required to run in parallel should be stable in operation at all loads from no load to full load.

<u>13.25 - Parallel running of d.c. generators.</u> The design of d.c. generators and their connections should be such that, when they operate in parallel, the individual load on each machine does not normally differ from the theoretical load (proportional to rating) by an amount greater than 12 % of the rated full-load of the largest machine or 25 % of the rating of the individual machine in question. This requirement applies when the combined load on the sets is varied between 20 % and 100 % of the combined ratings.

For each generator of a group required to run in parallel, the voltage drop across the series field and its connection to the switchboard (which may incorporate a resistor) should be approximately equal.

<u>13.25 - Polarity of series winding.</u> The series winding of each 2-wire generator should be connected to the negative terminal of each machine.

(a) Shunt- or stabilized shunt-wound generators rated at 50 kW and above should satisfy the following tests:

(i) When the voltage has been set at full load, the steady voltage at no load should be between 12.1/2 % and 15 % higher than the full-load voltage.

(ii) When the voltage has been set at no load the application of full load should not cause a drop in steady voltage of more than 17 %.

(iii) When the voltage has been set either at full load or at no load, the voltage obtained at any value of load should not exceed the no-load voltage.

(b) Compound-wound generators rated at 50 kW and above should be so designed in relation to the governing characteristics of the prime mover, that with the generator at full-load operating temperature, and starting at 20 % load with voltage within 1 % of rated voltage, it should give at full load a voltage within 1.1/2 % of rated voltage. The average of the ascending and descending voltage regulation curves between 20 % load and full load should not vary more than 3 % from rated voltage.

(c) Generators falling below the limits given in (a) and (b) above should be the subject of special consideration.

13.23 - Field regulation of d.c. generators. Means should be provided at the switchboard to enable the voltage of each generator to be adjusted separately. The equipment provided should be capable of adjusting the voltage of the d.c. generator to within 0.5 % of the rated voltage for machines above 100 kW and 1 % of the rated voltage for smaller machines, at all loads between no load and full load, with the d.c. generator coupled to its prime mover, at any permissible temperature within the working range. The regulator should be capable of reducing the no-load voltage to 10 % below the rated voltage with the generator cold.

13.24 - Stability of d.c. generators. Generators which are required to run in parallel should be stable in operation at all loads from no load to full load.

13.25 - Parallel running of d.c. generators. The design of d.c. generators and their connections should be such that, when they operate in parallel, the individual load on each machine does not normally differ from the theoretical load (proportional to rating) by an amount greater than 12 % of the rated full-load of the largest machine or 25 % of the rating of the individual machine in question. This requirement applies when the combined load on the sets is varied between 20 % and 100 % of the combined ratings.

For each generator of a group required to run in parallel, the voltage drop across the series field and its connection to the switchboard (which may incorporate a resistor) should be approximately equal.

13.25 - Polarity of series winding. The series winding of each 2-wire generator should be connected to the negative terminal of each machine.

13.27 - Equalizer connections. Every equalizer connection should have a cross-sectional area not less than half that of the negative connection from the generator to the switchboard and should preferably be of such a size that its resistance is not more than half the sum of the resistances of the series field and its connection to the switchboard.

13.28 - Momentary excess current. Generators should be capable of withstanding on test for 15 seconds a current 50 % in excess of the rated current, the voltage being maintained as near the rated value as possible, consistent with the maximum capacity of the prime mover. This is not a routine test but is a manufacturer's type test.

13.29 - Commutation. Generators should work with fixed brush-setting, from no load to the momentary excess current specified in Clause 13.28, without injurious sparking or injury to the commutator or brushes.

13.30 - D.C. generators for special purposes. D.C. generators for special purposes (e.g. lifts, capstans, etc.) and including exciters will have such special voltage characteristics as are required for the service concerned and the recommendations of Clauses 13.19 - 13.29 will not necessarily be applicable. The generators will be short-time or continuously-rated as necessary, and when tested under rated conditions should comply with the temperature rises specified in Clause 13.12. In short-time-rated machines, continuous rating of the field windings will frequently be a requirement. The generators should comply with the relevant commutation requirements in Clause 13.29.

13.31 - Rated voltage d.c. generators other than for ship's services. Generators other than for ship's services and motors for special purposes should satisfy the relevant recommendations, including the high-voltage test, and where applicable, the requirements for commutation.

D.C. MOTORS

13.32 - Momentary excess torque. A d.c. motor should be capable of withstanding on test for 15 seconds a torque 50 % in excess of that corresponding to its rating, the voltage being maintained at rated value. This is not a routine test but is a manufacturer's type test.

13.33 - Commutation. A d.c. motor should work with fixed brush-setting, from no load to the momentary excess torque specified in Clause 13.32, without injurious sparking or injury to the commutator or brushes. This is not a routine test but is a manufacturer's type test.

13.34 - Speed tolerances. The following tolerances on rated speed are recognized for d.c. motors run at full load and at working temperatures unless otherwise specified :

(a) Shunt motors

(i) 0.75 - 2.5 kW per 1 000 r.p.m. (subject to a minimum actual power of 1 kW) ± 10 %

(ii) 2.5 - 10 kW per 1 000 r.p.m. ± 7.5%

(iii) not less than 10 kW per 1 000 r.p.m. ± 5 %

(b) Series motors

(i) 0.75 - 2.5 kW per 1 000 r.p.m. (subject to a minimum actual power of 1 kW) ± 15 %

(ii) 2.5 - 10 kW per 1 000 r.p.m. ± 10 %

(iii) not less than 10 kW per 1 000 r.p.m. ± 7.5%

NOTE: For the purpose of this clause, compound motors with shunt characteristics are regarded as shunt motors, whilst compound motors with series characteristics are regarded as series motors.

SHIP's SERVICE A.C. GENERATORS

NOTE: Unless otherwise stated, the following recommendations do not necessarily apply to machines smaller than 50 kVA or machines intended solely for special purposes such as the supply for lifts, deck machinery etc.
Machines rated below 50 kVA and those required for special purposes, should be the subject of special consideration.

13.35 - Number and size of a.c. service generating sets. The number and ratings of ship's service a.c. generators should be as described for d.c. installations in Clause 13.19 except that in the determination of the size of generators particular attention should be given to the starting current drawn by squirrel-cage motors connected to the system. When the generating-sets operate in parallel, and are carrying initially the minimum load necessary for the operation of the ship, they should have sufficient reserve output with respect to the largest idle motor on the system to enable the motor to be started; moreover the voltage drop due to such starting current should not cause any motor already operating to stall, or have any adverse effect on other equipment in use.

13.36 - A.C. voltage-regulators. Each a.c. service generator unless of the self-regulated type should be operated in conjunction with a separate automatic voltage-regulator. The voltage-regulator should be of a type capable of withstanding shipboard conditions. When it is intended that two or more generators will be operated in parallel continuously, reactive drop compensating means should be provided to divide the reactive power properly between the generators.

13.37 - A.C. voltage regulation. It is recommended that the voltage regulation should in every case satisfy the following tests; it is recognized that in certain circumstances such as referred to in 13.35 current-consuming appliances requiring a more critical regulation may be in use, and suitable provision should be made. The load on the alternator immediately prior to these tests, should not exceed 90 % of the rated output (kVA) of the alternator at a power factor of 0.8 lagging.

(a) The regulation of every generating set when driven by a prime mover whose governor has the characteristics specified in Clause 13.05 should be such that at all loads from zero to full-load the rated voltage is maintained under steady conditions within ± 2.5 %, except that for emergency generating sets, the limit may be ± 3.1/2 %.

(b) When the automatic voltage-regulator has been set to give rated voltage, and a current equal to 50 % of the full-load current of the alternator at any power factor between 0 and 0.4 lagging is suddenly drawn, or a current equal to 25 % of the full-load current is suddenly removed, the maximum voltage change should not exceed 20 %. The automatic voltage-regulator should then restore the voltage to within ± 3 % of the rated voltage in not more than 3 seconds, except that for emergency sets the restoration may be within ± 5 % of the rated voltage in not more than 3 seconds.

13.38 - Parallel operation. When a.c. service generators are operated in parallel, the wattless loads of the individual generating sets should not differ from their proportionate share of the total wattless load by more than 10 % of the rated wattless output of the largest machine.

NOTE: It is assumed that the speed of the prime mover decreases with application of load and increases with its removal, permanent variation being such that the speed does not at any load vary by more than 1 % of full-load speed from the straight line joining full-load and no-load speeds.

13.39 - Excitation. Each generator should be provided with excitation of sufficient capacity to enable rated voltage to be maintained on the alternator at 150 % rated current and 0.5 power factor for 2 minutes.

A.C. MOTORS

13.40 - Momentary excess torque.

(a) A polyphase synchronous motor should be capable of withstanding for 15 seconds without dropping out of synchronism a torque 50 % in excess of the torque corresponding to its rating, the voltage and frequency of the a.c. system with which it is synchronized being maintained at their rated value required to meet the specified conditions at rated load. This is not a routine test but is a manufacturer's test.

(b) A polyphase induction motor should be capable of withstanding for 15 seconds, without stalling or abrupt change in speed (under gradual increase of torque), a maximum torque as specified below, the voltage and frequency being maintained at their rated values.

For induction motors of the normal type (e.g. wound-rotor or ordinary squirrel-cage motors) the maximum torque should be at least 60 % in excess of that corresponding to the rating.

In the case of induction motors, for which the field of application is specified in the order, and in the case of induction motors of special type (e.g. motors with eddy-current rotors or double-cage rotors of the Boucherot type) with special inherent starting properties, the value of the excess torque should be a matter of agreement between manufacturer and purchaser.

13.41 - Commutation. A.C. commutator motors should work practically sparklessly over the specified range of load and speed. The commutation test should be applied at the conclusion of the temperature test of the motor.

TESTS FOR GENERATORS AND MOTORS

13.42 - Performance test. Sufficient tests should be made at the manufacturer's works to ensure that the machine is in accordance with these recommendations. Wherever practicable spare armatures should be given the tests applicable to the complete machine.

13.43 - High-voltage test. The high-voltage test should be applied between the windings and the frame with the core connected to the frame and to the windings not under test, and should be applied only to a new and completed machine with all its parts in place under conditions equivalent to normal working conditions, and unless otherwise specified the test should be carried out at the makers' works at the conclusion of the temperature test of the machine.

The test-voltage should be alternating and should be as near as possible to sine wave-form.

The test should be commenced at a voltage of not more than one-half of the full test-voltage. The voltage should then be increased to the full value steadily or in steps of not more than 5 per cent of the full value, the time allowed for the increase of the voltage from half to full value being not less than ten seconds. The full test-voltage should then be maintained for one minute in accordance with the values as indicated in the following Table 13.III, Pages 100-101-102.

