Rules and Regulations for the Construction & Classification of Submersibles & Diving Systems

July 2019

A guide to the Rules

and published requirements

Rules and Regulations for the Construction & Classification of Submersibles & Diving Systems

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Rules updating

The Rules are generally published annually and changed through a system of Notices between releases.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Offshore Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

July 2019

■ *Section 1* Background

1.1 Lloyd's Register Group Limited is a registered company under English law, with origins dating from 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members subsidiaries and affiliates of Lloyd's Register Group Limited, including but not limited to: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited. Lloyd's Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as 'LR'.

■ *Section 2* Governance

2.1 Lloyd's Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;

appointed Technical Committees and determined their powers, functions and duties.

2.2 LR has established National and Area Committees in the following:

Countries:	Areas:
Australia (via Lloyd's Register Asia)	Benelux (via Lloyd's Register EMEA)
Canada (via Lloyd's Register North America, Inc.)	Central America (via Lloyd's Register Central and South America Ltd)
China (via Lloyd's Register Asia)	Nordic Countries (via Lloyd's Register EMEA)
Egypt (via Lloyd's Register EMEA)	South Asia (via Lloyd's Register Asia)
Federal Republic of Germany (via Lloyd's Register EMEA)	Asian Shipowners (via Lloyd's Register Asia)
France (via Lloyd's Register EMEA)	Greece (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)	

Japan (via Lloyd's Register Group Limited)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

■ *Section 3* **Technical Committee**

3.1 LR maintains a Technical Committee, at present comprised of a maximum of 80 members, and additionally an Offshore Technical Committee with specific responsibility for LR’s Rules for Offshore Units, at present comprised of a maximum of 80 members. Membership of the Technical Committees includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd’s Register Group Limited
- Chairman of the Classification Committee of Lloyd’s Register Group Limited

Members Nominated by:

- Technical Committee or Offshore Technical Committee
- Professional bodies representing technical disciplines relevant to the industry
- National and International trade associations with competence relevant to technical issues related to LR's business

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committees.
(b) A maximum of five further representatives from National Administrations may be co-opted to serve on the Technical Committees. Representatives from National Administrations may also be elected as members of the Technical Committees as Nominated Members.
(c) Further persons may be co-opted to serve on the Technical Committees by the relevant Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committees is to consider:

(a) any technical issues connected with LR’s business;
(b) any proposed alterations in the existing Rules;
(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions and Codes, or Common Rules, Unified Requirements and Interpretations adopted by the International Association of Classification Societies, these may be implemented by LR without consideration by the relevant Technical Committee, although any such changes may be provided to the Technical Committees for information.

Where changes to the Rules are required by LR to enable existing technical requirements within the Rules to be recognised as Class Notations or Descriptive Notes, these may be implemented by LR without consideration by the relevant Technical Committee, although any such changes will be provided to the relevant Technical Committee for information

3.5 The term of office of the Chairman and of all members of each Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the relevant Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committees are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Matters may also be considered by the Technical Committees by correspondence.

3.8 Any proposal involving any alteration in, or addition to the General Regulations, of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than the General Regulations, will following consideration and approval by the relevant Technical Committee either at a meeting of that Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committees are empowered to:

(a) appoint sub-Committees or panels; and
(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4* **Naval Ship Technical Committee**

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd’s Register Group Limited

Member nominated by:

- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules. Where appropriate, Naval Ship Technical Committee may also recognise alternative LR Rule requirements that have been approved by the other Lloyd’s Register Technical Committee as adjunct to the Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, the General Regulations of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than the General Regulations, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and
(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

Section 5
Applicability of Classification Rules and Disclosure of Information

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval. Recognising the long time period that may occur between the initial design contract and the contract for construction for offshore units for fixed locations, the date determining effective classification requirements will be specially considered by LR in such cases.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System. LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

Section 6
Ethics

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

Section 7
Non-Payment of Fees

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

Section 8
Limits of Liability

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

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

8.4 Except in the circumstances of section *Pt 1, Ch 1, 8 Limits of Liability 8.2* above, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	Conditions for Classification	Character of Classification and Class Notation	Survey - General
	Section 1	Section 2	Section 3
Unit Type			
Manned Submersible	x	x	x
Wet Submersible	x	x	x
Unmanned Submersible	x	x	x
Submersible Craft	x	x	x
Diving Bell	x	x	x
Submersible Vehicle	x	x	x
Submersible Habitat	x	x	x
Submersible Container	x	x	x
Passenger Submersible	x	x	x
Rescue Submersible	x	x	x

■ Section 1
Conditions for Classification

1.1 General

1.1.1 Submersibles, diving systems and deck compression chambers referred to in these Rules are defined in *Pt 1, Ch 2, 2.2 Definitions*.

1.1.2 Submersibles, diving systems and deck compression chambers built in accordance with LR's Rules and Regulations, or in accordance with requirements equivalent thereto, will be assigned a class in the Register of Offshore Units, Submersibles and Diving Systems (in accordance with the current certificate of class) and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules.

1.1.3 Classification is conditional upon strict observation of the restrictions imposed on service operation, and upon the proper maintenance of the submersible or chamber and identified ancillary equipment which is required to comply with the Rules. It assumes that the state of training of the crew is such as to enable operations within the approved limits to be carried out safely. Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the Unit is registered.

1.1.4 In the case of a tethered and manned submersible, classification is dependent on the lifting gear which is used to place the submersible in the sea and remove it from there. Where lifting gear is classed or included in the class of the submersible or diving system it is to comply with LR's *Code for Lifting Appliances in a Marine Environment, July 2019*. However, in other cases the Owner is expected to ensure that the installation of towing and/or lifting gear is satisfactory, complies with the appropriate National Regulations and is classed or certified by a recognized Certifying Authority.

1.1.5 The classification of a compression chamber or transfer under chamber located in air will be inclusive of supports and attachments to a floating or fixed structure and all essential services related to that specific chamber.

1.1.6 A log book is to be kept by the operations controller, or equivalent, for each classed item and it is to be made available to the Surveyors on request. For each submersible the log book is to contain details of each dive.

1.1.7 Submersibles which have integral hyperbaric chambers will be operated with a compression chamber available on the support vessel or installation. These compression chambers can be used in dealing with cases of illness or emergency conditions when the submersible is operating its hyperbaric chamber at internal depths greater than 10 m.

1.1.8 Submersibles, which have a chamber consisting of an assembly of component parts with mechanical joints to facilitate, dismantling between dives and interchange of parts to effect different underwater tasks, will be classed in accordance with these Rules and Regulations. However before each dive the Owner is to establish that the submersible has been properly assembled, is pressure tight and otherwise suitable for the intended service.

1.1.9 Where diving operations are to be undertaken in connection with the maintenance, survey or repair of an offshore installation, the offshore installation manager (OIM) and masters of craft adjacent to the installation are to be informed. Work is not to commence until copies of the relevant 'permit to work' are obtained from the OIM to reduce risk to personnel and the submersible having regard to the prevailing environmental conditions and the configuration of the structure.

1.1.10 Any damage, defect or breakdown which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay.

1.1.11 Submersibles designed to carry passengers will be specially considered and may require additional provisions for their safety. National Authority requirements should be agreed and proof of that agreement be made available to Lloyd's Register. Special consideration will be given to rescue submersibles.

1.1.12 On completion of the construction of the diving system or unit and following each subsequent Special Survey, the unit specific Inspection and Testing Programme shall be developed by the Operator for the following five year survey cycle. The Programme shall be presented to Lloyd's Register for approval.

1.2 Survey Planning

1.2.1 A planned inspection and testing programme is to be developed by the Operator and submitted to LR for approval in advance of the first annual survey in the five year cycle, *see Pt 1, Ch 2, 1.1 General*. The programme should include and address the following:

(a) overall design configuration and operation limitations of the diving unit;

(b) appropriate regulatory requirements;
(c) main structural arrangement plans;
(d) areas to be surveyed and extent of the insulation/cladding removal;
(e) inspection and testing schedules for all relevant components, equipment and systems;
(f) inspection and testing methods and procedures;
(g) extent, frequency and circumstances for application of NDE and thickness measurement;
(h) locations for non-destructive testing and thickness measurement;
(i) condition of coatings and corrosion prevention systems;
(j) methods for reporting and recording of damage or deterioration found and remedial measures;
(k) allowable wastage limits (corrosion margins and wear allowances) for the structure and stress bearing components;
(l) due date for the portholes' replacement.

1.3 Application

1.3.1 Except in the case of a special directive by the Committee, no new Regulation or alteration to any existing Regulation relating to character of classification or class notation is to be applied to an existing submersible, diving system or deck compression chamber.

1.3.2 Except in the case of a special directive by the Committee, no new Rule or alteration to any existing Rule materially affecting classification is to be applied compulsorily within 6 months of its adoption, where it is desired to use existing previously approved plans for a new contract; written application is to be made to the Committee.

1.4 Interpretation of the Rules

1.4.1 The interpretation of the Rules is the sole responsibility, and is at the sole discretion, of LR. Any uncertainty in the meaning of the Rules is to be referred to LR for clarification.

■ *Section 2*
Character of Classification and Class Notation

2.1 General

2.1.1 For the purpose of these Rules the terms used have the meanings defined in the following paragraphs unless expressly provided otherwise.

2.1.2 A submersible is, for the purpose of these Rules, a vessel, whether sea-going, used in fresh water or fixed to the sea bed (or forming part of a marine structure), designed to be capable of submerging beneath the surface to an maximum operating depth and for an approved operating time. It may be manned or unmanned. Included under this heading are submarines, habitats, submersible diving chambers or submersible personnel transfer chambers, observation chambers, diving bells and underwater containers, including items for sub-sea completions required for purposes such as mineral workings.

Note Stationery items of exposed (unprotected) plant and equipment situated on the sea bed or anchored thereto are not submersibles within the meaning of the Rules (e.g. an open framework wellhead completion).

2.1.3 A submersible may be propelled, towed, suspended, anchored or bottom supported. Propulsion may be by tracks, wheels, propellers, water jets or other approved means.

2.2 Definitions

Types of submersibles are defined as follows:

2.2.1 **A manned submersible** is a submersible designed to be capable of carrying personnel while submerged. Such vessels may be self-contained or externally sustained. Surface access only may be available, or underwater pressurized or non-pressurized access may be fitted.

2.2.2 **A wet submersible** is a manned submersible designed to be free flooding so that the pilot, crew and passengers dive to a given operational depth while wearing diving' equipment of either scuba or umbilical type.

2.2.3 **An unmanned submersible** is a submersible designed to be operated by remote control or autonomously, and without carrying personnel while submerged.

2.2.4 **A submersible craft** is a submersible designed to be operated while suspended, towed or self-propelled without contact with the bottom or sea bed.

2.2.5 **A diving bell** is a tethered, submersible compression chamber which can be lowered into the water and from which divers can operate.

2.2.6 **A submersible vehicle** is a self-propelled submersible propelled by contact with the bottom or sea bed, or a towed submersible intended to operate, in service, only on the bottom or sea bed.

2.2.7 **A submersible habitat** is a manned submersible designed for operation as living quarters, on a temporary or permanent basis, or work chamber under water but not arranged to be self-propelled or towed, while submerged with personnel on board.

2.2.8 **A submersible container** is an unmanned submersible containing plant or other equipment that must be protected from the sea, has an internal volume in excess of 1 m3 and is anchored to the sea bed or a fixed offshore structure.

2.2.9 **A passenger submersible** is a craft designed to carry passengers in addition to the crew, for leisure or commercial purposes who are not permitted to operate equipment to control the submersible or participate in its operation.

2.2.10 **A rescue submersible** is a craft specifically designed to evacuate personnel from underwater habitats or crafts in emergency situation.

2.2.11 **An Atmospheric Diving Suit (ADS)** is a tethered one man submersible in which the operator's arms, or arms and legs, move inside articulated joints to provide mobility and protection to carry out the underwater task. The operator is not subject to a pressure greater than 100 millibars above atmospheric pressure.

2.2.12 **An Atmospheric Diving Suit System (ADS System)** includes the ADS and associated support components/systems such as support stands, access and service platforms, the handling system and the ADS control station.

2.3 Other Definitions

2.3.1 Other definitions appropriate to these Rules are as follows:

- **A bottle** is a pressure container for the storage and transport of gases under pressure.
- **A chamber** is a pressure vessel with access for personnel and with means of controlling the differential pressure between the inside and the environment.
- **Autonomous units**: Submersible craft which although manned in some cases, are designed to operate without physical connection to surface support vessel.
- **Breathing Gas** All gases which are used for breathing during diving operations.
- **Breathing Mixture** All mixtures which are used for breathing during diving operations.
- **Category A machinery** space means spaces and passageways as defined in the 1974 International SOLAS Convention as amended.
- **Collapse depth**: The depth at which general collapse of the pressure hull will take place.
- **Compression** is the gradual increase of pressure to match a given water depth.
- **Compression chamber** A pressure vessel for human occupancy under pressure.
- **Crew** refers to the person or persons within the submersible required to operate equipment to control the submersible. They may be required to exit from certain submersibles while under water.
- **Deck compression chamber** and transfer chamber are the pressure vessels and equipment used in association with a submersible having hyperbaric capacity, but sited on board an attendant floating or fixed structure.
- **Decompression** is a controlled return to atmospheric pressure from a hyperbaric or equivalent pressure.
- **Decompression stop (or stage)** is a pause at a particular pressure level or depth of water, during ascent to the surface pressure, to avoid the occurrence of decompression sickness.
- **Depth** should normally be measured to the lowest part of the submersible's pressure hull, or equivalent structure on vessels without a pressure hull.
- **Diving system** means the whole plant and equipment necessary for the conduct of diving operations and includes certain types of tethered submersibles such as diving bells and observation chambers, transfer chambers, and deck compression chambers and relevant LARS.
- **Diving System-SAT** – this notation will be assigned to the systems designed for saturation operation.

- **Diving System Surface** – this Class notation will be assigned to the systems operating to the maximum depth of 60msw with diving time restriction.
- **An explosion** is the violent bursting of a body outwards. It may be caused by a decrease in external pressure.
- **Tethered** signifies having externally sustained means comprising some or all power and life-support systems fed from a vessel in attendance, or from a fixed structure.
- **Fixed System** A diving system installed permanently on ships or fixed offshore structures or offshore installations.
- **Free flooding** means capable of being flooded by water at any depth without the use of pumps.
- **A hull penetration** is an opening which allows systems and fittings to be inserted into a pressure chamber.
- **Handling System** The plant and equipment necessary for raising, lowering and transporting the diving bell between the work location and the surface compression chamber usually called Launch and Recovery Systems - LARS.
- **Hazardous Area** Those locations in which an explosive gas-air mixture is continuously present, or present for long periods (zone 0), in which an explosive gas-air mixture is likely to occur in normal operation (zone 1); in which an explosive gas-air mixture is not likely to occur and, if it does, will persist for only a short time (zone 2).
- **Hyperbaric Evacuation System** A system whereby divers under pressure can be safely evacuated from a ship or fixed or offshore installation to a position where decompression can be carried out.
- **Hyperbaric Evacuation Unit – (HEU**) A unit where divers under pressure can be safely evacuated from a ship or floating structure to a place where decompression can be carried out (please refer to IMO Guidelines Res A.692 m).
- **Hyperbaric Lifeboat – (HLB)** please refer to Hyperbaric Evacuation Unit.
- **Hyperbaric pressure** is the pressure, in excess of atmospheric, resulting from the depth of submergence.
- **Implosion** is the violent collapse of a body inwards.
- **Isobaric pressure** is a constantly maintained pressure, usually not significantly differing from atmospheric.
- **Laid up** is the state when the submersible and its systems and components have been treated in order to afford protection from dirt, corrosion, unauthorized interference, etc., during an inactive period. Such treatment would include the suitable sealing of any systems, from which items may have been removed for separate storage, to prevent deterioration or loss.
- **Life-support systems** are those providing and maintaining breathing atmosphere, temperature, humidity, waste disposal, feeding and fumes to render a submersible or chamber habitable.
- **Linked** means connected, while in operation, to an attendant ship, submersible or structure by a mooring line, suspension cable or umbilical.
- **Living compartment** means the part of the surface compression chamber which is intended to be used as the main habitation for divers during diving operations and which is equipped for such purpose.
- **Log Book** means the documented record of inspection and maintenance and details of dives performed. Log Books may be in the form of a Register and may contain other information of a more specific nature.
- **Main Components** of a diving system Surface compression chamber, diving bell, handling system, fixed gas storage facilities, gas treatment and life support systems.
- **A manipulator** is a remotely operated work arm.
- **Mating Device** The equipment necessary for the connection and disconnection of a diving bell to a surface compression chamber.
- **Maximum Operating Depth** of the Diving System The depth in metres of seawater equivalent to the maximum pressure for which the diving system is designed.
- **Operating time** is the total duration of normal life-support and/or power system, whichever be the lesser, including time for descent and ascent, but excluding emergency reserves.
- **Passengers** are persons carried within the submersible but not permitted to operate equipment to control the submersible. If trained as divers they may be required to exit from certain submersibles while under water.
- **A pilot** is a person in direct command of the submersible and all personnel on or within it.
- **Portable Diving System (P)**: A diving system designed and built to remain largely independent of the vessel or offshore unit on which they are installed and may be easily disconnected and transported to the other vessel or the offshore unit, commissioned and installed again.
- **Pressurized access is a hatch**, airlock, etc., for the dry entry and exit of personnel to and from one chamber to another at hyperbaric pressure, in a controlled way.
- **Pressure vessel** A container capable of withstanding an internal working pressure of 1 bar or over.
- **Recognized** means recognized by the Committee of Lloyd’s Register.
- **Recompression** is the return to high pressure following previous high pressure exposure — usually associated with divers to prevent or treat decompression sickness.

- **Saturation diving** is the technique in which divers are exposed to hyperbaric pressure, or its equivalent, for a period such that the decompression required will not change for any additional time at this pressure.
- **Scrubber** – an apparatus used to remove impurities from breathing gas.
- **Self-sustained** means having power and life-support equipment and systems incorporated in the submersible.
- **Surface access is a hatch** for entry and exit of personnel or equipment which is suitable for use only when the submersible is not submerged.
- **Surface compression chamber**: A pressure vessel for human occupancy, that is not intended to be submerged, with means of controlling and monitoring the pressure and the other life supporting parameters. *See also* definition of **Life-support systems**.
- **A surface controller** is the person with overall responsibility for the operation of a submersible and for the personnel, tracking, communications and life-support systems associated with it. In diver lock-out submersibles, the controller should be in the control cabin but is not to be the pilot.
- **An umbilical** is the connecting link to a submersible which may contain one or more life-support hoses, surveillance, communication or remote control leads and/or power supply cables.
- **Underwater access is a hatch** for entry and exit of personnel or equipment when the submersible is submerged.
- **Work time** is the operating time less time for descent and ascent.

2.4 Character Symbols

2.4.1 All submersibles, diving systems and compression chambers, when classed, will be assigned one or more character symbols as applicable. For the majority of sea-going submersibles, the character assigned will be 100A or ✠100A. This character will also be assigned to a deck compression chamber or diving system arranged to be used in conjunction with a submersible that is so classed.

2.4.2 A full list of character symbols for which submersibles, diving systems and deck compression chambers may be eligible is as follows:

✠	This notation will be assigned to new submersibles, diving systems and deck compression chambers constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules.
✠̄	This notation will be assigned, at the time of classing, to new submersibles, diving systems and deck compression chambers constructed under the survey of a recognised authority in accordance with the Rules and Regulations equivalent to those of LR. In addition, the whole of the machinery will be required to have been installed and tested under LR's Special Survey in accordance with LR's Rules.
✠̇	This distinguishing mark, will be assigned to existing submersibles built under supervision of another IACS member society and later assigned class with LR. For such units the class notations will be reviewed separately and equivalent notations will be assigned.
100	This character figure will be assigned to all units considered suitable for sea-going service.
A	This character letter will be assigned to all units which have been built or accepted into class in accordance with LR's Rules and Regulations, and are maintained in good and efficient condition.
1	This character figure will be assigned to: (a) Units which are anchored permanently to the sea bed or a fixed offshore structure, in accordance with the Rules. (b) Units having on board anchoring or mooring equipment in accordance with the Rules. (c) Units classed for special service, for which no specific anchoring and mooring Rules have been published, having on board, in good and efficient condition, anchoring or mooring equipment approved by the Committee as suitable and sufficient for the particular service.
(F)	This character letter will be assigned to the Fixed Diving System as defined in *Pt 1, Ch 2, 2.3 Other Definitions*.
(P)	This character letter will be assigned to the Portable Diving System as defined in *Pt 1, Ch 2, 2.3 Other Definitions*.
T	This character letter will be assigned to tethered units which are intended to perform their primary designed service function only while they are anchored, moored, towed, suspended or linked, and which have adequately attached equipment, in good and efficient condition.

U	This is an additional character letter which will be assigned to all submersibles which will be unmanned at all times, e.g. ✠100ATU; a new tethered and unmanned submersible.
100ASE	These characters will be assigned at the time of classing to a deck compression chamber in compliance with the Rules and Regulations and to the satisfaction of the Committee. The equipment may be static or ship borne and is to be maintained in a good and efficient condition. The equipment may have been classed originally with a particular submersible but is no longer associated with it. Alternatively, the Owner may have requested separate classification of such equipment as spare units or for other reasons acceptable to the Committee.
✠ 100AT ADS	These characters will be assigned to a new ADS constructed under LR's Special Survey, and in accordance with LR's Rules.
✠ 100AT ADS System LA	These characters will be assigned to a new ADS System constructed under LR's Special Survey, and in accordance with LR's Rules.
LA	These character letters will be assigned to all diving systems where the lifting appliance is considered to be an essential feature, and is mandatory. *See Pt 5, Ch 7 Lifting Appliances*.

2.4.3 In cases where anchoring, mooring, towing, suspending or linking equipment, or a diving system or deck compression chamber, is essential to the safe operation of a submersible and is included in the class of that underwater craft, the class of the submersible will be liable to be withheld if any of the associated equipment is found to be seriously deficient.

2.5 Class Notation

2.5.1 A class notation will be appended to the character of classification assigned to be submersible (and/or a diving system or deck compression chamber) as deemed necessary by the Committee or when requested by an Owner and agreed by the Committee. This class notation will consist of one of, or a combination of: a type notation (based on the definition in *Pt 1, Ch 2, 2.2 Definitions*), a special duties notation, a special features notation and/or a service restriction notation, as appropriate.

2.6 Descriptive Notes

2.6.1 In addition to any class notation, descriptive notes may be assigned on the Owners' request at the discretion of the Committee. These notes will give more details than the class notation, and/or will provide additional information about design and operation. Descriptive notes are not LR class notations and are provided solely for the information of users.

2.6.2 **ShipRight()**. Where one or more of LR's ShipRight procedures as detailed in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 1, Ch 2, 2.8 Descriptive notes 2.8.2* have been satisfactorily applied, then a descriptive note showing the associated characters of the procedure(s) within brackets will, at the Owner's request, be entered in column 6 of the *Register Book*.

■ *Section 3* Survey – General

3.1 Statutory Surveys

3.1.1 The Committee will act, when authorised on behalf of Governments, in respect of National and International statutory safety and other requirements for submersibles, diving systems and associated equipment.

3.1.2 The Committee will also act, when authorized, in respect of National safety and other regulations relating to the application of submersibles and diving systems to specific underwater surveys and requirements associated with offshore mineral exploration and exploitation.

3.2 New Construction Surveys

3.2.1 When it is intended to build a unit for classification with LR, construction plans and all necessary particulars relevant to the hull/structure, equipment and machinery, as detailed in the Rules, are to be submitted for approval of LR before the work commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approval plans are also to be submitted for approval.

3.2.2 The following plans are required for the class society's review and approval and are to be submitted as applicable to the particular design features:

(a) General arrangement showing principal dimensions, location of viewports, location of systems and equipment, design pressure, design temperature, number of occupants in each chamber and in the system (or complex), expected maximum mission time and volume of chamber measured internally;
(b) Pressure vessel fabrication including scantlings and dimensioned weld details, out-of-roundness and fabrication tolerances, material specifications, degree of non-destructive testing, hydrostatic test pressure;
(c) Openings and reinforcement details;
(d) Welding procedures and PQR's;
(e) Outboard profile;
(f) Foundations and support arrangements;
(g) Life support systems, both normal and emergency, with indicated capacities;
(h) Dimensioned details of viewports, penetrations, hatch details, hatch rings and lugs;
(i) Fire protection, detection and fighting equipment;
(j) Emergency systems;
(k) Electrical systems;
(l) Piping systems including fittings, valves, hoses, pump capacities and pressure relief devices;
(m) Details of permanently installed breathing gas bottles;
(n) Umbilical details;
(o) Details of diver heating systems;
(p) Sanitary systems;
(q) Communication systems;
(r) Control hydraulic, electric and pneumatic power systems;
(s) Atmosphere and breathing gas analysing systems;
(t) Compressors and breathing gas mixtures;
(u) Helium reclaim systems;
(v) Transfer and mating systems;
(w) Hyperbaric evacuation system;
(x) Local and remote control systems and control consoles.

3.2.3 The following documentation is to be submitted for review, as applicable:

(a) A schematic or logic diagram giving the sequence of the diving procedure;
(b) Operating procedures;
(c) Procedure for manual and emergency electric power, breathing gas and water supplies;
(d) List of degree of enclosure of all components;
(e) List of materials, fittings, contacts, support of all components;
(f) Electric feeder list, giving feeder protection and user protections and their settings;
(g) Generators, motors and batteries characteristics.
(h) Hazard analysis (Failure Mode Effect and Criticality Analysis).

3.2.4 The following calculations and data are to be submitted for approval, as applicable:

(a) Pressure vessel stress analysis including window calculations in compliance with *Pt 3, Ch 1, 8 Spherical shell/shell sections subject to external pressure* and *Pt 3, Ch 2, 3 Window geometry and thickness* and design analysis
(b) Life support system analysis;
(c) Analysis of a total loss of power (emergency);
(d) Electrical load analysis and electric fault analysis including power source and power requirements of units;
(e) Foundation stress analysis;
(f) Lifting stress analysis;
(g) Standard wiring practices and details including such items as cables, wires, conduit sizes and their support, pressure boundary penetrations and sealing arrangements, cable splicing, watertight and explosion proof connections;
(h) Results of tests witnessed by the Surveyor including hydrostatic test results, system operational test results, materials test results, operational test results of the completed chamber at rated pressure and out-of-roundness measurements.

3.2.5 An operating manual describing normal and emergency operational procedures is to be provided and is to be submitted for review, and contain the following as applicable:

(a) System description;
(b) Operational mission times and pressure capabilities;
(c) Life support system description including capacities;
(d) Methods for recharging life support systems;
(e) Electrical system description;
(f) Operation check-off lists (list to include equipment requiring maintenance or inspection prior to each dive/operation and verification of the existence of appropriately updated maintenance;
(g) Emergency procedures, developed from systems analysis, for situations such as power failure, loss of communications, life support system malfunction, fire, etc.;
(h) Liaison with support vessels;
(i) Special restrictions based on uniqueness of design and operating conditions;
(j) Colour-coding adopted.

3.2.6 The design criteria is to include the maximum operating depth; the maximum operating time; limitations on sea area and sea states; target sea states for launch and recovery; maximum speed for towing; whether self or externally sustained; surface or underwater; type of access; type of control; type of mobility and details of anchoring, towing or linking; lifting gear (*see Pt 1, Ch 2, 1.1 General 1.1.4*); etc., as appropriate. A hazard analysis to an agreed scope is also to be submitted for consideration.

3.2.7 Where the proposed construction of any part is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before or during service may be required. In such cases an appropriate notation may be assigned.

3.2.8 All data submitted for approval or consideration by the Committee will be treated in the strictest confidence. If the Owner, or his contractor, does not wish specific information to be included in the Register Book, LR is to be notified in writing.

3.2.9 The proposed maintenance and operating instructions are to be forwarded to LR for information in connection with the design appraisal and plan approval.

3.2.10 The materials used in the construction of the unit and its machinery intended for classification are to be fabricated in accordance with the requirements of Lloyd's Register's Rules for Manufacture, Testing and Certification of Materials, or made, tested and certified to the recognised standard agreed with Lloyd's Register. The steel is to be manufactured by an approved process at works approved by LR. Alternatively, tests to the satisfaction of LR will be required to demonstrate the suitability of the steel.

3.2.11 Each unit intended for classification is to be built under LR's Special Survey. From the commencement of the work to the completion including the final tests or trials under working conditions, as appropriate, the Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules and approved plans. In this connection the Surveyors are to be satisfied that the facilities, equipment, inspection and supervision at the works of the builder and sub-contractor are such that acceptable standards can be obtained in the manufacture of the unit, and for the construction and installation of the equipment and appendages. The following requirements also apply:

(a) Chambers subject to external pressure are to be subjected to an external hydrostatic test pressure of 1,3 times the maximum approved working pressure. If testing is carried out by simulation, in a test chamber, the external test pressure should be 1,4 times the maximum approved working pressure;
(b) Chambers are to be dimensionally checked before and after such tests;
(c) Special consideration will be given to the test requirements of deep diving submersibles;
(d) Mechanical components are to be designed, built and certified to a recognised standard;
(e) Acrylic windows are to be tested in accordance with *Pt 3, Ch 2, 7 Testing and inspection*;
(f) Flexible hoses shall be type approved for the intended use – *see Pt 5, Ch 3, 2.4 Hose lines and umbilicals*;
(g) Umbilical's shall be tested in accordance with *Pt 5, Ch 3, 2.4 Hose lines and umbilicals*, *see also Pt 5, Ch 5, 4 Hose Approval Tests*, *Pt 5, Ch 5, 5 Hose Completion Tests* and *Pt 5, Ch 5, 6 Umbilicals Composed of Multi-Size Hoses and Electrical Cables*;
(h) Buoyancy and stability shall be tested in accordance with *Pt 4, Ch 2, 5.6 Testing of buoyancy and stability*;
(i) Penetrations shall be tested in accordance with *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.2-Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.10*;

(j) Breathing gas systems should be tested in accordance with *Pt 5, Ch 3, 2.12 Testing* and *Pt 5, Ch 4, 6 Testing and Cleaning* and *Pt 5, Ch 4, 7.8 Control and sensing* after installation;

(k) Corrosion protection systems to be installed in accordance with *Pt 4, Ch 3 Corrosion Protection*;

(l) Safety interlocks to be tested;

(m) Main and emergency sources of power included safe guards to be tested;

(n) Control, alarm and safety systems provided in accordance with *Pt 6, Ch 2, 4 Testing and Trials* to be tested;

(o) Fire Protection, detection and extinction provided in accordance with *Pt 5, Ch 8 Fire Protections, Detection and Extinction* to be tested;

(p) Lifting gear shall be surveyed and tested in accordance with *Pt 5, Ch 7, 1.4 Periodic surveys*

3.2.12 For compliance with *Pt 1, Ch 2, 3.2 New Construction Surveys 3.2.7* at the option of the Manufacturer, LR is prepared to consider methods of survey and inspection for construction which formally include procedures involving the management of the manufacturer's works, organization and Quality System. The minimum requirements for the approval of any such proposed Quality Assurance methods are laid down in Lloyd's Register's *Rules for the Manufacture, Testing and Certification of Materials, July 2019*

3.2.13 Copies of approved plans, essential certificates and records including the operations log book should be retained on the parent, floating or fixed structure.

3.2.14 Unless the Committee so directs, the installation of a tethered submersible or a submersible anchored permanently to the sea bed is to be made under the survey of LR's Surveyors. The Owner of the installation is to submit prior to the survey, a report on the condition of the sea bed (if appropriate), and is to arrange for such remote television and video recording equipment to be available as may be required for the Surveyors to effect the survey.

3.2.15 The date of completion of the Special Survey will normally be the date of build to be recorded in accordance with current certification of class. If the period between the completion of construction and commissioning is unduly prolonged, the dates of these two stages may be separately indicated in accordance with current certification of class.

3.2.16 When a unit, intended for classification, is laid up for a period on completion, the Committee upon application by the Owner, prior to the item entering service, may direct an examination to be made by LR's Surveyors. If, as a result of the survey no noticeable deterioration is reported the subsequent Special Survey will date from the time of this additional survey.

3.2.17 Diving simulators are not generally subject to classification by LR. Where a plant is to be classed at the request of the operator, the Rules for Classification of Diving Systems shall be applied as and where relevant.

3.3 Existing submersibles diving systems and deck compression chambers

3.3.1 **Classification of units not built under survey**. The requirements of the Committee for Classification of units which have not been built under LR's Survey are indicated in *Pt 1, Ch 3, 4 Classification of units not built under survey*. Special Consideration will be given to units transferring class to LR from another recognised Classification Society.

3.3.2 **Reclassification**. When reclassification or class reinstatement is desired for a submersible, diving system or chamber for which the class previously assigned has been withdrawn or suspended, the Committee will direct that a survey appropriate to the age of the submersible, diving system or chamber and the circumstances of the case, be carried out by LR's Surveyors. If at such survey the unit be found or placed in a good and efficient condition in accordance with the requirements of the Rules and Regulations, the Committee will be prepared to reinstate her original class or assign such other class as may be deemed necessary. The data of reclassification will be recorded by LR.

3.3.3 The Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the unit indicates this to be appropriate.

3.4 Damage, Repairs and alterations

3.4.1 If a diving system has suffered damage affecting its class or if such damage may be assumed, or if the hull or parts of the machinery of the support vessel have sustained damage affecting the diving system the Owner should notify Lloyd's Register promptly and a Damage Survey is to be carried out.

3.4.2 All repairs, alterations and modifications, and all significant replacements, are to be recorded in the log book in a manner that will enable their later identification, by LR's Surveyors.

3.4.3 In addition, transferable diving systems are to undergo an Annual Survey and inspection of the supporting structure after each re-assembly and whenever there is a change of ship. Plan approval for the interface with the ship structure and systems may be required.

3.4.4 All repairs and modifications to the pressure hull, diving system or deck compression chamber, which may be required in order to be retained in Class, and all repairs and modifications affecting the buoyancy, stability and life-support systems, and all major repairs and modifications to the propulsion and manoeuvring systems, are to be carried out to the satisfaction of LR's Surveyors.

3.4.5 Depending on the nature and extent of the repairs and modifications, the Surveyors may require a subsequent test to the proof pressure and/or subsequent analysis.

3.4.6 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of the pressure hull, equipment or machinery are to be submitted for approval, and such alterations are to be carried out to the satisfaction of LR's Surveyors.

3.4.7 When at any survey the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Committee by the Surveyors.

3.4.8 When at any survey it is found that any damage, defect or breakdown (*see Pt 1, Ch 2, 1.1 General 1.1.10*) is of such a nature that does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Committee for consideration.

3.5 Existing units — Periodical Surveys

3.5.1 All units are to be surveyed at intervals in accordance with the requirements given in *Pt 1, Ch 3 Periodical Survey Regulations*.

3.5.2 Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the unit is registered.

3.5.3 The date of the last examination will be displayed on the Interim Certificate and Class Direct and recorded on the Certificate of Class as appropriate.