Table 13.III

Item No.	Machine or part	Test-voltage (r.m.s.)
1	Insulated parts of machines of size less than 1 kW or 1 kVA	500 V + twice the rated voltage
2	Rotating machines of size 1 kW or 1 kVA to less than 10,000 kW or kVA (see Note 2)	1,000 V + twice the rated voltage with a minimum of 1,500 V (see Note 1)
3	Rotating machines of size 10,000 kW or kVA or more (see Note 2):	
	Rated voltage	
	Up to 2,000 V	Twice rated voltage + 1,000 V
	Exceeding 2,000 V but not exceeding 6,000 V.	2.5 times rated voltage
4	Separately excited field windings of d.c. machines	1,000 V plus twice the maximum rated field circuit voltage with a minimum of 1,500 V.
5	Field windings of synchronous generators.	10 times the rated excitation voltage with a minimum of 1,500 V and a maximum of 3,500 V.

Item No.	Machine or part	Test-voltage (r.m.s.)
6	Field windings of synchronous motors.	
	a) When intended to be started with the field windings short-circuited or connected across an exciter armature, or to be started with the a.c. windings idle.	1,000 V plus twice the maximum rated excitation voltage with a minimum of 1,500 V.
	b) When intended to be started either with a resistance connected in series with the field windings, or with the field windings on open circuit with or without a field dividing switch.	1,000 V plus twice the maximum value of the r.m.s. voltage, which can occur under the specified starting conditions, between the terminals of the field winding, or in the case of a sectionalized field winding between the terminals of any section with a minimum of 1,500 V. (See Note 3).
7	Secondary (usually rotor) windings of induction motors or synchronous induction motors if not permanently short-circuited (e.g. if intended for rheostatic starting).	
	a) for non-reversing motors or motors reversible from standstill only.	1,000 V plus twice the open-circuit standstill voltage as measured between slip-rings or secondary terminals with rated voltage applied to the primary windings
	b) For motors to be reversed or braked by reversing the primary supply while the motor is running.	1,000 V plus four times the open-circuit standstill secondary voltage as defined in Item 7(a).
8	Exciters (except as below)	As for the windings to which they are connected.
	<u>Exception 1.</u> Exciters of synchronous motors (including synchronous induction motors) if connected to earth or disconnected from the field windings during starting.	1,000 V plus twice the rated exciter voltage, with a minimum of 1,500 V.
	<u>Exception 2.</u> Separately excited field windings of exciters - (see Item 4.)	

Note 1. For two-phase windings having one terminal in common, the rated voltage for the purpose of calculating the test voltage shall be taken as 1.4 times the voltage of each separate phase.

Note 2. High-voltage tests on machines having graded insulation should be the subject of special agreement.

Note 3. The voltage occurring between the terminals of the field windings or sections thereof under the specified starting conditions may be measured at any convenient reduced supply voltage, and the voltage so measured shall be increased in the ratio of the specified starting supply voltage to the test supply voltage.

CHAPTER 14

CONTROL GEAR, MOTOR STARTERS AND MAGNETIC BRAKES AND CLUTCHES

14.00 - General. Motor control gear, brakes and clutches should in design, location and other respects comply with the recommendations of Chapter 3.

14.01 - Casings and enclosures.

(a) General. General requirements are given in Chapter 3.

(b) Windows. Glazed windows of enclosing cases should be as small as possible, consistent with their purpose, and suitable protection should be arranged where necessary, against accidental breakage of the glass.

(c) Unauthorized access. The provision of means for locking handles or doors of enclosing cases or compartments is recommended where it is desirable to prevent unauthorized manipulation or access.

(d) Control gear for open-deck mounting. Control gear and resistors for deck machinery, when exposed to the weather, should be of watertight construction (see Clause 3.13). Provision may however be made where conditions are suitable for the ventilation of resistors while they are in use.

14.02 - Direction of rotation of handwheels etc. Handwheels and handles of starters and non-reversing controllers should be arranged to rotate in a clockwise direction to start the motors. For controlling the speed of motors or the voltage of generators the rotation should be clockwise to increase speed or voltage. If the movement of the handle is in a straight line it should be upwards or to the right to produce the above effects.

This recommendation does not apply to combined starter regulators operated by a single handle which is rotated clockwise to start the motor and anticlockwise to increase speed by shunt field control.

14.03 - Manually-operated controls.

(a) Mechanical strength. Manually-operated controls such as levers and handwheels should be mechanically strong and their movements should be limited by strong mechanical stops.

(b) Safety in handling. Manually-operated controls should be so arranged and so guarded that the operator cannot inadvertently touch live metal or be injured by arcing from the apparatus.

(c) Temperature of handles. The temperature rises of handles and other parts which it is necessary to handle in use should not be greater than 15 centigrade degrees.

14.04 - Resistors.

(a) Supports. Resistors and their mountings should be self-supporting, rigidly fixed, or supported throughout their length with incombustible insulating material.

(b) Corrosion. The elements of all resistors should be either:

(i) of corrosion-resistant material,

or (ii) effectively treated against corrosion,

or (iii) embedded in a material which will protect against corrosion.

(c) Inter-connections. Internal connections between resistors or from resistors to terminal boards should not include soldered joints (unless such joints are also secured mechanically), but brass or copper brazing or adequate welding may be used. Such connections should be so supported as to prevent breakage by shipboard vibration or displacement which might cause contact between such conductors and earthed metal or other conductors of differing potential. They may be either :

(i) bare connections, sufficiently rigid or supported to prevent movement,

or (ii) connections insulated with continuous non-ignitable non-hygroscopic material,

or (iii) connections insulated with beads, care being taken to prevent short-circuiting at crossings in the event of beads breaking or becoming displaced.

14.05 - Resistor sections. To prevent destructive arcing between contacts in service, the resistor sections in starters and regulators should be adequate in number and suitably graded.

14.06 - Connections to resistors. The connections between resistors and the corresponding starters, regulators or controllers should be so made as to prevent any such conductor or its insulation being subjected to an excessive temperature.

The attachment of external connections from resistors should be made at suitable terminals, with mechanical clamps, or with sockets which should not be of the soldered type unless a separate terminal board or other arrangement of terminals, not subjected to high temperature, is provided.

14.07 - Electrical clearances. The distances between live parts of different potential, and between live parts and the case or other earthed metal, whether across surfaces or in air, should be adequate for the working voltage under the conditions of installation, and should not be less than those specified for marine service by an appropriate authority.

Any parts of the case in proximity to the arc from line contactors, circuit-breakers or other contacts liable to arc, or in proximity to rewirable fuses of non-filled type, should be lined with arc-resisting insulating material.

14.08 - Making and breaking circuit. Making and breaking of the circuit or resistor switching in normal operation at full line-voltage should be ensured without projection of molten metal and without destructive arcing. Magnetic blowouts and renewable arc-rupturing contacts should be provided where required.

A maker's type-test certificate showing that a similar starter or controller has been subjected to at least 5,000 making and breaking or resisting-switching operations under conditions no less severe than those encountered in normal service without excessive wear, is considered to establish compliance with this recommendation, unless special requirements are specified, e.g. a greater number of operations may be required for apparatus intended for frequent duty.

14.09 - Renewal of wearing parts. Contacts and other parts subject to arcing or wear should be readily renewable.

14.10 - Operation at voltages above or below normal. Contactors, relays and other electromagnets should be capable of functioning satisfactorily even when the line voltage falls to 80 % of the normal bus-bar voltage for d.c. equipments, or 85 % of normal voltage at normal frequency for a.c. equipments, when the coil is at the temperature which it will attain under normal service at the normal line voltage.

They should also function satisfactorily and without injury to their coils, when the voltage rises 10 % above the normal voltage, and on a.c. supplies, when the frequency of the supply varies up to 5 % from the normal for prolonged periods.

14.11 - Voltage drop across series coils. The voltage drop across series coils such as overload-trip coils and brake solenoids, should not be such as to reduce materially the voltage at the motor terminals.

14.12 - Nameplates and labels. A permanent nameplate should be attached to a principal part of each starter, controller, resistor or regulator, and should bear the necessary identification marks to facilitate re-ordering. Permanent labels should be fitted indicating the purpose or effect of controls, including the effect of rotation of handles or handwheels.

14.13 - Temperature limits.

(a) Resistors. The temperature limits should satisfy the requirements of an appropriate authority.
For totally-enclosed resistors, the maximum rise in temperature on any part of the case should not exceed 200 °C. Any part of the case of a resistor (or adjacent material) the temperature rise of which is likely to exceed 35 centigrade degrees should be so located or guarded as to prevent accidental contact with the hand in normal routine work.
The temperature rise of issuing air from ventilated resistors should not exceed 175 centigrade degrees when measured at a point 25 mm (or 1 in.) from the case.

(b) Coils. The temperature limits of release, blowout, contactor-operating and relay coils which are left in circuit continuously at rated voltage and/or current should satisfy the requirements of an appropriate authority.

(c) Contacts and conductors. Contacts and conductors should be capable of carrying such currents (continuous or intermittent) as correspond to the normal rating of the motor with which the control gear is to be used, without injury to themselves or damage (such as loss of spring tension) to adjacent parts of adjacent insulation. They should also withstand currents corresponding to such overloads as the machine or apparatus may be required to carry.

(d) Parts other than coils, contacts and conductors. Magnet cores and other parts, whether insulated or not, should not reach a temperature which might harm adjacent material.

14.14 - Limitation of starting current. D.C. motors rated above one kW should be provided with a starter or controller suitable for limiting the starting current to the extent, if any, necessitated by the rating of the available generating plant and of the cable network or by the requirements for satisfactory starting of the motor.

For a.c. motors direct-on-line starting may be satisfactory where the generating capacity and cable network permit.

14.15 - Undervoltage release and protection. Motors rated above 0.5 kW should be provided with either :

(a) undervoltage protection, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted,

or (b) undervoltage release, operative on the reduction or failure of voltage, but so arranged that the motor re-starts automatically and without excessive starting-current on restoration of voltage, provided that the initiating control (which may be governed by thermostatic, pneumatic or hydraulic devices) still makes the requisite connections for a restart.

NOTE: This clause does not apply to steering-gear motors or to any motors the continuous availability of which is essential for the safety of the vessel.

14.16 - Overload protection. Motors rated above 0.5 kW should be provided with means for the automatic disconnection of the supply in the event of the current becoming excessive owing to any overloading of the motor.

NOTE 1. This clause does not apply to steering-gear motors. (See 9.14).

NOTE 2. The primary function of an overload (as distinct from an overcurrent) device is to cause the circuit to be opened in the event of the current rising above a predetermined value due to the overloading of the motor. An overcurrent device is also required, either associated with the overload device in the starter or separately installed, to protect the motor circuit against electrical faults, and such overcurrent protection should comply with the recommendations of Clauses 9.25 and 9.26.

14.17 - Breaking capacity. Fuses, circuit-breakers or other apparatus operating on overcurrent, forming part of the control gear, should be of adequate breaking capacity for the position in the supply network at which they are installed. The breaking capacity of apparatus operating on overcurrent should be in accordance with the requirements of the appropriate authority.

14.18 - Isolating switches. Means should be provided for the isolation from all live poles of the supply of every motor rated at 0.5 kW or above and its control gear. Where a starter or controller is mounted on or adjacent to a main or auxiliary distribution switchboard, a switch on the switchboard may be used for this purpose. Otherwise an isolating-switch within the starter or controller enclosure or a separate enclosed isolating-switch should be provided.

14.19 - Starters remote from motors. When the starter or controller or other apparatus for cutting off all voltage from the motor is remote from the motor, it is recommended that either :

(a) provision should be made for locking the circuit isolating-switch in the "off" position,

or (b) an additional disconnecting-switch should be fitted near the motor,

or (c) the fuses in each live pole or phase should be so arranged that they can be readily removed and retained by persons authorized to have access to the motor.

14.20 - Starters on switchboards. When motor control gear is mounted on or forms part of a distribution switchboard or where the control gear for several motors is mounted in switchboard form, it should comply with the recommendations for distribution switchboards, so far as they apply (see Chapter 8).

14.21 - Master-starter system. Where a single-master-starter system (i.e. a starter used for controlling a number of motors successively) is used, the apparatus should provide, for each motor, undervoltage and over-current protection and means of isolation not less effective than that required for systems using a separate starter for each motor. Where the starter is of the automatic type, suitable alternative or emergency means should be provided for manual operation. Where the starter is used for the starting of motors for essential services, the starting portion should be duplicated and means should be provided for the duplicate gear to be put into operation in the event of failure of one of the starters.

14.22 - Magnetic brakes.

(a) Construction. Series-wound and compound-wound brakes should release on first-step starting current of the motor. Series-wound brakes should hold off under all working conditions including during light running. The shunt coil of compound-wound brakes should be capable of holding the brake off when no current is flowing in the series coil.

Shunt brake-coils should be so constructed or protected that they are guarded against damage to windings by inductive discharge. A series resistor and/or discharge resistor may be used.

Shunt-wound and compound-wound brakes should operate at such voltages as will enable the requirements of Clause 14.11 to be met.

(b) Enclosure. For deck-mounted brakes, the operating coils should be enclosed in a watertight case with drip-proof protection of the brake sheave and shoes or band, or the whole brake should be enclosed in a watertight case.
For brakes mounted below deck, the operating coils should have drip-proof protection.

(c) Temperature rise. The temperature rise of coils when tested in accordance with the brake rating should not exceed that permitted on the motors with which they are being used. Where the coils are in close proximity to the linings, the brakes should be tested under conditions such that any heat transmitted from the friction surfaces is taken into account. Where the motor with which the brake is being used can run light for periods in excess of the time of its full-load rating, the rating of the brake coils should correspond to the light running period.

14.23 - Magnetic clutches. The recommendations made in Clause 14.22 for shunt-wound brakes apply generally to magnetic clutches. When the coil is energized, the clutch should take up the drive smoothly and positively. No end-thrust should be exerted from the clutch, the pressure between members being balanced within the clutch itself. Magnetic clutches should be balanced. Suitable means for taking up wear on the linings should be provided.

Collector rings for current supply to the clutch should be of non-corrodible material. Double brush-contacts should preferably be fitted to ensure positive contact.

14.24 - Use of type-test data. It is not intended that tests should be made on individual items of apparatus to prove compliance with these recommendations (or additional requirements which may be specified), where it can be shown that the apparatus is similar to apparatus for which type-test data can be supplied by the manufacturer, except for such individual tests as are specified below.

14.25 - Tests of operation. All apparatus should be tested to verify the operation of all mechanisms and controls, the operation, in accordance with the scheme of control, of all electro-magnets, and the operation in accordance with their calibration, of overcurrent and other releases.

14.26 - High-voltage tests. A high-voltage test should be applied on each apparatus at the manufacturer's works between the current carrying parts and the earthed frame or case, and between each circuit and other circuits of differing potential, with all covers in their normal position, and after exposure to the ordinary atmosphere for at least twenty-four hours prior to the test.

The test voltage should be as follows :

(a) For supplies under 60 volts, test voltage - 500 volts.

(b) For voltages exceeding 60 but not exceeding 500 volts, test voltage 1,000 volts plus twice rated voltage.

The specified test-voltage should be applied for one minute at any frequency between 25 and 100 c/s.

Items of equipment included in control gear but for which a test-voltage lower than the above is specified by an appropriate authority, may be disconnected during the above test and tested separately at the appropriate lower test-voltage.

(For example, it is permissible to test fractional-horsepower motors rated at 0.5 kW or less, or small instruments, at 1,000 volts).

CHAPTER 15

SEMI-CONDUCTOR RECTIFIERS FOR POWER PURPOSES

15.01 - General

(a) This section deals with power semi-conductor rectifiers of the copper-oxide, selenium, germanium, and silicon types. It should be noted that each of these types of semi-conductor rectifier will exhibit different characteristics with respect to changes in resistance characteristics with age, use and temperature history.

(b) A semi-conductor rectifier cell is a device consisting of a conductor and semi-conductor forming a junction. The junction exhibits a difference in resistance to current flow in the two directions through the junction. This results in effective current flow in one direction only. A semi-conductor rectifier stack is a single columnar structure of one or more rectifier cells.

(c) Semi-conductor rectifier cells may be arranged in series stacks which themselves may be connected in various combinations of series and/or parallel circuits to form bridge, half wave, voltage doubler, or other combination circuits.

(d) Rectifier cells may be operated either single phase or polyphase.

15.02 - Installation and location

(a) Semi-conductor rectifiers should be installed in such a manner that the circulation of air to and from the rectifier or its enclosure (if any) is not impeded and that the temperature of the inlet air to air cooled rectifiers does not exceed that for which the rectifier is supplied. Caution should be exercised in the mounting of rectifiers near resistors, steam pipes, engine exhaust pipes, or other sources of radiant heat energy.

(b) Naturally cooled rectifier cabinets should be designed with sufficient ventilating openings, or with sufficient radiating surface in the case of totally enclosed rectifiers, to operate temperature within allowable temperature limits.

(c) Rectifiers may be of the immersed self-cooled type. Immersed type rectifiers should be suitable for operation without leakage during rolling of the ship in accordance with Clause 3.25.

15.03 - Accessibility

Semi-conductor rectifier stacks should be mounted in such a manner that they may be removed from equipment without dismantling the complete unit.

15.04 - Insulation

(a) The insulation and clearances of semi-conductor rectifier stacks and units should be capable of withstanding without breakdown for a period of one minute, the application of a 50 or 60 cycle second alternating current r.m.s. potential of 1000 volts plus twice the rated a.c. voltage with a minimum of 1500 volts between current carrying parts of the a.c. input circuit and

(1) non-current-carrying metal parts which may be earthed

and (2) current carrying parts of an insulated secondary circuit where such a circuit exists.

If the semi-conductor rectifier stack is connected in an insulated secondary circuit operating below 60 volts, it should be capable of withstanding an alternating current test voltage of 600 volts, r.m.s. to any non-current-carrying metal part which may be earthed. If the secondary voltage is in the range of 60 to 90 volts, the alternating current test voltage should be 900 volts r.m.s.

(b) Rectifier units having watertight enclosures should successfully meet the above insulation test after having been subjected to the water test given in Section 3.13.

(c) For purposes of maintenance and inspection, measurements of insulation resistance of rectifier stacks made with an applied d.c. potential of 500 volts should give an insulation resistance of not less than ten (10) megohms. Should such measurements indicate the need for drying by means of electric heaters, light bulbs, or some other means of applying heat, special care should be taken not to exceed the total maximum temperature limitations.

(d) Mercury type fungus protection even in minute quantity will damage selenium type metallic rectifiers and should not be used in the vicinity.

15.05 - Terminals

The alternating current terminals of semi-conductor rectifier stacks should be marked with the letters A.C. or ~
The positive d.c. terminal should be marked with a plus (+).
The negative d.c. terminal should be marked with a minus (-).

Solder type or solderless type terminals should be supplied on metallic rectifier stacks.

15.06 - Ambient temperature

(a) Because of the harmful effects on semi-conductor rectifiers of excessive temperatures for even a short time, it is recommended that all semi-conductor rectifiers be rated for continuous 45 °C ambient.

(b) In the case of water cooled rectifiers, equipment must operate satisfactorily with a maximum cooling water inlet temperature of 30 °C.

(c) All equipment must operate satisfactorily down to 0 °C ambient conditions.

(d) Cooling water temperatures and ambient air temperatures should be determined at the point where the cooling medium enters the rectifier unit enclosure.

(e) Where higher than the above ambient temperatures may be encountered semi-conductor rectifiers should be derated to limit the total maximum temperature.

15.07 - Temperature rise

The temperature rise under all operating conditions should be limited to such a value as will permit the rectifier to meet the specified performance requirements.

15.08 - Application

(a) Where forced cooling is utilized the circuit should be so designed that power cannot be applied to or retained on rectifiers unless effective cooling is maintained.

(b) All applications of semi-conductor rectifiers should operate satisfactorily with the following increase in forward resistance due to aging of the cells. To meet this requirement, it may be necessary to incorporate compensating taps on transformers or provide other means of compensation

Copper Oxide	100%
Selenium	75%
Germanium	25%
Silicon	25%

(c) All applications of semi-conductor rectifiers should operate under conditions of plus or minus 5% frequency and/or plus or minus 10% voltage variations from the nominal value.

(d) All applications should contain schematic and wiring diagrams, or instruction books should be provided.

15.09 - Transformers

Transformers used with rectifiers should have separate windings for the primary and secondary circuits.

When the transformer supplying the rectifier is located within the same enclosure as the rectifier, the maximum operating temperature of any individual part should not exceed the temperature limits established herein for that part.

15.10 - Nameplates

(a) The following information should be included on the name-plate of semi-conductor rectifiers:

(1) Marine semi-conductor rectifier
(2) Manufacturer's name and address
(3) Manufacturer's serial number
(4) Rated a.c. volts
(5) Rated a.c. amperes
(6) Number of phases
(7) Frequency
(8) Rated d.c. volts
(9) Rated d.c. amperes
(10) Duty cycle (continuous or intermittent)
(11) Maximum ambient temperature

(b) It is also desirable that the following information be shown on the rectifier stack :

Manufacturer's Identification

(c) When the above items cannot be shown on the rectifiers because of space limitations, at least a nameplate large enough to identify the manufacturer's name and catalogue number of the unit should be supplied.