3.5.4 All units classed with LR are also to be subjected to Special Surveys in accordance with the requirements given in *Pt 1, Ch 3, 2.4 Special Surveys (Manned and unmanned submersibles, containers, diving systems or deck compression chambers)*. These surveys become due at 5-yearly intervals, the first at 5 years from the date of build or date of the first Special Survey for classification, and thereafter 5 years from the date of the previous Special Survey.

3.5.5 When it is inconvenient for an Owner to fulfil all the requirements of a Special Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that LR's Surveyors are afforded an opportunity, about the due date, to carry out an Annual Survey in accordance with *Pt 1, Ch 3 Periodical Survey Regulations*. Such a postponement may be granted for a period not exceeding five months. If an extension is agreed, the next period of classification will start from the date of the Special Survey before the extension was granted.

3.5.6 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, if such work is to be credited towards the Special Survey. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases the recorded date will be the fifth anniversary. In cases where the unit has been laid up or has been out of service because of a major repair or modification prior to the existing Special Survey due date, consideration may be given to a new record of Survey being assigned as the final date of survey.

3.5.7 Units which have satisfactorily passed a Special Survey will have a record displayed on the Interim Certificate and Class Direct and the new Certificate of Class issued indicating the date.

3.5.8 When, at the request of an Owner, it has been agreed by the Committee that the Complete Survey of the unit may be carried out on a Continuous Survey basis, all compartments of the unit are to be opened for survey and testing in rotation within the interval of five years for each component as appropriate. If any examination during Continuous Surveys reveals any defect, further parts are to be opened up and examined as considered necessary by the Surveyor. Units which have satisfactorily completed the cycle will have a record displayed on the Interim Certificate and Class Direct and recorded on the Certificate of Class as appropriate indicating the date of completion. If the survey on continuous basis has been agreed the Owner shall present for LR approval comprehensive survey program covering all items and survey activities planned over the five year cycle.

3.5.9 Annual Surveys are to be held on all units within three months, before or after each anniversary of the completion, commissioning or Special Survey in accordance with the requirements given in *Pt 1, Ch 3 Periodical Survey Regulations*. The date of last Annual Survey will be displayed on the Interim Certificate and Class Direct and recorded on the Certificate of Class as appropriate.

3.5.10 Intermediate Surveys are to be held on all units at the second or third Annual Survey after completion, commissioning or Special Survey in accordance with the requirements given in *Pt 1, Ch 3 Periodical Survey Regulations*. The date of completion of the last Intermediate Survey will be displayed on the Interim Certificate and Class Direct and recorded on the Certificate of Class.

3.6 Certificates

3.6.1 A certificate of Class valid for five years subject to endorsement for Annual and Intermediate Surveys will also be issued to the Owners on satisfactory completions of examinations, tests and trials for the newly constructed unit.

3.6.2 LR's Surveyors are permitted to issue provisional (interim) certificates to enable a submersible, diving system or deck compression chamber to enter or continue in service provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

3.6.3 The full class notation and abbreviated descriptive notes shall be stated on the Certificate of Class and the provisional (interim) certificates.

3.7 Notice of surveys

3.7.1 It is the responsibility of the Owner to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with these Rules and the instructions of the Committee.

3.7.2 The Owners of a diving system should notify Lloyd's Register in advance on any planned load tests or pressure tests of the system or its components.

3.7.3 LR will give timely notice to an Owner about forthcoming surveys. The omission of such notice, however, does not absolve the Owner from his responsibilities to comply with LR's survey requirements for maintenance of class.

3.8 Withdrawal / suspension of class

3.8.1 When the class of a submersible, diving system or deck compression chamber, for which the Regulations as regards surveys on the hull and systems and components have been complied with, is withdrawn by the Committee in consequence of a request from the Owner, the notation 'Class withdrawn at Owners' request' (with date) will be assigned.

3.8.2 When the Regulations, as regards surveys on the hull, or systems, or components, have not been complied with and the submersible, diving system or deck compression chamber is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation will be assigned.

3.8.3 When it is found from reported defects in the hull, or systems, or components, that a submersible diving system or deck compression chamber is not entitled to retain class in accordance with the current certificate of class, and the Owner fails to repair such defects in accordance with LR's requirements, the class will be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation indicating that class has been suspended or withdrawn because of reported defects will be assigned.

3.8.4 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will be published by members of the LR Group and displayed on Class Direct. In cases where class has been suspended by the Committee and it becomes apparent that the Owners are no longer interested in retaining LR's class, the notation will be amended to withdrawn status.

3.8.5 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey is not completed within three months of the due date of the survey.

3.8.6 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed, *see Pt 1, Ch 2, 3.5 Existing units — Periodical Surveys 3.5.8*, or is not under attendance by the Surveyors with a view to completion prior to resuming operations.

3.8.7 When a condition of class is imposed, this will be assigned a due date for completion and the installation's class may be suspended if the condition of class is not dealt with, or postponed by agreement, by the due date.

3.8.8 When the Committee is satisfied that a unit has been operated in a manner contrary to the agreed at the time of classification, or is being operated in environmental conditions which are more onerous than, or in areas other than, those agreed by the Committee, the class will be withdrawn or suspended in relation to those operations.

3.8.9 For reclassification and reinstatement of class, *see Pt 1, Ch 2, 3.3 Existing submersibles diving systems and deck compression chambers 3.3.2*.

3.9 Non-use and lay-up

3.9.1 When a unit is to be laid-up, the owner is to advise LR. The Owner shall develop the procedure for storage and the maintenance and inspection schedule during the lay-up. Maintenance activities shall be recorded in the unit's logbook.

3.9.2 The maintenance of class is dependent on LR's Surveyors making a General Examination of the storage facilities and conditions every 2 years from the initial date of lay-up.

3.10 Appeal from Surveyors' recommendations

3.10.1 If the recommendations of LR's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a Special Examination to be held.

3.11 Ownership details

3.11.1 The Owner will ensure a member of the LR Group - Marine and Offshore division is promptly informed in writing of any change to their contact details and, in the event of a vessel/asset transfer or sale, is to supply details of the new Owner in writing. The new Owner is to promptly inform a member of the LR Group - Marine and Offshore division in writing of their contact details. If the new Owner fails to do so and if LR cannot verify the ownership record, then the class of that vessel/asset will be specially considered by the Classification Committee.

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	General Requirements	Periodical Surveys and Class Notation	Inspections	Classification of units not built under survey
	Section 1	Section 2	Section 3	Section 4
Unit Type				
Manned Submersible	x	x	x	x
Wet Submersible	x	x	x	x
Unmanned Submersible	x	x	x	x
Submersible Craft	x	x	x	x
Diving Bell	x	x	x	x
Submersible Vehicle	x	x	x	x
Submersible Habitat	x	x	x	x
Submersible Container	x	x	x	x
Passenger Submersible	x	x	x	x
Rescue Submersible	x	x	x	x

Section 1
General requirements

1.1 General

1.1.1 All submersibles, diving systems and deck compression chambers together with their equipment, machinery and ancillary gear, are required to be maintained in good order by inspection testing and attention at regular intervals. The Surveyor is to be satisfied that the provision for maintenance and overhaul is adequate for the standard of work to be carried out.

1.1.2 Time-based schedules for servicing, maintenance and overhaul are to be complied and incorporated in the operating instructions for the craft or chamber. Such schedules are to be approved by LR. The times and results of work carried out in accordance with the schedules, together with details of any replacements, are to be recorded in the log book for each submersible, diving system or deck compression chamber. The records are to be readily available for examination by LR's Surveyors.

1.1.3 The following surveys and inspections are to be effected for maintenance of class and it is the Owner's responsibility to ensure that they are carried out at the specified times, and to provide facilities for supervision by LR's Surveyors, where required.

1.1.4 Sub-sea installations are to be surveyed as agreed and details should be included in the operating and maintenance instructions for each individual case. These requirements should cover Annual, Intermediate and Special Survey intervals.

1.1.5 When it has been agreed that the complete survey of the system and machinery may be carried out on the Continuous Survey basis, all compartments of the system and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see Pt 1, Ch 2, 3.5 Existing units — Periodical Surveys 3.5.9*.

1.2 Surveys for damage or alterations

1.2.1 At any time when a system and/or machinery is undergoing alterations or damage repairs, any exposed or opened parts of the system and/or machinery normally difficult to access are to be specially examined.

1.3 Unscheduled Surveys

1.3.1 In the event that LR has cause to believe that its Rules and Regulations are not complied with, LR reserves the right to perform unscheduled surveys of the system, machinery, and the applicable statutory requirements whether or not the appropriate statutory certificate has been issued by LR.

Section 2
Periodical Surveys

2.1 Annual Surveys (Manned submersibles and chambers)

2.1.1 The Surveyors are to carry out an Annual Survey of each classed manned submersible, diving system or deck compression chamber. At each survey the Surveyors are to examine the log book, the calibration records of instruments essential for safety and verify that the Operator's inspections and maintenance have been recorded.

2.1.2 Where a manned submersible is part of a sea bed installation or is attached to or forms part of a submerged structure, the Surveyors are to undertake the survey as agreed with LR. The survey may be carried out by the use of television or video recording equipment.

2.1.3 The Surveyors are to carry out a General Examination of the hull, chamber, pressure controls and equipment for damage, deterioration or contamination such as may be caused by the leakage, spillage or carry-over of oil or other detrimental substances. The Surveyors are also to examine the following where applicable:

(a) Life-support system including umbilicals;
(b) Instruments such as time clocks, pressure gauges and depth gauges. The accuracy of main instruments reading is to be checked (e.g. depth gauge, gas analyser, etc.);
(c) Navigational, tracking and communications systems;

(d) Electric batteries, fuel cells and other power sources;
(e) Corrosion control system;
(f) Manoeuvring controls, including ballast systems and arrangements for ballast movement or jettisoning;
(g) Emergency arrangements;
(h) Propulsion equipment;
(i) Examination of viewports and confirm certification remains valid;
(j) Safety interlocks/medi locks fitted on equipment such as food and medical locks, or on other equipment requiring the placement of a safety interlock, and should be tested to confirm their correct operation and that no accidental pressure loss can occur resulting from their operation;
(k) Compressors, Safety devices and gas purity test records;
(l) Heating, cooling and ventilation arrangements;
(m) Control, alarm and safety systems;
(n) Analysers;
(o) Gas storage and safety device arrangements;
(p) Fire protection, detection and extinction arrangements to be examined;
(q) Escape and evacuation arrangements including hyperbaric lifeboats where fitted;
(r) Documents relating to the diving system and operational records;
(s) Entire compression chamber system, including all fixtures, penetrations, doors and covers, seals, locking systems etc. inspected for visible damages, cracks, deformation, corrosive attack and fouling;
(t) All other pressure vessel apparatus, valves, fittings and safety equipment subject to external inspection;
(u) Entire power supply system, including the emergency supply, of the diving system is to be subjected to external inspection. Insulation measurements are to be performed on the electrical equipment.
(v) Switching from the main to emergency electricity supply is to be tested;
(w) All high-pressure gas supply and charging hoses and the hoses belonging to the heating system and the umbilical are to be checked for visible damage and tightness.

In general, controls, systems and circuits need not be stripped down or dismantled for the surveys unless this is normal maintenance procedure or the Surveyors have reason to believe that the system or any component part is defective.

2.1.4 For the lifting gear the following is to form part of an Annual Survey: *See also* LR *Code for Lifting Appliances in a Marine Environment, July 2019 Ch 12, 1.7 Launch and recovery systems for diving operations* and *Ch 12, 3 Survey requirements*, *Table 12.3.5 Annual Thorough Examination of cranes and launch and recovery systems for diving operations* regarding periodic survey of lifting gear:

(a) An inspection of the wire, rope or cable;
(b) A reeving test is to be made in conjunction with the inspection of the cable anchoring device on the drum, and the spool mechanism, if fitted;
(c) A General Examination of the frame and operating equipment;
(d) A static test of 1.5 times the safe working load, and having regard to the range of operation a functional test at 1.25 times the safe working load;
(e) A static test of the secondary brake, where fitted;
(f) A dynamic test on the brake. The brake should be capable of stopping 1.1 times the safe working load in air under simulated power failure;
(g) Where the diving system is approved with hoisting factor of more than 1.7, the test loads indicated in d) and f) are to be increased by the ratio of F_h/1.7 as specified in *Code for Lifting Appliances in a Marine Environment, July 2019 Ch 12, 1.7 Launch and recovery systems for diving operations 1.7.2*.

A test is to be carried out for lifting gear designed to operate on dynamic response, or for those incorporating shock absorption other than relying on the rope, to demonstrate satisfactory operation of the controls under simulated power failure at maximum outreach with maximum in air working load.

2.1.5 On completion of the examination and tests, submersibles other than those with permanent moorings are to undergo a test dive to a depth agreed by the Surveyors. On completion the Surveyors are to examine the submersible for leaks or damage.

2.1.6 For the purpose of Annual Survey the Surveyors may accept at their discretion a report from a competent representative of the Owner or a recognized Authority as an alternative to witnessing the whole or part of the foregoing tests and inspections.

2.2 Intermediate Survey (Manned submersibles and chambers)

2.2.1 Intermediate Survey shall be carried out at the second or third Annual Survey after a Special Survey, of a manned submersible or compression chamber. The following requirements apply in addition to those given in *Pt 1, Ch 3, 2.1 Annual Surveys (Manned submersibles and chambers)*.

(a) The hull or main pressure vessel is to be tested in accordance with *Pt 5, Ch 4, 6.4 Gas leak test for all chambers and breathing gas systems*;

Note For equipment designed for 1 atmosphere internal pressure this requirement is met by the Annual Survey test dive. *See Pt 1, Ch 3, 2.1 Annual Surveys (Manned submersibles and chambers) 2.1.5*;

(b) Pressure circuits are to be tested for leaks and correct functioning at the working pressure. This is to include pressurized sanitary discharges where fitted. The life-support system is to be checked over a period of at least one hour. To conserve helium, air testing with the minimum of this gas for leak detection may be used on appropriate circuits;

(c) Functional tests on mechanical and electrical equipment, life support systems, fire warning and extinguishing systems, all alarm systems. Functional and purity check on all breathing gas compressors.

2.3 Intermediate Survey (Unmanned submersibles and containers)

2.3.1 Unless more frequent surveys are requested by the Owners or deemed necessary by the Committee, unmanned submersibles and containers are to be surveyed by LR's Surveyors at or around second or third anniversary of Special Survey provided interval between any two periodical surveys does not exceed thirty six months. The requirements equivalent to *Pt 1, Ch 3, 2.1 Annual Surveys (Manned submersibles and chambers)* relevant to the particular unmanned submersibles are to be complied with.

2.4 Special Surveys (Manned and unmanned submersibles, containers, diving systems or deck compression chambers)

2.4.1 Prior to the commencement of the Special Survey, a meeting is to be held between the attending Surveyor(s), the Owner/Owner's representative and the thickness measurement company representative so as to ensure the safe and efficient conduct of the survey and thickness measurements to be carried out. In preparation for the survey and thickness measurements and to allow for a thorough examination, some removal of insulation may be required.

2.4.2 Thickness measurements are normally to be taken by means of ultrasonic test equipment and are to be carried out by a firm approved in accordance with LR's *Approval for Thickness Measurement of Hull Structure*.

2.4.3 The survey will not be considered complete until all required thickness measurements have been carried out. Such measurements are to be witnessed by the Surveyor(s) to the extent necessary to control the process.

2.4.4 At the Special Survey the Surveyors are to complete the tests and inspections required at Annual Surveys, *see Pt 1, Ch 3, 2.1 Annual Surveys (Manned submersibles and chambers)*, and are to undertake all the tests and inspections required to establish to their satisfaction, the condition and operation of the unit as a whole. The Owner is to provide proper facilities for the survey to permit thorough inspection of the shells, fittings and attachments. Important equipment is to be opened up, as necessary, for inspection.

2.4.5 Acrylic viewport windows are to be dismounted and examined for incipient cracks. Window seating's are to be examined for corrosion, Unless otherwise agreed, the windows should be renewed at 10 year intervals.

2.4.6 Where a submersible is anchored to the sea bed or forms part of an underwater structure, the whole or selected areas of the external surface as deemed necessary by the Surveyors are to be suitably cleaned by water jet equipment or other means to permit inspection. If the underside of the submersible is silted up, this is to be cleaned to facilitate inspection of the surface and any attachments.

2.4.7 Where the structure is retained on the sea bed by gravity, the support is not to be disturbed by the cleaning required by *Pt 1, Ch 3, 2.4 Special Surveys (Manned and unmanned submersibles, containers, diving systems or deck compression chambers) 2.4.6*. If significant scour has occurred it is to be rectified.

2.4.8 The extent of the Special Survey on a sub-sea installation is to be defined before it is effected, and the divers are to be approved by LR and informed fully of the required work and competent to undertake it. Sub-sea installations may be externally inspected by the means of ROV provided the operator of the vehicle is approved by LR for the in water survey activities. Divers and ROV operators are to be provided with close circuit television equipment and video recording equipment so that the Surveyors can view the necessary areas of the chamber, and the equipment, and check that any tests and opening up have been effected.

2.4.9 Following examinations and tests to be carried out:

(a) The pressure vessel or hull, and associated items contributing to the strength are to be examined for cracks, wastage and damage. Stripping of the shell to bare steel or other material of construction will not normally be required. However, some regions may be required to be exposed if the Surveyors have doubts about the condition and cannot establish it by other means.

(b) All ballast systems are to be examined and checked for proper operation. This includes releasable ballast weights;

(c) Pressure chambers and pressure hulls, except those located permanently under the sea, are, unless otherwise approved, to be subjected to over pressure tests generally to the level applied at the time of manufacture. In the case of a deck compression chamber, diving bell or other type of submersible, which may be subjected to external or internal pressure, either directly or due to differential pressure between compartments, over pressure tests are to be applied appropriate to the modes of service pressurisation. Prior to a pressure test, any delicate equipment that might be damaged by the test pressure should be removed or protected otherwise. Pressure tests may be hydrostatic or pneumatic. In the latter case the test pressure should be 1.1 times the maximum working pressure and conditions are to be in accordance with the requirements of a design pressure vessel code, including measures to protect personnel;

(d) On completion of these pressure tests, equipment which was subjected to the pressure should be examined for damage and checked for satisfactory operation;

(e) Emergency ballast release and buoyancy tests are to be performed with the diving bell;

(f) All important piping systems are to be pressure tested hydraulically, or by gas as appropriate. The test pressure and conditions are to be in accordance with the requirements of a design pressure vessel code, including measures to protect personnel;

(g) Where a system normally contains a fluid or material which could present a hazard in the event of leakage or rupture, the integrity and tightness are to be established. This applies particularly to systems containing mercury. As this material can also promote cracking of certain metals, components should be examined for cracks;

(h) Propulsion and other components or systems are not normally required to be opened up where they are originally accepted on ‘maintenance by replacement’. The Surveyor is to ascertain that these units have not exceeded the scheduled running time or time for replacement or overhaul, or are unlikely to do so before the next Annual Survey is due. The mountings of these items are to be examined and the state of each item is to be judged from external appearance and functional tests as far as practicable;

(i) All glands at penetrations of the hull are to be carefully examined together with associated cables, shafts, etc. Propellers fitted to submersibles and their connections are to be examined;

(j) Lifting gear, including winches and frames, is to be carefully examined together with the attachments to the floating or fixed structure and is to be opened up for examination as necessary;

(k) Dimensional checks and non-destructive wall thickness tests are to be performed on the diving bell. Where necessary, buoyancy aids, cladding and layers of thermal insulation are to be removed for this purpose;

(l) Shackles and links of lifting gear for tethered or towed submersibles are to be thoroughly examined and tested;

(m) Pressure vessels and apparatus not capable of satisfactory internal inspection and those whose satisfactory condition cannot be definitely established by internal inspection are to be inspected by another non-destructive method of examination or are to be subjected additionally to a hydraulic pressure test.

2.4.10 At the first special survey critical areas as established by the attending surveyor and areas with the indications of coating defects should be subject to random ultrasonic thickness measurements.

2.4.11 At the second and subsequent special surveys dimensional checks and ultrasonic thickness measurements are to be performed on the diving bell, deck compression chambers and hyperbaric lifeboat compression chamber to the extent necessary to establish any corrosion diminution. Buoyancy aids, cladding and layers of thermal insulation are to be removed for this purpose where necessary.

2.4.12 Acceptance criteria for the thickness measurements required by *Pt 1, Ch 3, 2.4 Special Surveys (Manned and unmanned submersibles, containers, diving systems or deck compression chambers) 2.4.12* and *Pt 1, Ch 3, 2.4 Special Surveys (Manned and unmanned submersibles, containers, diving systems or deck compression chambers) 2.4.13* above shall be established based on design corrosion allowances as indicated by the plan approval.

2.4.13 At the Special Survey, any component found not to be in accordance with the Rules or the terms of approval, or any material, workmanship or arrangements found to be unsatisfactory are to be rectified or replaced to the satisfaction of the Surveyor.

2.4.14 On completion of all inspections and tests, trials are to be carried out to the Surveyor’s satisfaction.

2.5 Survey requirements for reactivation after lay-up

2.5.1 At the end of a period of storage and before re-commissioning the Owner is to submit the unit and equipment to a survey by the Surveyors, as indicated in *Table 3.2.1 Surveys after lay-up*.

Table 3.2.1 Surveys after lay-up

Period of storage	Manned (M) or unmanned (U)	Type of survey
6 to 18 months	M	Annual Survey
18 months to 5 years	M	Intermediate Survey
Over 5 years	M	Special survey
1 to 5 years	U	Intermediate Survey
Over 5 years	U	Special survey

2.5.2 If the Surveyors consider as a result of any of these surveys that the hull or chamber, or equipment has been damaged or dismantled, or has deteriorated significantly, the Owner will be advised and requested to make provision for further examination by the Surveyors.

■ *Section 3* Inspections

3.1 Owner's inspections

3.1.1 Between periodic surveys carried out by LR's Surveyors the Owner is expected to perform inspections and checks in accordance with a maintenance schedule agreed with Lloyd's Register.

3.1.2 In general, a classed submersible, diving system or deck compression chamber, and associated important equipment, are to be inspected and checked at intervals of about one month.

3.1.3 Manned submersibles, including wet submersibles, should be inspected and checked before each dive. In the case of those making more than one dive during a period of 24 hours without need for replenishment or replacement of on-board life-support systems or power supplies, full checks and inspections need only be made before each launch.

3.1.4 An unmanned submersible should be inspected and checked before each launch.

3.1.5 Steel cables, or fibre or nylon ropes, of tethered submersibles and those used for towing, lifting or lowering other types of submersibles, should be checked before each dive and should be inspected at least once per month. The cables and ropes are to be renewed at approved intervals. Where renewal is also dependent on a specified maximum number of lifts, these are to be carefully recorded and totalled.

3.1.6 Manned habitats which are entered only occasionally should be inspected and checked before and during each entry.

3.1.7 The log book for each classed unit is to be maintained properly and in accordance with operating instructions. The log book is to be kept in a safe place and not carried or kept on the submersible.

■ *Section 4* Classification of units not built under survey

4.1 General

4.1.1 When classification is desired for a unit not built under the supervision of LR's Surveyors, application is to be made to the Committee in writing.

4.2 Unit and equipment

4.2.1 The necessary plans, calculations, particulars and specifications of the unit and equipment are to be submitted for the approval of the Committee, together with certificates or other evidence of proving tests which have been carried out, and of surveys conducted by recognized authorities. The existing or proposed maintenance and operating instructions, as applicable, and a statement of the level of pilot and crew training, considered by the designer or Owner to be adequate for the operation of a submersible, are to be provided for consideration.

4.2.2 If the unit has already been in service, the log book is to be made available for inspection by the Surveyors.

4.2.3 Provided that the requirements of *Pt 1, Ch 3, 4.2 Unit and equipment 4.2.1* and *Pt 1, Ch 3, 4.2 Unit and equipment 4.2.2* are found to be satisfactory, the Committee will direct that a survey be held, and the Owner is to arrange that all necessary access and facilities are made available to permit the survey to the scope of Special Survey unless agreed otherwise by the Committee.

4.2.4 On the basis of a satisfactory report from the Surveyors on the survey, the Committee will assign a class notation as applicable. The date of completion of the survey will normally be the date taken as of initial acceptance by the Committee. This date will be displayed on the Interim Certificate and Class Direct and recorded on the Certificate of Class. The stated date will govern the time of the first Special survey.

4.3 Previously-classed-unit

4.3.1 Where Classification is desired for a unit which is classed by another recognized Classification Society special consideration will be given to the scope of the survey.

4.4 Plans, documents and calculations

4.4.1 Plans, documents and calculations to be submitted for information and approval in accordance with the requirements of *Pt 1, Ch 2, 3.2 New Construction Surveys* as applicable.

Contents

■ *Section 1*
Rules for the Manufacture Testing and Certification of Materials

1.1 Reference

Please see *Rules for the Manufacture, Testing and Certification of Materials, July 2019*

Contents

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

Unit Type	Pressure chamber and hull structure Section 1	Compression chambers Section 2.1	Diving bell Section 2.2	Doors and access points Section 2.3	Sea transport design requirements Section 2.4	Air transport design requirements Section 2.5	Documentation Section 3	Pressure chambers Section 4	Submersible hull Section 5	Design pressure Section 6	Design temperature Section 7	Spherical shell/shell sections subject to external pressure Section 8	Reinforcement of openings Section 9	Design features and loading factor Section 10	Submission of calculations Section 11	Fabrication and testing requirements Section 12
Manned Submersible	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Wet Submersible	x	x		x	x	x	x	x		x	x	x	x	x	x	x
Unmanned Submersible																
Submersible Craft																
Diving Bell	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
Submersible Vehicle																
Submersible Habitat	x	x		x	x	x	x	x		x	x	x	x	x	x	x
Submersible Container																
Passenger Submersible	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Rescue Submersible	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x

■ *Section 1*
Pressure chamber and hull structure

1.1 General

1.1.1 The requirements of this chapter apply to all pressure vessels for human occupancy including but not limited to submersibles, diving bells, hyperbaric chambers for life boats, diving systems, deck decompression chambers and non conventional vessels as such Diving Suits. Attention should also be given to any relevant Statutory Regulations of the country in which the unit is to be operated.

1.1.2 The pressure chambers are to be designed, manufactured and tested in accordance with the requirements of these Rules and any applicable National or International pressure vessel Standards/Regulations taking into consideration the additional loads specified in this Rule.

1.1.3 All penetrations on the pressure boundaries are to be attached to the shell by full penetration welds, irrespective of the diameter of the penetration, unless otherwise approved by LR. All joints of the pressure chambers/pressure boundaries are also to be of full penetration type.

1.1.4 It should be noted that a reinforcing pad on the penetration opening is not permitted. The preferred method of compensation for Penetration opening in the shell is:

(a) Increased shell plate thickness locally or
(b) Increased branch thickness or
(c) A combination of (a) and (b).

1.1.5 Intermediate heads for the pressure chambers should be designed and attached using the adopted national or internal pressure vessel design code. In the case where the intermediate heads' attachment are not covered by the adopted code, the heads shall be attached based on the guidance given is ASME PVHO-1.The basic allowable stress will be as per the adopted Design Code/Standard factored by the reduction factors given in ASME PVHO-1 Para 1-7.1.

1.1.6 All diving bells and compression chambers/PVHOs are to be fitted in a prominent position with a permanently mounted name plate containing at least the following details:

(a) Name of manufacturer
(b) Serial number and year of manufacture
(c) Maximum permissible working pressure or operating depth
(d) Test pressure
(e) Capacity (in litres) (of each chamber compartment)
(f) Maximum permissible number of divers
(g) Date of test and test stamp.
(h) LR Rules for Submersibles and the Adopted Design Code/Standard and year of the Rule/Code/Standards.

1.1.7 All other pressure vessels and gas bottles are to be prominently and permanently marked with the following details:

(a) Name of manufacturer
(b) Serial number and year of manufacture
(c) Capacity (in litres)
(d) Test pressure (bar)
(e) Empty weight (of gas bottles)
(f) Date of test and test stamp.

1.1.8 Permanently installed gas bottles, gas containers and gas piping systems are, in addition, to be marked with a permanent colour code in accordance with *Table 1.1.1 Marking of gas system* and with the chemical symbol designating the type of gas concerned. The marking of gas bottles must be visible from the valve side.

Table 1.1.1 Marking of gas system

Type of gas	Chemical symbol	Valve End Colour code
Oxygen	O2	White
Nitrogen	N2	Black
Air	-	White and Black
Helium	He	Brown
Oxygen/Helium-Gas mixture	O2/He	White and Brown
Note:	Extract from BS1319:1976 and IMO resolution A536 "Code of Safety for diving systems"	

1.1.9 Piping, control surfaces, etc., external to the hull of the submersible will also need protection. Protective items should be so arranged that they can be secured in position when required.

1.1.10 An appropriate FMECA (Failure Mode Effect and Criticality Analysis) which includes a safety hazards analysis, shall be carried out by the manufacturer in accordance with IEC 60812 or IMCA D-039. For diving systems an analysis concerning the function and availability of the diving system after occurrence of a single failure is to be submitted for LR review.

■ *Section 2*
Design Principles

2.1 Compression Chambers

2.1.1 Compression chambers within the Diving system are to be so designed that at least two persons can simultaneously pass in or out through the locks without exposing the other divers in the system to a pressure change.

2.1.2 In diving systems where divers are required to remain under pressure for a continuous period of more than 12 hours, the living compartment of the compression chamber is to be so designed and equipped that:

(a) Persons are able to stand upright in it,
(b) Each diver is provided with a bunk on which he is able to stretch out comfortably.
(c) Inner height of the chambers shall be no less than 2000 mm over the deck plate (measured in the middle of the chamber).
(d) Ensures the divers have a safe and comfortable working environment.

2.1.3 For surface oriented diving operations the main chambers shall have a minimum inner diameter of 1600 mm and 2000 mm length, with possibility of occupants to lie down comfortably. When surface oriented diving with decompression stops are planned, the inside diameter of the chamber shall be at least 1800 mm.

2.1.4 The living compartment of compression chambers and other compression compartments are to be provided with a lock through which provisions, medicines and equipment items can be passed to and from. The lock should be such that provisions are made so the occupants of the chamber are not exposed to a pressure change. Please also refer to *Pt 5, Ch 4, 12.11 Medical Lock*.

2.1.5 Locks are to be designed to prevent accidental opening under pressure. Suitable interlocks are to be fitted.

2.1.6 Each compression chamber compartment is to be provided with viewports enabling all occupants to be observed from outside.

2.1.7 Wherever necessary, compression chamber windows are to be protected against mechanical damage from inside and outside.

2.1.8 Each compression chamber compartment should be adequately lit, to provide a safe and comfortable working environment. For more details refer to *Pt 6, Ch 1, 1.5 Design and construction 1.5.20* of these rules, and NORSOK U-100 or any other recognised code/standard may also be used for guidance.

2.2 Diving bells

2.2.1 Each diving bell is to be so equipped that it is fully protected against excessive working pressures and inadmissible pressure drops.

2.2.2 Each diving bell is to be provided with extra lifting points designed to take the entire dry weight of the bell including ballast and equipment, plus the weight of the persons inside the bell. After release of the ballast weights, the diving bell, at its maximum service weight and with its trunk flooded, must exhibit a positive buoyancy equal to at least 3 per cent of its displacement at maximum operating depth. In these circumstances, the bell should have sufficient stability to maintain a substantially upright floating position.

2.2.3 Close to main lift attachment, the diving bell is to be provided with spare connections for hot water (3/4" NPT female thread) and breathing gas (1/2" NPT female thread), ¼” NPT female (gas analysis) ¼” NPT (depth) and communication and emergency power supply connections as per IMO 808E and IMCA D051 is to be provided. The manifold is to be clearly marked and effectively protected. Where applicable NORSOK U-100 or any other recognised code/standard may also be used for guidance.

2.2.4 Diving bells are to be designed to allow entry and exit even in an emergency.

2.2.5 Diving bells are to be equipped with a device for the recovery of an unconscious diver.

2.2.6 The dimensional design of diving bells shall be such as to provide adequate space for the proposed number of divers and their Seating is to be provided for each diver in the diving bell.

2.2.7 Diving bells are to be provided with viewports.

2.2.8 The lifting and towing points on diving bells are to be designed with a design factor adequate to the accelerations and used in lifting and towing forces defined in *Pt 3, Ch 1, 10.1 General 10.1.2*/*Pt 4, Ch 1, 3 Attachment Points* and *Pt 4, Ch 1, 4 Alternative Lifting Points*. Any doubling pad used in lifting or towing points connection shall be checked for through thickness properties and integrity. Plates shall have an adequate penetration weld within the bell body.

2.3 Doors and access points

2.3.1 Diving bell hatches and mating devices which are not sealed by pressure are to be fitted with a locking mechanism which prevents opening under pressure. The locking mechanism is to be so designed that the correct closure position is clearly apparent before pressure is applied.

2.3.2 Devices are to be fitted to enable doors to be opened from both sides. Hatch trunks are to be fitted with pressure compensating valves.

2.3.3 Doors and hatches for persons are required to have a clear opening at least 600 mm in diameter. For diving bell lockout/-in hatches the clear diameter shall be at least 700 mm. The bottom trunk for the entry into and exit from the diving bell shall have an inner diameter of minimum 800mm.

2.3.4 The trunks are to have a minimum internal diameter of 610 mm (24"). Longer trunks are to be adequately designed and reinforced to ensure stability. They are to be provided with handholds and footholds on horizontal plane for personnel safety.

2.4 Sea transport design requirements

2.4.1 When submersibles and diving systems are stowed on the deck of a ship or floating offshore unit, their cradle or other means of support should be capable of retaining them securely in position without damage or uplift under the following conditions acting simultaneously:

(a) a horizontal (transverse or longitudinal) acceleration of 0,5 g_n (This is equivalent to an angle of roll or pitch of 30°)

(b) a vertical acceleration of 1,0 g_n

(c) a wind force of 0,00246 N/mm^2 (250 kg/m^2) on the projected area of the submersible and its cradle.

Note

* (1) Wind force may be applied separately from the acceleration loads defined above.

* (2) The accelerations from the actual ship motion analysis can be used in the case where they are more stringent please refer to *Pt 5, Ch 1, 2.2 Environmental conditions* for environmental loads.

(3) For the operational phase please refer to *Pt 5, Ch 1, 2.2 Environmental conditions* for environmental loads.

(4) Handling system loads, hydrostatic test loads and docking/mating loads need also to be considered for permanently installed units.

2.5 Air transport design requirements

2.5.1 British Civil Aircraft regulations specify crash case design requirements as given below for certain items and it is suggested that eye-plates, etc., intended for securing submersibles to their cradles, or their equivalent, be designed to this standard wherever air freighting is a possibility:

(a) 4,5 g_n downwards to 2,0 g_n upwards

(b) 1,5 g_n aft to 9,0 g_n forward

(c) zero to 2,25 g_n sideways But maximum resultants considered need not exceed 9,0 g_n. It is, realized that certain components within a submersible may not be able to survive such accelerations, which are based on crash conditions, but it is considered that the values of acceleration recommended will be an adequate design basis, for all items, for normal flight conditions.

■ *Section 3* Documentation

3.1 General

3.1.1 Plans and calculations are to be submitted, as necessary, to amplify and verify the specifications, to LR's satisfaction. The plans and calculations will depend on the design and purpose of the submersible or chamber but will generally include the following where applicable:

(a) Chamber or hull strength.