15.11 - Tests

Tests should be made at manufacturer's works. Tests should be made to insure that semi-conductor rectifiers are in accordance with these recommendations. When a rectifier is a duplicate of one already tested, only such check tests need be made as may be necessary to demonstrate that the rectifier operates successfully.

Test voltages for the transformer should be the same as those specified herein for the rectifier.

CHAPTER 16

ACCESSORIES

16.01 - General requirements.

(a) Accessories should be so designed and constructed that the passages for the insulated conductors are of ample size and are free from rough projections, sharp angles, and abrupt bends. All outlets for cables should have well-rounded edges or be suitably bushed.

(b) Accessories should be so designed, and the insulated conductors should be so installed that stress cannot be applied by the conductors to any terminal to which the conductors may be connected.

(c) Accessories should be so designed and fixed that dust and moisture cannot readily accumulate on live parts and their insulation.

16.02 - Enclosures. Enclosures should preferably be of cast brass, bronze, or iron, or of welded iron, or of welded sheet steel with corrosion-resistant finish, or of flame-retarding insulating material.

16.03 - Flameproof accessories. Where accessories are required to be of the flameproof type and accessories of suitable type are obtainable which have been type-tested and approved by a recognized competent independent testing authority, such accessories only should be used.

Where a certificate has been obtained from a recognized competent independent testing authority it will be sufficient to furnish a copy of the relevant certificate when required, provided there is no departure from the design so tested and approved.

Where accessories approved by a recognized competent independent testing authority as required above are not obtainable accessories complying with I.E.C. Publication 79 Recommendations for the construction of flameproof enclosures of electrical apparatus may be used.

16.04 - Lampholders.

(a) Lampholders for incandescent filament lamps should be of the following standard types ※

Table 16.I

I.E.C. designations for lamp caps

Name of cap	Designation
Screw caps:	
Goliath	E.40
Medium	E.27
Small	E.14
Miniature	E.10
Bayonet:	
Normal	B.22
Small single-contact	B.15 s
Small double-contact	B.15 d

※ The designations adopted by the International Electrotechnical Commission for lampholders and lamp-caps are given in Table 16.I, above.

For lamps of rating not exceeding 200 W.	Standard bayonet (B.22) or Medium Edison screw (E.27)
For lamps of rating exceeding 200 W.	Goliath Edison screw (E.40)

(b) Lampholders should be constructed wholly of flame-retarding and non-hygroscopic material and supports of live parts should be of non-ignitable material preferably of ceramic material. All metallic parts should be of robust proportions. Goliath lampholders should be provided with effective means for locking the lamp in the holder.

16.05 - Ceiling roses. Ceiling roses should be constructed of flame-retarding, non-conducting, non-hygroscopic material.

16.06 - Socket-outlets and plugs.

(a) The live parts of socket-outlets and plugs should be so proportioned that their average temperature does not exceed that of the surrounding air by more than 30 centigrade degrees when the normal working current is flowing through them continuously.

(b) Socket-outlets and plugs should be so constructed that they cannot be readily short-circuited whether the plug is in or out. It should be impossible to insert only one pin of the plug into the socket-outlet.

(c) The clearances of socket-outlets and plugs not interlocked with switches should be such that an arc cannot be maintained if the plug be normally withdrawn from the socket while a current 50 % greater than that for which they are rated is flowing at rated voltage.

(d) Plugs should conform to all applicable requirements for socket-outlets and should have provision for connection to be so made that no strain is transmitted to the terminals and contacts. The plugs or socket-outlets should be so designed that when in place they will be held in positive contact.

(e) Interlocked socket-outlets should be such that it is impossible to withdraw the plug when the switch is in the "on" position or to close the switch when the plug is withdrawn.

(f) Socket-outlets for single-phase a.c. circuits and for d.c. circuits should be of the double pole and earthing-pin type or such other type as may be approved by the appropriate authority and for three-phase supplies they should be of the three pole and earthing-pin type or such other approved type as may be approved by the appropriate authority. See also 16.06 (h).

(g) The socket outlets may if required be interlocked with a switch. See also 16.06 (j).

(h) Watertight socket-outlets and plugs should be of specially robust construction and should be provided with effective means to maintain the socket-outlet watertight after the plug is removed therefrom. Where a loose cover is used for this purpose, it should be anchored to its socket-outlet e.g. by means of a chain. When the plug is inserted in its socket-outlet the combined fitting and the interlocking switch, if any, should also be watertight.

(i) Every socket-outlet rated at 16 amperes or above should be provided with a switch so interlocked that the plug cannot be inserted or withdrawn when the switch is in the "on" position.

(j) Where differing distribution systems supplying socket-outlets are in use, the socket-outlets and plugs should be of such design that an incorrect connection cannot be made.

(k) All plugs and sockets for 110 V. and 220 V. direct current and exceeding 42 V. but not exceeding 380 V. alternating current are to be provided with an additional contact for earthing the casing of the apparatus. The earthing contact is to have an advance of at least 5 mm (0.2 in.) in relation to the live contact pins when inserting the plug.

16.07 - Joint-boxes. Live parts should be mounted on durable non-ignitable, non-hygroscopic insulating material, of permanently high dielectric strength and insulation resistance. The live parts should be so arranged by suitable spacing or shielding with non-ignitable insulating materials, that conductors of opposite polarity or conductor and earthed metal cannot readily be short-circuited. The live parts should preferably be supported by ceramic material with glazed surface or of material with equivalent properties.

16.08 - Inspection- and draw-boxes. If the conduits are of metal inspection- and draw-boxes should be of metal and should be in rigid electrical and mechanical connection with the conduits. For steel conduits this connection should be obtained by screwing into the box or into a device clamping both sides of the wall of the box. For copper conduits this connection should be obtained by brazing or soldering a suitable ferrule on the conduit, the ferrule being secured to the box by screwing or by clamping to the wall of the box.

CHAPTER 17

LIGHTING

17.01 - Lampholders for general purposes. Lampholders should be of standard types in accordance with Clause 16.04.

17.02 - Use of watertight fittings. Lamps which are exposed to the weather, spray, drip or condensed water should be enclosed in weather-proof fittings. Lamps which are used near readily combustible materials should be installed in totally enclosed fittings.

17.03 - Use of flameproof fittings. Lamps which are used in spaces containing explosive or inflammable powder or gases should be installed in flameproof fittings, with the exception of accumulator compartments where watertight fittings may be used.

17.04 - Exposure to mechanical damage. Lamps which are exposed to more than ordinary risk of mechanical damage should be installed in fittings of substantial construction and should be protected against such damage.

17.05 - Shades of combustible material. No shade of combustible material should be used unless it is separated from the lamp by a metallic grid or suitable support.

17.06 - Portable lighting fittings. Portable lighting fittings for the illumination of decks, holds, engine-rooms and similar spaces should be provided with lampholders which are either completely shrouded in insulating material or so protected by metallic guards insulated from the holders that live parts cannot be touched. Switches should not be incorporated in portable lighting fittings in these spaces.

17.07 - Navigational lights. All lamps for navigational lights should be metal-filament lamps and should be in accordance with an international standard.

DISCHARGE LAMP INSTALLATIONS-GENERAL

17.08 - Ancillary gear. All reactors, capacitors and switching apparatus forming part of a discharge-lamp installation should be enclosed in earthed metal. The temperature-rise of these parts should be in accordance with the appropriate I.E.C. Publication*.

17.09 - Discharge of capacitors. Every capacitor of 0.5 microfarad or more should be provided with a protective leak or other protective means which should reduce the voltage of the capacitor to not more than 50 V. within one minute after disconnection from the supply source.

17.10 - Warning notices. In ships where d.c. is normally used, switchboards and distribution boards for a.c. circuits should be provided with notice boards bearing the inscription,

WARNING
.... volts a.c.

* In preparation.

DISCHARGE LAMP INSTALLATIONS - VOLTAGES OF 250 V. AND ABOVE

17.11 - Design of lamps and lampholders. Electrodes for discharge lamps and lampholders in installations supplied at 250 V. or above should be of robust construction, having regard to the voltage employed, and should be so designed that no danger of contact with live parts can arise if the glass tube is broken.

17.12 - Protection of live parts. All live parts of discharge lamps should be so placed and installed that they cannot be touched inadvertently, the creepage distance along the surface of the glass tube being taken into consideration.

17.13 - Clearances. The installation should be carried out with due regard to the voltage employed. The distance between live parts or between these parts and other metallic parts, measured in cm, should everywhere be not less than the value obtained by dividing the voltage measured in kilovolts by 2.5 subject to a minimum clearance of 2 cm.

17.14 - Earthing. All non-current-carrying metallic parts of the installation should be effectively earthed except that it is not always necessary to earth metallic clips or clamps used in positions remote from terminals to support discharge lamps but it may be found desirable to earth such clips or clamps in order to reduce interference with radio reception. See also Clause 4.01.

17.15 - Separation of windings. All motor-generators and transformers should have their high- and low-voltage windings electrically separated.

17.16 - Switches. Switches enabling the installation to be completely isolated from the supply should be provided for motor-generators and transformers. Such switches should be placed in the immediate vicinity of the installation and should be specially marked.

17.17 - Warning notice. The installation should be provided with durable and suitably placed notice-boards bearing the inscription,

WARNING
HIGH VOLTAGE

SEARCHLIGHTS

17.18 - Insulation of live parts. Searchlight lamps should have all live parts insulated from the frame or case.

17.19 - Parts handled by operator. All parts of a searchlight lamp which have to be handled for its operation or adjustment should be insulated from the supply with strong non-ignitable material of substantial proportions and be so disposed that there is no risk of shock to the operator.

17.20 - Earthing. The frame of every searchlight lamp should be provided with a suitable terminal for earth connection, and such terminal should be effectively connected to earth. See Clauses 4.01 and 4.02.

17.21 - Control of supply. Every searchlight lamp should be controlled by a fuse and a switch on each insulated pole. Where more than one pole is insulated the switch should break all poles simultaneously.

17.22 - Suez Canal lights. For vessels navigating the Suez Canal, provisions should be made to meet the 'Suez Canal Maritime Company' requirements, particularly those relating to searchlights.

ARC LAMPS

17.23 - Application of arc lamps. Arc lamps should be used only for searchlights or cinematograph projectors.

17.24 - Series resistors. If a series resistor is used with an arc lamp the controlling double pole switch should be so placed in the supply leads that both the series resistor and the arc lamp are disconnected when the switch is in the "off" position.