(b) Accelerations and dynamic loads.

(c) Resistance and propulsion loads, powers and reactions.

(d) Main and auxiliary power requirements.

(e) External loads due to external pipings, external attachment and loading resulting from acceleration referred to in *Pt 3, Ch 1, 2.4 Sea transport design requirements 2.4.1*, including loads e.g. trunking load, expansion, wind.

(f) Deck deflections as applicable.

(g) Fatigue assessment due to pressure cycles / external (acceleration) cyclic loads based on wave scatter data of the region. Wave scatter data from a recognised source should be used.

(h) Cradle or support design and arrangement.

3.1.2 The calculation procedure proposed for determining the scantlings of the pressure chamber or hull, or its equivalent, is to be submitted for consideration at an early stage and the derived calculations, and conclusions drawn there from, are, where practicable, to be submitted for scrutiny before construction Of the submersible is commenced.

3.1.3 Where computers are used for calculations, LR is to be satisfied as to the capability, accuracy and reliability of the software programs used and of the arrangements used to verify input data before processing.

3.1.4 Calculations of pressure chamber or hull stresses are, where practicable, to take into account the interaction of the pressure chamber or hull with attached hatches, windows, rigid fixtures, mechanical components and hull penetrations, etc., with particular reference to the possibility and effect of stress flow distortions due to constructional details and techniques and to pressure at various depths of submergence.

3.1.5 The drawings of a pressure chamber or hull are to show clearly all relevant dimensional tolerances including permissible out-of-roundness and local departures from shape. The design calculations should take account of the combination of the most unfavourable tolerances.

3.1.6 In calculating the scantlings of isobaric chambers, including the attachments and fastenings of access hatches, windows and viewing ports, consideration is to be given to the possibility of accidental pressurization of the chamber in the reverse sense to that used for the basic design. The differential pressure used in the design calculations for this eventuality should not be less than two atmospheres unless especially agreed otherwise by LR.

3.1.7 When dynamic loads are being calculated, and use is being made of statistical methods, LR may require an increased load factor if the available statistical data is considered to be insufficient or unreliable.

3.1.8 The type and sophistication of the calculations will depend on the design, materials and purpose of the components under consideration, and it is anticipated that for many items computers will be used for stress analysis. Designers are free to submit, for consideration calculations based on design philosophies other than those given in *Pt 3, Ch 1, 3.1 General 3.1.1* and *Pt 3, Ch 1, 3.1 General 3.1.3*.

3.1.9 Where applicable, for habitats on the sea bed, the design of sea bed mounting is to be carefully considered and all external parts shall be faired to prevent snagging.

3.1.10 The whole concept is to be designed with a view to access and maintenance.

■ *Section 4* Pressure Chambers

4.1 General

4.1.1 Pressure vessels associated with diving systems and submersibles are to be designed generally in accordance with the appropriate pressure vessel standards, National Regulations or International Standards, taking into consideration the additional loads specified in these Rules and project specifications.

4.1.2 Scantlings are to be selected to take care of corrosion during service. Adequate corrosion allowance should be considered

4.1.3 The design, construction and testing of manned pressure chambers is to be to LR class 1 pressure vessel requirements or highest integrity class of the applicable pressure vessel code requirements.

■ *Section 5*
Submersible Hull

5.1 Design approach

5.1.1 Plating thickness for the pressure hull structure should be sufficient in combination with stiffeners (of suitable geometric proportion) to control overall buckling and orient the first failure mode encountered with increasing design pressure to inter-stiffener buckling.

5.1.2 Ring stiffeners of suitable shape "I" or "T" and suitably sized are to have an effective means of load transfer between the frame and the pressure hull plate. Stability of the stiffeners is to be checked against web buckling/frame tripping.

5.1.3 Frame /web tilting can alter the circumferential stress on the pressure hull plate and therefore adequate safety margins are to be ensured in the frame design. The largest value of bending stress in the frame design in conjunction with the worst buckling mode is to be considered.

5.1.4 Stiffeners which are external to the pressure hull plating are to be attached to the plating by full penetration welding (as per internal frame stiffeners) to avoid local stress concentration points.

5.1.5 Common sites for discontinuities such as the junction of hemisphere-cylinder/cone-cylinder/cylinder – bulkhead are to be considered during design for suitable strengthening such as providing local higher thickness inserts to minimise the stress/ mean stress levels.

5.1.6 Suitable precautions shall be taken such as not to attach structure and components to the knuckle portion of torispherical head so as to avoid the creation of a stress concentration that could adversely affect the structural performance under load.

5.1.7 Buckling response is sensitive to the geometry of the shell. The greater the deviation of the profile from the design requirement the greater the adverse effect on collapse pressure. Design of the pressure hull structure shall be checked for final approval based on the as-built circularity/out of roundness, and any deformed stiffeners including deformations as a result of any external pressure tests.

5.1.8 Internal structures such as transverse bulkheads, decks and tanks are to be adequately designed against instability and buckling due to collapse of the hull structure to which the components are directly connected/welded. Bulkheads and deck plates should be designed against applicable lateral loads. The effect of attachment across the hull diameter may affect the out of circularity due to the interaction with the welded component resulting in lowered collapse pressure. These sites are to be suitably assessed.

5.1.9 Consideration should be given to the indirect attachment of deck plates to the shell, where the deck would otherwise be subject to in plane loads due to shell deflection under hydrostatic pressure.

5.1.10 Consideration should be given to hull girder bending and the resultant stresses to determine if they are significant with respect to stresses from external pressure.

5.1.11 Viewports shall be designed as per *Pt 3, Ch 2 Acrylic Windows* and ASME PVHO-1. Design by analysis may have to be carried out for configurations not covered by code. Deflection of the frame at the sealing area is to be assessed against serviceability limits. The same considerations should be applied to other openings penetrations and hatches as required.

5.1.12 Suitable allowances on scantling thickness shall be provided to compensate for the possible corrosion, erosion and wear and tear during service.

5.1.13 Internal tanks that form part of the pressure hull boundary, and are therefore subject to external pressure should be adequately strengthened to prevent failure due to pressurisation.

5.2 Design Analysis

5.2.1 Analysis shall be carried out to a recognised method from a relevant and recognised international code of pressure vessel design, to determine collapse pressures due to general elastic stability/overall buckling of pressure envelope, symmetric and asymmetric buckling in the interframe areas in conjunction with frame tripping. Additional areas of discontinuities/stress concentration and the effects of external loads should be checked for failure by appropriate analytical methods, where not adequately covered by the pressure vessel codes. The collapse curves used from the pressure vessel code should be an equivalent to the actual material used for hull construction in terms of ultimate and yield strength. A conservative approach should be taken in arriving at the collapse pressure if there are differences in the material properties.

5.2.2 Alternatively the above may be checked by elastic/elastic-plastic FEA, eigenvalue/bifurcation buckling analysis and by elastic-plastic buckling analysis as required, specifically considering the as-built deformed geometry. No strain hardening shall be considered in the elastic-plastic material model.

5.3 Fatigue Assessment

5.3.1 Noting the likelihood of tensile residual stresses in structure created during the fabrication. Suitable consideration should be given to cyclic stresses and therefore fatigue during the life of the pressure hull structure. Fatigue assessment methods as per recognised design codes may be used to arrive at the cumulative damage ratio at the site of peak stress ranges. The magnitude of residual stresses locked in should be suitably considered. A suitable reduction factor of not less than 2 should be applied to overall fatigue life if the components are not adequately protected against corrosion. Further factors should be considered where the locations are not readily inspectable. FEA may need to be carried out to determine the peak stresses at locations not covered by code rules.

5.4 Construction and weld design requirement

5.4.1 The submersible pressure hulls of metallic construction are to be constructed in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2019*, unless more stringent requirements are specified in the applicable design and construction code.

5.4.2 All weld designs for the pressure hull, primary and secondary stiffeners, bulkheads, decks, and other structural members, are to be submitted to LR for approval.

5.4.3 Weld joints of main seam welds and attachment welds shall be staggered and located in such a way to avoid intersection of welds.

5.4.4 All the weld joints within plating and shell cut-out attachments are to be full penetration type with suitable groove/bevel. Penetrations into the shell are to be attached by full penetration groove and fillet weld. The leg length of the fillet should not be the less than the smaller of the thickness of the two parts being joined or as recommended by the applicable code.

5.4.5 Where frames/stiffeners/rings are attached to pressure hull plating by welding, suitable consideration is to be given to the weld profile to avoid stress concentrations. Spacing of the frames should be such that there is access for effective welding and NDE.

5.4.6 Where internal bulkhead/deck plates are to be attached to pressure hull plating, weld types and profiles are to be suitable so as to avoid stress concentrations. Sizing of the weld is to be based on the applicable load with required safety margin.

5.4.7 Caution should be exercised on the use of welds having any form of taper transition and it is recommended that such joints are avoided and replaced by alternative integral design such as forgings etc.

5.5 NDE

5.5.1 All main seam welds are to be examined by RT (100 per cent), and examined by MT/PT (100 per cent) for surface flaws or indications.

5.5.2 Attachment welds for shell cut-out and frame/stiffeners are to be examined by UT (100 per cent) and examined by MT/PT (100 per cent) for surface flaws or indications.

5.5.3 NDE is to be performed after the completion of fabrication/welding/rework/repair/PWHT, if and where applicable.

5.6 Pressure test

5.6.1 Pressure testing is to be carried out as per *Pt 3, Ch 1, 12 Fabrication and testing requirements* of the Rules, after completion of fabrication/welding and heat treatment, if and where applicable.

■ *Section 6*
Design Pressure

6.1 General

6.1.1 The design pressure is to be that corresponding to the maximum depth at which the submersible will operate in normal service, or the maximum working pressure. In no case shall the design pressure exceed the calculated maximum allowable pressure obtained for the weakest part of the pressure hull. Pressure chambers subject to both internal and external differential pressures are to be designed to be suitable for both operating pressure conditions.

■ *Section 7*
Design Temperature

7.1 General

7.1.1 Manned pressure chambers are to be designed to be suitable for an operating range of minus 18°C to +66°C unless otherwise specified. However the compression chambers installed under environmentally controlled condition where the lowest possible temperature which the PVHOs or the system may be exposed to during installation and operation irrespective of pressure is not below minus 10°C, the minimum design temperature of minus 10°C can be accepted. Other pressure chambers such as SDC/Diving Bell/Rescue Chambers/Hyperbaric Life Boats are to be designed for a minimum design temperature of minus 18°C unless otherwise justified that the equipment will never be exposed to temperature below minus 10°C.

7.1.2 Manned chambers outside the limits in *Pt 3, Ch 1, 7.1 General 7.1.1* are to be placed in a suitably protected location where the ambient temperature range of the location is within the limitations given by *Pt 3, Ch 1, 7.1 General 7.1.1*.

7.1.3 The design temperature for other pressure vessels associated with diving systems, submersibles and underwater installations is to be based on appropriate environmental and operating conditions and in compliance with the adopted code/standard.

■ *Section 8*
Spherical shell/shell sections subject to external pressure

8.1 General

8.1.1 Pressure boundaries are to be checked for external pressure as applicable based on the procedure and allowable stress specified in the applicable pressure vessels design code.

Note It is permitted to use actual minimum material properties extracted from LR approved material certificates instead of specified minimum values specified in codes/standards to derive the allowable design stress for the material concerned. The material should be from an LR approved works and appropriate records are retained of:

(a) The tests made to determine the relevant values corresponding to ultimate tensile strength σ_u and yield strength σ_y
(b) The tests made to derive the relevant value corresponding to yield strength at design temperature which can be related to material(s) used in the part(s) of vessel(s) under consideration.

Section 9
Reinforcement of openings

9.1 General

9.1.1 In general the calculations for the amount of reinforcement required shall be in accordance with the applicable pressure vessel code/standard.

Section 10
Design features and loading factor

10.1 General

10.1.1 The design of external attachments and shell/hull penetrations subjected to external loads are to be given careful consideration in order to ensure that the chamber structure is not overstressed under the combined pressure and external loads.

10.1.2 Unless otherwise agreed, the unfactored accelerations of the submersible as a whole, due to collisions or other emergencies, should be assumed to be not less than 3 g_n in the horizontal direction. When a submersible/diving bell is designed to be slung or jacked up and down during launching, recovery or storage, then upward and downward accelerations should be assumed to be not less than 2 g_n. Generally the sea state for man-submersible handling systems should not exceed Sea State4. Special consideration will be given to cases where diving operations service in more severe sea state is envisaged for manned diving operations.

10.1.3 When the effect of impact loads, sudden control forces and similar loads are being calculated, the resulting accelerations of the submersible as a whole should be such as to give dynamic balance.

10.1.4 Viewports and windows of manned submersibles are to be arranged in positions suitable for the control of the submersible. Where control can be shared between the pilot and another crew member, then both pilot and crew members should be provided with viewports having similar views to one another in the forward and one other direction (generally downwards in the case of submersible craft).

10.1.5 All diving bells and compression chambers are to be fitted with viewports to allow observation of the occupants from the outside.

10.1.6 Tanks forming an integral part of the hull of a submersible are generally to be designed to be suitable for a hydraulic test pressure of 1.5 times the maximum differential pressure for which they are designed to be used in service.

10.1.7 Attention is drawn to the danger of leaving hatches, etc., open when a submersible is being launched, towed, or recovered, and consideration should be given to the introduction of design features to minimize such an occurrence. It is presumed that the operating instructions will prohibit the opening of surface access hatches during launching and recovery operations. Where appropriate, alarm systems should be provided to avert this kind of situations.

10.1.8 Submersibles and chambers designed for atmospheric internal pressure are to be provided with means to accommodate under/over pressure on return to the surface.

10.1.9 Transfer under pressure systems such as chamber/bell mating systems, diver evacuation system, food and equipment locks are to be provided with safety interlocks which prevent inadvertent uncontrolled loss of pressure. Also doors between such compartments should not be able to be opened until pressures have been equalized. Interlock should prevent the lock or mating trunk being pressurized unless the clamp or door is properly secured.

10.1.10 Hatches' manway can be designed in line with the guidelines of Appendix 1-6(g) of ASME Sect VIII Div 1, or the appropriate requirements of the adopted national or international design code/standard. Care is to be taken so that the centreline of the spherically dished head passes through the centroid of the flange. O-ring if applicable is to be located at the most appropriate radius of the flange. The connection of the dished head to flange shall include fillet(s) of radius not less than 10mm.

10.1.11 The retainer ring and the fasteners for the viewports shall be fabricated from materials that are compatible with the viewport flanges. The retainer ring and the associated fastening arrangement shall be designed with an adequate safety factor based on UTS, and a design pressure forcing the window against the retainer ring shall not be less than 5 psi(g) if there is no higher pressure acting during operation. ASME PVHO-1 may be used for guidance.

10.1.12 Diving bells, pressure vessels and hard structure of Diving Systems subjected to greater external pressure than internal pressure, the Designer shall provide evidence that the structure has sufficient collapse strength to withstand maximum operating pressure (including a factor of safety).

■ *Section 11*
Submission of Calculations

11.1 General

11.1.1 Where particular designs or the materials of construction (such as carbon reinforced plastics or glass reinforced plastics) are beyond the scope of preceding sections detailed calculations, together with supporting experimental evidence of satisfactory service of an equivalent design are to be submitted for consideration. Should the material creep at ambient temperatures, the factor of safety used for the design is to be that applicable to the hull structure at the designed depth/pressure and maximum design temperature.

11.1.2 Consideration is to be given, at the design stage of a chamber or submersible, to the avoidance of fatigue failure from cyclic or repeated stress during the working life due to pressure cycles / external load (acceleration) cycles. In this respect compliance with the relevant requirements of a National or international code/standard for the design and construction of pressure vessels (e.g. PD 5500, ASME Sect VIII) is acceptable to LR.

■ *Section 12*
Fabrication and testing requirements

12.1 General

12.1.1 The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships, Book A, Procedure MQPS 0-4*.

12.1.2 All manned chambers under internal and external pressure require the following to be carried out;

(a) 100 per cent radiography on all major welds. Welds not subjected to radiography shall be examined by other approved non-destructive testing methods. The use of gamma ray examination may be used only if specifically approved;

(b) in general, 'tell-tale' holes should not be drilled in compensating plates which will be subjected to external pressure. Where 'tell-tale' holes have been drilled in compensating plates, they are to be fitted with taper-screw plugs and seal welded prior to the hydrostatic pressure test, and are to remain efficiently plugged and sealed during service;

(c) post weld heat treatment may be required. Each case will be considered individually based on applicable Pressure Vessel code;

(d) diving bells/chambers subject to external pressure are to be subjected to an external test pressure of 1,3 times the maximum agreed working pressure when tested in open water and to an external test pressure 1,4 times the maximum agreed working pressure if tested in the test chamber. Test pressures other than the foregoing will be given consideration;

(e) after hydrostatic test, all pressure retaining welds and / or seal welds shall be examined in accordance with the requirements for either magnetic particle examination or liquid penetrant examination;

(f) intermediate heads for the pressure chambers should be designed and attached using the adopted national or international pressure vessel design code. In the case where the intermediate heads' attachment are not covered by the adopted code, the heads may be attached based on the guidance given in ASME PVHO-1. The basic allowable stress will be as per the applicable design code/ standard;

(g) spherical shell and spherical segment head shall be post weld heat treated irrespective of thickness. Heat treatment of the formed heads and the testing of the formed heads material will be considered individually;

(h) production tests will be carried out in line with the requirements of the code being followed in agreement with the attending Surveyor;

(i) the lifting block or the reinforcement plate for attaching the lifting block on the top of the diving bell are to have through thickness properties and be subject to appropriate NDE (UT & MT). The attachment welds are to be subject to UT & MT to Surveyor's satisfaction.

Section

■

Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	Windows, flanges, retaining rings and seals	Documentation and marking	Limiting conditions	Protection	Materials	Window geometry and thickness: General	Thickness	Other components: windows, flanges	Window seats	Impact protection	Seals	Retaining rings	Dimensional tolerances of surface finish	Manufacturer of windows: manufacturing process	Fabrication procedure	Installation of windows	Testing and inspection: pressure testing	Inspection
	Section 1	Section 1.2	Section 1.3	Section 1.4	Section 2	Section 3.1	Section 3.2	Section 4.1	Section 4.2	Section 4.3	Section 4.4	Section 4.5	Section 4.6	Section 5.1	Section 5.2	Section 6	Section 7.1	Section 7.2
Unit Type																		
Manned Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Unmanned Submersible																		
Submersible Craft																		
Diving Bell	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Vehicle																		
Submersible Habitat	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Container																		
Passenger Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Section 1
General

1.1 Windows, flanges, retaining rings and seals

1.1.1 Acrylic Windows in the hull of pressure chambers used in diving systems for human occupancy require careful design, manufacture installation and maintenance of the windows, flanges, retaining rings and seals.

1.1.2 Before commencement of the manufacture of windows (or viewports) for submersibles and habitats intended to be classed with LR, the Surveyors are to be satisfied with the conditions and processes of manufacture. Plans of Windows are to be submitted for approval, and the Surveyors are to witness the pressure tests defined in *Pt 3, Ch 2, 7 Testing and inspection*.

1.1.3 Flat acrylic windows shall be renewed every 10 years; for some other type windows may have an extended life depending on shape, construction, geometry and design, for more details reference shall be made to PVHO-1.

1.1.4 The design, materials, manufacturing, inspection and testing of the acrylic windows / viewports are to be as per ASME PVHO-1 latest edition or the edition applicable during order acceptance. Replacements will be as per the code edition as agreed.

1.2 Documentation and markings

1.2.1 The documentation required by *Pt 3, Ch 2, 1.2 Documentation and markings 1.2.2* to *Pt 3, Ch 2, 1.2 Documentation and markings 1.2.5* is to be supplied by the manufacturer.

1.2.2 A material test certificate from the Supplier for each batch of acrylic plastic giving the minimum values of the physical properties in as cast or annealed condition indicated in ASME PVHO-1

1.2.3 A certificate of fabrication for each window indicating all forming, machining, polishing, heat treatment and inspection methods used by the manufacturer

1.2.4 A certificate of pressure testing indicating test pressure, test temperature, rate of pressurization and duration of pressure test.

1.2.5 All windows are to have identification markings corresponding to the suppliers' certification details. Windows complying with these requirements and those of ASME PVHO-1 are to be identified with the markings required by ASME PVHO-1 preceded by the symbols "LR". Wherever possible, the marking is to be engraved in the non-load-bearing portion of the window edge.

1.3 Limiting conditions

1.3.1 The requiring of these Rules do not apply to acrylic plastic Windows under the following conditions:

(a) Operating temperatures below minus 20°C and above +66°C;
(b) Where the rate of pressurization or depressurization exceeds 1.0 N/mm^2 per second;
(c) In environments other than water, sea water, air or gases used in life-support Systems;
(d) Where the number or total duration of pressure cycles during the operational life of the pressure chamber exceeds 10,000 cycles or 40,000 hours, respectively;
(e) Where the underwater operating pressure exceeds 138 N/mm^2;
(f) Where the exposure to nuclear radiation exceeds 4 Megarads.

1.3.2 LR may give consideration to designs outside these rule requirements.

1.4 Protection

1.4.1 Plans are required to indicate what protection is to be afforded to viewports, etc.

1.4.2 Where acrylic plastics are used, covers are to be supplied to protect them during transport and storage. If these covers are made of polyethylene or similar material they will not, themselves, cause damage to the viewports during fitting or removal.

■ *Section 2* Materials

2.1 Acrylic plastic

2.1.1 These Rules apply only to windows manufactured from cast stocks of acrylic plastic satisfying the physical requirements set out in ASME PVHO-1. Laminated material is not acceptable for use in the manufacture of acrylic windows. All acrylic sheet casting shall have a nominal thickness of ½ inch or greater

2.1.2 A minimum of two test samples are to be cut and tested from each sheet of casting. The acrylic castings from which the windows are produced must meet the minimum physical properties as well after the castings have been annealed.

■ *Section 3* Window geometry and thickness

3.1 General

3.1.1 These Rules, in general, apply only to window geometries shown by *Figure 2.3.1 Standard Window Type and Geometry – 1* and *Figure 2.3.2 Standard Window Type and Geometry – 2 need to get HQ from Energy*.

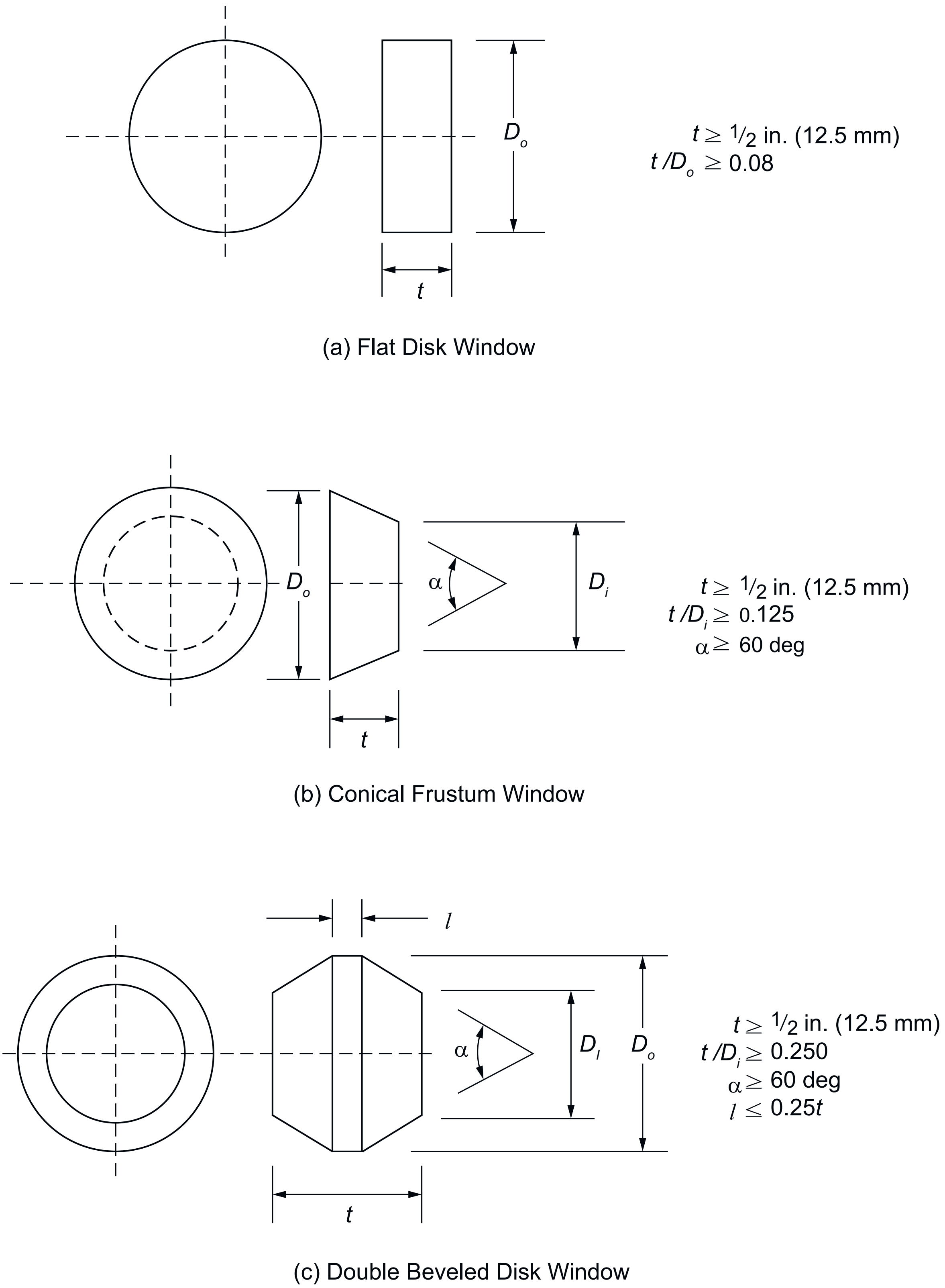
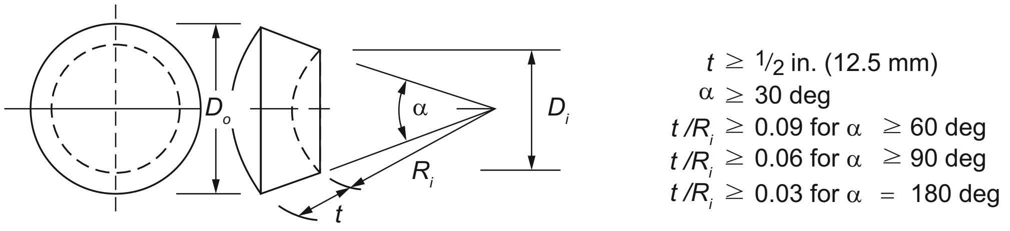
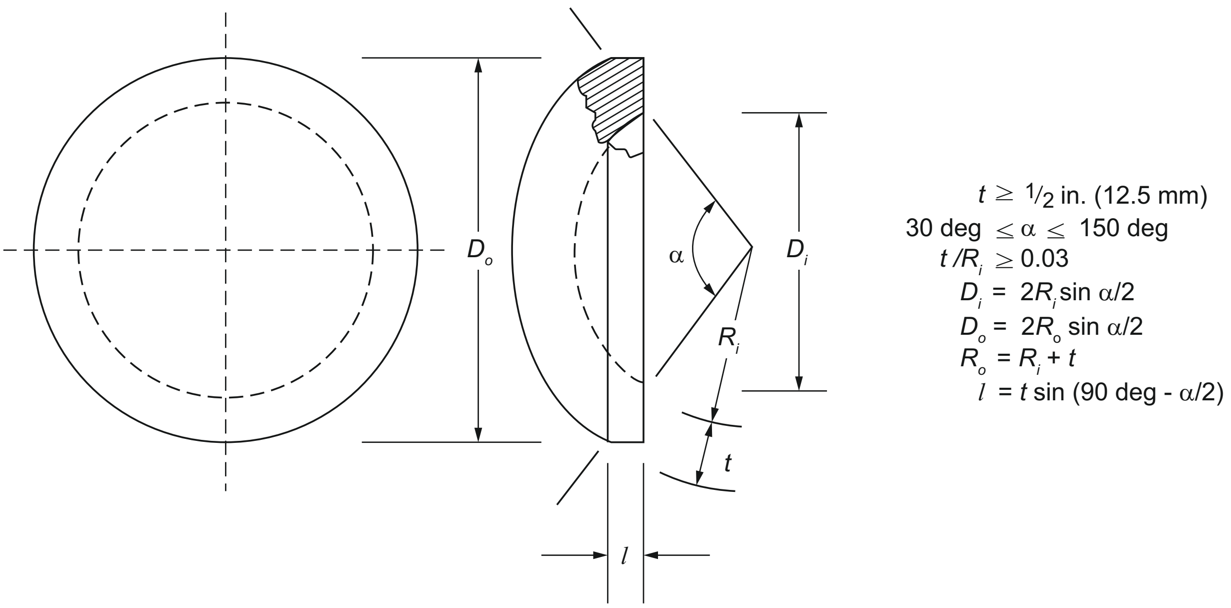


Figure 2.3.1 Standard Window Type and Geometry – 1



(a) Spherical Sector Window With Conical Edge



(b) Spherical Sector Window With Square Edge

Figure 2.3.2 Standard Window Type and Geometry – 2 need to get HQ from Energy

3.2 Thickness

3.2.1 The thickness of the window is a function of window geometry, maximum operating pressure, and operating temperature at the maximum operating pressure. Where not covered by these rules, windows may be designed using ASME PVHO-1 or equivalent national or international code/standard.

■ *Section 4*
Other components

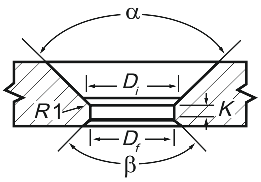
4.1 Windows, flanges

4.1.1 Window flanges are to be designed to meet the reinforcement requirements for pressure chamber penetrations and in addition the following minimum requirements should be met. Also refer to ASME PVHO-1.

4.2 Window seats

4.2.1 Radial deformation of the window seat at the internal or external design pressure shall be not more than 0,002D_i (D_i = as shown in *Figure 2.4.1 Seat cavity requirements (Also refer to ASME PVHO-1)*).

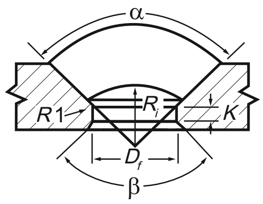
4.2.2 The angular deformation of the window seat shall not exceed 0,5 degrees at the design pressure. Specifications for some standard flanges are given in *Figure 2.4.1 Seat cavity requirements (Also refer to ASME PVHO-1)*.



D_i /D_f Ratios

Operational Pressure Range	Included Angle, deg 60	90	120	150
N=1	1.02	1.03	1.06	1.14
N=2	1.04	1.06	1.12	1.28
N=3	1.08	1.09	1.17	1.36
N=4	1.10	1.20	1.20	1.42

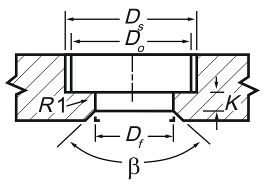
(a) Conical Frustum Window



[2R_i sin(α/2)]/D_f Ratios (Spherical Sector With Conical Edge)

Operational Pressure Range	Included Angle, deg 30-180
N =1	1.02
N =2	1.03
N =3	1.05

(b) Spherical Sector Window With Conical Edge



1.250 ≤ D_o/D_f

(c) Flat Disk Window

GENERAL NOTES
(a) For α between values shown, interpolation is required.
(b) 1⁄32 in. (1.0mm) ≤ $R1$ ≤ 1⁄16 in. (2.0 mm).
(c) K is selected on the basis of the structural analysis.
(d) β is selected on the basis of optical requirements.

Figure 2.4.1 Seat cavity requirements (Also refer to ASME PVHO-1)

4.3 Impact protection

4.3.1 Large viewport windows are to be provided with impact protection capable of absorbing a 1,0 m/second collision between the diving system and a rigid flat wall. Windows of thicknesses ≥ 90 mm are considered to be acceptable without special impact protection.

4.4 Seals

4.4.1 The sealing arrangement of acrylic windows shall satisfy the requirements of *Pt 3, Ch 2, 4.4 Seals 4.4.2* to *Pt 3, Ch 2, 4.4 Seals 4.4.4*. Also refer to ASME PVHO-1.

4.4.2 A primary seal of soft elastomer gasket material resistant to damage by ozone is to be fitted between the retaining ring and the window on the high pressure side. This seal shall be of sufficient thickness to permit an initial compression as specified in *Pt 3, Ch 2, 4.5 Retaining Rings* without permanent set.

4.4.3 In the case of flat disc windows a secondary support is to be fitted between the window and the sealing surface correctly bonded with contact cement to the metal flange seat and of thickness not exceeding 3.0 mm. The hardness of this seal should be less than 80 Shore hardness A.

4.4.4 Sealing ring grooves are not allowed in any bearing surface of the viewport unless the cyclic fatigue life of the assembly is determined by testing at the required design pressure and temperature and is greater than 10000 pressure cycles. The test details are to be submitted for approval.

4.5 Retaining Rings

4.5.1 Retaining rings shall provide the following minimum initial compression of the seals (also refer to ASME PVHO-1):

(a) Conical frustum windows: $\left(\dfrac{0.015D_i}{\tan\left(\frac{\alpha}{2}\right)}\right)\text{n}\ \ mm$

(b) Spherical sector windows: $\left(\dfrac{0.015R_i}{\sin\left(\frac{\alpha}{2}\right)}\right)\text{n}\ \ mm$

(c) Flat disc windows *(0.01 (t) + 0.05) mm, t=thickness of window*

Where n is given in Table 2.4.1 Operational pressure gauge.

Table 2.4.1 Operational pressure gauge

n	*Operational pressure gauge, in N/mm^2*
1	1 – 17.2
2	17.3 – 34.5
3	34.6 – 51.7
4	51.8 – 69

4.6 Dimensional tolerances and surface finish

4.6.1 Dimensional tolerances and surface finish are to meet the requirements of *Pt 3, Ch 2, 4.6 Dimensional tolerances and surface finish 4.6.2* to *Pt 3, Ch 2, 4.6 Dimensional tolerances and surface finish 4.6.11*. Also refer to ASME PVHO-1.

4.6.2 The minimum Window thickness shall be equal to or greater than the nominal value determined using the maximum operating conditions.

4.6.3 The major diameter of the conical bearing surface on a Window shall be within +0/-0,002D_o of the nominal value. Where D_o is shown in the *Figure 2.4.1 Seat cavity requirements (Also refer to ASME PVHO-1)*.

4.6.4 The included conical angle of the windows must be within +0,25/- 0 degrees of the nominal value.

4.6.5 The included conical angle of the Window seat in the flange must be within +0/0,25 degrees of the nominal value.

4.6.6 The major diameter of the conical seat cavity in the flange must be within +0.002D_o/- 0 of the nominal value.

4.6.7 The spherical surfaces of a window shall not differ from an ideal Spherical sector by more than ± 0,5 per cent of the specified nominal external Spherical radius for the given standard CF values.

4.6.8 Tolerances on a flat disc Window diameter are to be in accordance with *Figure 2.4.1 Seat cavity requirements (Also refer to ASME PVHO-1)* or ASME PVHO-1.

4.6.9 All seating surfaces of windows and flanges are to be machined to a finish of 1,3 μm. RMS

4.6.10 Viewing surfaces shall be polished to satisfy ASTM D702 Optical Clarity requirement.

4.6.11 All other surfaces shall be finished to 2,5 μm RMS minimum. Saw cut finish is not acceptable on any Window surface.

■ *Section 5*
Manufacture of windows

5.1 Manufacturing procedure

5.1.1 Acrylic plastic windows are to be manufactured from material satisfying the requirements of these Rules, by recognised manufacturers, and the manufacturing procedure shall be subject to scrutiny by LR.

5.1.2 Each window shall be annealed prior to installation after all forming, including polishing has been completed. The annealing procedure shall be in accordance with the plastics manufacturer's instructions.

5.2 Fabrication procedure

5.2.1 During the fabrication process each window shall be checked against the fabrication documents.

5.2.2 Fabrication processes or materials causing degrading of the original physical properties of the acrylic casting shall not be used.

■ *Section 6*
Installation of windows

6.1 Cavity seat preparation

6.1.1 Before installation of a Window the cavity seat in the flange must be thoroughly cleaned with suitable cleaning materials. After installation a check should be made to establish that the bolting of the viewport has been evenly tightened.

6.1.2 *See also Pt 3, Ch 1, 10.1 General 10.1.8*.

■ *Section 7*
Testing and inspection

7.1 Pressure testing

7.1.1 Each window shall be pressure tested at least once prior to being put into service.

7.1.2 The window may be pressure tested together with the chamber after installation into the chamber or placed within a test fixture whose window seat dimensions, retaining ring, and the seals are identical to the chambers in which case the test pressure is to be the design pressure for the chamber. In no case must the test pressure exceed 1,5 times the design pressure or 138 N/mm^2, whichever is the lesser value. During this test, the temperature of the pressurizing medium should be the design temperature of the window Alternate test procedure in excess of design pressure and lower temperature may be adopted as specified in ASME PVHO-1 with in the limitations indicated. The test pressure shall be maintained for a minimum of one hour but not more than 4 hours. The test may be carried out using a test fixture whose window seat dimensions, retaining rings and seals are identical to those of the chamber.

7.2 Inspection

7.2.1 After completion of pressure tests the window shall be visually inspected for the presence of crazing, cracks or other permanent damage.

7.2.2 The presence of crazing, cracks or other permanent damage shall be cause for rejection of a window. PVHO-1 may be used for guidance.

7.2.3 For further information *see* Safety Standard for Pressure Vessels for Human Occupancy ANSI/ASME PVHO-1, latest edition.

Contents Part 4

Section

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	External Structure	Launch and recovery	Attachment points	Alternative lifting points	Access hatch	Anchoring systems: General	Anchors and cables	Tethering and towing systems: Wires and ropes
	Section 1.1	Section 2.1	Section 3	Section 4	Section 5	Section 6.1	Section 6.2	Section 7.1
Unit Type								
Manned Submersible	x	x	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x
Unmanned Submersible	x	x	x			x	x	x
Submersible Craft	x	x	x			x	x	x
Diving Bell	x	x	x	x	x	x	x	x
Submersible Vehicle	x	x	x			x	x	x
Submersible Habitat	x	x	x	x	x	x	x	x
Submersible Container	x	x	x			x	x	x
Passenger Submersible	x	x	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x

■ Section 1
External structure

1.1 General

1.1.1 LR does not lay down any strict environmental or pressure differential loadings in these Rules (except as in *Pt 4, Ch 1, 1.1 General 1.1.2* to *Pt 4, Ch 1, 1.1 General 1.1.4*). The designer is, however, to satisfy LR that the loadings used are satisfactory and the Class will be based in those conditions used.

1.1.2 Tanks forming an integral part of a submersible are generally to be suitable for a hydraulic test pressure of 1,5 times the maximum differential pressure for which they are designed to be used in service.

1.1.3 Hull structure which does not form part of the pressure hull or other pressurized system is to be designed with a load factor of not less than 2 against failure under the worst combination of loading during service operations. Failure, in this context, is assumed if the component has fractured, collapsed or distorted to an extent rendering it, or associated components, inoperable or dangerous to operate in the designed manner.

1.1.4 Where practicable, the outer fairing, other non-pressurized structure or equipment attachment to a submersible, should be designed so that in the event of shock from collision or similar accident, local collapse can occur sufficient to avoid acceleration in excess of 3g for the unit as a whole, without causing the loss of the unit. A clearance of not less than 150 mm between the fairing and critical life-support components should be arranged, where practicable, in the areas most susceptible to damage. Fairing or other protection should be arranged in way of hull penetrations; especially of umbilicals, to minimize damage (e.g. being sheared off).

1.1.5 Diving baskets are to be provided with adequate mechanical protection to protect the divers and to prevent damage to the critical components of the basket during handling operations and other normal or emergency operations. The lower section of the basket is to be provided with a platform enabling the divers to stand safely. Baskets are to be provided with internal handholds to support the divers and gates or chains to prevent the divers from falling out.

1.1.6 For the purpose of the design calculations the un-factored acceleration of the submersible from the point of view of collisions should be generally assumed to be not less than 3g in the horizontal direction. The vertical acceleration, including those during launch and recovery of the unit, should be assumed to be not less than 2g. Generally the sea state for manned submersible handling systems should not exceed Sea State 4. Special consideration will be given to cases where diving operations service in more severe sea state is envisaged for manned diving operations.

1.1.7 The effect of loads due to launching and recovery together with wave impact should also be examined. Particular attention should be paid to the strength of the lifting point attachment to the submersible.

1.1.8 The Builder shall supply material and welding specifications including procedure tests required for the fabrication. Procedure qualification tests are to be carried out using representative materials and thicknesses. These tests are to be witnessed by the LR Surveyor and are to be to the Surveyor's satisfaction. The Builder shall maintain a complete record of procedure qualification test results.

1.1.9 Calculations used to establish the adequacy of the exostructure should be submitted for approval at an early stage. The calculations should take account of the hydrostatic loads due to submergence together with loads due to manoeuvring and underwater tasks to be undertaken. In addition forces due to collision with underwater obstructions should be taken into account.

1.1.10 The design methods used to establish the adequacy of the exostructure, including buoyancy/ballast tanks, may follow any recognized engineering practice and may be performed using a specialist software program for structural analysis and design. The maximum pressure differential, wave slam and similar loadings are to be adequately catered for.

1.1.11 The Operating Manual is to specify the design loadings used for class approval and the unit is not to be operated in any environment which would produce more severe loadings (*Pt 1, Ch 3, 4.4 Plans, documents and calculations 4.4.1* refers).

Section 2
Launch and Recovery

2.1 General

2.1.1 Hazards to personnel (including but not limited to crew and recovery staff) during launch and recovery are to be minimised.

2.1.2 Refer to *Pt 1, Ch 1 General Regulations* for Regulations appertaining to lifting appliances used for submersible.

Section 3
Attachment Points

3.1 General

3.1.1 Where applicable each submersible craft shall be provided with lifting point(s) and a towing point.

The lifting point shall be so designed and arranged that it will be capable of withstanding the forces associated with launching and recovering the submersible craft. In designing the lifting attachment due regard should be paid to the worst anticipated operating conditions and the dynamic forces of the launch and recovery operation in association with any compatible lifting system and support craft. Suitable tests should be applied to attachment points to simulate dynamic forces. Test loading is to be not less than that laid down for classed launch and recovery systems (*see Pt 5, Ch 7, 1.4 Periodic surveys 1.4.1*).

3.1.2 The lifting point should be of sufficient strength to allow in an emergency situation the craft to be raised to the surface with any compartment flooded.

3.1.3 The towing point shall be so designed and attached that it shall be capable of withstanding the forces associated with towing the submersible craft at its maximum towing speed having, regard to the worst anticipated operating conditions and the dynamic forces arising there from.

3.1.4 In craft which use towing as the sole means of propulsion arrangements must be provided to permit the towing cable to be severed or jettisoned in an emergency.

3.1.5 The structural analysis of the pressure hull and the exostructure shall take account of any loads arising from the use of the lifting and towing points having regard to any dynamic forces which may occur and the worst anticipated operating or emergency conditions.

Section 4
Alternative Lifting Points

4.1 General

4.1.1 Every manned submersible except an autonomous craft shall be provided with at least one alternative lifting point to which lifting arrangements can be attached in an emergency.

4.1.2 The alternative lifting point(s) should be of sufficient strength to:

- Take the entire dry weight of the submersible including ballast and equipment as well as the divers staying in the submersible;
- Allow the craft to be raised to the surface with any compartment flooded;
- 150kg is to be allowed for each fully equipped diver and 95kg for each crew and passengers where applicable.

4.1.3 The structural analysis of the pressure hull and the exostructure shall take account of any loads arising from the use of these lifting points having regard to any dynamic forces which may occur and the worst anticipated operating or emergency conditions.

■ *Section 5*
Access Hatches

5.1 General

5.1.1 Every buoyant one atmosphere submersible craft shall be provided with an access hatch which should be operable from both sides. Where practicable this hatch should be so positioned and protected that the crew may exit when the craft is on the surface. *See also Rules for the Manufacture, Testing and Certification of Materials, July 2019*, *Ch 2, 5.2 Strain age embrittlement tests 5.2.2*.

5.1.2 The access hatch may be the largest penetration of the pressure hull and special consideration should be given to its effect on the pressure hull structural analysis. The factors to consider are:

(a) The detail geometry changes caused by the penetration.
(b) The possibility of an interaction with adjacent penetration.
(c) The compatibility of materials used in the construction of the hatch.

5.1.3 Special consideration will be given to the design of hatches intended to be used under pressure for the transfer of personnel or cargo. Such hatches and seatings should be designed and stiffened to avoid distortion. Seat designs will also require special consideration and may be required to withstand pressures in both directions.

■ *Section 6*
Anchoring System

6.1 General

6.1.1 It is a requirement that autonomous craft be provided with anchors and cables of adequate weight and strength having regard to the size and intended service of the craft.

6.1.2 The arrangement of the anchoring system and details of the proposed equipment are to be submitted for consideration.

6.1.3 In order to reduce the risk of entanglement anchors should be stowed and fit flush with the exostructure. Where the possibility of entanglement does exist consideration should be given to ways of jettisoning the equipment in an emergency.

6.2 Anchors and cables

6.2.1 Anchors and cables are to comply with the requirements of LR's *Rules for the Manufacture, Testing and Certification of Materials, July 2019*. In addition, attention must be given to any relevant statutory requirements for testing, etc., of the National Authority of the country in which the submersible is registered or in which it is to be operated.

■ *Section 7*
Tethering and Towing Systems

7.1 Wires and ropes

7.1.1 The wires and ropes used as part of suspension, mooring, anchoring and towing cables are to be of sufficient size, and made from materials which take into account the operating environment. All such systems used with the submersible in the submerged condition should be fitted with quick-release mechanisms operated within the submersible. Consideration should be given to the effects of corrosion, biological attack, fish bite, longitudinal velocity of craft and water velocity, including inter-boundary layer waves, and transverse oscillation. Proposals, with supporting calculations, should be submitted for consideration. The use of wire ropes of cross-lay construction is not normally recommended unless such ropes are of a non-spin type.

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	General: application	Plans: Particulars to be submitted	Design data: Particulars to be submitted	Calculations: Calculations to be submitted	Buoyancy and stability: general	Submersible vehicles	Submersible craft	Submersible habitats	Habitats	Testing of buoyancy and stability
	Section 1.1	Section 2.1	Section 3.1	Section 4.1	Section 5.1	Section 5.2	Section 5.3	Section 5.4	Section 5.5	Section 5.6
Unit Type										
Manned Submersible	x	x	x	x	x	x*	x*			x
Wet Submersible	x	x	x	x	x	x*	x*			x
Unmanned Submersible	x	x	x	x	x	x*	x*			x
Submersible Craft	x	x	x	x	x		x			x
Diving Bell	x	x	x	x	x	x*	x*			x
Submersible Vehicle	x	x	x	x	x	x				x
Submersible Habitat	x	x	x	x	x			x	x	x
Submersible Container	x	x	x	x	x	x*	x*			x
Passenger Submersible	x	x	x	x	x	x*	x*			x
Rescue Submersible	x	x	x	x	x		x			x

Notes

*- unit type is to comply with the entirety of one section of the rules marked *.

■ *Section 1*
General

1.1 Application

1.1.1 This Chapter details the factors to be taken into account in assessing the buoyancy and stability requirements for submersible systems.

1.1.2 Account is to be taken of any relevant National Regulations where these exist, or of practicabilities related to underwater operations.

Section 2
Plans

2.1 Particulars to be submitted

2.1.1 The following plans are to be submitted for consideration in connection with stability assessment:

(a) General arrangement;
(b) Lines plan, main hull and appendages;
(c) Capacity plan;
(d) Hydrostatic data;
(e) Hatches, access openings, and windows or ports, etc.;
(f) Ballast systems and arrangements.

Section 3
Design Data

3.1 Particulars to be submitted

3.1.1 Particulars submitted are to be sufficient to enable a proper assessment of the intended operating conditions and loads to be made. Details will depend on the type and intended service of the submersible or chamber, but will normally include the following where applicable:

(a) Class notation desired maximum operating depth;
(b) Number of occupants, crew and passengers;
(c) Whether internally or remotely controlled and manoeuvred and by what means;
(d) Proposed stability and buoyancy criteria.

Section 4
Calculations

4.1 Calculations to be submitted

4.1.1 Calculations are to be submitted covering the following aspects of stability assessment:

(a) Buoyancy and stability for both the surfaced and submerged conditions including emergency configurations where applicable.
(b) Weights and centres of gravity.

Section 5
Buoyancy and stability

5.1 General

5.1.1 The designer is to specify the type of buoyancy required, whether submerged beneath the effective wave height or floating. Drawings and calculations are to be submitted to show the make-up of the weight and centre of gravity and also the make-up of the buoyancy of the capsule/chamber in the operational condition. These calculations are to be verified by a weighing test on each completed capsule/chamber and by a flotation test in calm water on each new design or configuration of capsule/

chamber. Where the position of the vertical centre of gravity is of special importance an inclining experiment may be necessary in order to verify the calculated centre of gravity.

5.2 Submersible vehicles

5.2.1 Submersible vehicles should have a suitable centre of gravity and sufficient negative buoyancy when operating on the sea bed to enable them to remain stable and under control under the following conditions:

(a) Traversing, climbing or descending a slope with a declivity of 25°;
(b) Operating in surf (where applicable) generated by a wave having a height 2,5 times the significant height of the waves relevant to the limited sea state for which classification is sought;
(c) Performing the work for which they are intended.

Whether or not these criteria operate independently, or in combination, should be indicated in the calculation. The stability recommendation a) should apply irrespective of whether or not the wheel traction and propulsion power (or their equivalent) will permit the operation of the vehicle on such gradients.

5.2.2 If a manned submersible vehicle is not fitted with an escape trunk extending above the water surface, then consideration should be given to incorporating into the design some means of releasing the pressure hull from the remaining structure, or of using jettisonable ballast so that the pressure hull may float to the surface in case of an emergency, and float in such a position so that the crew can disembark.

5.3 Submersible craft

5.3.1 All submersible craft are to have sufficient reserve of buoyancy and stability to enable a properly trained crew and launching staff to launch, operate and recover them in all sea states and conditions for which they are intended, including emergency recovery conditions with jettisonable ballast dropped.

5.3.2 **Hatches**

The number and location of access hatches should be subject to special consideration bearing in mind the length of the craft, the length of the pressure hull, the number of passengers, the conditions of operation and rescue facilities. The following should be taken into account when determining the number, size and location of access hatches:

(a) Access hatches have an essentially important function when passengers and crew must be evacuated in an emergency situation;
(b) Hatches should be arranged with consideration given to all relevant risks such as fire, smoke, hydrostatic stability of the craft after passenger movement, possible down flooding due to adverse sea state, etc.; and,
(c) The number of hatches should not be unnecessarily increased beyond the safe minimum.
(d) Two means, one of which should be visual, should be available to ensure that hatches are closed and secured prior to diving.
(e) Means should be available to ensure that hatches are clear of water before opening, and that pressures on either side of the hatch are equalized. Hatches should be outward opening.
(f) The means for opening and closing of hatches should permit operation by a single person in all anticipated conditions.
(g) Provisions should be made for opening/closing hatches from both sides.
(h) Hatches should have means for securing them in the open and closed position.

5.3.3 Passenger submersibles should be fitted with a means of speedily altering trim and ballast dependent on the number of passengers embarked on each tour.

5.3.4 During submergence and surfacing, all submersible craft should have sufficient stability and sufficiently sensitive means of adjusting buoyancy to enable a properly trained crew to maintain effective control over the craft as a whole. Positive stability should be maintained in the event of a power failure. Attention should be paid to the possibility of air becoming trapped below suspended types of submersible craft during launching.

5.3.5 Self-propelled types of submersible craft should be capable of maintaining neutral buoyancy at any predetermined depth down to the maximum diving depth over the full range of water salinities in which they are intended to be able to operate. Neutral buoyancy should be maintained for all service conditions of loading; both without and with passengers, when passengers are carried, and at all speeds of operation.

5.3.6 Towed unmanned submersible craft should normally be arranged to have slight positive buoyancy at zero velocity, relying on dynamic forces to maintain their required depth of submergence. Towed manned craft should operate with either slight positive buoyancy or neutral buoyancy.

5.3.7 Suitable ballast arrangements should be fitted to all submersible craft and special attention is to be paid to the attachment of the system to the hull of the craft. Where ballast can be jettisoned, the arrangements should be such that the system can be operated with the craft at a trim and/or angle of heel at least 20° in excess of the maximum anticipated under normal operating service conditions, and the craft should retain positive stability during the ascent, and on the surface, with the ballast jettisoned. In the case of a diving bell the angle of heel considered in the design should be at least 10° in excess of the maximum anticipated under normal operating conditions.

5.3.8 The stability, while submerged, of the submersible craft in pitch and roll should be such that movements of the crew, passengers or equipment within the submersible, or the exit or entrance of crew or passengers and work operations carried out by the submersible, will not result in an uncontrollable change in attitude exceeding 5°, or such small angle as can be accepted by any hydroplanes or other control surfaces, without causing unexpected stall or negative incidence of attack within the normal operating range of the controls. In particular, such movements should not result in an uncontrolled dive.

5.3.9 Designers and builders should ensure, by means of calculation, model experiments and/or full scale trials, that submersible craft remain controllable in pitch, yaw, heave, roll, direction, etc., for all craft speeds; and also for all anticipated current speeds when the craft is anchored, moored or suspended. Particular care should be taken to avoid pitch instability on self-propelled craft, roll and directional instability on towed craft and oscillations and rotations of suspended craft. *See also Pt 4, Ch 2, 5.3 Submersible craft 5.3.8*.

5.3.10 Where submersible craft are designed to operate also as habitats or submersible vehicles, they are to comply with these Rules.

5.3.11 Passenger submersibles should have at least two means of emergency return to the surface and the capability of remaining on the surface in a stable condition.

5.4 Submersible habitats

5.4.1 Submersible habitats intended for saturation diving to depths in excess of 10 m should be so arranged that the submersible as a whole, the pressure hull, or the hyperbaric escape chamber can be released from the sea bed and float to the surface in an emergency. This facility need not be applicable where the habitat is manned only when a submersible craft, with pressurized access and sufficient accommodation for all crew and passengers, is in attendance.

5.4.2 Diving bells whose emergency ascent is initiated by the release of ballast at its maximum service weight and with its trunk flooded, must exhibit a positive buoyancy equal to at least 3 per cent of its displacement at maximum operating depth. In these circumstances, the bell should have sufficient stability to maintain a substantially upright position after release of ballast.

5.4.3 Where a habitat is arranged with more than three legs, then it should remain stable if the configuration of the sea bed is such that only three legs (irrespective of which three) are in contact with the ground in all currents and at all values of orbital wave motions for which the submersible is classed to operate. In the event of subsidence of the sea bed, settling of one or more legs or scouring of the sea bed in way of the legs, the habitat should remain stable for angles of heel up to 25°.

5.5 Habitats

5.5.1 The habitat should have sufficient reserve buoyancy and stability to allow it to be towed, together with the means of altering the buoyancy so that it may be controlled during emplacement on the sea bed. The negative buoyancy after emplacement may be increased by the use of additional anchoring, having regard to tide flows, scouring, external loads, etc. The habitat should be stable when on the sea bed, even when subsidence may occur under one or more legs, and not impose unacceptable loads on any associated equipment. For this purpose model testing should be carried out and the results submitted for consideration.

5.6 Testing of buoyancy and stability

5.6.1 Tests are to be carried out to prove the buoyancy and stability of the completed submersible to the satisfaction of the Surveyors. Results and hydrostatic curves are to be submitted for consideration.

5.6.2 When diving bells and submersibles are fitted with releasable ballast weights, a shallow water buoyancy test, with ballast released, should be carried out. For atmospheric submersible units, this test should be achieved with the access hatches open to ensure that stability is maintained on the surface. It is recommended-that the lifting wire remains attached to the submersible during this test.

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

Unit Type	Corrosion protection
Manned Submersible	x
Wet Submersible	x
Unmanned Submersible	x
Submersible Craft	x
Diving Bell	x
Submersible Vehicle	x
Submersible Habitat	x
Submersible Container	x
Passenger Submersible	x
Rescue Submersible	x

■ *Section 1* General

1.1 Scope

1.1.1 This Chapter gives methods of corrosion protection that may be considered for various locations but the selection should take into account such factors as the following:

(a) Application, environmental aspects;
(b) Design life;
(c) Weight aspects;
(d) Type of material;
(e) Ease and frequency of inspection;
(f) Toxicity;
(g) Electrical hazards and maintainability of protection on surfaces.

1.2 Application

1.2.1 All steelwork is to be suitably protected against loss of integrity due to the effects of corrosion. Suitable protective systems may include coatings, metallic claddings, cathodic protection, corrosion allowances, or other approved method. Combinations of methods may be used.

1.2.2 The type of protection is to be suitable for the intended location and for this purpose the steel structure should be considered in the terms as indicated in *Pt 4, Ch 3, 1.2 Application 1.2.3* to *Pt 4, Ch 3, 1.2 Application 1.2.5*.

1.2.3 Intermittently submerged steelwork may be protected by:

(a) Extra steel in excess of that needed for strength.
(b) Coatings.
(c) Sacrificial anodes where the immersion period is of adequate duration.

1.2.4 Closed flooded compartments may be protected by:

(a) Extra steel in excess of that needed for strength.
(b) Coatings.
(c) Cathodic protection.
(d) Corrosion inhibitors together with biocides.
(e) Chemicals for pH control together with biocides.
(f) Sacrificial anode.

1.2.5 Free flooding compartments are to be avoided as far as possible. Any which cannot be avoided should be protected by:

(a) Extra steel in excess of that needed for strength.
(b) Coatings.
(c) Cathodic protection.
(d) Sacrificial anode.

1.3 Plans and information

1.3.1 In order that an assessment may be made of protection systems, full details as outlined in *Pt 4, Ch 3, 1.3 Plans and information 1.3.2* to *Pt 4, Ch 3, 1.3 Plans and information 1.3.6* are to be submitted.

1.3.2 The following plans and information are to be submitted for all cathodic protection systems:

(a) A surface area breakdown for all areas to be protected.
(b) The resistivity of the sea water.
(c) All current densities used for design purposes.
(d) The type and location of any reference electrodes, their methods of attachment and the method for transmitting the potential data.
(e) Full details of any coatings used and the areas to which they are applied.
(f) Details of any electrical bonding or insulation.

1.3.3 In addition to the information required by *Pt 4, Ch 3, 1.3 Plans and information 1.3.2* the following plans and information are to be submitted for all sacrificial anode systems:

(a) The design life of the system (years).
(b) Anode material and capacity of anode material (A h/kg).
(c) The dimensions of anodes, including details of the insert and its location (cm).
(d) The net and gross weight of the anodes (kg).

(e) The means of attachment.
(f) Plans showing the location of the anodes.
(g) Calculation of anodic resistance as installed and when consumed to their design utilization factor.
(h) Closed circuit potential of the anode material (V).
(i) Details of any computer modelling.
(j) The anode design utilization factor.

1.3.4 In addition to the information required by *Pt 4, Ch 3, 1.3 Plans and information 1.3.2*, the following plans and information are to be submitted for all impressed current systems:

(a) The anode composition, and where applicable, the thickness of the surface plating, consumption and life data.
(b) Anode resistance, limiting potential and current output.
(c) Details of construction and attachment of anodes and reference electrodes.
(d) Size, shape and composition of any dielectric shields.
(e) Diagram of the wiring systems used for the impressed current and monitoring systems including details of cable sizes, underwater joints, type of insulation and normal working current in the circuits, and the capacity, type and make of protective devices.
(f) Details of glands and size of steel conduits.
(g) Plans showing the location of anodes and reference electrodes.
(h) If the system is to be used in association with a coating system then a statement is to be supplied by the coating manufacturer that the coating is compatible with the impressed current cathodic protection system.

1.3.5 The following plans and information are to be submitted for all coating systems:

(a) Evidence that any primers used will have no deleterious effect on subsequent welding or on subsequent coatings. *See also Pt 4, Ch 3, 3.2 Prefabrication primers*.
(b) Details of the painting specification with regard to:
(c) The generic type of the coating and its suitability for the intended environment,
(d) The methods to be used to prepare the surface before the coating and the standard to be achieved. Reference should be made to an established International or National Standard.
(e) The method of application of the coating.
(f) The number of coats to be applied and the total dry film thickness.
(g) Details of the area to be coated.

1.3.6 In addition to the information required by *Pt 4, Ch 3, 1.3 Plans and information 1.3.4*, for all coating systems the following may also be required:

(a) When a coating contains aluminium and is intended to be used in areas where flammable gases may accumulate, a statement from an independent laboratory confirming that appropriate tests have shown that the coating does not increase the incentive sparking hazard in the area to which it is applied, or
(b) where a coating is to be applied in accommodation spaces, machinery spaces and areas of similar fire risk, a statement that the coating is not formulated on a nitrocellulose or other highly flammable base and has low flame spread characteristics in compliance with IMO *FTP Code - International Code for Application of Fire Test Procedures – Resolution MSC.61(67)* or any other equivalent national specification is required.

■ *Section 2*
Cathodic Protection

2.1 General

2.1.1 The cathodic protection system should be capable of polarizing the steelwork to a sufficient level in order to minimize corrosion. This may be achieved using sacrificial anodes with or without an impressed current system.

2.1.2 All parts of the structure should be electrically continuous and where considered necessary, appropriate bonding straps should be fitted.

2.1.3 The cathodic protection system should be capable of polarizing the steelwork to potentials measured with respect to a silver/silver chloride (Ag/AgCl) sea water reference electrode to within the following ranges:

(a) Minus 0,80 volts to minus 1,05 volts for aerobic conditions.
(b) Minus 0,90 volts to minus 1,05 volts for anaerobic conditions. Potential, more negative than minus 1,05 volts Ag/AgCl sea water, must be avoided in order to minimize any damage due to hydrogen absorption and a reduction in the fatigue life. For steel with a tensile strength in excess of 800 N/mm^2, the maximum negative potential should be limited to minus 0,95 volts. The potential for steels with surfaces operating above 25°C should be 1 mV more negative for each degree above 25°C.

2.2 Sacrificial anodes

2.2.1 Sacrificial anodes should be manufactured in accordance with the requirements of this sub-section.

2.2.2 Drawings showing anode nominal dimensions, tolerances and fabrication details are to be submitted for approval prior to commencement of casting.

2.2.3 Approval for the manufacture of anodes is not required although the anodes should be type approved. The works should have a quality management system certified by a recognized third party certification body. However, alternative arrangements may be accepted provided they ensure a consistent quality for the anodes.

2.2.4 The anode materials are to be approved alloys of zinc, aluminium or magnesium with a closed circuit potential of at least minus 1,00 volt (Ag/AgCl sea water reference electrode).

2.2.5 The anode material is to be cast around a steel insert designed so as to retain the anode material even when it is consumed to its design utilization factor. The steel inserts are to have sufficient strength to withstand all external forces that they may normally encounter. The anodes are to be sufficiently rigid to avoid vibration in the anode support. The steel inserts are to be of weldable structural steel bar, section or pipe with a carbon equivalent (CE) not greater than 0,45 per cent determined using the following formula:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

Note Rimming steel is not permitted.

2.2.6 Where the steel insert is a welded fabrication, it will be necessary for welding procedures and welders to be approved. Adequate examination of production welds is to be carried out by appropriate non-destructive testing.

2.2.7 The steel insert is to be degreased if necessary and blast cleaned to a standard equivalent to Sa 2,5 of the Swedish Standard SIS 055900, with a minimum surface profile of 50 μm. This standard of cleanliness is to be maintained up until the time of casting. For zinc anodes, blast cleaning may be followed by galvanizing or by an approved zinc plating process.

2.2.8 The chemical composition of the heat is to be determined prior to casting. No alloying additions are to be made following chemical analysis without further analysis. For heats greater than 1 tonne, a further sample is to be analysed at the end of the cast. All anodes cast are to comply with the approved specification.

2.3 Electrochemical testing

2.3.1 Electrochemical performance testing is to be carried out by the manufacturer in accordance with previously approved procedures designed to demonstrate batch consistency of the as cast electrochemical properties.

2.4 Certification

2.4.1 The manufacturer is to provide copies of the material certificate or shipping statement for all acceptable anodes. This certificate is to include at least the following information:

(a) Name of manufacturer.
(b) Description of anode, alloy designation or trade name.
(c) Cast identification number.
(d) Chemical composition.
(e) Details of heat treatment where applicable.
(f) Results of electrochemical test.
(g) Weight data.
(h) Purchaser’s name and order number and the name of the structure for which the material is intended.

2.4.2 The manufacturer must confirm that the tests have been carried out with satisfactory results in accordance with the approved specification and these Rules.

2.5 Installation of sacrificial anodes

2.5.1 The location and means of attachment of anodes is to be submitted for approval.

2.5.2 The anodes are to be attached to the structure in such a manner that they remain secure throughout the service life.

2.5.3 The location and attachment of anodes must take account of the stresses in the members concerned. The anode supports may be welded directly to the structure in low stress regions with long fatigue lives provided they are not attached in way of butts, seams, nodes or any other stress raisers. They are not to be attached to separate members which are capable of relative movement.

2.5.4 All welding is to be carried out by qualified welders using a qualified welding procedure.

2.5.5 The welds are to be examined using magnetic particle inspection or other acceptable means of non-destructive testing.

2.5.6 Attachment to studs fired into the structure is not permitted.

2.5.7 Anodes should not be located in positions where mechanical damage may be experienced.

2.5.8 Magnesium anodes should not be used in way of higher tensile steel or coatings which may be damaged by the high negative potentials unless suitable dielectric shields are fitted.

2.6 Impressed current anode systems

2.6.1 Impressed current cathodic protection should not be used on those items where:

(a) The electric current would pose a hazard to divers.
(b) Where stray electric current may cause enhanced corrosion on other equipment.
(c) Where the hydrogen and chlorine gases produced may pose a hazard. (*See* Code of Practice for the Safe Use of Electricity Under Water- Association of Offshore Diving Contractors (1983)).

2.6.2 Impressed current anode materials may be of lead-silver alloy or platinum over such substrates as titanium, niobium or tantalum. Alternative materials may also be considered for specific applications.

2.6.3 The design and installation of electrical equipment and cables is to be in accordance with the requirements of *Pt 6 Electrical Installations and Control Engineering Systems* of these rules.

2.6.4 All equipment is to be suitable for its intended location. Cables to anodes are not to be led through tanks intended for the containment of low flash point fuels.

2.6.5 Cable and insulating material should be resistant to chloride, hydrocarbons and any other chemicals with which they may come in contact.

2.6.6 The electrical connection between the anode cable and the anode body must be watertight and mechanically and electrically sound.

2.6.7 Where impressed current cathodic protection systems are filled (for external hull protection only) and where cables pass though the shell, it is essential for the cables to pass through a small cofferdam.

2.6.8 Where the power is derived from a rectified a.c. source adequate protection is to be provided to trip the supply in the event of:

(a) A fault between the input or high voltage windings of the transformer (i.e. mains voltage) and the d.c. output of the associated rectifier, or
(b) The ripple on the rectified d.c. exceeding 5 per cent.

2.6.9 Suitable dielectric shields should be fitted in order to avoid high negative potentials.

2.7 Fixed potential monitoring systems

2.7.1 A permanent monitoring system is to be installed on structures protected by an impressed current cathodic protection system.

2.7.2 Zinc sea water or Ag/AgCl reference electrodes should be used.

2.7.3 The location and attachment of the reference electrodes must take account of the stresses in the members concerned and they should not be attached in highly stressed areas or in way of butts, seams, nodes or any other stress raisers.

2.7.4 The location of the reference electrodes should be such as to enable the performance of the cathodic protection system to be adequately monitored.

2.8 Cathodic protection in tanks

2.8.1 Impressed current cathodic protection systems are not to be fitted in any tank.

2.8.2 Particular attention is to be given to the locations of anodes in tanks that can contain explosive or other flammable vapour, both in relation to the structural arrangements and openings of the tanks.

2.8.3 Aluminium and aluminium alloy anodes are permitted in tanks that may contain explosive or flammable vapour but only at locations where the potential energy of the anode does not exceed 275J (28kgfm). The weight of the anode is to be taken as the weight at the time of installation, including any inserts and fitting devices. The height is to be taken as the distance from the bottom of the tank to the centre of the anode but exception to this may be given where the anodes are located on wide horizontal surfaces from which they cannot fall. Where the anode is located on, or closely above, a horizontal surface (such as a bulkhead girder) not less than 1 m wide, provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface the height of the anode may be measured above that surface.

2.8.4 Magnesium alloy anodes should not be attached to high tensile steel.

2.8.5 Anodes filled internally should preferably be attached to stiffeners, or aligned in way of stiffeners on bulkhead plating. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or the centreline of the mild steel plate but well clear of the free edges. Where higher tensile steel face plates are fitted the anodes should be attached to the webs.

2.9 Potential surveys

2.9.1 Potential surveys are to be carried out at agreed intervals on permanently submerged steelwork.

2.9.2 Should the results of any potential survey measured with respect to a Ag/AgCl sea water reference cell indicate values more positive than minus 0,8 V for aerobic conditions or minus 0,9 V for anaerobic conditions then remedial action is to be carried out at the earliest opportunity.

■ *Section 3*
Coatings and paint systems

3.1 General

3.1.1 The painting specification as well as specifications for preparation, application and curing are to be submitted for approval.

3.1.2 Paints, varnishes and similar preparations having nitrocellulose or other highly flammable bases are not to be used in accommodation or machinery spaces or in other areas with an equal or higher fire-risk. Particular regard is to be paid to the possible effects in an oxygen enriched atmosphere.

3.1.3 Where a coating is to be applied in accommodation spaces, machinery spaces and areas of similar fire-risk, the coating is to have low flame spread characteristics.