CHAPTER 18

ACCUMULATOR (STORAGE) BATTERIES

18.01 - Scope. This chapter relates to accumulator (storage) batteries which are installed permanently in position, and not to batteries of the portable type.

18.02 - Types of battery. In general, accumulator batteries may be of lead-acid or of nickel-alkaline type, due consideration being given to suitability for any specific application.

18.03 - Construction and assembly. All plates should be of rigid construction, and should be designed for the least practicable shedding of active material.

18.04 - Trays. The cells should be grouped in crates of rigid construction and suitable material equipped with handles to facilitate handling. The number of cells in a tray will depend on the weight and on the space available for installation. The weight of trays should preferably not exceed about 113 kg (or 250 lb.).

18.05 - Rating plate. Each tray should be provided with a durable nameplate securely attached, bearing the maker's name and type designation, the ampere-hour rating at some specific rate of discharge (preferably that corresponding to the duty for the specific application) and, for lead batteries, the specific gravity of the electrolyte when the battery is fully charged.

18.06 - Inter-connections. Inter-cell connections and terminals for connection between trays and for external wiring should be suitable for the maximum current to be carried. For diesel-engine starting-batteries with very high discharge-rate this may require connecting bars of rigid lead sheathed copper in posts or other special provision.

18.07 - Open sparking. Lighting fittings should be of watertight type and provided with a thick glass and a strong metal guard.

18.08 - Location.

(a) Batteries should be located where they are not exposed to excessive heat, extreme cold, spray, steam, or other conditions which would impair performance or accelerate deterioration. Batteries for emergency service, including emergency diesel-engine starting, should be located where they are protected as far as practicable from damage due to collision, fire or other contingency.

(b) A large storage-battery, such as for emergency lighting, should be installed in a room assigned to the battery only, but may be installed in a suitable deck-box if a room is not available.

(c) Batteries of moderate size (20 - 36 volts) such as those for engine starting or communications supply, should preferably be installed in the space with the emergency lighting-battery. However, such batteries may be installed in a battery locker (or lockers) in the emergency-generator room, machinery space or other suitable location. Batteries should not be installed in sleeping quarters.

(d) Small batteries of 12 volts or less for emergency radio supply etc., should each be installed in a battery box located as desired, except that it should not be within 180 cm (or 6 ft.) of radio apparatus or other delicate equipment which would be made inoperative by slight corrosion from battery gases.

(e) Starter-batteries should be located as close as practicable to the engine or engines served, to limit voltage drop in cables at the high current required.

18.09 - Access. Batteries should be arranged to permit ready access for inspection, testing, replenishing and cleaning.

18.10 - Lining of shelves and boxes. Shelves in battery rooms or lockers for acid batteries should have a watertight lining of sheet lead of 1.6 mm (or 0.0625 in.) minimum thickness, not less than 76 mm (or 3 in.) deep. For alkaline batteries the shelves should be lined in a similar manner with steel, not less than 0.8 mm (or 0.0312 in.) thick. Alternatively, a battery room may be fitted with a watertight lead (steel for alkaline batteries) span over the entire deck, carried up not less than 15 cm (or 6 in.) on all sides. Deck boxes should be lined in accordance with the above alternative method. Boxes for small batteries should be lined to a depth of 8 cm (or 3 in.) consistent with the methods described above.

18.11 - Fixing and supports. Battery trays should be securely checked with wood strips or equivalent to prevent movement. Each tray should be fitted with non-absorbent insulating supports, not less than 19 mm (or 0.75 in.) high on the bottom, and with similar spacer blocks at the sides, or with equivalent provision to assure 19 mm (or 0.75 in.) spaces all round each tray for circulation of air.

18.12 - Painting. The interior of all battery compartments, including shelves and other structural parts therein, should be painted with corrosion-resistant paint.

18.13 - Ventilation.

(a) All rooms, lockers and boxes for storage batteries should be arranged and/or ventilated to avoid accumulation of inflammable gas. Particular attention should be given to the fact that the gas evolved is lighter than air, and will tend to accumulate in any pockets at the top of the space. When batteries are arranged in two or more tiers, all shelves except the lowest should have not less than 5 cm (or 2 in.) space, front and back, for circulation of air.

(b) All battery rooms should be adequately ventilated. Natural ventilation may be employed if ducts can be run directly from the top of the room to the open air above, with no part of the duct more than 45° from vertical. If natural ventilation is impracticable, mechanical exhaust-ventilation should be provided with intake at the top of the room. Fans should be capable of completely changing the air in the battery room in not more than 2 minutes. Interior surfaces of ducts and fans should be painted with corrosion-resistant paint. Any fan motor associated with a duct used to remove the air from an accumulator room should be placed external to the duct, which should be arranged to discharge into a safe space. Adequate openings for air inlet should be provided near the floor.

(c) Battery lockers should, if practicable, be ventilated similarly to battery rooms by a duct led from the top of the locker to the open air or to an exhaust-ventilation duct but, in machinery spaces and similar well-ventilated compartments, the duct may terminate not less than 91 cm (or 3 ft) above the top of the locker. Louvres or the equivalent should be provided near the bottom for the entrance of air.

(d) Deck boxes should be provided with a duct from the top of the box, terminating at least 122 cm (or 4 ft) above in a goose-neck, mushroom-head or the equivalent, to prevent entrance of water. Holes for air inlet should be provided on at least two opposite sides of the box. The entire deck box, including openings for ventilation, should be sufficiently weather-tight to prevent entrance of spray or rain.

(e) Boxes for small batteries require no ventilation other than openings near the top to permit escape of gas.

18.14 - Charging facilities.

(a) For floating service, or for any other condition where the load is connected to the battery while it is on charge, the maximum battery-voltage should not exceed a safe value for any connected apparatus. A voltage regulator should be used for any application where safe voltage cannot otherwise be assured. The voltage characteristics of the generator, or generators, rectifier or rectifiers which will operate in parallel with the battery, should be suitable for each application.

(b) Where a low-voltage battery is floated on the line with a resistor in series, all connected apparatus should be capable of withstanding line voltage to earth (ground).

(c) Where the voltage of an emergency-lighting battery is the same as that of the ship's d.c. supply, the battery may be arranged for charging in two equal sections, a charging resistor being provided for each. Alternatively, a booster generator may provide charging voltage. With either method, the arrangement of automatic-transfer switching should be such that emergency supply is available whether the battery is on charge or not.

(d) Except as otherwise provided below, the charging facilities for any battery should be such that the completely discharged battery can be completely charged in not more than 8 hours without exceeding a safe charging-rate. Extra-low-voltage batteries provided in duplicate for communications supply (one in service, the other on charge) should be charged at a rate commensurate with the average discharge rate.

(e) For batteries which normally stand idle for long periods, trickle charging to neutralize internal losses should be provided where practicable.

(f) Where the batteries are charged from line voltage by means of a series resistance, protection against reversal of current should be provided when the charging voltage is 20 % of the line voltage or higher.
This requirement will not apply where semi-conductor rectifiers are used.

18.15 - Semi-conductor rectifiers. They should not be located in positions where they would be subject to the gases from accumulators.

CHAPTER 19

HEATING AND COOKING APPLIANCES

19.01 - Temperature limits of exposed parts. Electric heating and cooking appliances should be so constructed that parts which must necessarily be handled in use cannot become heated to a temperature exceeding 55 °C.

19.02 - Heating elements. The heating elements should be of materials durable at the highest temperature which they attain and should be so arranged that they can be readily replaced.

19.03 - Internal connections.

(a) Electrical connections between heating elements should be effected either by joining parts of the elements themselves or by such construction that the connecting conductor will not deteriorate at the maximum temperature to which it may be subjected.

(b) The connections between the elements and the switches and to the supply cables should be carried out with the aid of terminals. The connections should be such that the terminals and switches are not increased in temperature above that for which they are designed. For rubber-insulated cables the temperature of terminals should not exceed 75 °C.

(c) Connections between heating elements and between heating elements and terminals to which insulated cables may be connected, unless self-supporting or rigidly fixed in position, should be continuously insulated with suitable incombustible material.

19.04 - Support of live parts. All live parts, whether heating elements or terminals, should be carried on incombustible material, which is non-hygroscopic or effectively protected against intrusion of moisture.

19.05 - Guarding of live parts. The heating elements should be suitably guarded. The guards should be of robust construction and so fitted that they cannot be brought into contact with any current-carrying part. Live parts of cooking appliances should be so protected that the cooking utensils cannot be brought into contact with them.

19.06 - Earthing. All heating and cooking appliances, whether portable or fixed, should be provided with suitable terminals for earthing the metallic framework, and such terminals should be effectively connected to earth.

19.07 - Stability. Portable heating and cooking appliances should be of such shape or so weighed that they cannot easily be overturned. Suitable stowage positions should be provided.

19.08 - Tests. Heating and cooking appliances should be tested by the makers and should, when cold, be able to withstand the application of an a.c. voltage of 1,000 volts plus twice the rated voltage, at a frequency of 25 - 100 c/s, for one minute, between all current-carrying parts and the metallic frame.

19.09 - Guarding of inflammable materials. All inflammable materials in the vicinity of heating and cooking appliances should be protected by suitable non-ignitable and thermal-insulating materials.

19.10 - Types of space-heating appliance (electric radiators). Space heaters should be of the convector type, except that heaters of the visible-element type may be used provided they are designed and installed in such a manner as to minimize the risk of fire.

19.11 - Construction of space-heating appliances (electric radiators). Space heaters should be durable and all parts should be of strong construction. All screws and nuts should be locked. The openings of the protecting guards should be sufficiently narrow to prevent the heating elements from being accidentally touched or short-circuited.

19.12 - Design of space-heating appliances (electric radiators). Space-heating appliances should be so designed or protected that clothing or other inflammable material cannot readily be placed over them in such a manner as to cause risk of fire.

19.13 - Mounting of space-heating appliances (electric radiators). Space-heating appliances should be so mounted that there will be no risk of dangerous heating of the deck or bulkhead.

19.14 - Avoidance of inflammable gases. In positions where inflammable gases are likely to accumulate, heating appliances capable of igniting them should not be installed.

CHAPTER 20

INTERNAL COMMUNICATIONS

20.01 - Scope. The scope of this chapter includes every kind of electrical internal communication such as :

- Engine-room and docking telegraphs
- Fire alarms (automatic or manually actuated)
- Alarms for the engine room
- Alarms for watertight doors
- Sirens
- Bells and call systems
- Remote temperature control and indication
- Helm indicators
- Automatic steering control
- Electrical compass systems
- Telephone installations
- Loudspeaker installations and public address systems
- Light signalling systems
- Clocks
- Logs.