3.1.4 Paint or other similar coatings containing aluminium should not be used in positions where flammable vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

3.1.5 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used, unless previously agreed, at least two coats are to be applied.

3.1.6 Coatings are to be applied to blast cleaned surfaces prepared to at least an equivalent of Sa 2,5 of the Swedish Standard SIS 055900. All resulting dust is to be removed from the surface prior to the application of any paint.

3.2 Prefabrication primers

3.2.1 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied. Approved coatings are listed in LR publication Approved Prefabrication Primers and Corrosion Control Coatings.

3.2.2 The tests are to be carried out in the presence of a Surveyor to LR or by an independent laboratory specializing in such work, a copy of the test report is to be submitted, together with radiographs and macrographs.

Contents

Section

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	Plans and particular: plans and particular to be submitted	Principles for design and construction of diving systems: General principles	Environmental conditions	Atmosphere conditions in the chambers	Interface between diving systems and The ship or supporting structure	Chamber equipment and fittings	Corrosion protection	Materials: General
	Section 1.1	Section 2.1	Section 2.2	Section 2.3	Section 2.4	Section 2.5	Section 2.6	Section 3
Unit Type								
Manned Submersible	x	x	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x
Unmanned Submersible	x	x	x		x	x	x	x
Submersible Craft	x	x	x	x	x	x	x	x
Diving Bell	x	x	x	x	x	x	x	x
Submersible Vehicle	x	x	x	x	x	x	x	x
Submersible Habitat	x	x	x	x	x	x	x	x
Submersible Container	x	x	x		x	x	x	x
Passenger Submersible	x	x	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x

Section 1
Plans and Particulars

1.1 Plans and particulars to be submitted

1.1.1 Plans, particulars, specifications and where applicable, calculations as detailed in *Pt 5, Ch 2 Machinery* to *Pt 5, Ch 7 Lifting Appliances* are to be submitted for consideration. Any subsequent alterations to the basic design, materials or manufacturing procedure are to be submitted for consideration before being put into operation.

Section 2
Principles for design and construction of diving systems

2.1 General principles

2.1.1 Wherever practically possible, diving systems are to be designed and constructed in such a way that no single point failure can lead to injuries or fatalities of the divers or operating personnel whilst working with the dive system.

2.1.2 Diving systems and their components are to be designed to meet the service conditions stated in the specification of the system.

2.1.3 Diving systems are to be constructed to ensure that persons under pressure can be safely conveyed from the surface compression chamber to the underwater work location (and back).

2.1.4 Diving systems are to be designed and built to ensure safe operation and facilitate proper maintenance and the necessary surveys.

2.1.5 All parts of a diving system are to be designed, constructed and mounted in such a way as to Facilitate cleaning and disinfection.

2.2 Environmental conditions

2.2.1 Diving systems together with their accessories and ancillary equipment are to be designed for the Environmental conditions likely to occur at the proposed Point of installation or work location. As a minimum requirement, allowance is to be made for the following conditions:

- The inclined positions stated in *Table 1.2.1 Design Angles of Inclination*.
- The other environmental conditions stated in *Table 1.2.2 Environmental conditions*.

Table 1.2.1 Design Angles of Inclination

Component/Systems	*Angle of Inclination (Degrees)*			
	Athwart ship/Roll		*Fore-and-Aft/Pitch*	
	Static	*Dynamic*	*Static*	*Dynamic*
PVHOs	15	22.5	10	10
Machinery	15	22.5	5(4)	7.5
Life Support Systems	15	22.5	10	10
Electrical/Electronic Appliances and Control Systems	22.5(2)	22.5(2)	10	10
Emergency Power Installations	22.5	22.5	10	10
Emergency Fire Pumps and their Drives	22.5	22.5	10	10
Notes:				

1 Athwart ship and fore-and-aft inclinations occur simultaneously.
2 Up to an angle of inclination of 45 degrees, switches and controls are to remain in their last set position.
3 In vessels designed for carriage of liquefied gases and of chemicals, the emergency power installation is to remain operable with the vessel flooded to its permissible athwart ship inclination up to a maximum of 30 degrees.
4 Where the length of the vessel exceeds 100 m the fore-and-aft static angle of inclination may be taken as 500/*L* degrees, where *L* is the length of the vessel in meters.
For diving systems installed on column-stabilized, self-elevating or surface offshore facilities, the PVHOs, machinery and systems essential for the safe operation of the diving system are to be designed for operation under the inclinations specified *Pt 5, Ch 1 General Requirements for Offshore Units* of LR's Rules for Offshore Units, *Table 1.2.1 Inclination of ship units and other surface type units* to *Table 1.2.3 Inclination of self-elevating units* as applicable.

Table 1.2.2 Environmental conditions

Location	*Temperature (°C)*	*Humidity (%)*	*Other Conditions*
In chambers	*5 to 55*	*100*	*Salty air*
Outside chambers in air [1 2]	*-10 to + 55*	*100*	
Outside chambers in water	*-2 to + 32*	*-*	*Salt water containing 3.5% salt*
Control room	*5 to 55*	*80*	*-*
Notes			
1. In the case of the facilities installed on the open deck, allowance is to be made for icing and temporary inundation with salt water and spray.			
2. Other values may be permitted for installation in closed spaces.			
3. The calculated inclined angles from the actual ship motion analysis can be replaced with the above accelerations.			

2.3 Atmosphere conditions in the chambers

2.3.1 Diving systems are to be so equipped that a breathable atmosphere can be maintained in surface compression chambers and diving bells throughout the entire operating period.

2.3.2 Facilities must be provided for keeping the partial pressure of the CO2 in the chamber atmosphere permanently below 0,005 bar assuming a CO2 production rate of 0,05 Nm^3/h per diver.

2.3.3 In the case of facilities installed on the open deck, allowance is to be made for icing and temporary inundation with salt water and spray.

2.3.4 Other values may be permitted for installation in closed spaces. In diving bells it must be possible to keep the partial pressure of the CO2 below 0,015 bar as a minimum requirement. Under emergency conditions it must be possible to hold the partial pressure of the CO2 below 0,02 bar for at least 24 h.

2.3.5 Diving systems using mixed gas and designed for operating periods of more than 12 hours at a time must be capable, under steady conditions, of keeping the temperature in the surface compression chamber constant to ±1 °C in the 27 - 36 °C range while maintaining a maximum humidity of at least 50 per cent.

2.3.6 Surface compression chambers are to be designed and equipped in such a way that a homogeneous atmosphere (CO2 and O2 concentrations, temperature and humidity) can be maintained in the chamber.

2.3.7 In the steady state, the permanent noise level (over 8 hours) in the living compartment and surface compression chamber may not exceed 65 dB(A) excluding self-induced noise.

2.4 Interface between diving system and the ship or supporting structure

2.4.1 The diving system and breathing gas facilities should be arranged in spaces or locations which are provided with adequate ventilation and lighting.

2.4.2 When any part of the diving system is sited on deck, particular consideration should be given to providing reasonable protection from the sea, from icing or from any damage which may result from other activities on board the ship or supporting structure.

2.4.3 Provision should be made to ensure that diving systems and ancillary equipment are securely fastened to the ship or supporting structure and consideration given to the relative movement between the components. In addition, the fastening arrangements should be able to meet any required survival conditions.

2.4.4 Diving systems on ships and other floating structures may only be located and operated in areas not subject to an explosion hazard. In exceptional cases, installation subject to special conditions may be permitted in zone 2 area.

2.4.5 As far as possible, the area in which the diving system is installed is to be kept free of fire loads. In addition, only those electrical cables needed to operate the diving system should be routed through this area.

2.4.6 Diving systems and breathing gas storage facilities are not to be located in engine rooms.

2.5 Chamber equipment and fittings

2.5.1 The equipment and fittings of surface compression chambers and diving bells must be suitable for operation in hyperbaric atmospheres. Under these conditions they shall not give off any toxic or strong irritant gases. The same also applies to protective coatings and paints used inside the chambers.

2.5.2 Toxicity off-gas testing is to be carried out on all PVHO's or Pressure Hulls that have internal paint or contain non-metallic materials excluding acrylic windows.

2.5.3 Off-gas testing is not required for PVHO's or pressure hulls where the primary means of life support is by ventilation of the atmosphere and/or by BIBS supply such that the off-gassed volatiles are continuously removed and do not accumulate within the pressure boundaries of the PVHOs or pressure hulls.

2.5.4 Gas sample analysis for the off-gas testing is to be conducted by a laboratory that is accredited by an independent third-party as being compliant with an applicable quality assurance standard for laboratories (such as ISO/IEC 17025, ANSI/ASQC Q2 or equivalent.

2.5.5 Only incombustible or at least flame and fire retardant materials should be used in the chambers.

2.6 Corrosion protection

2.6.1 Diving systems and all their accessories are to be effectively protected against corrosion, *see Pt 4, Ch 3 Corrosion Protection*.

2.6.2 Anti-corrosion coatings exposed to the conditions within the chambers must confirm to the requirements stated in *Pt 4, Ch 3 Corrosion Protection*. In addition they may not tend to blister or flake under hyperbaric conditions.

■ *Section 3* **Materials**

3.1 General

3.1.1 Materials are to be suitable for the proposed application and are to be manufactured and tested in accordance with appropriate requirements of LR's *Rules for the Manufacture, Testing and Certification of Materials, July 2019*. Materials not covered by the Rules may be accepted provided that they comply with an approved specification and such tests as may be considered necessary are carried out to LR's satisfaction.

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

Unit Type	Plans and Particulars: plans and particulars to be submitted Section 1	Mechanical equipment: Propulsion and dynamic positioning machinery Section 2.1	Equipment – General Section 2.2	Noise and vibration levels Section 2.3	Propulsion systems, steering Equipment and associated control: General Section 3.1	Protection of shafting Section 3.2
Manned Submersible	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x
Unmanned Submersible	x	x	x	x	x	x
Submersible Craft	x	x	x	x	x	x
Diving Bell	x		x	x		
Submersible Vehicle	x	x	x	x	x	x
Submersible Habitat	x	x	x	x		
Submersible Container	x	x	x	x		
Passenger Submersible	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x

■ *Section 1*
Plans and Particulars

1.1 Plans and particulars to be submitted

1.1.1 The following plans and particulars are to be submitted for appraisal:

(a) Manoeuvring systems and arrangements.
(b) Propulsion systems and arrangements.
(c) Towing, lifting, anchoring, mooring and stowage equipment and arrangements, including protection of viewports and other delicate components.
(d) Hydraulic systems and arrangements.
(e) Any associated winch systems.

■ *Section 2* Mechanical equipment

2.1 Propulsion and dynamic positioning machinery

2.1.1 Details of the type of machinery proposed for the propulsion and dynamic positioning of a submersible are to be submitted for approval. In selecting the machinery the following factors should be taken into consideration:

(a) Noise and vibration levels, *see Pt 5, Ch 2, 2.3 Noise and vibration levels*.
(b) Standard of containment of high speed rotating parts in the event of mechanical failure.
(c) Reliability of known similar machinery (which may be prototype).
(d) Probability of contamination of life-support gases in the event of mechanical or other failure.
(e) Probability of injury to crew, passengers, divers or recovery staff by moving parts.
(f) Degree of protection of moving parts against damage, obstruction or jamming by fish, seaweed, mud, plastic sheeting, or other substances that may be encountered in service.
(g) Design life of the various component parts.
(h) Ease of access for maintenance, fault tracing and repair.

2.2 Equipment — General

2.2.1 Equipment external to the pressure hull is, where practicable, to be faired to reduce the possibility of mechanical damage.

2.2.2 It is recommended that repair by replacement be adopted where practicable, unless it is easier to make repairs in situ.

2.2.3 Propellers and means of traction where applicable, are to be fitted with guards for the protection of divers.

2.2.4 Process production equipment and systems within submersible habitats should be designed and manufactured to relevant Codes of Practice.

2.2.5 Provision should be made to compensate for differential thermal expansion between the habitat and process/production equipment.

2.3 Noise and vibration levels

2.3.1 Apart from the sonar or echo sounding devices, vibration and noise generation from all equipment should be kept as low as possible, especially when helium breathing mixtures are employed.

2.3.2 Noise levels should in general be kept below 65 dB(A) inside chambers excluding self-induced noise.

2.3.3 Vibration levels in vertical and horizontal planes should conform to the following limits:

(a) Vertical direction:
  (i) $1 \leq f \leq 8$ Hz $v \leq 0.3$ m/sec^2 r.m.s.
  (ii) $8 \leq f \leq 80$ Hz $v \leq 10(\log f - 2.50)$ m/sec^2 r.m.s.
(b) Horizontal direction:
  (i) $1 \leq f \leq 2$ Hz $v \leq 0.02$ m/sec^2 r.m.s.
  (ii) $2 \leq f \leq 80$ Hz $v \leq 10(\log f - 2.00)$ m/sec^2 r.m.s.

Where "f" is vibration frequency in Hz and "v" is the acceleration in m/sec^2 r.m.s.

Section 3
Propulsion Systems, Steering Equipment and associated Control

3.1 General

3.1.1 Submersibles are to be provided with adequate means for surface and underwater manoeuvring. Adequate manoeuvring controls and displays are to be provided for the safe operation of submersibles.

3.1.2 Submersibles are to be provided with propulsion systems and/or thrusters and steering equipment that are suitable for the intended service. The output of the propulsion systems and/or thrusters is to be sufficient to achieve the submersible's manoeuvring speed.

3.1.3 Propulsion systems, thrusters, steering equipment, and their supporting structures are to be designed for continuous service and for the intended depth. Motor casings are to be designed for the intended depth or are to be pressure compensated.

3.1.4 Detailed plans of foundations or attachments for propulsion systems, thrusters, and steering equipment are to be submitted for review.

3.2 Protection of Shafting

3.2.1 Shafts exposed to seawater are to be protected against galvanic corrosion. The use of graphite-impregnated packing in stuffing boxes is to be avoided because of the possibility of corrosion. Stainless steel, nickel-copper alloys or other shafting materials adversely affected by stagnant water are to be provided with a positive means of water circulation in sterntubes or similar enclosures that tend to trap water in contact with the shafting.

Section

Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	Plans and particular: Plans and particular to be submitted	Piping design requirements: Application	Pipe connections	Pipe fittings	Hose lines and umbilicals	Safety relief valves	Ballast systems	Bilge system	Drainage of chambers	Compression air system	Hydraulic equipment	Wall thickness of pipes and tubes subjected to external pressures	Testing	Requirements for piping systems fittings: General requirements for piping systems fittings	Oxygen safety in diving systems	Additional safety measure in gas Piping systems: General safety requirements
	Section 1.1	Section 2.1	Section 2.2	Section 2.3	Section 2.4	Section 2.5	Section 2.6	Section 2.7	Section 2.8	Section 2.9	Section 2.10	Section 2.11	Section 2.12	Section 3.1	Section 4.1	Section 5.1
Unit Type																
Manned Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Unmanned Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Submersible Craft	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Diving Bell	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Vehicle	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Submersible Habitat	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Container	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Passenger Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Section 1
Plans and Particulars

1.1 Plans and particulars to be submitted

1.1.1 The following plans and particulars are to be submitted for appraisal:

(a) General arrangements including ergonomic data and details of hazardous areas where applicable.

(b) Bilge and ballast system including material specifications for pipes, valves and fittings giving details of dimensions and working pressures.

(c) Life support systems. Please refer to *Pt 5, Ch 3, 2 Piping Design Requirements*.

(d) Hydraulic and Pneumatic systems, please refer to *Pt 5, Ch 7, 2 Submersible Handling Systems*.

■ *Section 2* **Piping Design Requirements**

2.1 Application

2.1.1 All pipe systems, whether inside or outside the pressure hull, are to conform to the requirements of *Pt 5 Main and Auxiliary Machinery* of the *Rules and Regulations for the Classification of Ships, July 2019*. All pipes and fittings are to be of approved type. Where quick release couplings are permitted they are to be permanently connected to the flexible pipes. For general requirements for piping system fittings *see Pt 5, Ch 3, 3.1 General Requirements for Piping Systems Fittings*.

2.1.2 Piping systems are to be designed, constructed and tested in accordance with *Rules for the Manufacture, Testing and Certification of Materials, July 2019* and *Rules and Regulations for the Classification of Ships, July 2019 Pt 5 Main and Auxiliary Machinery*, as applicable. However, piping systems for life support systems are to be designed, constructed, and tested in accordance with the requirements for Class I piping systems.

2.1.3 Piping systems are to be so designed that protuberances are faired to reduce the possibility of damage, for example, when alongside support craft or during work operations.

2.1.4 Where necessary external pipes may be protected against corrosion by suitable bonding or coatings.

2.1.5 Piping systems should be so designed as to minimize the noise inside the diving bell and surface compression chamber during normal operation.

2.1.6 Piping systems which could be subjected to higher pressures than their design pressure are to be fitted with a pressure relief valve.

2.1.7 Piping systems carrying mixed gas or oxygen under high pressure are not to pass through accommodation spaces, engine rooms or similar compartments.

2.1.8 High pressure gas systems are to be reduced in pressure as close as possible to the gas storage.

2.1.9 All pipes penetrating pressure chambers including diving bells are to be provided with internal and external isolating values. These valves are to have positive means of indication to show whether they are open or shut and are to be capable of being secured in either position. The securing arrangements are to be such that the valves can be operated in an emergency. Where appropriate, one valve should be of the non-return type. Where it is not practicable to fit isolating valves direct to the shell, distance pieces of short rigid construction may be fitted between the valves and shell plating. The number of screwed fittings, if employed for this purpose, should be kept to a minimum.

2.1.10 Any components fitted between the shell penetrations and isolating valves are to be designed for an internal and external pressure of not less than that equivalent to the maximum diving depth.

2.1.11 All high pressure piping should be well protected against mechanical damage.

2.1.12 All piping is to be approved metallic construction suitable for the service intended, except where flexibility is essential in which case flexible hoses of approved type having integral closely woven wire braid reinforcement with properly attached end fittings of swaged crimped or similar type are acceptable as short joining lengths between permanent piping.

2.1.13 All connections to instrumentation and pressure gauges are to be provided with suitable isolating valves, *see Pt 5, Ch 3, 3.1 General Requirements for Piping Systems Fittings 3.1.5*.

2.1.14 Mechanical components such as valves and fittings, which are procured from recognized suppliers may, with the prior agreement of LR, be accepted on the evidence of manufacturers full documentation supplemented by final system testing to the satisfaction of LR's Surveyors. *See also Ch 1, 2 Approval and survey requirements* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2019*.

2.1.15 All valves, fittings, controls, indicators and warning devices are to be provided with identification plates made of a material which is at least flame retardant. The identifying marks are to be clear and unmistakable (e.g. stating the short designation and/or the function of the item concerned).

2.1.16 Means must be provided for the complete evacuation, drainage and venting of piping systems.

2.1.17 Compression chambers and diving bells are to have suction guards on exhaust line openings inside each compartment.

2.1.18 Gas lines and electrical cables are to be routed separately.

2.1.19 Expansion in piping systems is to be compensated by pipe bends or compensators. Attention is to be given to the suitable sizing of fixed points.

2.1.20 Materials used in the breathing gas system shall not produce noxious, toxic or flammable products under specified design conditions.

2.1.21 In oxygen pressure systems, all the materials in contact with this gas shall be shock tested according to EN 738-1, -2 and - 3:1997/1998 “Pressure regulators for use with medical gases” or equivalent standard applicable to the particular component. (*See also* EN 849:1996, EN ISO 11114-3:1997 and EN ISO 2503:1998 in informative references)

2.1.22 For piping systems of copper, corrosion resistant alloys and austenitic steels with chromium-nickel content above 22%, the test can be waived.

2.1.23 Precautions shall be taken to avoid galvanic corrosion.

2.1.24 Non-metallic materials retaining pressurised gas shall be considered for gas-permeability.

2.2 Pipe connections

2.2.1 For general design requirements of piping system fittings *see Pt 5, Ch 3, 2.3 Pipe fittings*.

2.2.2 Wherever possible, pipes should be joined by full penetration butt welds.

2.2.3 Flanged connections and flange bolts conforming to a recognized standard may be used.

2.2.4 Other types of connections may be submitted for consideration.

2.2.5 Screwed pipe connections are to be of an LR approved type.

2.3 Pipe fittings

2.3.1 All surface compression chambers and diving bells are to be equipped at a centralized position outside the chamber with such valves, gauges and other fittings as necessary to control and indicate the internal pressure and safe environment of each compartment. The external pressure on the diving bell is also to be indicated inside the bell.

2.3.2 Valves in oxygen systems where the system pressure is above the exemption pressure as defined in IGC13/12/E, are to be screw down type and slow opening except that ball valves may be used as emergency shut-off valves fitted directly to the shell.

2.3.3 Gas valves, including pressure-reducing valves and their systems, are to be tested to 1,5 times design pressure. It is to be demonstrated that they are capable of delivering the specified quantity of gas at a pressure equivalent to the intended maximum diving depth.

2.3.4 All valves are to be constructed as to prevent the possibility of valve covers or glands being loosened when the valves are operated.

2.3.5 All valves are to be clearly labelled and provided with open/shut indication.

2.3.6 Shutoff devices must conform to a recognized standard. Valves with screw-down bonnets or spindles are to be protected against unintentional unscrewing of the bonnet.

2.3.7 Manually operated shutoff devices are to be closed by turning in the clockwise direction.

2.3.8 Hose fittings are to be made of corrosion resistant material and are to be so designed that they cannot be disconnected accidentally.

2.4 Hose lines and umbilicals

2.4.1 Except for umbilicals, non-metallic hoses are to be reduced to a minimum and are only to be installed in short lengths.

2.4.2 Hose lines, including their connectors, must be of proven suitability for the media, pressures and temperatures concerned. When selecting the material, special attention is to be paid to toxicity, incombustibility, gas permeability, and where applicable, compatibility with oxygen. Only types approved by LR may be used.

2.4.3 Hose lines for liquids/gases are to be designed for a bursting pressure equivalent to at least 4 and 5 times respectively the maximum permissible working pressure, *see Pt 5, Ch 5, 4.6 Resistance to burst*.

2.4.4 Hoses are to be permanently coupled to their connectors.

2.4.5 Systems with hose lines are to be fitted with a device for relieving the pressure before the hoses are disconnected.

2.4.6 Unless equipped with load cables, umbilical hose lines must be fitted with load relieving devices.

2.4.7 Umbilicals must be protected against abrasion and damage. Where protective sheathing is used, care is to be taken to ensure that minor leaks cannot lead to an internal pressure build-up. Metal inserts are to be avoided.

2.4.8 Electrical cables in the umbilical must conform to the requirements stated in *Pt 6 Electrical Installations and Control Engineering Systems*.

2.5 Safety Relief Valves

2.5.1 Equipment and piping systems which may be subjected to pressures higher than the design pressure must be fitted with overpressure protection.

2.5.2 All compression chambers and diving bells shall be provided with pressure relief valves or overpressure alarms. Where pressure relief valves are proposed these may be fitted on the chamber or bell or, alternatively on each gas pressurizing line. Where relief valves are fitted on a chamber a quick operating manual shut-off valve should be installed between the chamber and the pressure relief valve which should be wired open with a frangible wire. This valve should be readily accessible to the diving supervisor monitoring the operation of the chamber.

2.5.3 Heat exchangers and heaters in life support system are to be protected by suitably sized safety relief devices set at a pressure not exceeding their maximum allowable working pressure (MAWP) and they are to be installed with no intervening valves between the pressure container and the safety relief device with the exception of PVO's. The maximum allowable working pressure is the maximum pressure permissible at the top of the pressure vessel, heat exchanger or heater in its normal operating condition and at the designated concurrent temperature specified for that pressure. If the safety devices are mounted outside the main pressure hull, they are to be constructed of suitable non-corrosive materials and are to be inspected on a regular basis in accordance with the procedure outlined in the approved Maintenance Manual. For these safety devices, the designer is to consider the effect of seawater back-pressure acting on the downstream side of the safety device.

2.5.4 If the safety devices are mounted on equipment or piping within PVHO, then it is to be demonstrated by calculations that the release of the fluid contained in the pressure vessel will not increase the pressure within the main pressure hull by more than 1 atmosphere, nor raise the partial pressure of the atmospheric gases above their maximum allowable levels. Special consideration will be given to the equivalent alternative arrangements.

2.6 Ballast systems

2.6.1 Ballast systems should be designed to operate under all specified angles of heel and trim including maximum anticipated damage conditions.

2.6.2 In an autonomous or free-swimming submersible where pumps are required for the transfer or discharge of ballast a stand-by pump should be provided.

2.6.3 On passenger submersibles, pumps are to be provided which are capable of quickly transferring ballast and altering trim according to the number of passengers embarked on each trip.

2.6.4 Internal ballast or trim systems which may be subjected to the dive pressure should be suitable for the maximum design diving depth and are to be tested to 1,5 times this pressure.

2.6.5 Ballast control and tank flow valves are to be of a failsafe design or, alternatively provided with stand-by facilities.

2.6.6 Where compressed air is used to discharge ballast or to trim tanks the capacity should be sufficient to discharge all the tanks at the maximum diving depth with a reserve of 50 per cent. On passenger submersibles the reserve should be 100 per cent.

2.6.7 The compressed air storage vessels should not be used for other purposes and should be fully charged before the start of each dive.

2.6.8 In a passenger submersible two separate means of enabling the craft to return to the surface should be provided and for keeping the surfaced craft in a stable condition.

2.6.9 Sufficient instrumentation and equipment should be provided to ensure that the operator is fully aware of the ballast, heel and trim conditions at all times.

2.6.10 Water leakage monitoring devices should be provided in all compartments with audible and visual alarms at the control station. Monitoring devices for battery compartments should be suitable for use in such spaces.

2.7 Bilge systems

2.7.1 Autonomous submersibles should be provided with an efficient bilge system capable of pumping out all watertight compartments except those containing water ballast, fuel oil, etc., under all practicable conditions of list and trim.

2.7.2 Autonomous submersibles are to be provided with at least two self-priming pumps capable of draining all compartments. Where appropriate, one pump may be driven off propulsion shafting.

2.7.3 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another. For this reason screw down non-return valves are to be provided at bilge pump manifold and branch bilge suctions.

2.7.4 Where bilge pipes pass through watertight bulkheads, screw down non-return valves attached to the bulkheads capable of being closed from both sides are to be provided.

2.7.5 In addition a mud box and screw down non-return valve should be provided within the space the bilge suction serves.

2.7.6 Bilge systems which may be subjected to the dive pressure should be suitable for the maximum design diving depth and are to be tested to 1,5 times this pressure.

2.8 Drainage of chambers

2.8.1 Where drainage of pressure chambers is achieved by means of pressure differential, a self-closing shut-off valve is to be provided inside the chamber close to the chamber penetration.

2.9 Compressed air systems

2.9.1 Air storage pressure vessels are to be designed and manufactured to a relevant National Standard.

2.9.2 Where compressed air is used for essential ballasting movements, not less than two means of supplying the compressed air are to be provided. Alternatively where the craft is designed for trips of short duration (for example less than 6 hours) consideration could be given to recharging the storage vessels from shore.

2.9.3 Each compressor stage must be equipped with a pressure relief valve or rupture disc, neither of which can be disabled. This safety device must be designed and set in such a way that the specified pressure in the compressor stage concerned cannot be exceeded by more than 10 per cent. The setting must be safeguarded against unauthorized alteration.

2.9.4 Each compressor stage must be provided with a suitable pressure gauge indicating clearly the final pressure of that stage.

2.9.5 Where a compressor stage comprises more than one cylinder and each cylinder can be closed off individually, a pressure relief valve and a pressure gauge must be provided for each cylinder.

2.9.6 Cooling liquid systems with a shutoff device must be so designed that the specified coolant pressure cannot be exceeded.

2.9.7 Dry-running reciprocating compressors must be equipped at each stage with a device which activates a warning signal and shuts down the drive motor if the final compression temperature stated in the operating instructions is exceeded.

2.9.8 Diaphragm-type compressors must be equipped at each stage with a diaphragm rupture indicator which shuts down the compressor as soon as damage occurs to the drive or compressor diaphragm

2.10 Hydraulic equipment

2.10.1 Fluids having low flash points and fluids having high viscosity at low temperatures are not to be used. Fire-resistant non-toxic fluids are recommended.

2.10.2 Materials used for all parts of hydraulic seals are to be compatible with the working fluid at the appropriate working temperature and pressure.

2.10.3 Pumps are to be accessible for maintenance and are to be mounted where they will be protected from damage and dirt.

2.10.4 Overpressure protection is to be provided on the discharge side of all pumps. Where relief valves are fitted for this purpose they are to be fitted in close circuit, i.e. arranged to discharge back to the suction side of the pump.

2.10.5 System piping is not to be used as a means of supporting equipment.

2.10.6 Provision is to be made for operation of the equipment in the event of loss of pressure in the system.

2.10.7 Hydraulic piping is to be located clear of oxygen or oxygen enriched systems.

2.11 Wall Thickness of Pipes and Tubes Subjected to External Pressure

2.11.1 The minimum thickness of piping subject to external pressure is to be the greater of the thickness determined by the following equations:

$$t = \left[\frac{\left(1 - v^2\right)\left(12WR^3\right)}{E}\right]^{\frac{1}{3}} + c$$

$$t = \frac{3WR_o}{Q_y}$$

Where:

W = External Pressure

T = Thickness

E = Modulus of Elasticity

R = Mean Radius

R_o = Outside Radius

v = Poisson's Ratio

Q_y = Yield Strength

C = 0.00 for plain-end pipe or tubing

= 1.27 mm (0.05 in.) for all threaded pipe 17mm (3/8 in.) O.D. and smaller

= depth of thread h for all threaded pipe over 17 mm (3/8 in.) O.D.

= depth of groove for grooved pipe

2.12 Testing

2.12.1 On completion of manufacture but before insulation or painting, all piping systems are to undergo a hydraulic pressure test at 1,5 times the design pressure.

2.12.2 The gas storage facilities, diving system and life support systems including the gas piping are to be subjected to a tightness test at the maximum permissible working pressure using Nitrogen with 10% He to facilitate locating possible leaks. The maximum permissible leakage rate is represented by a 1 per cent pressure drop in 24 hours for the entire compression chamber system taking into account any temperature change. Please also *see Pt 5, Ch 4, 6.3 Oxygen System Testing* and *Pt 5, Ch 4, 6.4 Gas leak test for all chambers and breathing gas systems* respectively.

2.12.3 Wherever possible, all butt welds in LSS piping systems are to be subjected to 100 per cent NDT for class I piping systems.

2.12.4 Piping systems for breathing gas and oxygen are to be subjected to a purity test.

■ *Section 3*
Requirements for Piping Systems Fittings

3.1 General Requirements for Piping Systems Fittings

3.1.1 Care must be exercised when designing piping components for the diving system to ensure that gas or liquid flow is in the proper direction through the component. Most components have a designed direction for flow and this should be observed. Where components permit bi-directional flow, they shall be installed to take best advantage of the design. For example, valves serving as both inlet and outlet on high-pressure vessel shall be installed so that when they are closed the vessel pressure acts from below the seat and not on the valve stem packing.

3.1.2 Piping components shall always be installed in accordance with the manufacturers' recommendations, unless a deviation is approved by LR.

3.1.3 All manually operated piping system components shall be readily accessible and easily operable under normal and emergency conditions.

3.1.4 All piping system components shall be selected to permit adequate flow for the most demanding mission conditions expected for the diving system. These conditions shall be specified when justifying the selection of a component.

3.1.5 Adequate stop valve and/or check valve protection shall be provided to prevent loss of control of the system, e.g. isolation valves shall be provided for all gauges and regulating valves and double valve protection shall be provided on fill and drain lines for all gas pressure vessel. Double valve protection shall consist of one isolation valve for each pressure vessel bank and isolation valves for each pressure vessel in the bank. Pressure vessel drain lines shall be separate for each individual flask. Flask drain lines shall not be manifolded. Hull and back-up valves are required on PVHO’s to prevent uncontrolled depressurization or flooding.

3.1.6 Brazed joints are permitted in copper and copper-alloy piping systems. Special care must be taken to ensure surface cleanliness and full penetration of the weld joints in order to prevent entrapment of particulate and eliminate uncleanable surfaces.

3.1.7 Mechanically attached fittings such as elastic strain preload (ESP), swaged (Category I UIPI) and shape memory alloy (SMA) types are not permitted in breathing gas piping systems.

3.1.8 Pipe threads are typically not allowed in life support systems or systems subjected to external pressure without specific LR approval. Experience has shown that pipe thread connections are susceptible to corrosion, shock and vibration damage, and leakage. Consideration must be given to pressure limitations due to a reduction in wall thickness of the pipe at the tapered threads. Should a component only be procurable with pipe threaded end fittings, a means must be provided upstream and downstream of the component to permit its removal without disturbing the threaded joints. Any compound (e.g. anti-seize thread tape) or lubricant used in threaded joints shall be suitable for the service conditions.

3.1.9 Flared pipe fittings and their joints shall conform to the range of wall thickness and method of assembly recommended by the manufacturer. Care should be taken with cutting and flaring tools so as to not induce work hardening of the tube end, which can make the material more susceptible to brittle fracture. Flared fittings are to be of LR type approved.

3.1.10 Flareless, mechanical friction or bite-type connections shall not be used on piping components where failure could cause uncontrolled depressurization or flooding of pressure vessels, life support systems, electrical assemblies or other life-critical components. The use of such fittings in control and monitoring systems may be permitted only if the component can be quickly isolated from the rest of the system in case of failure and redundant means of providing the control and monitoring functions is available; or the fittings are on LR approved equipment.

3.1.11 Fittings where direct impingement of entrained particles may occur, such as short radius elbows and tees, shall be made from monel. In areas where carbon steel or stainless steel construction is permitted, fittings with the same composition may be used if the velocity limit is reduced by half. Piping downstream of control valves shall be made from monel, for a distance of 10 times the pipe diameter. For pipe sizes below DN 50, carbon steel shall not be used; stainless steel shall be used, subject to the velocity limitations given in the *Rules and Regulations for the Classification of Ships, July 2019 Pt 5, Ch 12 Piping Design Requirements*.

3.1.12 In carbon steel and stainless steel piping systems, branches shall be made with equal tees, reducing tees or swept outlets. In monel piping systems, branches should also be made with equal tees, reducing tees or swept outlets, but branch outlets (weldolets) and branch fittings (nipples) may be used.

3.1.13 Oxygen piping systems shall be kept as simple as possible, with the smallest possible number of valves, fittings, branches and nozzles. Consideration should be given to the combination of several instrument connections in one fitting or nozzle.

3.1.14 Oxygen piping shall be located as far as possible from other piping. Pipes containing flammable fluid or steam shall not be laid within 1 m distance of oxygen piping. The free space may be utilised for lines carrying water, nitrogen or other nonflammable fluids at ambient temperature. At points where the above requirements cannot be fulfilled, the oxygen system shall be fire protected.

3.1.15 Running of oxygen piping through enclosed spaces should be avoided. If unavoidable, flanged connections or valves shall not be used and the enclosed space shall not contain lines carrying flammable fluids. Oxygen piping shall not support other pipes.

3.1.16 Expansion bellows shall not be used.

3.1.17 In the absence of design justification the following connections shall not be accepted:

- Slip-on flanges,
- lap flanges,
- socket weld valves and fittings, or
- threaded connections.