20.02 - Voltages. It is recommended that only the following voltages be used, those which are underlined being preferred :

D.C. : 6 - 12 - 24 - 50 - 60 - 110 - 220 volts

A.C. : 12 - 24 - 42 - 48 - 110 - 220 - 250 volts.

20.03 - Motor-generators and transformers. Motor-generators and transformers used for the reduction of voltage for communication circuits should, together with their control gear, comply with the recommendations applicable to power and lighting circuits (see Chapters 12, 13 and 14).

20.04 - Supply from power or lighting circuits. Where a communication system derives its supply direct from power or lighting circuits and in other cases where the voltage of supply exceeds 50 volts a.c. or 60 V. d.c., all cables, wires, switches, resistors, distribution boards, accessories, instruments and other apparatus should be designed and installed throughout in all respects in accordance with the recommendations applicable to power and lighting circuits.

20.05 - Supply at a voltage not exceeding 50 V. a.c. or 60 V. d.c. Where a communication system derives its supply from motor-generators, primary or secondary batteries or static transformers and is entirely electrically isolated from the lighting and power circuits, and the voltage of supply does not exceed 50 volts a.c. or 60 V. d.c., the switches, resistors, distribution boards, accessories, instruments and other apparatus should be of robust design and so installed as to ensure an ample margin of safety, having regard to the voltage employed.

20.06 - Cables. Cables used for internal communication should be fitted in a similar manner to cables installed for lighting and power supply and should be segregated from the latter unless either the lighting and power cables or the communication cables are metal sheathed.
Cables should be suitable for the rated voltage and current of the connected load. Voltage drop should be so limited that normal operation of the connected equipment is ensured.

20.07 - Fuse protection. Communication circuits other than those supplied from primary batteries should be protected on each insulated pole by fuses of a current rating corresponding to the rating of the cable. Where a feeder is used for a number of internal communication circuits, each circuit, as well as the feeder itself, should be protected by fuses.

20.08 - Arrangement of circuits. Communication circuits should be so arranged and terminal boxes so designed, fitted and labelled or otherwise marked as to facilitate fault-finding and enable the necessary repairs to be made with the minimum possible disturbance to other circuits.
The circuits should be so arranged that cross-talk and other interference are obviated.

20.09 - Engine-room telegraphs. The receiver at each end should be provided with a visual and audible control and the receiver in the engine-room should be provided with an aural alarm of distinctive timbre and of sufficient strength to be audible above the general noise-level. In the event of failure of supply, indication should be given on the bridge and in the engine-room.

20.10 - Engine-room alarm sounders. All aural alarms in the engine-room should be so designed as to be readily distinguishable from one another.

20.11 - Fire alarm bells. Fire alarms should emit a powerful and readily distinguishable note.

20.12 - Construction and installation. All apparatus should be constructed and installed in accordance with Clauses 3.13 to 3.25.

CHAPTER 21

ABATEMENT OF RADIO INTERFERENCE

21.01 - Scope of this chapter.

(a) For the purpose of this chapter, interference is defined as follows :

> Any radiation or any induction which endangers the functions of a radio-navigation service or of a safety service or obstructs or repeatedly interrupts a radio service. (See also Clause 21.19).

(b) This chapter deals mainly with interference caused by ships' electrical installations and ships' equipment. Recommendations are made for the best practice for radio-receiving-room construction, aerial layout, electrical installations and ships' equipment, for ensuring the greatest freedom from interference and for reducing to a minimum the need for suppressors.

Interference of the following types is not dealt with :

i) Atmospheric noise,
ii) Reception of unwanted transmissions.

(c) Interference between various items of radio (including radar) equipment installed on shipboard is not fully dealt with since its avoidance is in part related to installation planning and design of the radio equipment. Attention should be paid to the risk of such interference when the installation is designed and tested.

(d) It is recognized that this chapter applies primarily to passenger ships and for other types of ships it represents a code of good practice.

MEASURES RELATING TO THE RADIO RECEIVING INSTALLATION

21.02 - Position of aerials.

(a) All aerials, whether for transmission or reception, should be erected as far above and as far away as possible from electrical machinery and from parts of the ship's structure such as funnels, stays and shrouds.

(b) Receiving aerials should be so designed and erected as to be subject to the least possible interference from all transmitting aerials, including those used for radar.

(c) Receiving aerials should be so designed and erected that risk of interference between receiving systems is minimized.

(d) The erection of additional aerials after the direction-finding apparatus has been calibrated should be avoided as far as possible, and if it is necessary to erect additional aerials, the direction-finding apparatus should be re-checked without delay.

(e) Receiving aerials for the radio receivers for use by officers, crew and passengers should consist of a communal aerial as remote as possible from the ship's aerials.

21.03 - Aerial leads.

(a) The leads of all aerials used exclusively for reception should be screened. The screen should be effectively earthed at the receiver and should extend continuously from the receiver input to as high a point above the ship's structure as practicable.

NOTE 1: Where a single aerial is used for both transmission and reception, it may not be practicable to screen the lead.

NOTE 2: Where a twin feeder, balanced to earth, is used between aerial and receiver, this may be unscreened.

(b) The leads of all direction-finding apparatus should be screened. The screen should be effectively earthed at the receiver and should extend continuously from the receiver input to the lower part of the direction-finding aerial, which should be placed as high as practicable.

21.04 - Radio cabin.

(a) The radio cabin should be placed as high as possible in the ship as to facilitate compliance with Clause 21.02 and should preferably be a complete metal box built into the ship so that electromagnetic screening is provided.
(See also Clause 21.20 (a)).

(b) Special precautions should be taken to bond electrically the plates and bulkheads of the radio cabin to each other and to the upper and lower decks, unless a welded construction is used. When metal-sheathed or metal-interleaved plywood is used, the panels should be bonded at several points one to the other and to the ship's structure.

(c) If the radio cabin is not of wholly metallic construction, the non-metallic bulkheads, deckheads or decks should be screened internally. The metal screening should be earthed to the main metal structure of the ship at several points. The door to the radio cabin should be of metal, or if of wood screened on the whole of the inside with metal, and should be earthed to the structure of the ship.

NOTE: Suitable screening materials are copper sheet not less than 0.56 mm (or 0.022 in.) thick, or copper netting of similar thickness having a mesh not larger than 6.4 mm (or 0.25 in.).

(d) The number and size of holes cut in the metal structure or screening of the radio cabin should be the minimum necessary for providing essential services such as power, lighting, ventilation, communication and remote control. Port-holes, windows and hatches should be provided with detachable metal screens capable of being electrically connected to the metal structure or screening. Cables, ducts and pipes which do not terminate in the radio cabin (including ventilation trunks) should not be installed within it, and those cables, ducts and pipes which must enter the room should be bonded at their point of entry to its metal structure or screening.
All cables should preferably enter at one point.

21.05 - Earthing of apparatus and cable screens.

(a) A copper earth-busbar should be fixed along the bulkheads and bonded at several points to the ship's structure and to the metal structure or screening of the room. All apparatus within the radio-receiving room should be earthed to this busbar.

(b) Cables associated with receivers and transmitters respectively should be kept apart as far as possible.

<u>21.06 - Housing of power plant.</u> Power converting plant placed within the radio cabin should be housed in a separate screened enclosure, unless by virtue of its construction it is self-screened.

<u>21.07 - Cable entries.</u> When necessary cables should be fitted with suppressors at their point of entry into the radio cabin, unless they terminate close to the point of entry in equipment which itself provides adequate screening and suppression.

<u>21.08 - Other radio apparatus.</u> Non-essential radio-frequency apparatus, e.g. broadcast receivers for entertainment, and the associated wiring should be suitably placed and if necessary screened, so that it neither interferes with essential services, e.g. communication, direction-finding and certain navigational aids, nor increases their susceptibility to interference from other sources.

MEASURES RELATING TO THE RIGGING

<u>21.09 - Insulation or bonding of rigging.</u> All rigging should either be insulated from or bonded to the ship's structure, in accordance with the following considerations :

(a) Stays which are subject to considerable tension, such as mast shrouds and funnel stays, should be bonded. A point near the lower end of such stays should be solidly earthed by means of a stranded copper conductor not smaller than 20 mm^2 (or 0.03 in^2) cross-section and earthing connection protected against corrosion.

(b) Subject to compliance with (a) above, insulation should be used where possible in preference to bonding as it gives more reliable results and reduces the need for maintenance. In particular, rigging within 9 m (or 30 ft.) of the direction-finder, especially where it forms a loop about the direction-finder aerials, should be insulated from the ship's structure and sub-divided into portions not exceeding 6 m (or 20 ft.) in length, insulated from each other.

MEASURES RELATING TO THE WIRING INSTALLATION

<u>21.10 - General.</u> Interference above an acceptable level may be greatly reduced and sometimes eliminated by observance of the recommendations made in Chapter 11 for the installation of cables and conduits, and of the following Clauses 21.11 - 21.14.

<u>21.11 - Types of cable.</u> All permanently installed cables within 9 m (or 30 ft.) of any aerial system, radio cabin or direction-finder, unless a metal deck or bulkhead intervenes, should be metal-sheathed, metal-braided or otherwise adequately screened. In such situations flexible cables should be screened wherever practicable.

<u>21.12 - Cable runs.</u>

(a) It is important that cables other than those feeding services in a radio cabin should not be installed therein. Cables which must pass through a radio cabin should be run in steel conduit or trunking throughout their length. Cables which must pass near a radio cabin should be grouped into a minimum number of runs separated as far as practicable from the room, at least by one metal bulkhead or metal deck. Direct attachment of cables to the opposite side of a metal bulkhead or metal deck bounding the radio cabin should be avoided.

(b) Where it is necessary to use single-core cable, the lead and return conductors should be fixed as close to one another as possible and should be so run as to avoid loops or partial loops.

(c) Particular care should be taken to segregate cables carrying pulses of high amplitude and power cables supplying units in which such pulses are present. The use of screened cable alone is often inadequate in such cases and it may be necessary to use screened cable run in heavy-gauge conduit.

21.13 - Bonding and earthing. Metallic sheaths of cables and conduit should be earthed, and bonded to any adjacent cable sheaths or conduit, at the ends and also at as many intermediate points as practicable, such points being well distributed and readily accessible. The metallic screens of flexible cables should be earthed close to the point where they are connected to the supply, and bonded to the metal-work of appliances to which they are connected.

21.14 - Wiring of sound-reproducing equipment. Where sound-reproducing equipment is installed, all cables including flexible cables, carrying audio-frequency currents, should be metal-sheathed, metal-braided or otherwise adequately screened and earthed, or run in earthed metallic conduit.

MEASURES RELATING TO OTHER INSTALLATIONS

21.15 - General. Despite the observance of the recommendations made in Clauses 21.02 - 21.14, it may be found that certain machines and appliances, owing to their position on the ship or their mode of operation, cause interference above an acceptable level.

Suppressors should be fitted on those machines and appliances which cause interference above an acceptable level, with the exception of machines and appliances which are normally used only in port and which do not cause such interference with radio services in use in port.

21.16 - Internal-combustion engines. Electrical ignition systems for internal-combustion engines, including those which may be used on lifeboats, should be completely screened. All leads should be screened and should be as short as practicable, particularly the lead from the ignition coil (if any) to the distributor. Although screened, the ignition system should not be hermetically sealed, since provision for ventilation is necessary.

21.17 - Electro-medical and similar apparatus. Electro-medical and similar radio-frequency apparatus should be installed only in compartments similar in construction and wiring to the radio cabin (see Clauses 21.04 - 21.07).

21.18 - Navigational instruments and associated equipment. Navigational instruments and associated equipment, such as radar equipment, gyro-compasses, echo-sounders, revolution indicators, clear-view-screen motors, navigation-light indicators and impulse clocks, should be screened as far as practicable and should be fitted with suppressors where necessary.

APPENDICES

to CHAPTER 21

21.19 - Nature and causes of interference. Interference of the type considered in this chapter may be regarded as the random excitation of a radio-receiving system by fluctuating electro-magnetic fields. The greater the intensity and the higher the rate of change of these fields, the more widespread the interference.
Causes of changes in electro-magnetic fields are

(a) Abrupt variations of current, as occur in commutators, motor-starters, switches, contactors, bells, electro-medical equipment, mercury-arc rectifiers, revolution counters, electrical steering-gear, gyro-compasses, lifts, thermostats, etc.

(b) Abrupt variation in contact resistance or other resistance of structures in an electric field, as may occur in rigging and loose metallic structures such as a metal topmast, derrick, rail, etc.

Interference caused by such changes in fields may be the result of radiation or induction from the point at which they occur or of radiation or induction from conductors connected to or running near the source of the interference.

Interference radiated or induced directly from the source is greatly reduced when the interfering equipment is housed within a metal box or cage, or below one or more metal decks, but conductors may transmit this interference far beyond the original source. It is thus just as important to prevent interference from being conveyed along conductors as to reduce radiation and induction of interference from the source. Interference by radiation and induction from conductors may be greatly reduced by the fitting of suppressors either at the interfering appliance or on the conductors. Interference from conductors is greatly increased when conductors form partially-closed loops, or when lead and return conductors are widely separated. It is thus preferable to use twin cable where practicable, or if single-core cables are used, to run the lead and return conductors together.

21.20 - Relevant international documents.

(a) Regulations made at the International Conference on Safety of Life at Sea, London, 1948.
Chapter IV, Part C, Regulation 9(a), states :

" The ship's radiotelegraph station shall be so located that no harmful interference from extraneous mechanical or other noise will be caused to the proper reception of radio signals. The station shall be placed as high in the ship as is practicable so that the greatest possible degree of safety may be secured."

Chapter IV, Part C, Regulation 10(r), states :

" All steps shall be taken to eliminate so far as is possible the causes of, and to suppress radio interference from electrical and other apparatus on board."

(b) Radio Regulations of the International Telecommunication Union, drawn up at Atlantic City, 1947.
Chapter V, Article 13, Section II(377) states :

" Administrations shall take all practicable and necessary steps to ensure that the operation of electrical apparatus or installations of any kind does not cause harmful interference to a radio service operating in accordance with the provisions of the present Regulations."

CHAPTER 22

LIGHTNING CONDUCTORS

22.01 - Ships requiring lightning conductors. Lightning conductors should be fitted to each mast of all wooden, composite and steel ships having wooden masts or topmasts. They need not be fitted to steel masts in steel ships.

22.02 - Size of conductors. In wooden and composite ships fitted with wooden masts the lightning conductors should be composed of continuous copper tape or rope having a section not less than 75 mm^2 (or 0.15 in^2) which should be riveted with copper rivets or fastened with copper clamps to a suitable copper spike not less than 12 mm (or 0.5 in.) in diameter, projecting at least 150 mm (or 6 in.) above the top of the mast. Where tape is used the lower end of the tape should terminate at the point at which the shrouds leave the mast, and should be securely clamped to a copper rope having a section not less than 75 mm^2 (or 0.15 in^2). The copper rope should be led down the shrouds and should be securely clamped to a copper plate not less than 0.2 m^2 (or 2 ft^2) in area, fixed well below the light-load waterline and attached to the ship's side in such a manner that it shall be immersed under all conditions of heel.

22.03 - Wooden ships with steel masts. In wooden and composite ships fitted with steel masts, each mast should be connected to a copper plate in accordance with Clause 22.02 above, the copper rope being securely attached to and in good electrical contact with the mast at or above the point at which the shrouds leave the mast.

22.04 - Steel ships with wooden masts. In steel ships fitted with wooden masts, the lightning conductors should be composed of copper tape or rope terminating in a spike, as set forth in Clause 22.02 above. At the lower end this copper tape or rope should be securely clamped to the nearest metal forming part of the hull of the ship.

22.05 - Installation details. Lightning conductors should be run as straight as possible, and sharp bends in the conductors should be avoided. All clamps used should be of brass or copper preferably of the serrated contact type, and efficiently locked. No connection should be dependent on a soldered joint.

22.06 - Resistance. The resistance of the lightning conductor measured between the masthead and the point on the earth plate or hull to which the lightning conductor is connected should not exceed 0.02 ohms.

22.07 - Earthing in dry dock. Suitable means should be provided to enable ships when in a dry dock, or on a slipway, to have their lightning conductors or steel hulls connected to an efficient earth on shore.

CHAPTER 23

TANKERS

23.01 - Scope. The following recommendations are additional to those contained in other chapters of these Recommendations and apply to vessels either carrying oil in bulk having a flash point below 65 °C or carrying exclusively bulk oil cargoes regardless of flash point. Where flame-proof construction and apparatus are specified in this chapter, the recommendations applicable to flameproof apparatus made in other Chapters, particularly Chapter 16 - Accessories, should be observed.

23.02 - Ships service systems of supply.
See Chapters 6 and 7.

Hull return systems should not be permitted in tankers.

The d.c. voltage should not exceed 250 V.

23.03 - Power supply and distribution. The generating plant, switch-boards and storage batteries should be separated from the cargo tanks by cofferdams or equivalent safety spaces and from the pump-room by a gastight bulkhead.

23.04 - Spaces barred to electrical equipment. No electric equipment should be installed in cargo pump-rooms, between decks or spaces where flammable vapour or gas may normally be expected to accumulate, except as otherwise provided herein.

23.05 - Pump-rooms.

(a) Electric motors driving equipment located in pump-room spaces should be separated from the equipment by a gastight bulkhead or deck. Flexible couplings or other means of maintaining alignment should be fitted in the shafts between the pumps and the motors and in addition suitable stuffing boxes should be fitted where the shafts pass through gastight bulkheads or decks.

(b) The lighting fixtures for such spaces should be permanently wired and fitted outside the space. Pump-rooms immediately adjacent to an engine-room or similar safe spaces may be lighted through permanently fixed glass lenses or ports fitted in the bulkhead and/or deck to maintain the watertight and gastight integrity of the structure. The externally mounted lighting fixture may be designed so that the gastight flanged port forms a part of the fixture. The lighting fixtures may be of the waterproof type where not immediately in contact with the bulkhead or deck.

(c) Where the location of the pump-room does not permit use of bulkhead lighting arrangements or where deck installations would not furnish sufficient light in lower cargo pump-rooms, explosion-proof lighting fixtures may be installed and wired with lead and armoured, metal braided or mineral insulated cable. The switches for explosion proof pump-room lights should be located in a safe place outside of the pump-room and their enclosures should be of the degree required by the location.

23.06 - Wiring.

(a) Except as permitted in 23.05 electric wiring should not enter oil tanks nor should it pass through cargo pump-rooms or cofferdams adjacent to and extending below the top of any oil tank.

(b) All cables which may be exposed to oil or oil vapour should be leaded and armoured, metal braided or mineral insulated, and all metallic protective coverings should be grounded at least at each end.

(c) Cables installed on deck or fore and aft gangways should be located near the centre line and should be run in substantial steel channels, pipes or the equivalent. Cables and protective supports should be so installed as to avoid strain or chafing and due allowance made for expansion or working of structure.

23.07 - Switches and socket-outlets. Switches and socket-outlets other than those of flameproof construction, should not be fitted within 3 m (or 10 ft.) of any oil-tank outlet or vapour outlet.

23.08 - Portable lamps. No portable lamps other than self-contained battery-fed lamps of an explosion proof type should be used in the pump-rooms or in cofferdams adjacent to and extending below the top of any oil tank or where flammable vapour or gas may normally be expected to accumulate.

23.09 - Warning light. A red signal light or lights in accordance with the requirements of certain governmental or local regulations, should be provided to show when cargo oil is being loaded or unloaded.

CHAPTER 24

ELECTRIC PROPULSION PLANT

GENERAL CONSIDERATIONS

24.01 - Scope. This chapter relates to the electric propulsion equipment proper and deals with generators, motors, electric couplings, control, and cables, together with such aspects of the mechanical equipment as are essential to the successful functioning of the entire system.

24.02 - Structural features. Propulsion generators and motors should be of substantial and rigid construction and arranged for fitted bolts to secure them to their foundations. All foundations of machines should be substantial and secured to the ship's structure. Control assemblies should be secured to a solid foundation and self-supported, or braced to the bulkhead or deck above.

24.03 - Torque and critical speeds.

(a) The torque available in the propulsion motors for manoeuvring should be reasonably in excess of the trailing action of the propeller, to enable the latter to be stopped or reversed in a reasonable time when the vessel is travelling at maximum service speed.

(b) Adequate torque margin should be provided in a.c. propulsion systems to guard against the motor pulling out of step during rough weather and, on a multiple-screw vessel, when turning.

(c) The prime movers, generators and motors should be so constructed, erected and supported that when running at any and every working speed all revolving and reciprocating parts are well balanced so as not to give rise to any excessive vibration.

(d) The normal running speeds of the propulsion system should not be in the vicinity of a torsional critical speed having a torsional vibration of excessive magnitude.

(e) In order to prevent excessive torsional stresses careful consideration should be given to co-ordination of the mass-elastic constants of the entire propelling system including generator, motor, shafting, propeller, and electrical oscillations in alternating-current systems.

24.04 - Lubrication.

(a) Means should be provided to ascertain the temperature of the lubricating-oil discharge when a circulating system is used.