3.1.18 Changes in diameter shall be minimised.

3.1.19 Dead ends in piping shall be avoided.

3.1.20 The oxygen flow in piping shall be in one direction only. If flow in two directions cannot be avoided, arrangements are to be analysed for potential risks.

3.1.21 To assist removal of the degreasing agent after cleaning, low points in equipment and piping, shall have drain connections without a valve but closed with a blind flange or other provisions to remove the cleaning agent, *see also Pt 5, Ch 4, 6 Testing and Cleaning*.

3.1.22 Connections for purging and venting shall be situated such that purging and venting of the system can only be done in the normal direction of the oxygen flow.

3.1.23 Nitrogen systems used for automatic purging shall be equipped with a filter and two pressure indicators. They shall be designed to prevent the possibility of oxygen flowing back into the nitrogen system.

■ *Section 4*
Oxygen Safety in Diving Systems

4.1 General Safety Requirements

4.1.1 Fires have occurred when using high-pressure oxygen in diving operations. These have happened mainly when high-pressure oxygen has been opened up onto unpressurised lines. This has resulted in either explosions or localised fires. The majority of these incidents are caused by a combination of contaminated oxygen systems or the use of materials in the oxygen systems which are incompatible with oxygen and isentropic heating caused by too rapid pressurisation of the lines.

4.1.2 It is also important to note that if polytetrafluoroethylene (PTFE) reaches a high enough temperature it creates phosgene gas, which is lethal.

4.1.3 The following points should be considered when designing and using oxygen supplies in diving systems:

(a) Reduce high-pressure oxygen to low-pressure (40 bar, maximum) at the main supply quad.
(b) Avoid long runs of flexible hose.
(c) All materials and fittings should be oxygen compatible.
(d) Avoid ball valves in high-pressure systems.
(e) Avoid sharp bends in oxygen piping.
(f) All oxygen piping connections and oxygen supply connections on storage cylinders should be blanked when not in use.

4.1.4 All diving breathing mixtures should be checked on receipt and re-checked immediately prior to connecting them to a diving gas supply or breathing apparatus charging system.

4.1.5 When using commercially supplied air quads, nitrox mixes and pure oxygen, it is recommended that oxygen analysers, fitted with audio and visual Hi-Lo alarms, are provided for surface supplied diving operations. To ensure the accuracy of the analysis, the sample point should be taken downstream of the dive control panel and immediately prior to the diver's umbilical. The design must allow for simple safe analysis of any gas being supplied to the diving system including its gas storage banks.

4.1.6 Metallic materials wetted by oxygen shall not propagate a flame, shall not burn, and shall be impact resistant with oxygen at the maximum operating pressure of the system in accordance with ASTM G94, Standard Guide for Evaluation Metals for Oxygen Service. Non-metallic material wetted by oxygen shall be resistant to impact ignition, and shall have the lowest possible heat of combustion in accordance with ASTM G63, Standard Guide for Evaluating Non-Metallic Materials for oxygen Service. Additionally, where non-metallic material is utilised in, the design shall minimise the surface area and volume exposed to oxygen.

■ *Section 5*
Additional Safety Measure in Gas Piping Systems

5.1 General Safety Requirements

5.1.1 This section outlines potential design faults regarding divers' gas supply and the consequences of a primary failure.

5.1.2 The gas supply system to a diver should be designed in such a way that, in the event of the diver's umbilical being cut or severed, it should not deprive any other diver or standby diver of their gas supply.

5.1.3 The gas supply system in a diving bell should be designed in such a way that, if the main surface to bell umbilical pressure is lost, the emergency bell on board gas is brought on-line to the diver or divers. This can be done either manually or automatically, with a safeguard against exhausting back into the main umbilical.

5.1.4 The gas supply system to the bell standby diver should give the option of using either unlimited surface gas supply or the independent limited on board gas supply.

5.1.5 When designing new diving bells or modifying existing bells, consider the provision of an independent gas supply to each diver and the standby diver.

5.1.6 The breathing gas supply to divers' masks must be designed in such a way that if the diver's umbilical supply fails the gas from the reserve or bailout cylinder does not exhaust into the sea.

5.1.7 Oxygen systems over 8.0 bar and compressed air systems over 33 bar shall have slow-opening shut-off valves.

5.1.8 Pressure regulators for breathing gas are to be of proven design and manufactured to cope with the pressures and volumes that are required to meet the operational requirement for the diving systems designed requirement.

5.1.9 Wherever possible, the pressure in oxygen lines is to be reduced at the gas storage facility to a pressure which is still compatible with an adequate gas supply to the diving system, *see also Pt 5, Ch 3, 4.1 General Safety Requirements 4.1.3*(a).

Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

Unit Type	Plans and particulars: General Section 1.1	Submission of plans Section 1.2	Approval of life support arrangements: General requirements Section 2.2	Gas storage: general Section 3.1	Oxygen storage Section 3.2	Gas cylinder national colour codes Section 3.3	Gas distribution and supply: General requirements Section 4.1	Design and installation Section 4.2	Pipes, valves and fittings Section 4.3	Oxygen supply and distribution Section 4.4	Compression chambers Section 4.5	Diving bells Section 4.6	Emergency breathing systems Section 4.7	Oxygen distribution and supply: General requirements Section 5.1	Control (1 ATM Submersible) Section 5.2	Pipes, valves and fittings Section 5.3
Manned Submersible	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Unmanned Submersible																
Submersible Craft																
Diving Bell	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Vehicle																
Submersible Habitat	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Submersible Container																
Passenger Submersible	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x

	Testing and cleaning: General	Oxygen system cleaning	Oxygen system testing	Gas leak test for all chamber and breathing gas systems	Carbon dioxide (CO2) removal system: General requirements	Expiration rate	Allowable concentration	Expendable methods of CO2 removal	Regenerative methods	Dust filteration	Removal of hydrogen, carbon monoxide and other contaminants	Control and sensing	Testing	Air and gas for breathing purposes: General	Maintenance of breathable atmosphere	Containment control system
	Section 6.1	Section 6.2	Section 6.3	Section 6.4	Section 7.1	Section 7.2	Section 7.3	Section 7.4	Section 7.5	Section 7.6	Section 7.7	Section 7.8	Section 7.9	Section 8.1	Section 8.2	Section 8.3
Unit Type																
Manned Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Unmanned Submersible														x		x
Submersible Craft														x		x
Diving Bell	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Vehicle														x		x
Submersible Habitat	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Container														x		x
Passenger Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	Air purity standards	Gas purity standards	oil lubricated compressors	Conditioning of chamber atmosphere	Breathing gas treatment and mixing	Emergency life-support	Pressure, temperature and humidity control: general requirements	Pressure	Temperature	Diver heating	Chamber heating	Instrumentation: General requirements	Oxygen	Carbon dioxide	Other gases (e.g. carbon monoxide, hydrogen, Freon etc.)	Test and calibrations
	Section 8.4	Section 8.5	Section 8.6	Section 8.7	Section 8.8	Section 8.9	Section 9.1	Section 9.2	Section 9.3	Section 9.4	Section 9.5	Section 10.1	Section 10.2	Section 10.3	Section 10.4	Section 10.5
Unit Type																
Manned Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Unmanned Submersible																
Submersible Craft																
Diving Bell	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Vehicle																
Submersible Habitat	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Container																
Passenger Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	Temperature and thermal protection in the event of an emergency in atmospheric submersible craft	Food and water supply systems: general requirements	Diver lock-out compartment: general requirements	Pressurisation	Depressurisation	Gas supplies	Carbon dioxide removal	Temperature control	Humidity	Communications	Instrumentation	Food and water supply	Medical lock	Additional provisions to be provided: First aid kit at the sight of diving equipment	Power supply: emergency source of power	Video monitoring systems: general
	Section 10.6	Section 11.1	Section 12.1	Section 12.2	Section 12.3	Section 12.4	Section 12.5	Section 12.6	Section 12.7	Section 12.8	Section 12.9	Section 12.10	Section 12.11	Section 13.1	Section 14.1	Section 15.1
Unit Type																
Manned Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wet Submersible	x	x												x	x	x
Unmanned Submersible															x	
Submersible Craft															x	
Diving Bell	x	x												x	x	x
Submersible Vehicle															x	
Submersible Habitat	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Container															x	
Passenger Submersible	x	x												x	x	x
Rescue Submersible	x	x												x	x	x

■ *Section 1* **Plans and Particulars**

1.1 General

1.1.1 These Rules apply to all those plant components and parts which are needed to ensure life support and a safe environment for the occupants of a diving system.

1.1.2 The documents to be submitted to LR for approval are listed in *Pt 5, Ch 4, 1.2 Submission of plans*.

1.1.3 The necessary tests and markings are stated in this chapter.

1.2 Submission of plans

1.2.1 The following plans (in diagrammatic form) and particulars are to be submitted for appraisal:

(a) Life-support systems and arrangements, including gas and distribution.
(b) Emergency life-support details.

Section 2
Approval of Life Support Arrangements

2.1 General Requirements

2.1.1 For Class acceptance of the life support arrangements full details, and calculations where necessary, together with arrangement drawings of the proposed systems should be submitted for consideration. The details should include the following:

2.1.2 Gas Supplies - Gas cylinder specification materials used in construction, working and test pressure, number of cylinders and copies of cylinder test Certificates.

2.1.3 Gas distribution and supply systems piping materials and scantlings, pipe couplings, valves, pressure hull penetrators and other associated fittings. Where special materials are used in oxygen systems such as, valve seats, the ignition temperatures of the materials should be provided.

2.1.4 Systems for the removal of Carbon Dioxide, other gases and moisture including maximum concentrations of toxic or flammable gases anticipated in the compartments with maximum number of persons present under the normal operating conditions.

2.1.5 Details of system(s) proposed together with calculations where applicable, giving expected generation and removal rates of undesirable gases over the range of temperatures and humidity expected.

2.1.6 Method of Carbon Dioxide removal in event of main power failure.

2.2 Oxygen Systems Control

2.2.1 Means of maintaining and controlling the partial pressure of oxygen is to be provided.

2.3 Emergency Breathing Apparatus

2.3.1 Details and arrangements together with amount of gas available. Confirmation that equipment is suitable for all toxic gases that could accumulate in the manned compartments.

2.4 Emergency Power Supplies

2.4.1 Type and capacity of supply available, power demand requirements of the items of equipment capable of being supplied from the emergency power supply.

2.5 Instrumentation

2.5.1 Details and types of instrumentation proposed to control and monitor the atmosphere in the manned compartments.

2.6 Thermal Protection

2.6.1 Means of providing thermal protection for occupants of the unit.

2.7 Provisions

2.7.1 Amount of food and water to be carried.

2.8 Medical Lock (where applicable)

2.8.1 Details and dimensions of medical lock proposed.

2.9 Combustible materials

2.9.1 Details of any materials used in the construction, or the furnishing of the unit, that are combustible at normal oxygen levels.

Section 3
Gas Storage

3.1 General

3.1.1 Every diving system is to be provided with a permanently installed gas storage plant or suitable space for portable gas containers.

3.1.2 The capacity of the gas storage shall be such that, for all the planned diving operations, a sufficient number and quantity of gas mixtures are available to supply all the compression chambers, diving bells and divers with an adequate quantity of the correct gases at all operating depths and under normal and emergency conditions.

3.1.3 Emergency gas is to be stored separate from the normal supply and must not be opened during normal operation.

3.1.4 Where it is intended to use hydrogen or hydrogen mix gases during diving operations full details of the proposed arrangements for storing, distributing and utilizing these gases should be submitted for consideration taking into account the high flammability of the hydrogen and the special precautions necessary for the safety of personnel involved in the diving operations.

3.1.5 It is to be ensured that gas storage cylinders, and associated valve and piping, are adequately designed against fatigue, as applicable for the proposed dive cycles.

3.2 Oxygen Storage

3.2.1 Oxygen bottles are to be stored preferably on the open deck or in separate well ventilated non-hazardous locations a suitable distance from any flammable substances.

3.2.2 Spaces in which oxygen is stored must be separated from the adjoining spaces by bulkheads and decks of Type "A"-60 and must be arranged to facilitate speedy exit in case of danger.

3.2.3 Piping systems containing gases with more than 23 per cent oxygen should be treated as systems containing pure oxygen, and the oxygen should be stored in bottles or pressure vessels exclusively intended for such gases. Where pure oxygen is supplied to a chamber, a separate piping system should be provided.

3.2.4 Gaseous oxygen may be stored at any pressure up to 345 bar.

3.2.5 The oxygen gas cylinder must comply with the specification for the pressure at which it will be used and be suitable for oxygen storage. In addition, the cylinder must be capable of withstanding external pressure up to the collapse depth with zero internal cylinder pressure.

3.2.6 Gas cylinders are to be manufactured in accordance with recognised codes and standards for TPV Regulations.

3.2.7 Oxygen should be stored in at least two independent cylinder sub systems. Each sub-system must be arranged so that a failure, by leakage, of any system will not bleed into any other system.

3.2.8 Each group of cylinders should be piped separately to the submersible craft.

3.2.9 Each oxygen line into a compartment, if connected to a common manifold, should be fitted with a non-return valve.

3.2.10 If a low pressure oxygen system can be pressurised to the maximum cylinder pressure then the low pressure system should be designed and tested to the same cylinder pressure.

3.3 Gas Cylinder National Colour Codes

3.3.1 Gas cylinders are to be painted in colours in accordance with National Codes of Practice or as per latest IMCA guidance. It is essential that the code in use on any particular submersible be clearly marked on that submersible or in the control cabin of diving chambers. Particular care should be taken with oxygen and air as some codes use black for air and light grey for nitrogen. *See* Table 4.3.1.

Table 4.3.1 BS 1319:1976 Medical Gas Cylinders and Anaesthetic Apparatus lists the following colour codes for gas bottle identification:

Name of gas	*Symbol*	*Valve end*	*Body*
Oxygen	O_2	*White*	*Black*

Helium	*He*	*Brown*	*Brown*
Oxygen and helium mixture	O_2+	*White and Brown*	*Black*
Air	*Air*	*White and Black*	*Grey*
Nitrogen	N_2	*Black*	*Grey*

With the addition of the symbol stencilled on the neck.

■ *Section 4* **Gas Distribution and Supply**

4.1 General Requirements

4.1.1 The gas distribution systems are to be comprised of piping and components essential to the distribution of gases for normal and emergency operation, and are to be painted with colours appropriate to their function, and marked with the appropriate flow direction.

4.1.2 Each service in the life-support system to a bell or compression chamber is to be capable of being supplied from two sources unless otherwise approved. The arrangements are to be such that loss of any one supply will not render the other supply inoperable.

4.1.3 For wet submersibles, sufficient additional breathing gases should be available to enable decompression stops to be carried out with submersibles operating below 10 m. Such supplies should be readily connectable to breathing apparatus.

4.1.4 Filters or automatic pressure reducers are to be so arranged that they are capable of being removed without affecting the vital gas supplies.

4.1.5 Special attention is to be paid to the oxygen supply, CO2 removal (which may be by chemical means or molecular sieves), emergency breathing arrangements and monitoring devices, particularly if 'locking in' and 'locking out' are arranged. The CO2 removal system should be capable of operating for a survival period as specified in *Pt 5, Ch 4, 8.9 Emergency life-support*, in addition to the planned dive times.

4.1.6 Oils used in compressors for gases intended for breathing purposes are to conform to the requirements of the appropriate National or International Authority Standards. Mineral-based oil is not to be used in the compressor itself or where it is likely to contaminate the compressed gases. Consideration may be given to the incorporation of absorption type purifiers.

4.1.7 Means should be provided in the gas mix distribution system to prevent the escape of 'on board' gas to the sea in the event of a break in the umbilical gas supply.

4.1.8 The gas supply is to be designed so that a pressure increase up to 2 bar in the living compartment of the compression chamber can be effected at a rate of at least 2 bar/min followed by a rate of 1 bar/per min.

4.1.9 The gas venting system is to be designed so that the pressure in a compression chamber or diving bell can be reduced to 1 bar at a rate of at least 1 bar/per min.

4.1.10 Sets of breathing apparatus which, activated by respiration, supply breathing gas to persons exposed to excess pressures and also remove exhaust gas independently of the chamber atmosphere are to be designed for a gas flow equal to 3 times the required breathing rate per minute (AMV). The required breathing rate per minute depends on the proposed activity and the environmental conditions. When designing the supply and exhaust facilities for breathing masks, the number of persons simultaneously connected to the system is to be allowed for as follows (*see* Table 4.4.1):

Table 4.4.1 Built in Breathing System

Number of Persons (N)	*Quantity of Breathing gas [operating litres/min]*
1	*1 x AMV x 3*

2	2 x AMV x 1.8
3	3 x AMV x 1.6
4	4 x AMV x 1.4
5	5 x AMV x 1.3
6	6 x AMV x 1.2
7	7 x AMV x 1.1
8	8 x AMV x 1.1
N>8	N x AMV x 1.0

4.1.11 The gas circulating systems are to be so designed that the chamber conditions are maintained.

4.1.12 Each compression chamber compartment and each diving bell is to be equipped with at least the following gas systems:

(a) 2 independent gas supply systems for compression (for surface decompression chambers) which may deliver into a single inlet pipe immediately at the chamber
(b) 1 chamber exhaust gas system
(c) 1 built in breathing systems (BIBS)
(d) 1 mask exhaust gas system (BIBS)
(e) 1 gas circulating system for maintaining the breathable chamber atmosphere.

4.1.13 Where pure oxygen or gas containing more than 23 per cent O_2 by volume is supplied to the chamber, a separate piping system is to be provided for this purpose.

4.1.14 Valves in gas systems are to be so arranged that a valve leakage cannot lead to an unintended mixture of gases and oxygen or oxygen-like gas cannot penetrate into lines intended for other gases. Intersections between oxygen and non-oxygen systems are to be isolated by twin shutoff valves with venting valves in between.

4.2 Design and Installation

4.2.1 When considering materials to be used in the system due consideration should be given to the effects of electrolytic action and chilling of materials.

4.2.2 All piping and fittings used in the supply and distribution systems should be made from material suitable for the intended service.

4.2.3 Each independent gas supply should be equipped with a gauge capable of monitoring supply pressure when the supply valve is open. Each independent gas supply pressure hull penetration should be equipped with a quick acting shut-off valve. Taper cocks are not acceptable.

4.2.4 Pipes should be formed to eliminate distortion of unions; and the piping system should be designed to have the minimum number of unions.

4.2.5 Non-destructive testing is to be carried out upon completion of all welded pipes.

4.2.6 Pipes, valves, fittings and cylinders subject to external pressure should be capable of withstanding maximum design depth pressure with zero internal system pressure.

4.2.7 Piping, cylinders, valves etc. are to be adequately secured. Cylinders, valves and external piping should be adequately protected from damage.

4.3 Pipes, Valves and Fittings

4.3.1 All valves must be designed to a recognised code or standard.

4.3.2 The maximum permissible working pressure of the valves should be readily identifiable.

4.3.3 Valves or cocks liable to seizure due to changes in temperature or otherwise should not be used.

4.3.4 Valves should be so designed that when the valve is shut the valve gland is not under internal pressure.

4.3.5 Valve rotation should be anticlockwise for opening.

4.3.6 Valves should be clearly marked to indicate their purpose.

4.3.7 Wherever practicable valves should indicate clearly when they are open or shut.

4.3.8 The valve spindle should not rely on the gland to retain the spindle in the valve body.

4.3.9 All valves to be constructed so as to prevent the possibility of the valve or glands being slackened back or loosened when the valves are operated.

4.4 Oxygen supply and distribution

4.4.1 For the design requirements of oxygen supply and piping refer to *Pt 5, Ch 4, 5 Oxygen Distribution and Supply*.

4.5 Compression chambers

4.5.1 At least one breathing mask is to be provided for each occupant inside each separately pressurized chamber compartment. One spare breathing mask should be provided inside each separately pressurised chamber compartment. An additional spare mask should be included for every ten occupants.

4.5.2 The BIBS are to be connected to the BIBS gas supply and exhaust gas system either permanently or by plug and socket connectors.

4.5.3 The exhaust gas (exhalation line) side of the BIBS is to be protected against any inadmissible pressure drop or inadmissible pressure difference.

4.5.4 The supply of gas to the chamber is to be arranged so as to ensure a homogeneous gas distribution inside the chamber is achieved as quickly as possible.

4.5.5 The open end of the exhaust pipes are to terminate in a safe location.

4.6 Diving bells

4.6.1 Besides their normal breathing gas supply diving bells and divers in the water must also carry an independent reserve gas supply.

4.6.2 The supply of breathing gas to the diving bell is to be designed in such a way that, should the diving bell umbilical fail, the reserve chamber supply can be switched manually or automatically to the divers without flowing back into the chamber umbilical.

4.6.3 The divers' umbilical system is to be so designed that each diver has his own independent supply.

4.6.4 In the diving bell at least one breathing mask is to be provided for each diver, plus one spare, and this must be connected to both the normal and the reserve gas supply. Divers' masks and helmets with a gas supply may be recognized as breathing masks.

4.6.5 Automatic pressure reducers are to be provided for the breathing masks.

4.6.6 The emergency oxygen supply is to be fitted with a dosage system to enable the oxygen in the diving bell to be maintained at the correct partial pressure.

4.6.7 The diving bell is to be equipped with two independent exhaust gas lines, which must be arranged to avoid flooding of the electrical equipment. An exhaust gas valve is to be mounted close to the divers' exit.

4.6.8 For the requirements of leak testing and cleaning please refer to *Pt 5, Ch 4, 5 Oxygen Distribution and Supply*.

4.7 Emergency breathing system

4.7.1 An emergency breathing system should be fitted for use in case of fire or smoke in manned compartment(s). This may be a Built-in Breathing System (BIBS) supplied from breathing gas cylinders, or a portable breathing apparatus using its own supply. In some cases both systems may be employed. In either system a face mask connected to the breathing gas supply should be provided for each diver. The system shall be operable for sufficient time to enable an autonomous submersible craft to surface from its maximum operating depth and be able to open the hatch and for all other submersible to be recovered from maximum operating depth; this time shall be a minimum of 30 minutes. Special consideration will be given to craft operating at depths greater than 1,000 metres.

4.7.2 An open circuit system is recommended. If a closed circuit breathing system is used, the resultant pressure build up in the Chamber must be considered.

4.7.3 Either a full-face mask or an oral-nasal mask with eye protection should be provided. It should be possible to communicate whilst wearing breathing masks. Masks should be easily donned, close fitting, and comfortable for the duration of the emergency. The equipment should be designed so that the crew can exit from the submersible craft without first removing the face mask.

4.7.4 Sufficient breathing systems should be provided so that an emergency mask for each member of the crew can be reached in a minimum of time.

4.7.5 Portable breathing apparatus should be examined regularly for possible leakage.

4.7.6 The dive control station and local control stations for handling systems are to be provided with emergency breathing devices with communication equipment to enable the personnel to perform their duties in smoky/polluted environments. The emergency breathing devices are to be capable of functioning for at least 30 minutes. The emergency breathing devices may be self-contained or umbilical supplied.

4.7.7 Diving bells are to be provided with emergency breathing gas using a Built-in Breathing System (BIBS). The BIBS is to be independent of the normal surface supply.

■ *Section 5*
Oxygen Distribution and Supply

5.1 General Requirements

5.1.1 In addition to the requirements of *Pt 5, Ch 4, 3 Gas Storage* the following shall be complied with.

5.1.2 Materials used in oxygen and oxygen enriched systems are to be compatible with oxygen and due consideration taken of the pressure and velocity of supply. Although nota preferred material the use of stainless steel for piping will be the subject of special consideration.

5.1.3 Before filling oxygen and oxygen enriched systems, all traces of oil and grease are to be removed.

5.1.4 Oxygen supply should be based on a minimum consumption of 30 litres per hour for each man (measured at 20 ^{O}C).

5.1.5 The oxygen supply is to be free from hydrocarbons or flammables.

5.2 Control (1 ATM submersibles)

5.2.1 The system should be designed to maintain the partial pressure of oxygen within the following physiologically accepted limit: Recommended minimum 150 mm Hg (0.2 bar) and maximum of 0.5 barg for long term exposure.

5.2.2 The oxygen content of any compartment should not normally exceed 23 per cent by volume of the breathing mixture on account of the fire hazard. Suitable control and safety arrangements are to be provided.

5.2.3 If a manual delivery control system is provided for compressed oxygen it should include a cylinder shut-off valve, and a flow controller. A flow indicator may be fitted. A manually operated by pass must be provided.

5.2.4 When an automatic control system is used to maintain the partial pressure of oxygen, manual operation of the system must also be possible. Automatic control systems should include a shut-off valve, a flow controller and a manually operated by pass.

5.2.5 Failure of the automatic control is to be indicated by alarm at control station and manual back up system is to be readily available.

5.3 Pipes, Valves and Fittings

5.3.1 Allowance should be made for any relative movement between an oxygen cylinder and the hull to prevent overstressing of pipes and unions.

5.3.2 Flexible hoses are not to be used unless approved for the purpose.

5.3.3 Flanged pipes should not be used.

5.3.4 Pipes should be secured clear of electrical cables as far as is practicable.

5.3.5 Valves and fittings designed to operate without lubrication should be used as far as practicable. In view of the explosive and contamination risks involved, parts requiring lubrication should be lubricated with approved lubricants only. Fluorocarbon grease is recommended. To lubricate threads, and to assist in obtaining high pressure seals at threads, PTFE tape may be used, but extreme care must be taken that ragged ends of tape do not penetrate the bore of pipes or valves.

5.3.6 All valves for oxygen service must have the manufacturer's warranty that they are suitable for this service at the desired operating pressure of the system.

5.3.7 Pressure regulating devices used in oxygen control systems must be of a design proven in performance and reliability.

5.3.8 Valves, couplings and fittings should be designed such that there is no leakage of water into the oxygen system at the collapse depth.

■ *Section 6*
Testing and Cleaning

6.1 General

6.1.1 A functional test is to be carried out to verify the satisfactory functioning of the life support systems under normal and emergency conditions.

6.1.2 Indicating and monitoring instruments are to be tested for the accuracy of their readings and their limit value settings.

6.1.3 Automatic control systems are to be checked for satisfactory performance under service conditions.

6.1.4 Normal and emergency communications equipment is to be subjected to a functional test. The effectiveness of the helium speech unscrambler is to be demonstrated for the maximum operating depth of the diving system. Reference is made to modified rhyme test developed by US naval submarine medical centre.

6.1.5 Proof is required of the autonomy of the safety systems.

6.1.6 Details of the proposed method of testing, purging and cleaning of all pipe systems should be submitted for approval.

6.1.7 Arrangements are to be provided for venting and testing all systems while they are being charged with liquids or gases.

6.2 Oxygen System Cleaning

6.2.1 All components such as valves and fittings should be cleaned and stored in sealed plastic bags clearly marked `cleaned for oxygen service'. Documentary evidence should normally be provided.

6.2.2 All components used in oxygen systems, including piping, must be thoroughly cleaned and de-greased. Where toxic agents are used for this purpose the system should be thoroughly flushed and cleansed. Care should be taken to ensure that no contamination of the system takes place during the installation process.

6.2.3 Shop air should not be used to blow out component parts after assembly. The use of compressed, oil-free, dry nitrogen is recommended.

6.3 Oxygen System Testing

6.3.1 As far as possible oxygen systems should be designed so that they may be disassembled for cleaning and testing outside the chambers without the need for separating any permanent or semi-permanent joints, brazed or welded. The number of couplings should be kept to a minimum.

6.3.2 It is recommended that individual components or assemblies be pre-tested before being made up into the complete system. After installation the complete system should be tested to at least 1.5 times the working pressure using water, air or nitrogen. On completion of the above test the system should be thoroughly dried and then pressurised with dry air or nitrogen to the normal operating pressure. The system should then be shut off and the leakage rate measured, where a pressure drop of 0,5 per cent in 12 hours shall not be exceeded, taking into account any temperature change.

6.3.3 Following completion of the leak rate test, the system must be purged and tested to ensure that all traces of test gases, including air or nitrogen, are removed before filling with oxygen to its operating pressure.

6.3.4 All manifolds and connections, complete with supply pipes and fittings, should be pressure tested at least once every four years to 1.5 times the working pressure. The pressure gauges on the system should be tested for accuracy at the same time. The first at four years from the date of build or date of Major Survey for Classification as recorded on the Class Direct website, and thereafter five years from the date recorded from the previous Major Surveys.

6.3.5 At intervals of approximately 12 months, the oxygen storage cylinders are to be visually examined for collected dirt and moisture, excessive corrosion and general condition.

6.3.6 All breathing gas cylinders are to be tested hydrostatically to at least 1.5 times the working pressure every five years. A certificate of test is to be obtained. Additional in service inspections as per IMCA D018 is to be complied with.

6.4 Gas leak test for all chambers and breathing gas systems

6.4.1 After installation breathing gas systems are to be hydraulically or pneumatically pressure tested to 1,5 times the design pressure. It is recommended that individual components or assemblies be pre-tested before installation.

6.4.2 Chambers and breathing gas systems are to be pressurized to the maximum working pressure using normal working gases except that air or nitrogen should be used for oxygen systems or nitrogen with 10% He or addition of suitable halocarbon trace gas to Nitrogen. A leak test should be carried out during which a pressure drop of 0,5 per cent in 12 hours shall not be exceeded, taking into account any temperature change.

6.4.3 Where a suitable halocarbon trace gas is used with air or nitrogen as the test media the system is to be subsequently purged as necessary to ensure that it is halogen free.

6.4.4 Any emergency breathing system which uses a separate gas storage system is to be pressurized and leak tested in a similar manner to *Pt 5, Ch 4, 6.4 Gas leak test for all chambers and breathing gas systems 6.4.2* and *Pt 5, Ch 4, 6.4 Gas leak test for all chambers and breathing gas systems 6.4.3* and the pressure drop is not to exceed 0,25 per cent in 12 hours

■ *Section 7*
Carbon Dioxide (CO2) Removal Systems

7.1 General Requirements

7.1.1 CO2 may be removed either by a chemical which cannot be regenerated such as soda lime granules, or lithium hydroxide, or else by a chemical which can be regenerated such as monoethanolamine (MEA) or molecular sieves.

7.1.2 It is recommended that the CO2 removal system is operable for the planned dive time plus a period of time consistent with the emergency rescue plan. Please refer to *Pt 5, Ch 4, 8 Air and Gas for Breathing Purposes*.

7.1.3 A regeneration system should be designed with an instantaneous removal rate of 45 litres of CO2 per man hour.

7.1.4 Absorbents should be contained in hermetically sealed packages until required for use. Such seals should be periodically checked. It should also be noted that some absorbents, including lithium hydroxide, have a limited shelf life.

7.1.5 The efficiency of granular carbon dioxide absorbents is detrimentally influenced by low temperature and relative humidity levels of lower than 70 per cent, when absorbent capacity is reduced. Temperature and humidity tests have shown that lithium hydroxide is the most efficient absorber, particularly at low temperatures, with sodasorb as the next best.

7.1.6 Non-corrosive, non-toxic materials should be used for the construction of the CO2 scrubber system. With alkali absorbents such as lithium hydroxide and potassium super-oxide, uncoated aluminium must not be used.

7.1.7 Back up equipment must be provided. The CO2 scrubbing system should be designed to function in case of a power failure, or should be capable of functioning as a passive system. A spare motor blower assembly is to be carried where possible. The back-up system could be one of the following:

(a) A separate power source to motor blower;
(b) A hand or foot-operated drive for the circulating blower;
(c) A passive system designed to operate without forced air circulation;
(d) Lung powered
(e) An independent in chamber CO2 removal system.

7.1.8 The acceptance of alternative means for CO2 removal other than those referenced in this section will be subject to review of supporting data demonstrating satisfactory performance under the intended service conditions.

7.2 Expiration rate

7.2.1 CO2 expiration rates vary over a wide range depending on the degree of activity. For submersibles the minimum rate per man should be taken as 17.5 litres per hour at 20 ^{o}C.

7.3 Allowable Concentration

7.3.1 Throughout the normal dive time the design goal should be a maximum CO2 partial atmospheric pressure level of 5.0 mbar. At the end of the emergency life support period the maximum CO2 partial pressure should not exceed 10 mbar.

7.4 Expendable methods of CO2 removal

7.4.1 Lithium hydroxide:

(a) This is a strong alkali and extreme care should be taken to avoid contact with eyes or skin.
(b) Canisters should be replaceable as complete units and should not be refilled on board. The removal system should be located in such a position as to prevent any of the chemical from falling on crew members. When used in an absorbent canister an efficient thick dust filter should be used.

7.4.2 Soda lime:

(a) This is a weak alkali and should be handled with some caution.
(b) A dust filter or fine mesh similar to that recommended for lithium hydroxide should be used. A `high moisture' soda lime should be used since ordinary soda lime will not perform adequately at medium to low humidity levels.

7.4.3 Other chemicals may be considered on the basis of satisfactory performance e.g. potassium superoxide. Superoxide can perform the dual functions of oxygen supply and CO2 removal. Great care should be taken in handling these chemicals and contact with water must be avoided to prevent the sudden release of oxygen and risk of explosion. Grease contamination must also be avoided.

Note the use of barium lime is not recommended.

7.5 Regenerative methods

7.5.1 Molecular sieve. This is a solid absorbent which is capable of removing carbon dioxide from an air stream and which can be regenerated. The entering air stream must be free of organics and moisture since these reduce the ability of the molecular sieve to remove CO2. Any desiccant beds such as silica gel or activated alumina which may be used should be placed in the regeneration flow before the molecular sieve to prevent moisture carry-over to the sieve beds. A means of disposing of the CO2 must be provided.

7.5.2 Liquid Reagents. A liquid scrubbing system using aqueous solution to remove carbon dioxide which can be regenerated. Contact with the eyes and skin must be prevented. Moisture and organic material carry-over (atmosphere contamination) should be controlled.

7.5.3 Other chemicals may be considered on the basis of satisfactory performance. Great care should be taken in handling these chemicals and contact with water must be avoided to prevent the sudden release of oxygen and risk of explosion. Grease contamination must also be avoided.

7.6 Dust Filtration

7.6.1 Dust filtration or a fine mesh shall be provided. Filter materials should be fire-resistant; oil impregnated filters should be avoided.

7.7 Removal of Hydrogen, Carbon Monoxide and Other Contaminants

7.7.1 Means shall be provided for the removal of all identified types of gaseous and vaporous contaminants from the submersible’s atmosphere.

7.7.2 Hydrogen concentration shall not exceed 10% LEL at any point in the enclosed Space.

7.7.3 The concentration levels of toxic and volatile compounds are not to exceed the values determined as guided by UK HSE EH75 for hyperbaric environment and HSE EH 040 as applicable. Alternatively, the limits specified in equivalent recognised national or international standards will be considered

7.8 Control and sensing

7.8.1 A simple on-off system for the circulating blower for the CO2 scrubbing system is sufficient; an automatic control is not required, but an indication light for an inoperative blower motor, or loss of air flow, is recommended.

7.8.2 A continuous indicating analyser for CO2 is desirable, although an intermittent indicator, such as an analyser tube, is acceptable. If a continuous indicating analyser is provided a backup indicator should be available.

7.9 Testing

7.9.1 The CO2 removal system should be tested to confirm system performance. All test data should be fully documented.

■ *Section 8*
Air and Gas for Breathing Purposes

8.1 General

8.1.1 The breathing mixture is the mixture of gases being breathed by the occupants of a submersible or any portion of a submersible. Where occupants are breathing directly from the atmosphere in any compartment, then that atmosphere constitutes the breathing mixture.

8.1.2 All the materials used inside a submersible craft and likely to be in contact with the atmosphere, including paints, adhesives, and lubricants, should be carefully examined and where necessary subjected to tests to ensure that as far as is practicable they are unlikely to give off toxic, irritant or disagreeable gases to an undesirable level under normal operating conditions. Autonomous craft will, in addition, usually produce other contaminants (through cooking, air conditioning / ventilation, sanitary tanks, internal lead acid batteries etc.), in sufficient quantities to require further cleansing of the atmosphere. Means of removing these contaminants from the atmosphere should be taken into account when such a craft is designed and built.

8.1.3 Means are to be provided to allow the occupants to check the internal atmosphere for levels of O2 and CO2, and pressure. Other dangerous gases which may occur in autonomous craft e.g. CO, will also require to be monitored. Operation of these instruments should be ensured under all circumstances for the whole duration of the planned dive time plus the survival period.

8.1.4 Instruments to measure the temperature and relative humidity of the one atmosphere manned compartments should be provided except in the case of one-man craft.

8.2 Maintenance of Breathable Atmosphere

8.2.1 Submersible unit must be provided with adequate equipment to maintain a breathable atmosphere. The equipment should provide the highest degree of reliability. It should be capable of operating with suitable efficiency during a failure of the main electrical supply.

8.2.2 Circulation of the breathing mixture should be provided as necessary to prevent any accumulation of flammable or toxic gases and to allow proper operation of the equipment.

8.2.3 Dust filtration or a fine mesh should be provided in the CO2 absorption and ventilation system.

8.3 Contaminant Control System

8.3.1 Care must be taken to avoid the use of materials which are safe at atmospheric pressure but become flammable when subjected to high levels of oxygen. Similarly the use of materials which emit toxic gases or which emit toxic gases when subject to fire or excess heat, shall be avoided. The use of PVC or PVC based material should be avoided.

8.3.2 Mercury thermometers and instruments should not be used inside manned enclosures.

8.3.3 All electrical and electronic equipment should be protected and insulated with non-reactive materials.

8.3.4 The partial pressure of dangerous gases should be kept below acceptable limiting values under normal operating conditions.

8.3.5 If a desiccant is used to remove moisture from the atmosphere in a submersible, a material should be used that is non-toxic, non-corrosive and non-flammable.

8.3.6 A wide band toxic contamination level indicator should be used during initial tests and trials to ensure that there is no build-up of toxic vapours in any compartment. They should also be fitted in submersible craft which contain thermal engines or leadacid batteries which emit toxic gases within the pressure hull.

8.4 Air purity standards

8.4.1 Isobaric diving requirements. Air supplied by bottles to be inhaled during isobaric diving at atmospheric pressure should be constituted in such a manner that a sample, at atmospheric pressure, complies with the following standard:

Nitrogen	*79 % ± 0.5 %*
Oxygen	*21 % ± 0.5 %*
Carbon Dioxide	*500 ppm maximum*
Carbon monoxide	*15 ppm maximum*
Oil	*0.5 mg/m*^{3}
Water	*500 mg/m*^{3} *at normal temperature and pressure*
Solid particles, dust, etc.	*Lack of residue on a Whatman 40 filter after passing 5,000 cc of air**
Odour and taste	*Freedom from both*
Nitrogen dioxide and nitrous oxide	*Nil (under 1 ppm)*

* Whatman 40 filter, rated as fast and of mean pore size (3.4 to 5 μm)

8.5 Gas purity standards

8.5.1 **Diving gases — Suppliers standard per U.K. Diving Safety Memorandum 711984**. The following minimum purity standards for diving breathing gases as supplied, has been agreed with the Association of Offshore Diving Contractors and the gas companies:

(a) Specification for Oxygen, Helium and Nitrogen Gases, whether pure or mixed, should not contain any impurity at concentration likely to cause toxic or harmful effects when breathed under pressure.
(b) Maximum permissible level of contamination in each supply gas component (ppm by volume).

Contaminant	Oxygen	Helium	Nitrogen
Nitrogen	100	200	-
Oxygen	-	50	50
Carbon dioxide	10	10	10
Carbon monoxide	1	1	1
Neon	10	10	10
Argon	4000	25	25
Hydrogen	10	10	10
Methane	25	5	5
Other hydrocarbons	3	1	1

Moisture	25	25	25

Oil mist should not exceed 1 mg/m^3

This list is not all inclusive and no other contaminants should be present in concentrations likely to cause toxic or harmful effects when breathed.

(c) Percentage of tolerance in mixture should be restricted to ±5 per cent of the minor components of the mixed gas.

(d) It is stressed that the above standards are for gas as supplied from gas companies and not the standards for chamber atmosphere purity or for helium reclamation systems. Reference is made to HSE EH75 – 2 Occupational exposure limits for hyperbaric conditions and EN 12021.

8.6 Oil lubricated compressors

8.6.1 Where oil lubricated compressors are used for the compression of oxygen or mixed gases containing oxygen, the oil mist should at no time exceed 1 mg/m^3 and the maximum pressure and percentage of oxygen which can be handled by the compressor should be stated by the manufacturer. A notice stating the maximum oxygen percentage and pressure is to be posted in a conspicuous position by the compressor.

8.6.2 For all oil lubricated compressors provision is to be made for intercepting and draining oil and water in the compressor discharge for which purpose a separator or filter is to be provided. A notice is to be placed adjacent to the compressor stating that the filters are to be drained before start-up and at regular intervals during running.

8.7 Conditioning of chamber atmosphere

8.7.1 Each compression chamber living compartment is to be equipped with an oxygen dosing device and a chamber gas circulating unit in which the CO2 can be absorbed and the air temperature and humidity can be regulated. The rate of circulation shall be such as to satisfy the conditions stated in *Pt 5, Ch 4, 9 Pressure, Temperature and Humidity Control*.

8.7.2 Chamber atmosphere conditioning should be designed in such a way as there is 100% redundancy of each individual compartments atmospheric conditioning system.

8.7.3 Diving bells are to be equipped with a chamber gas treatment unit and also with an autonomous reserve CO2-absorption unit for emergency use.

8.7.4 Diving bells are to be equipped with a heating system provided with redundant supplies and so designed that the divers in the diving bell and in the water are maintained in a thermal balance. For diving operations at depths greater than 150 m breathing gas pre-heaters are also to be provided for the divers in the water. The heating system shall be fitted with a temperature indicator and suitable safety features are to be provided to prevent over temperature by the heating system.

8.7.5 Measures are to be taken to enable the divers within the diving bell to be maintained in a safe thermal balance for at least 24 hours in an emergency.

8.8 Breathing gas treatment and mixing

8.8.1 The use of closed breathing gas circuits, gas mixing systems for direct breathing gas supply and helium reclaim systems requires LR's approval.

8.9 Emergency life-support

8.9.1 The diving bell is to be provided with its own bottles so that the occupants of the chamber can in an emergency be supplied with a sufficient quantity of breathing gas mixture for at least 24 hours at the maximum operating depth. An oxygen bottle for supplementing the oxygen supply is also to be carried on the diving bell.

8.9.2 The emergency life-support systems are to be capable of operating for the following periods of time:

1 atmosphere	96 hours in addition to the submersibles proposed dive time.
1 atmosphere 1 man	72 hours in addition to the submersibles proposed dive time.
Pressurized diving bells	24 hours in addition to the proposed dive time for depths up to 185 m (600 ft.). Special consideration will be given to operation in depths in excess of 185 m.

Special consideration will be given where it is impracticable for these requirements to be complied with.

8.9.3 Built-in breathing appliances such as BIBS with a reserve supply of oxygen or air are to be available to supply the crew and passengers for sufficient time to enable the submersible to surface and be recovered. Consideration should be given to arranging for emergency circulation of the atmosphere of manned compartments, at the rate of 30 air changes per hour for the purpose of clearing smoke, high CO2 levels, etc., following a fire or other accident. Provision is to be made for the absorption of CO2 and where possible, high speed scrubbers are preferred. Maximum partial pressures of toxic gases, equivalent to those of the national threshold limits at atmospheric pressures, are not to be exceeded.

8.9.4 In the case of a habitat the emergency life-support system should be entirely separate from the access chamber system. In one bar chambers where oxygen enrichment could occur means of preventing excess oxygen build up should be considered.

■ *Section 9*
Pressure, Temperature and Humidity Control

9.1 General Requirements

9.1.1 The submersible unit and chambers should be equipped with a suitable system of valves, gauges and measurement instrumentation equipment as is necessary to:

(a) Monitor the pressure, temperature and humidity of the atmosphere and the oxygen and carbon dioxide levels within each compartment;
(b) Control the pressure and the temperature and humidity within the chambers; and
(c) To release any overpressure from within the chambers before opening the hatch.

9.1.2 The system should be designed as far as is possible to avoid high relative humidity's in association with high temperatures in view of the deleterious effects on personnel, equipment and materials in the submersible. However all vital pieces of equipment in the craft and chambers should be designed to operate in a 100 per cent relative humidity environment.

9.1.3 If automatic temperature and humidity control systems are used, manual overrides of critical functions should be provided. The set point of the system should be manually adjustable.

9.2 Pressure

9.2.1 A pressure gauge should be fitted so that the submersible unit may be maintained at atmospheric pressure by regulation of the oxygen supply as the carbon dioxide is absorbed. It is recommended that this be an aneroid barometer with a pointer and should be accurate to within 2.5 per cent.

9.2.2 The compartments (chambers) shall be fitted with a safety valve or a visual and audible overpressure alarm alerting the operators at the control station.

9.3 Temperature

9.3.1 Means should be fitted in each manned compartment to measure internal temperature. Temperature can be measured by any appropriate means but mercury thermometers are not acceptable.

9.3.2 The use of a temperature gauge to measure external temperature is also recommended. This may take the form of a thermometer fitted outside the submersible craft and visible through a viewport or by an internal gauge with an external sensor.

9.4 Diver heating

9.4.1 Means are provided for:

(a) External body heating of the diver at depths in excess of 50 m for air diving system and at any depth for saturation diving.
(b) Respiratory gas heating in addition to means of external body heating of the diver for diving in depths in excess of 150 m. When the means of heating is by hot water it is recommended that a main and secondary hot water supply be provided. The use of electrically heated undersuits will be the subject of special consideration.
(c) Suitable safety features are to be provided to prevent overheating by the heating system.

9.5 Chamber heating

9.5.1 Submersibles and compression chambers should have sufficient power and/or hot water available for diver heating, under the emergency conditions.

Note Designers should bear in mind that helium atmospheres have a faster heat transfer rate than the normal constituents of air.

9.5.2 Bells shall have emergency means of preventing excessive heat loss by the divers for a period of 24 hours at dmax and shall be independent of the main umbilical.

Note This can be achieved by heating the bell environment, the divers directly by heated suits, or by passive thermal insulation as well as heating the divers' breathing gas by active or regenerative methods.

■ *Section 10* Instrumentation

10.1 General Requirements

10.1.1 Monitoring systems for the small manned submersibles will be generally based upon individual sensory units, rather than continuous automatic analysis systems.

10.1.2 Instrumentation must be adequate for maintenance of a safe and breathable atmosphere.

10.1.3 Atmospheric monitoring instruments should have a back-up unit, but not necessarily of the same type.

10.1.4 Each manned compartment should be provided with means of testing the atmosphere therein.

10.1.5 All instruments and gauges should be capable of withstanding the pressure, temperature, vibration, shock, humidity likely to be encountered.

10.1.6 Pressure gauges should be fitted showing the pressure drop across pressure reducing valves, together with the pressure within all gas storage cylinders, or within the discharge rail where two or more cylinders are on line.

10.1.7 All connections to pressure gauges and other instrumentation should be provided with suitable isolating valves.

10.2 Oxygen

10.2.1 Where applicable it is recommended that an oxygen monitor with a continuous read out should be provided. Simple analysers of the chemical gas absorption type should be carried on board. *See also Pt 6 Electrical Installations and Control Engineering Systems* for degree of monitoring and control.

10.2.2 If the instruments are battery powered spare batteries should be carried.

10.3 Carbon Dioxide

10.3.1 Where applicable it is recommended that a carbon dioxide monitor with a continuous read out should be provided. Simple analysers of the chemical gas absorption type should be carried on board. *See also Pt 6 Electrical Installations and Control Engineering Systems* for degree of monitoring and control.

10.3.2 The response time can be several minutes since a rapid accumulation of CO2 is not envisaged.

10.4 Other gases (e.g. carbon monoxide, hydrogen, Freon etc.)

10.4.1 These gases may be monitored by a wide band toxic contamination level indicator or simple analysers of the chemical gas absorption type. Consideration should be given to monitoring carbon monoxide when the dive operation duration exceeds a few days.

10.5 Tests and Calibrations

10.5.1 Tests and calibrations should be carried out on a regular basis. Care should be taken that items with a limited shelf life are in date. The procedures should be as simple as possible in order to permit quick and accurate calibration.

10.6 Temperature and Thermal Protection in the event of an Emergency in atmospheric submersible craft

10.6.1 Most craft do not have sufficient power to heat the crew compartment(s) and if an emergency situation prevents the craft from surfacing it will be necessary to provide thermal protection for the crew. Sufficient space is to be allocated within the submersible craft to stow thermal survival suits or bags for each crew member.

10.6.2 The autonomous submersible craft will normally have ample power reserves to provide air conditioning in the crew compartments and will probably have sufficient space to fit insulation material to the inside of the pressure hull throughout the crew compartments. However, it is recommended that thermal survival suits or bags are carried on board for use in emergency.

10.6.3 In one man submersible craft the provision of thermal protection creates a problem, as often there is insufficient space to stow thermal clothing, or to put it on, and the design of the craft may only allow the occupant to cover the upper half of his body. In these craft it is usually impractical to wear thermal clothing at all times, because the occupant is too hot during normal work. Possibilities for thermal protection include wearing leggings etc. to cover the lower half of the body and providing protection for the upper part of the body by building in a thermal top into which the occupant could zip himself.

■ *Section 11*
Food and Water Supply Systems

11.1 General Requirements

11.1.1 Supplies of food and water are to be available within the submersible to cater for the requirements of crew and passengers for normal operating time plus the time allowed for emergency recovery.

11.1.2 Provision should be made for the collection and containment, or discharge overboard, of the waste products of the crew and passengers within the submersible craft. Sufficient capacity should be provided for the whole duration of the planned dive time plus the survival period.

11.1.3 In autonomous submersibles means of chemical inactivation of retained waste materials will need to be provided. The choice of the chemical, and whether it should be powder or liquid, will depend on the amount of food waste and the length of the mission, having regard to the environmental operating conditions.

■ *Section 12*
Diver Lock-Out Compartment

12.1 General Requirements

12.1.1 Sufficient storage capacity is to be provided to contain the appropriate breathing mixtures to supply:

(a) Divers working from the lock-out compartment for the planned dive time; plus
(b) Divers occupying the lock-out compartment for a minimum period of 24 hours in excess of the planned dive time.

12.1.2 The 24 hour life support duration is to be available down to a maximum depth of 185 metres (600 feet). The Class will wish to review the life support periods at intervals in order that account may be taken of improvements in life support equipment.

12.1.3 The lock-out compartment during final stages of depressurisation may contain high oxygen partial pressures under certain conditions if mask breathing is not used and consequently there is a considerable fire hazard. Consideration should be given to the suitability and safety of electrical equipment provided in the lockout compartment.

12.2 Pressurisation

12.2.1 Means must be provided both inside the lock-out compartment and in the submersible craft command module or dive control compartment to control and monitor the pressures and the composition of the atmosphere inside the lock-out compartment.

12.3 Depressurisation

12.3.1 Controlled depressurisation of the diver requires precise control. Systems should be so designed that the lock-out compartment decompression rate can be controlled in accordance with the decompression tables to be used.

12.3.2 Depressurisation from saturated conditions must be controlled from outside the lock-out compartment.

12.3.3 Controls for depressurisation from short dives should be controllable from inside and outside the lock-out compartment, and an override capability should be provided outside to limit internal control.

12.3.4 In autonomous submersibles some form of recompression and storage or dumping must be provided. If stored, care should be taken to avoid gas contamination.

12.4 Gas supplies

12.4.1 **Oxygen** storage must be provided for decompression breathing and metabolic make-up.

12.4.2 **Pressurisation Gas**: Appropriate gas mixtures should be provided in sufficient quantity to pressurise the lock-out compartment as defined by the mission requirements. Gas banks should be divided into at least two separate groups (normal and reserve) for reliability and shall be piped separately to the supply panel in the command module. When lock out submersibles is to be used for protracted diving, it is recommended that consideration should be given to fitting a plug-in facility on the outside of the submersible craft to enable gas to be supplied through an umbilical from the surface.

12.4.3 **Emergency Gas**: The necessary piping should be provided to enable an emergency supply of breathing gas to be provided at a mask manifold in the lock-out compartment. At least one breathing mask should be provided for each diver. Masks should be readily accessible under emergency conditions.

12.5 Carbon Dioxide Removal

12.5.1 The lock-out compartment should be equipped with carbon dioxide removal equipment which will maintain the carbon dioxide partial pressure in the compartment at or below 10 mbar.

12.5.2 The CO2 scrubber blower or fan motor should be carefully selected so that spark hazards are minimised.

12.6 Temperature Control

12.6.1 Adequate chamber heating should be provided to maintain the diver in safe thermal balance at least for the duration of the planned dive time.

12.6.2 Diver heating is to be available for diving work below 50 metres for air diving system and at a depth for saturation diving system and respiratory gas heating is to be available for all diving work below 150 metres.

12.6.3 Insulation of the lock-out compartment to minimise heat loss is recommended. Heat retention is dependent on the type and thickness of the insulation material used and will directly affect the power from the submersible power plant necessary to maintain the required temperature in the lock-out compartment.

12.6.4 It is recommended that thermal suits are carried in the lock-out compartments for use in emergency.

12.7 Humidity

12.7.1 Where practicable provisions should be made to permit control of humidity within acceptable limits where it is planned to decompress the diver within the lock out compartment.

12.8 Communications

12.8.1 Two-way voice communication between the diver in the water, other diver(s) in the lock-out compartment and submersible craft personnel is required and should provide:

(a) A standard of sound reproduction adequate to enable the diver's breathing to be clearly heard;
(b) A suitable voice unscrambler when breathing mixtures which significantly distort sound transmission, are being used;
(c) A recording system capable of recording oral communications between divers and the control stand shall be provided. Diving Bells and chambers shall be fitted with a self-contained emergency communication system capable of working beyond the regular working depth of divers.
(d) An emergency means of communication between control stand and divers in the deck decompression chamber and in the diving bell is to be available. For diving bells, this may be a self-contained, through water communication system.

12.8.2 The system shall be fitted with an auxiliary power source so that it can be used in an emergency for the duration of the life support period.

12.8.3 Persons performing advanced first aid shall be offered priority and unimpeded access to telecommunication services with the duty diving doctor or any other competent personnel as may be required.

12.8.4 The layout and design of instrumentation and communication equipment pertaining to control stands shall be guided by ergonomics. Equally, the minimisation of factors such as noise, vibration or any other disturbance should be considered wherever possible

12.9 Instrumentation

12.9.1 An oxygen analyser is to be fitted. Analysers which are intended to read in per cent volume should have a range 0-100 per cent. Analysers reading in partial pressure should have a range 0-2 Bar absolute. At least one alternative analysis technique or instrument should be provided.

12.9.2 Means of measuring carbon dioxide content should be provided.

12.9.3 A depth indicator must be fitted both in the lock-out compartment and in the command module to provide an accurate reading of the depth in the lock-out compartment.

12.9.4 A depth indicator with double hull shut off valves should be provided in the lock-out compartment to indicate the external water pressure on the compartment.

12.10 Food and Water Supply

12.10.1 For short duration diving, water and food should be stored within the lock-out compartment in pressure balanced containers. Sufficient provisions should be included to maintain each diver for a minimum of 24 hours.

12.11 Medical Lock

12.11.1 The medical lock required by the Regulations is to be provided and be equipped with approved interlock mechanism and be sized to allow introduction to standard CO2 canister.

■ *Section 13*
Additional Provisions to be provided

13.1 First Aid Kit at the Sight of Diving Equipment

13.1.1 There must be a minimum amount of first aid equipment at the diving site. Reference is made to DMAC 15 (Medical Equipment to be Held at the Site of an Offshore Diving Operation, DMAC).

13.1.2 Passenger submersible craft are to be provided with first aid kit as per IMO requirements.

13.1.3 Hyperbaric evacuation units are to be provided with First aid equipment, food, water, sickness bags, waste disposal bags and necessary work instructions as per IMO Resolution A.692 and SOLAS.

■ *Section 14*
Power Supply

14.1 Emergency Source of Power

14.1.1 In an autonomous or free-swimming submersible the emergency source of power should be completely separate from the main power source and should be capable of maintaining the communication systems throughout the life-support period. Where applicable, emergency source of power should be capable of providing power for water leakage monitoring devices, and maintaining a breathable atmosphere.

14.1.2 Emergency power supply must be capable of returning the divers from the maximum system operating depth to the surface.

14.1.3 Emergency power supply shall be capable of feeding the following critical services:

(a) Emergency lighting;
(b) Emergency communication;
(c) Emergency heating;
(d) Environmental monitoring systems;
(e) Control/alarms for emergency systems;
(f) Emergency handling of the bell.

■ *Section 15*
Video Monitoring Systems

15.1 General

15.1.1 All chamber compartments, bells and habitats shall be equipped with video monitoring system, enabling the surface support crew to visually monitor the occupants and operations.

15.1.2 The ADS shall be equipped with a video camera enabling the ADS supervisor to visually monitor the area in front of the suit. The suit shall be equipped with ample lighting for illuminating the work area and for relocating purposes. A battery-operated strobe light shall be fitted to the suit. The pilot shall easily view all monitoring equipment in the suit.

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	Diving umbilicals
Unit Type	
Manned Submersible	x
Wet Submersible	x
Unmanned Submersible	x
Submersible Craft	x
Diving Bell	x
Submersible Vehicle	x
Submersible Habitat	x
Submersible Container	x
Passenger Submersible	
Rescue Submersible	

Section 1
General

1.1 General

1.1.1 These Rules apply to hoses and umbilicals intended for the operation of the diving system and its ancillary equipment.

1.2 Definition of an umbilical

1.2.1 An umbilical may consist of a sheathed or braided bundle of hoses and cables which provides the life-support between the surface and a submersible or diving bell and where applicable, between the bell and the diver. An umbilical may include an integral strength member or lifting line capable of raising the bell in the event of emergency.

1.2.2 Life-support hoses are those used for the supply and return of gases, gas mixes and hot water for heating purposes.

1.2.3 An umbilical as defined in *Pt 5, Ch 5, 1.2 Definition of an umbilical 1.2.1* does not include the life-support pipework on the deck of the diving support unit which should be of metallic construction except where hoses of an approved type are permitted.

1.2.4 The design pressure is the maximum permissible working pressure corresponding to the maximum depth at which the submersible will operate in normal service and is to be not less than the highest set pressure of any associated safety valve or relief valve.

Section 2
Design Details

2.1 Data

2.1.1 The following design data is to be submitted for consideration:

(a) Maximum design depth of the diving system.
(b) Minimum diameter of stowage coil or reel.
(c) Helix angle of hoses and electric cables.
(d) Weight of submersible in air and water and strength of lifting line if incorporated.
(e) Cross-sectional drawing of umbilical showing the arrangement and dimensions of hoses, electric cables and strength member.
(f) Type of covering for the umbilical and any packing materials.
(g) End sealing arrangements of umbilicals, hoses and electric cables.
(h) Name, type and model numbers of hoses, electric cables and connectors.
(i) Voltage and current ratings for all circuits.
(j) Details of materials used for the conductors, insulation, fillers and sheaths of electric cables.
(k) Anticipated minimum and maximum surface air temperatures.
(l) Minimum recommended static bend radius.
(m) Weight of 1 metre length of composite umbilical.

Section 3
Hoses

3.1 General

3.1.1 All hoses forming part of an umbilical are to be of approved type and tested in accordance with *Pt 5, Ch 5, 4 Hose Approval Tests* as applicable, and suitably marked for identification purposes. Any couplings should be made of corrosion resistant material.

3.1.2 Where pneumatic testing is specified in the following Sections, due consideration should be given to the stored energy in the event of a hose failure and means of protecting personnel provided accordingly.

3.1.3 The manufacturer's certification is to be submitted for consideration in respect of *Pt 5, Ch 5, 3.3 Hoses for breathing gases* and *Pt 5, Ch 5, 3.4 Hoses for hot water*.

3.2 Construction

3.2.1 Hoses are to incorporate closely woven single or multi-braided reinforcement with properly attached end fittings of crimped or similar type and are to be suitable for their intended service.

3.3 Hoses for breathing gases

3.3.1 The hose material should be oil resistant and at the maximum design pressure and within a temperature range of minus 40 to plus 60°C, should not:

(a) Generate noxious or toxic vapours *see* HSE EH75 for determination of allowable limits.
(b) Be affected by exposure to the gases.

3.4 Hoses for hot water

3.4.1 The hose material should have no chemical reaction with water at a temperature of 99°C.

Section 4
Hose Approval Tests

4.1 Hydrostatic strain test

4.1.1 A sample of hose not less than 300 mm long between end fittings which has passed the ball test referred to in *Pt 5, Ch 5, 5.2 Dimension, ball and hydrostatic tests 5.2.1* and with one end plugged but free, is to be tested as follows:

(a) The pressure inside the hose is to be raised to the design pressure, held for 2 minutes and then released.
(b) Reference marks are then to be made on the hose and their distance apart measured. These reference marks are to be not less than twice the bore of the hose from the end fittings.
(c) The hose is to be re-pressurized to the design pressure, held for 2 minutes and while the hose is pressurized, the distance between the reference marks measured. The change in length between the reference marks is not to exceed ±3 per cent, also the change in diameter is to be limited to 3 per cent.

4.2 Pressure impulse and bend tests

4.2.1 Four samples of hose up to 19 mm bore, of length 3,5 times the minimum bend radius shown in *Table 5.4.1 Bend radii* between end fittings, are to be bent through 180° until the distance between the parallel end fittings is twice the minimum bend radius. Hoses of 25 mm bore, of length 400 mm between end fittings, are to be bent at the minimum bend radius through 90°.

Table 5.4.1 Bend radii

Nominal Bore Size, mm	Minimum inside bend radius of external surface, mm
3	75
5	90
6.3	100
8	110
10	125
12.5	175
16	200
19	240
25	305

4.2.2 The hose samples, prepared as per *Pt 5, Ch 5, 4.2 Pressure impulse and bend tests 4.2.1*, are then to be filled with water maintained at a temperature of 90°C for hoses conveying liquids and 60°C for hoses conveying gases. They are to be pressure cycled 150,000 times for liquid hoses and 50,000 times for gas hoses at a rate of not less than 1,5 cycles per second at 1,25 times the design pressure, without showing any signs of failure. The maximum rate of pressure rise is to be 7000 bar/s.

4.2.3 After undergoing the tests in *Pt 5, Ch 5, 4.2 Pressure impulse and bend tests 4.2.2* the hose samples are to be destroyed.

4.3 Low temperature flexibility

4.3.1 An empty hose of minimum length 1,8 times the minimum bend radius shown in *Table 5.4.1 Bend radii* between end fittings, is to show no visible defect when tested in a straight condition and maintained at a temperature of — 40°C ± 2°C for a period of 3 hours and then bent through 900 at the minimum bend radius round a mandrill at the same temperature. The bend, for nominal bore size, is to be completed within the following times:

Up to and including 12,5 mm bore	5 Seconds
Over 12,5 mm — up to and including 19 mm bore	10 seconds
25 mm bore	20 seconds

On completion of the procedure in *Pt 5, Ch 5, 4.3 Low temperature flexibility 4.3.1* the hose is to be maintained in the bent condition for 1 hour after reaching room temperature and then pass a hydrostatic proof pressure test of twice the design pressure in the bent condition for a period of not less than 2 minutes.

4.4 Heat test

4.4.1 No sign of visible damage or indication of failure is to occur when a 100 mm length of hose, pressurized to the design pressure is:

(a) Held in contact with a flat plate for 15 minutes, where the temperature of the plate is to be maintained at:
  - (i) 130°C for hoses conveying liquids, and
  - (ii) 100°C for hoses conveying gases.

(b) For gas hoses — immersed in boiling water at atmospheric pressure for 15 minutes.

4.5 Tensile strength of hose

4.5.1 A sample of hose 1 metre long, with end fittings, is to show no sign of separation or failure when subjected to a steady pull of 1000 N for a period of 5 minutes. The hose assembly shall not leak at proof pressure.

4.6 Resistance to burst

4.6.1 A sample of hose as specified in *Pt 5, Ch 5, 4.1 Hydrostatic strain test 4.1.1*, with end fittings attached within the previous 30 days, is to show no sign of leakage or indication of failure below the minimum burst pressure specified below when subjected to a constant gradient hydrostatic pressure increase so as to attain the specified minimum burst pressure within a period between 15 and 30 seconds.

Burst pressures:

Evidence of the bursting pressure of each hose type is to be submitted to LR. For liquids, hoses must withstand at least 4 times, and for gases at least 5 times, the maximum permissible working pressure.

4.7 Resistance to leakage

4.7.1 A sample of hose as specified in *Pt 5, Ch 5, 4.1 Hydrostatic strain test 4.1.1*, with end fittings attached within the previous 30 days, is to show no sign of leakage or indication of failure after being subjected to a hydrostatic pressure of 70 per cent of the specified minimum burst pressure given in *Pt 5, Ch 5, 4.6 Resistance to burst 4.6.1* for a period of 5 to 6 minutes, with the pressure then released and reapplied for a further period of 5 minutes.

4.8 External pressure test

4.8.1 Isobaric / hyperbaric systems. (For definition *see Pt 1, Ch 2, 2.3 Other Definitions*). A sample of hose as specified in *Pt 5, Ch 5, 4.1 Hydrostatic strain test 4.1.1* with the internal pressure at atmospheric is to show no sign of collapse when subjected to an external hydrostatic pressure of 1,3 times that at the maximum design depth. With the external pressure applied proof of non-collapse is to be demonstrated by the ball test referred to in *Pt 5, Ch 5, 5.2 Dimension, ball and hydrostatic tests 5.2.1*. The hose sample is then to be examined to determine that:

(a) There are no signs of permanent distortion.
(b) There is no ingress of water into the hose, and
(c) Tested to show that there is no sign of leakage at the end fittings when the hose is pneumatically pressurized internally to 1,5 times the design pressure.
(d) A differential ratio of 1,5 between the internal and external pressures can be withstood without failure.

4.8.2 As an alternative to *Pt 5, Ch 5, 4.8 External pressure test 4.8.1* hoses for hyperbaric systems only, may be tested as follows:

(a) With the lower end plugged a sample of hose as specified in *Pt 5, Ch 5, 4.1 Hydrostatic strain test 4.1.1* with the internal pressure at atmospheric ‘is to be subjected to an external hydrostatic pressure of 1,3 times the design pressure to cause collapse. The hose is then to be pneumatically pressurized internally to the design pressure and a steel ball, in accordance with *Table 5.6.1 Ball Test*, inserted in the top end and allowed to roll or drop to the plugged end to determine that the hose has recovered from any deformation. The internal pressure is then to be released and after 5 minutes, the hose re-pressurized and the ball test repeated. This procedure should be repeated 50 times ensuring that the ball strikes the fitting at the opposite end each time the hose is re-pressurized.
(b) The hose sample is then:
    (i) To be examined to determine that there is no sign of damage likely to degrade the design specification of the hose.
    (ii) To be tested to show that there is no sign of leakage at the end fittings when the hose is pneumatically pressurized internally to 1,5 times the design pressure.
    (iii) To be hydrostatically pressurized to 75 per cent of the design burst pressure referred to in *Pt 5, Ch 5, 4.6 Resistance to burst*.

4.8.3 Where a hose is to be used for gas reclaim purposes or likely to operate at less than ambient pressure, a sample of hose is to be tested as indicated in *Pt 5, Ch 5, 4.8 External pressure test*.

4.9 Oxygen Shock Test

4.9.1 Couplings are to be oxygen shock tested when they are to be type approved for systems having an oxygen content by volume of more than 23%. A minimum of three couplings shall be tested. In case the couplings are manufactured in a wide range of sizes, where all the sizes are of same basic design, one small one medium and one of the bigger sizes shall be selected. The test is to be performed by quick opening of a ball valve producing a shock wave that moves through a copper tube into the test specimen. The test medium shall be oxygen of normal industrial grade pre-heated to +60°C. The line shall be flushed with oxygen before the test commences in order to remove as much air as possible. The pre-heater must be switched on for sufficient time ahead in order to ensure that all the oxygen has reached the required temperature before the testing starts. The test samples shall be subjected to 20 shocks of pressure increase from the atmospheric pressure to maximum design pressure.

4.9.2 The full oxygen pressure, with refill if necessary, shall act on the test samples for 10 seconds, and the time between each shock shall be 30 seconds.

Note The test is considered to be dangerous to personnel, as explosive fire may occur in the system. Strict safety precautions shall therefore be taken, and it is recommended that the test is performed in a special container without any personnel inside the container during the test.

4.9.3 A test as described in ISO 2503 or equivalent will be accepted.

4.10 Mechanical Properties

4.10.1 As proof of their mechanical properties, compact umbilicals are to be subjected to alternating bend tests and rupture tests *see Pt 5, Ch 5, 4.2 Pressure impulse and bend tests*. In addition, compact umbilicals are to undergo a tightness test, *see Pt 5, Ch 5, 4.9 Oxygen Shock Test*, in which all hoses are to be subjected simultaneously to their maximum permissible working pressure and the electrical lines are to be checked for compliance with the specified insulation and impedance values.

■ *Section 5*
Hose Completion Tests

5.1 Length

5.1.1 The minimum length of the hose is to be equal to the maximum diving depth together with the handling system requirements plus 5 per cent. Such hoses may be of a single length for use in the umbilical or, if required, with the minimum number of approved couplings for applications other than umbilical.

5.2 Dimension, ball and hydrostatic tests

5.2.1 The dimensions of the hose and inside and outside diameters are to be in accordance with *Table 5.6.1 Ball Test*.

5.2.2 A test ball of diameter given in *Table 5.6.1 Ball Test* is then to be passed through the full length of the hose.

5.2.3 Each hose, with end fittings and any couplings is to pass an internal hydrostatic proof test of twice the design pressure for at least 1 minute without showing any signs of failure.

5.3 Bonding separation test

5.3.1 Where gas hoses, designed for isobaric use, are also intended for hyperbaric use, the hoses are to be subjected to a permeation test as follows:

(a) The full length of each hose complete with end fittings, is to be pressurized with helium for a period of 36 hours to the design pressure at its intended operating temperature.
(b) At the end of this period and before the pressure is released, the external surfaces of the hose should be examined over their full length for any defects.
(c) The hose is then to be decompressed within 15 minutes and proof of non-collapse is to be demonstrated by the ball test referred to in *Pt 5, Ch 5, 5.2 Dimension, ball and hydrostatic tests*.