(b) An alarm system should be installed in conjunction with any forced lubrication system (pressure or gravity), arranged to function when the oil pressure fails.

(c) Where the machines are not to be located in the fore-and-aft position, special consideration should be given to the bearings.

(d) The requirements of Clause 13.16 should be complied with.

PRIME MOVERS

24.05 - Steam turbines. Steam turbines for electric propulsion should incorporate the following details:

(a) An effective governor for holding the turbine speed, when the load is removed, within 5 % of the designed number of revolutions per minute at full speed. If ship control involves adjustment of the turbine speed, this governor should be provided with adequate means for local manual control as well as for remote adjustment from the control station. The speed-control governor should be designed to permit the speed to be increased and decreased in suitable increments over the speed range.

(b) An emergency overspeed release to trip the throttle valve when the turbine speed exceeds the rated number of revolutions per minute by 10 - 15%. The release should have provision for manual tripping.

(c) Where exhaust steam is admitted to the turbine lower stages, an automatic shut-off should be provided, controlled by the governor and functioning when the emergency trip operates.

(d) Where provision is made for the extraction of steam, positive means for preventing a reversal of flow to the turbine should be provided.

(e) If exhaust steam is utilized, means to prevent water entering the turbine should be provided.

(f) In order to minimize the possibility of fire, steps should be taken to prevent lubricating oil from coming into contact with parts having a temperature in excess of 343 °C.

24.06 - Turbine design overspeed. The turbine should not be called upon to withstand a higher speed than 20 % in excess of the rated speed. If any test be made, it should only be made during the acceptance trial and the duration should not exceed five minutes.

24.07 - Diesel engines. Diesel engines for electric propulsion should incorporate the following details :

(a) An effective governor capable of quickly reducing the fuel-oil flow. Engines should have a no-load speed not in excess of 6 % above full-load rated speed. This governor should also provide for satisfactory parallel operation over the entire speed range required of the engines, except in cases where the arrangement of the plant makes parallel operation unnecessary. Where required by the nature of the propeller speed control, the speed control governor should be designed to permit the speed to be increased in suitable increments over the speed range.

(b) In addition to the speed-regulating governor, each engine should be fitted with an overspeed governor which will prevent the engine from exceeding its rated speed by more than 15 %.

24.08 - Diesel-engine rating.

(a) The rating of a diesel engine is the net brake horse-power which the engine will deliver continuously at the engine coupling, at its rated speed, when operating under the conditions described in Clauses 13.03 and 13.04, without correction for power required by auxiliaries which may or may not be driven by the engine.

(b) The engine should be capable, for periods of one hour, of developing a load of not less than 10 % above its rated output or such other percentages of overload and other time period as may be specified by the purchaser within the limits of variation in speed as defined in Clause 24.07, without undue heating of the engine or other mechanical difficulty.

(c) The engine should be capable of sustaining the above specified overload for the specified time, immediately following a run at rated output, during which steady conditions have been reached and jacket-water and lubricating-oil temperatures have become reasonably constant. The engine should be capable of continuing in operation at rated output immediately following the specified overload test.

<u>24.09 - Diesel-engine dynamic considerations.</u> Diesel engines intended as prime movers should have a flywheel effect sufficient to ensure that the angular deviation for alternating-current systems or the cyclic irregularity for direct-current systems is within the limit required for the application. The flywheel effect is expressed by WR^2 or GD^2, where :

W or G = Weight of the rotating masses in kilograms or pounds.
R = Radius of gyration in metres or feet.
D = 2 x radius of gyration in metres or feet.

<u>NOTE:</u> It is American practice to use WR^2 and European practice to use GD^2 and since both may be given in the same units it is essential that there be no misunderstanding as to which expression is being used.

<u>24.10 - Diesel-engine torsional vibration.</u>

(a) In the instances of engines which drive electric-propulsion generators, the torsional frequency of the shafting and its associated masses should be such that no torsional vibration of excessive magnitude occurs at any of the operating speeds of the engine.

(b) A torsional vibration is considered excessive when it gives rise to stresses which, when combined with other stresses ordinarily present in the shafting, exceed the safe working stress for the material of the shaft, or when the amplitude of torsional vibration is such as to be inimical to the life of the elements attached to or driven from the shaft, even though the attendant stresses are not excessive.

(c) Critical speeds occurring below the operating speed and through which the engine must pass in attaining operating speed should not have torsional vibration of such severity as to endanger the life of the shafting or its associated elements.

(d) If complete elimination of all critical speeds within the desired operating range is not practicable, the engine builder should recommend the avoidance of continuous operation at the speeds at which objectionable vibrations are expected to occur.

24.11 - A.C. generators and motors - general. A.C. propulsion generators and motors should be in general accordance with the applicable parts of Chapter 13 unless dealt with specifically in this chapter.

24.12 - Machine voltages. Generators and motors should be polyphase and of a voltage between phases not exceeding 7 500 volts. Voltages in excess of this value should be considered as special.

24.13 - Frequency. It is not necessary for the frequency used in propulsion equipment to be the same as that adopted for the ship's service generators.

24.14 - Construction.

(a) Motors may be of the induction type with a separate self-contained squirrel-cage rotor winding for starting, or of the ordinary form wound-rotor type with external starting resistance, or of the synchronous type with separate induction rotor winding for starting and direct-current excited field for normal running.

(b) Generators and motors with closed ventilating systems should be provided with means for obtaining the temperatures of the stationary windings. The temperatures should be indicated at a convenient location, preferably the control panel.

(c) Means should be provided to prevent circulating currents passing between the journals and the bearings.

24.15 - Inherent characteristics of generators. Generators should have inherent characteristics which protect them against damage due to short circuits.

24.16 - Machine ventilation and temperature control.

(a) Generators and motors should be either of the ventilated type with adequate wire or mesh screens to prevent injury to personnel or the entrance of foreign material or of the enclosed type with pipe ventilation.

(b) Generators and motors should be provided with forced ventilation when required by the service. The heated air should be carried away through ducts from the generator and motor enclosures, such ducts being arranged to prevent warm exhaust-air re-entering the intake and to prevent entrance of water or foreign material into either intake or exhaust ducts.

(c) Generator and motor ventilation may be provided by the recirculation of air through a closed or partially closed system, employing water-cooled air coolers. In this case arrangements should be such as to prevent the entrance of water, from leaking cooler tubes, into the generator or motor. Any air entering the generators and motors should be kept free, as far as practicable, from oil and other vapours, and from foreign material of any kind. Where the air coolers are of sufficient capacity to provide 40 °C cooling air at the maximum condition, allowable temperature-rises for generators and motors may be based on this temperature.

(d) Air ducts should be provided with dampers, and means of access for inspection and with alarm thermometers external to the machines. Dampers are not required for recirculating systems.

24.17 - Oil guards. Oil guards should be provided, if necessary, to prevent creepage of oil along the shaft to the machine windings.

24.18 - Accessibility for repairs. For purposes of inspection and repair, provision should be made for access to stator coils and armature coils, and for the withdrawal and replacement of the field coils of salient-pole a.c. machines. Facilities should be provided for supporting the shaft to permit the withdrawal and inspection of bearings.

24.19 - Protection from moisture. Effective means should be provided in generators and motors to prevent the accumulation of moisture when they are idle for appreciable periods.

D.C. GENERATORS AND MOTORS

24.20 - D.C. generators and motors - general. Generators and motors should be in general accordance with applicable parts of Chapter 13 unless dealt with specifically in this chapter.

24.21 - Machine voltages. The designed voltage between any two points or between any point in the system and earth for direct-current propulsion generators and motors should not exceed 1,000 volts. Where multiple motor armatures are used in series and the voltage exceeds 1,000 volts, the system should be such that one or more generators are interspersed between the armatures, or some other arrangement employed by which the voltage between any two points of the system is limited to a value not in excess of 1,000 volts. Voltages in excess of this value should be considered as special.

24.22 - Shaft currents. Means should be provided to prevent circulating currents passing between the journals and the bearings.

24.23 - Machine ventilation and temperature control. All parts of Clause 24.16 are also applicable to d.c. propulsion generators and motors.

24.24 - Oil guards. Oil guards should be provided, if necessary, to prevent creepage of oil along the shaft to the machine windings.

24.25 - Accessibility for repairs. For purposes of inspection and repair, provision should be made for access to armature coils and for the withdrawal and replacement of the field coils. Facilities should be provided for supporting the shaft to permit the withdrawal and inspection of bearings.

24.26 - Protection from moisture. Effective means should be provided in generators and motors to prevent the accumulation of moisture even when they are idle for appreciable periods.

24.27 - Overspeed protection. Where the system permits excessive overspeeding at light loads, overspeed protection devices should be arranged to interrupt the supply of power and the armatures should be suitably constructed to prevent damage due to temporary overspeeding.

ELECTRIC SLIP COUPLINGS

24.28 - Construction. Electric slip couplings should be of substantial and rigid construction.

24.29 - Protection. Electric slip couplings should be enclosed ventilated or otherwise provided with substantial wire or mesh screen to prevent personnel injury or the entrance of foreign material. They should be drip proof.

24.30 - Temperature limits. Limits of temperature-rise should be the same as for a.c. generators (see Table 24.III, Page 146), except that when a squirrel-cage element is used, the temperature of this element may reach such values as are not injurious. If the coupling is fitted with an integral fan, the temperature should not exceed these limits when the coupling is operated continuously at 70 % of full-load speed, full excitation, and rated torque. Vessels designed primarily for towing may require rated torque at a lower speed.

24.31 - Accessibility for repairs. The coupling should be designed to permit removal as a unit without moving the engine crankshaft or pinion shaft, and without removing the poles.

EXCITERS

24.32 - Exciters - general.

(a) Normally exciters for a.c. installations should be separately driven, while those for d.c. systems may be direct-connected.

(b) More than one means of excitation should be provided. Current may be derived from the auxiliary power or lighting sets as one means of excitation.

(c) Exciters should have characteristics suited to the control system used.

24.33 - Construction.

(a) Exciters should conform to the applicable requirements for d.c. generators and should be in general accordance with the relevant recommendations made in Chapter 13 unless dealt with specifically in this chapter.

(b) The strength of shafts and couplings of exciters for alternating-current systems should be suitable for the increased output necessary during manoeuvring.

24.34 - Exciter voltage variation. If the exciter is used solely for excitation of the propulsion generator, its voltage may be varied over the stable range of the exciter to vary the generator field excitation; otherwise booster generator or resistance should be used for accomplishing this purpose.

24.35 - Rotary-amplifier exciters.

(a) Rotary-amplifier-type exciters may be used for direct excitation of generators and motors or as pilot exciters in the field circuits of conventional exciters to provide rapid variation of the exciter voltage.