■ *Section 6*
Umbilicals Composed of Multi-Size Hoses and Electrical Cables

6.1 General

6.1.1 Umbilical should be suitable for external temperatures between minus 40°C and +60°C.

6.1.2 Umbilical of hoses tested in accordance with section 5 and electric cables complying with *Pt 6 Electrical Installations and Control Engineering Systems* are to be held together by sheathing or braiding.

6.1.3 In the case of sheathed umbilical provision is to be made for the escape of gas to avoid rupture of the sheathing in the event of a leaking hose.

6.1.4 Consideration should be given to the helix angle of wound components and this is to be agreed with the manufacturer.

6.1.5 The length of the umbilical if separated from hoisting rope is at least to allow an excursion of the bell to maximum diving depth plus 5 per cent, or actual bottom plus 5 per cent, whichever is greater.

6.1.6 The termination points when the umbilical enters connectors and penetrators are not to be subject to external loads or moments.

6.1.7 The ultimate tensile strength of the umbilical is not to be less than the twice the maximum load expected during normal and emergency operations.

6.2 Termination of umbilicals

6.2.1 The arrangement of individual hoses and electric cables between the termination of the umbilical and connections to the submerged submersible or diving bell are to be such that under normal operating conditions the hoses and cables are not subjected to any load.

6.2.2 The lifting line, or other strength member, if incorporated into the umbilical, is to be tested in accordance with the National Codes of Practice as applicable.

6.2.3 In addition to the connections mentioned in *Pt 5, Ch 5, 6.2 Termination of umbilicals 6.2.3*, the chamber or bell is to be provided with fittings at a suitable point close to the main lifting attachment, for the following services:

(a) ¾ inch nominal pipe thread (female) for hot water

(b) ½ inch nominal pipe thread (female) for breathing mixtures. These connections should be clearly marked for their intended purpose and be suitably protected.

Table 5.6.1 Ball Test

<table>
<tr><th rowspan="2">Normal</th><th colspan="2">Bore diameter, mm</th><th rowspan="2">Diameter</th><th rowspan="2">Maximum variation from concentricity cover to bore, mm</th><th rowspan="2">Test ball</th></tr>
<tr><th>Max.</th><th>Min.</th></tr>
<tr><td>3</td><td>3.56</td><td>2.97</td><td>8.00</td><td rowspan="3">0.8</td><td rowspan="2">60%</td></tr>
<tr><td>5</td><td>5.16</td><td>4.57</td><td>10.74</td></tr>
<tr><td>6.3</td><td>6.73</td><td>6.15</td><td>13.03</td><td>65%</td></tr>
<tr><td>8</td><td>8.31</td><td>7.72</td><td>14.99</td><td rowspan="5">1.0</td><td rowspan="3">70%</td></tr>
<tr><td>10</td><td>9.91</td><td>9.32</td><td>17.78</td></tr>
<tr><td>12.5</td><td>13.21</td><td>12.32</td><td>21.84</td></tr>
<tr><td>16</td><td>16.51</td><td>15.49</td><td>24.89</td><td rowspan="3">80%</td></tr>
<tr><td>19</td><td>19.81</td><td>18.65</td><td>27.94</td></tr>
<tr><td>25</td><td>26.16</td><td>25.1</td><td>35.05</td><td>1.3</td></tr>
</table>

6.2.4 For additional design requirements for hose and umbilicals refer to *Pt 5, Ch 5, 8 Additional Design Requirements*.

6.3 Testing (of composite umbilicals)

6.3.1 A sample is to be cut from a completed umbilical, or a sample made up in an identical manner, of a length at least 44 times the average diameter. The sample is to include any strength member or coupling/ joint and is to be bent through 1800 on a pulley having a diameter to accommodate the minimum recommended static bend radius as agreed with the manufacturer, provided that the resultant diameter is not less than 13 times the average diameter of the umbilical. The sample is to be cycled 3000 times at the design load, taken as 25 per cent of the break load. During the test and upon completion, the sample is to be examined for signs of damage likely to degrade the design specification (e.g., electrical continuity, physical damage, etc.). If a strength member is incorporated, the sample is to be attached to the pulley machine by that member and, where possible, using the same method of termination as that employed in service. The width of the pulley groove is to be not less than five per cent greater than the outside diameter of the umbilical. *See also Figure 5.6.1 Cycle Test*.

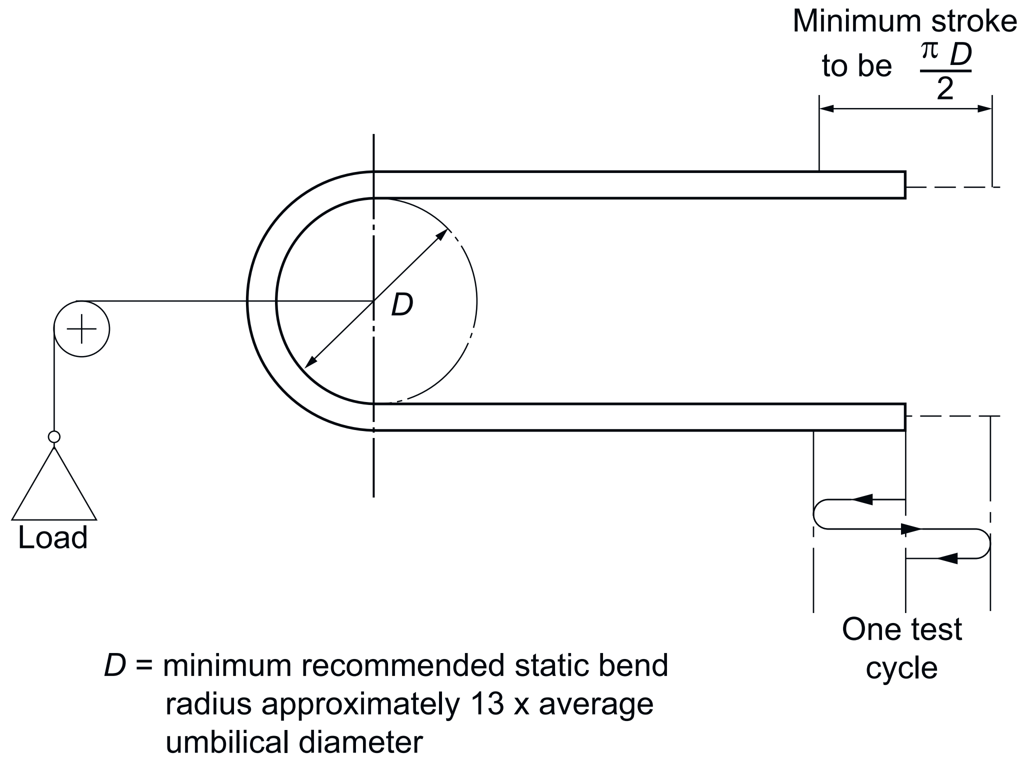


Figure 5.6.1 Cycle Test

6.3.2 Where it is intended that an umbilical is to be used in areas where it may be subjected to air temperatures above 32°C or below 0°C, then the test in *Pt 5, Ch 5, 6.3 Testing (of composite umbilicals) 6.3.1* is to be carried out at the anticipated maximum or minimum temperature. The manufacturers proposals are to be taken into account.

6.3.3 All hoses in completed umbilicals are to be hydrostatically pressurized simultaneously to 1,5 times the system working pressure and held for sufficient time for all electrical cables to be tested to their design specification.

■ *Section 7*
Existing Hoses and Umbilicals

7.1 General

7.1.1 When repairs have been carried out special consideration will be given to the tests which may be considered necessary to ensure that the hose or umbilical remains suitable for its intended purpose.

Section 8
Additional Design Requirements

8.1 Flexible Hoses

8.1.1 All flexible hoses, which are not permanently installed, shall be provided with suitable end caps that protect the hose end fittings from mechanical damage and prevent contamination when not connected for use.

8.1.2 In general, flexible hose fittings shall meet the same design requirements as those for pipe fittings. Additionally, all flexible hose end fittings shall be designed so they cannot be connected into the wrong system. This can be done by size selection, key fitting, or end fitting type. Colour coding or identification alone is not generally considered sufficient to ensure that hoses are not connected to the wrong system. Devices used for alignment or prevention of incorrect connection shall be sturdy enough to resist normal handling damage and manual override of any keying devices. Other fitting considerations are material compatibility, corrosion resistance, flammability, ease of operation/connection and tight sealing. Fittings must be identified by the manufacturer's part number, the size of the end connection which joins to the piping system, and the dash number to show the size hose to which it mates. For interpretation of manufacturers' markings, consult the appropriate manufacturer's catalogue. Fittings meeting LR class requirements will have the specification number, class of fitting (where applicable), type, size and manufacturer's trademark clearly indicated.

8.1.3 Quick disconnect fittings used on flexible hoses shall be readily accessible and capable of being disconnected under pressure in an emergency. Provision shall be made to prevent accidental disconnection, i.e., a positive locking mechanism requiring more than one mechanical action to disconnect. Quick disconnect fittings shall not be used on diver's umbilical breathing gas hoses unless specifically approved by LR.

8.1.4 Umbilical hoses must meet all the requirements for flexible hoses. Umbilicals are made up of hoses and cables that tether a diving system or a diver to a supply source for breathing gas, fluids, electrical power, communications and mechanical strength. They shall be resistant to abrasion; impact damage, cracking and deterioration under the conditions of the mission profile and retain sufficient flexibility for free movement. Umbilicals must possess adequate tensile strength for their design use, adequate flexibility to withstand coiling for storage and reeving over sheaves, and adequate burst strength (*see Pt 5, Ch 5, 4.6 Resistance to burst*). Where, hoses are subjected to external seawater pressure that is greater than internal pressure. In these applications, it must be demonstrated that the hose has sufficient reserve crush resistance for the intended service.

8.1.5 All umbilical connections shall be provided with suitable end caps/plugs that protect the hose end fitting from mechanical damage and that prevent entrance of contamination when not connected for use. Fittings on the dive system connections shall be similarly protected.

8.2 Length of umbilicals

8.2.1 The diver's excursion umbilical should be kept at a minimum to prevent the potential for snagging and must be physically restrained to prevent it from coming within five metres of hazards such as thrusters and propulsion systems. The diver's excursion umbilical should be clearly marked along the entire length to allow monitoring of the length deployed.

8.2.2 Dispensation for longer umbilical has to be granted by the parties involved including representatives of the personnel, safety delegates and authorities where required. A risk analysis shall be performed.

8.2.3 When determining maximum diver’s umbilical length, the following hazard points should be taken into consideration:

(a) The distance from the diver to the nearest hazard point (thrusters, sea water intake etc.) should be at least 5 meters;
(b) Duration of bail-out equipment;
(c) Breathing resistance;
(d) Thermal conditions;
(e) Umbilical storage, deployment, handling and recovery;
(f) Wet tendering;
(g) ROV survey with mapping of debris/ obstructions;
(h) Positioning and stability of the work-site;

8.2.4 The stand-by diver’s umbilical shall be at least 3 meters longer than the diver’s umbilical, and any use of an extended umbilical shall be logged.

Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	Plans and particulars: plans and particulars to be submitted	Environmental control: general	Ergonomic factors
	Section 1.1	Section 2.1	Section 3.1
Unit Type			
Manned Submersible	x	x	x
Wet Submersible	x	x	x
Unmanned Submersible	x	x	x
Submersible Craft	x	x	x
Diving Bell	x	x	x
Submersible Vehicle	x	x	x
Submersible Habitat	x	x	x
Submersible Container	x	x	x
Passenger Submersible	x	x	x
Rescue Submersible	x	x	x

■ *Section 1*
Plans and Particulars

1.1 Plans and Particulars to be submitted

1.1.1 The following plans (in diagrammatic form) and particulars are to be submitted for appraisal:

(a) General arrangements, including details of hazardous area if any.

(b) A hazard analysis (required by *Pt 1, Ch 2, 3.2 New Construction Surveys 3.2.1*) relevant to the risk of fire and toxicity for all internal elements of a manned submersible or chamber, It is to include the control on materials taken into the pressure hull with respect to the highest partial pressure of oxygen in the space, under normal and emergency conditions.

(c) A general engineering dossier:

(i) *describing the ergonomics of the dive, operations and on board control centres, and the submersible layout in terms of achieving maximum operator efficiency and passenger comfort;*

(ii) *the detailed arrangements of control stations demonstrating compliance with control station ergonomics in the relevant parts of ISO 11064, or equivalent industry standards.*

■ *Section 2*
Environmental control

2.1 General

2.1.1 Estimation of machinery heat production and heat conduction through the hull is to be confirmed before finalization of the system.

2.1.2 An outline of the facilities for the thermal protection of the divers in the event of a power failure and/or a possible forced and prolonged stay is to be provided.

2.1.3 The average rate of circulation of atmospheric gases in all manned chambers is to be maintained at about 6 to 10 air changes per hour, while the air flow passing personnel is to fall within the velocity range: 1 to 8 m/min. The circulation rate in machinery chambers, battery chambers and other unmanned chambers is to be agreed.

2.1.4 Materials producing atmospheric contamination are to be kept to a minimum within the pressure hull to prevent build-up of toxic concentrations. Suitable filters should be fitted in all necessary cases. Before initial operation and after every refit, or after any internal painting, the atmosphere should be tested using a wide-band analytical instrument. Finishes, such as paint containing lead and/or certain toxic solvents, should not be used inside the pressure hull.

2.1.5 Pressure vessels, where leakage of the contents could produce an uncontrolled atmosphere, are not to be stored within the hull or chamber or where the pressure rise in the chamber could exceed 1 bar.

2.1.6 The overall design is to be such that an explosion, violent movement or rapid build-up of pressure does not occur in the chamber under normal or abnormal operating conditions.

2.1.7 Provision is to be made for the collection and containment of the waste products of the crew and passengers within the submersible. Sufficient capacity shall be provided for the normal operational time plus the time allowed for emergency recovery.

2.1.8 Supplies of food and water are to be available within the submersible to cater for the requirements of crew and passengers for normal operating time plus the time allowed for emergency recovery.

2.1.9 Diving Systems are to be provided with safety interlocks where necessary to prevent any unintentional or Uncontrolled loss of pressure Particular attention should be directed to chamber/bell mating systems diver evacuation mating system, toilet interlocks food, medical and equipment locks.

2.1.10 All components in a diving System or submersible are to be so designed, constructed and arranged as to permit easy cleaning disinfecting, inspection and maintenance.

Section 3
Ergonomic factors

3.1 General

3.1.1 Ergonomic factors, consideration should be made for work in all parts of the dive system which does not involve just seated or standing operation at a workstation. Reference should be made to ISO 6385.

3.1.2 The working positions of the crew and the comfort of passengers are to be considered in order to maintain the maximum efficiency when working, assuming personnel of approximately average height and length of reach for the controls. Furniture such as seats, bunks, tables, lockers, etc., should be provided as appropriate. *Figure 6.3.1 Console for operation sitting or standing* is provided for guidance.

3.1.3 Where practicable, adjustable equipment should be considered to permit optimum use by personnel differing significantly in size.

3.1.4 The positioning of instruments, the shape and colour of switches and push buttons should be specially considered to minimize human error in operation, especially in the event of a lighting failure.

3.1.5 Manned submersibles should be provided with sufficient illumination in all areas to ensure efficient operation. Secondary illumination should be provided from a separate power source in living spaces, the secondary illumination should have a minimum level of 50 lx, and the normal average about 370 lx. Coloured lighting may be used as considered necessary. Reference is to be made to ISO 8995 or equivalent for illumination levels.

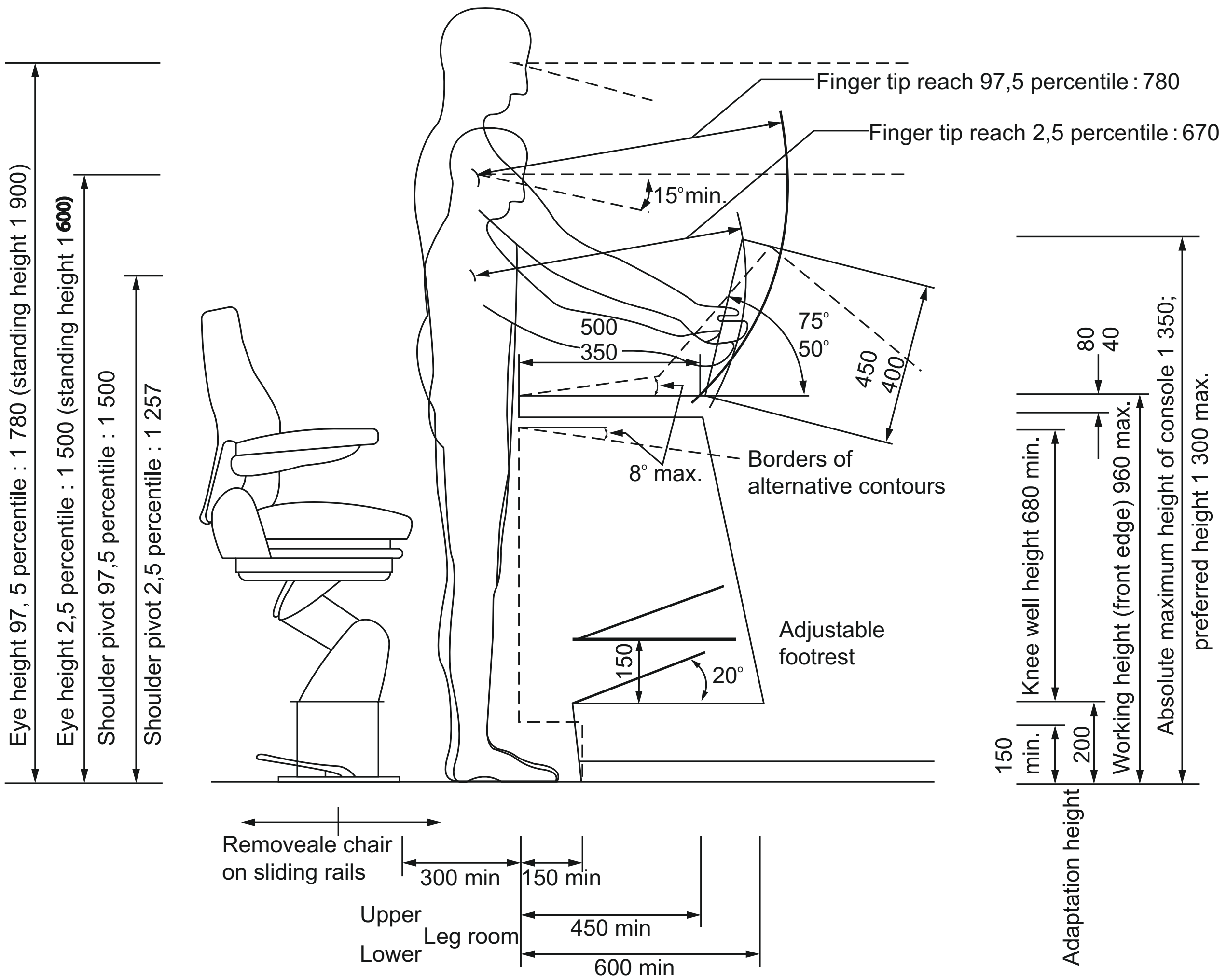


Figure 6.3.1 Console for operation sitting or standing

Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

Unit Type	Lifting Appliances
Manned Submersible	x
Wet Submersible	x
Unmanned Submersible	x
Submersible Craft	x
Diving Bell	x
Submersible Vehicle	x
Submersible Habitat	x
Submersible Container	x
Passenger Submersible	
Rescue Submersible	

Section 1
General Requirements

1.1 Scope

1.1.1 This Chapter applies to the following types of lifting appliance which are designed to handle, transfer and mating of submersibles in offshore conditions and where the submersible is classed by LR.

(a) A frame, derrick, crane or other form of deployment system used to deploy and recover a manned or unmanned tethered submersible.
(b) A frame, derrick, crane or other form of deployment system used to deploy and recover a remotely submersible (untethered).
(c) Any other deployment system used to handle submersibles and not described above.

1.1.2 The lifting appliance is to be designed for the same operating conditions as the submersible with which it is associated and where these exceed that given above will be subject to special consideration.

1.1.3 For a submersible handling appliance to be classed by LR this requires:

(a) Plan approval of the structural, mechanical, electrical and control plans.
(b) Survey during manufacture.
(c) Survey during installation and test.

1.1.4 To remain in class the lifting appliance is to be surveyed by LR's Surveyor's in accordance with *Pt 5, Ch 7, 1.3 Survey during manufacture and installation* and *Pt 5, Ch 7, 1.5 Damage Surveys*.

1.1.5 Where the submersible is not classed by LR the lifting appliance may still be certified by LR and the procedure given in this Chapter will also apply.

1.2 Plan approval

1.2.1 The lifting appliance is to be designed in accordance with the requirements given in *Ch 4, 4 Submersible handling systems* of LR's *Code for Lifting Appliances in a Marine Environment, July 2019* , and any additional requirements listed in these Rules.

1.2.2 Plans and calculations are to be submitted for approval as specified in *Code for Lifting Appliances in a Marine Environment, July 2019 Ch 1, 3.3 Crane systems* and *Ch 1, 3.7 Mechanical, electrical and control aspects*, *Ch 9, 2.1 Plans and information to be submitted* and *Ch 10, 2.2 Documentation 2.2.1*.

1.2.3 The operating conditions for which the submersible and lifting appliance are designed are to be clearly stated in the plan submission and final documentation.

1.3 Survey during manufacture and installation

1.3.1 The lifting appliance is to be surveyed during manufacture and installation on the ship, mobile offshore unit or platform on which it is mounted in accordance with LR's *Rules and Regulations for the Classification of Ships, July 2019*, Rules and Regulations for the Classification of Mobile Offshore Units, Rules and Regulations for the Classification of Fixed Offshore Installations, these Rules and Regulations and *Code for Lifting Appliances in a Marine Environment, July 2019* as appropriate.

1.3.2 The lifting appliance is to be tested in accordance with the requirements given in *Ch 12, 1.7 Launch and recovery systems for diving operations* of *Code for Lifting Appliances in a Marine Environment, July 2019* before being taken into use and subsequent to any repair, modification, or relocation, and the tests are to be witnessed by LR's Surveyor.

1.4 Periodic surveys

1.4.1 The lifting appliance is to be subjected to periodic surveys by LR's Surveyor in accordance with the requirements given in *Ch 12, 3 Survey requirements* and *Table 12.3.5 Annual Thorough Examination of cranes and launch and recovery systems for diving operations* of *Code for Lifting Appliances in a Marine Environment, July 2019*. *See also Ch 12, 2.4 Derricks, cranes and launch and recovery systems for diving operations*.

1.5 Damage Surveys

1.5.1 Damage surveys, the after damage repairs and re-testing of the lifting appliance shell be implemented according to *Code for Lifting Appliances in a Marine Environment, July 2019 Ch 12, 3.6 Damage surveys*.

1.6 Handling system for diving bells

1.6.1 A diving system should be equipped with a main handling and transfer equipment to ensure safe transportation of the diving bell between the work location and the surface compression chamber.

1.6.2 The handling system is to be designed with adequate safety factors considering the environmental and operating conditions, including the dynamic loads which are encountered while handling the diving bell through the air-water interface as specified in *Code for Lifting Appliances in a Marine Environment, July 2019 Ch 4, 4 Submersible handling systems*.

1.6.3 The handling system is to enable smooth and easily controllable handling of the diving bell.

1.6.4 The lowering of diving bells under normal conditions is not to be controlled by brakes, but by the drive system of the winches.

1.6.5 If the energy supply to the handling system fails, brakes are to be engaged automatically.

1.6.6 In the event of single component failure of the main handling system, an alternative means is to enable the divers to be brought back to the surface compression chamber. This alternative system must be supplied with power independently of the main handling system. In addition, provision is to be made for emergency retrieval of the bell should both the main and alternative systems fail. Diving bells whose emergency ascent is initiated by the release of ballast must be equipped with devices for releasing the hoisting and lowering strength member/ umbilical and the ballast weight. The equipment shall be so designed that two mutually independent operating actions have to be performed inside the chamber to initiate the release of ballast.

1.6.7 Handling systems and mating devices should enable easy and firm connection or disconnection of a diving bell to a surface compression chamber, even under conditions where the support ship or floating structure is rolling, pitching or listing to predetermined degrees.

1.6.8 Where a power actuating system is used for mating operations, an auxiliary power actuating system or an appropriate means is to be provided to connect a diving bell to a surface compression chamber, in the event of failure of the normal power actuating system.

1.6.9 The guide weight wires may be used for emergency recovery.

1.6.10 The mating system is to be provided with a safety interlock between the diving bell and the surface compression chamber.

1.6.11 Unless otherwise stated in the following sections, the mechanical, control and electrical equipment of the handling system is to conform to LR *Rules and Regulations for the Classification of Ships, July 2019*.

1.6.12 The handling, transporting and mating appliances are to be fitted with a prominent and permanently mounted name plate containing at least the following information in easily legible characters:

(a) Name of manufacturer;
(b) Serial number and year of manufacture;
(c) Static test load;
(d) Operational test load;
(e) Safe working load;
(f) Date of test and test stamp.

1.7 Emergency recovery of submersible

1.7.1 In order to assist in emergency recovery, quick attachment gear is to be provided on the support ship for hoisting the submersible without assistance from within. When a tethered buoy is employed for emergency communications, it is recommended that the attachment gear be designed so that it may be guided down the tether to engage in an emergency lifting lug on the submersible.

1.7.2 If emergency retrieval of the bell involves buoyant ascent, umbilicals, suspension lines or towlines are to be fitted with an emergency quick-release device operated by the crew. The release control is to have a suitable guard fitted.

1.7.3 If emergency retrieval of the divers involves bell to bell transfer, detailed arrangements and relevant FMEA are to be submitted for LR approval.

■ *Section 2*
Submersible Handling Systems

2.1 Introduction

2.1.1 Diver Handling Systems include any weight handling systems that are used to launch and recover divers through the air/sea interface from a support ship, diving vessel, or diving support installation. Inspection and load testing requirements apply to diver handling operations and should not be used for general crane applications. Diver Handling Systems may consist of a simple block and tackle arrangement, using a davit and capstan to raise and lower a diver stage, or may consist of a complex A-frame system that is used to launch and recover manned tethered underwater vehicles, such as the pressurized diving bell or untethered submersible unit.

(a) This section contains certification parameters for handling systems employed in the launch and recovery of manned Diving Systems from support ships. The methods of design and fabrication are discussed, and their required verification scope is identified. Preventive maintenance documentation, which is influenced by, and evolved from the basic design concepts as well as operational documentation, is also outlined.

(b) Diving System handling equipment to be certified under these requirements includes, but is not limited cranes, booms, davits, and A -frames; plus their associated winching and rigging components. Hydraulic, electrical, and pneumatic subsystems are also considered part of the handling system.

(c) All critical items, as defined in *Pt 5, Ch 7, 2.2 Definitions*, shall be included in the Scope of Certificate (SOC). The SOC will also contain all items necessary to ensure compliance with the objective and intent of certification.

(d) Weight handling components are typically included within the SOC for the Diving System. When the weight handling system is portable, it must be included within the SOC for each diving system it will be used to support.

2.2 Definitions

2.2.1 **Added Mass Effect.** The mass of water particles surrounding an object immersed in water that is accelerated with the object as the object is accelerated through the water. When a body is accelerated in a fluid, it behaves as though its mass is greater than it actually is due to the effect of the surrounding fluid. This additional mass must be added to the actual body mass to account for the change in inertia.

2.2.2 **Critical Item.** Any item within a system, equipment, or component whose failure would endanger the occupants of the Diving System. These failures may include uncontrolled dropping, shifting, or other sudden movement of the Diving System when it is supported by the handling system.

2.2.3 **Design Load.** The maximum force due to the rated load plus some or all of the following: (1) added mass effects, (2) entrained water, (3) any external payloads, (4) drag or wind loads, and (5) dynamic loads which are derived with the aid of the dynamic load factor.

2.2.4 **Diving Ship**. Any platform used to transport, launch, and retrieve a Diving System. Ships, boats, vessels, barges, and submarines are included in this definition. An example of a submarine support platform is one modified to carry a Dry Deck Shelter for operations with Swimmer Delivery Vehicles.

2.2.5 **Dynamic Load.** The load imposed on a system due to accelerations of gravity and ship motion. It is dependent upon the magnitude and frequency of ship motions, ship attitude, and the location of the handling system on the ship. The design load for the facility shall be calculated on the basis of maximum static and dynamic loads, which may be expected under specified maximum operational limits. The design load shall be at least twice the maximum static load.

2.2.6 **Dynamic Load Factor.** A calculated number given in acceleration units, g, where g is the acceleration of gravity. The force exerted by the system on its supports is determined by multiplying the dynamic load factor by the weight of the system.

2.2.7 **Fail-safe.** Components within the handling system that are designed to prevent uncontrolled dropping, shifting, or sudden movement of the Diving System during a hydraulic or electrical system failure or component/equipment malfunction.

2.2.8 **Handling System.** The mechanical, electrical, structural equipment and rigging used on board a support ship to launch and recover divers or a manned Diving System.

2.2.9 **Load Bearing.** Those components of the handling system that support the loads resulting from launching and recovering of a manned Diving System.

2.2.10 **Load Controlling.** Those components of the handling system that position, restrain, or control the movement of a manned Diving System. Towing is excluded from the SOC.

2.2.11 **Operational Load.** The maximum weight that will be lifted during diver handling operations. This is normally the weight of the stage plus the weight of fully dressed divers at 150 kg each.

2.2.12 **Safe Working Load (SWL) or Rated Load.** The maximum weight that may be lifted by the assembled handling system at its rated speed and under parameters specified in the equipment specifications (e.g., hydraulic pressures, electrical current, electrical voltages, etc.).

2.2.13 **Rigging.** Running rigging consists of the rope (wire rope or synthetic line) and end fittings intended to handle the Diving System that passes over sheaves or through rollers. Standing rigging is rope that is stationary and provides mechanical support to the handling system.

2.2.14 **Static Test Load.** A weight equal to 1.5 x SWL of the handling system. It is carried out at inboard, outboard and an intermediate position and used to physically verify the structural integrity of the handling system. The amplifying factor F_h/1.7 may apply according to *Code for Lifting Appliances in a Marine Environment, July 2019 Ch 12, 1.7 Launch and recovery systems for diving operations 1.7.2*.

2.2.15 **Dynamic Test Load.** A weight equal to 1.1 x SWL of the handling system. It is used to physically verify the adequacy of handling system's brakes by demonstrating that brake system is capable of stopping the load whilst being lowered at maximum speed to simulate a power failure. The amplifying factor F_h/1.7 may apply according to *Ch 12, 1.7 Launch and recovery systems for diving operations 1.7.2 Code for Lifting Appliances in a Marine Environment, July 2019*.

2.2.16 **Operational Test Load.** A weight equal to 1.25 x SWL of the handling system. It is carried out over the full range of operation of lifting appliance and used to physically verify the adequacy of fail-safe components. The amplifying factor F_h/1.7 may apply according to *Ch 12, 1.7 Launch and recovery systems for diving operations 1.7.2 Code for Lifting Appliances in a Marine Environment, July 2019*.

2.2.17 **SWL Test Load.** A weight equal to SWL of the handling system. Following the overload tests the handling system is to be operated with its SWL over complete operating cycle to demonstrate the effective operation of the system, the accuracy of overload and safe load indicators and the effectiveness of limit switches, etc.

2.3 Equipment Design Criteria

2.3.1 This section provides guidelines and criteria for the design and analysis of Diver Handling System components and associated structures designed and constructed in accordance with these Rules.

2.4 Types of Loads

2.4.1 The initial step in designing any handling system is to determine the design load that the system will encounter. The design load is derived from a combination of forces under worst-case operating conditions. Components should be sized according to the greatest design load, or combination of loadings that will be encountered. The following loads and forces should be considered when designing Diver Handling Systems:

(a) Asymmetric loads. When sizing structural members for handling systems that employ more than one load carrying member to support their payload, consideration should be given to factors which might cause asymmetric loading. Such factors affecting the Diving System that would result in asymmetric loading include, but are not limited to, the following: external water, free surface effects in the internal tanks, a shift in ballast, and external payloads.

(b) Dynamic loads. In addition to the load generated by lifting the normal rated capacity of the handling system, dynamic forces due to wave induced motions on the support vessel must also be considered.

(c) Dead loads. The dead loads consists of the masses of the structural parts of the Diver Handling System and materials permanently attached to the structure accelerated due to natural gravity and vessel motions in operational and stowage conditions.

(d) Wind Forces. The wind loads on the projected area of the handling system structure and on the Diving System, appropriate to the design conditions, are to be considered.

2.5 Environmental Considerations

2.5.1 Diver Handling Systems are subjected to extremely harsh and marine environmental factors that significantly impact the operational and maintenance characteristics of the system. Environmental factors which should be considered in the system design parameters are sea state, air temperature, water temperature, precipitation (rain and snow), ice, wind velocity, currents, and the corrosive effects of the salt water environment.

2.5.2 For the operational sea state specified, the uppermost value for the wave heights of the significant wave or the 10th highest wave should be taken as the design wave. The period of maximum energy of the sea spectrum should be chosen as the design period.

2.5.3 The maximum and minimum design operating temperatures of both the air and water must be taken into account during handling system design. This is particularly important for hydraulic systems where hydraulic fluid may become too viscous in extreme cold or lose its lubricating properties in extreme heat. Additionally, extremely cold air temperatures may affect the ductility of some metals and render structural members unsafe if not adequately designed.

2.5.4 The effect of rain, snow, sleet and ice can be dramatic on topside equipment not designed for it. Electrical connectors, junction boxes and motors that are not rated for harsh outside environments often fail in shipboard service. All pivoting or sliding load bearing surfaces should either be sealed from the weather or be designed to permit thorough inspections and be provided with an adequate number of lubrication fittings. Waterproof grease is required for these applications. Also, steels must have a protective coating of paint designed for a salt air environment.

2.5.5 Side loads may be induced in the handling system by high winds. This loading may be significant if either the Diving System or the handling system itself has a large surface area. The prudent designer will account for possible wind related effects in the system design.

2.5.6 In the same manner that wind affects the handling system topside, ocean currents affect any submerged components of the Diving System. Drag effects caused by ocean currents may be significant depending on the geometry of the Diving System and/or any submerged portions of the handling system. Drag effects must be taken into account in the design of the handling system.

2.5.7 Each component should be carefully reviewed for its susceptibility to corrosion, with special attention given to those components immersed in salt water. Furthermore, care should be taken to avoid galvanic corrosion when several different kinds of metals are in physical contact. Galvanic series charts or tables should be consulted when utilizing dissimilar metals.

2.6 System Considerations

2.6.1 The operation of the handling system is an integral part of the total Diving System, and as such, is limited by the coordination of personnel on deck and interface of the Diving System, handling system, and support vessel. For safe and efficient launch and recovery evolutions, the following items must be considered when developing a Diver Handling System:

(a) Positive Control. The motion of the Diving System during launch and recovery operations must be under positive control at all times.
(b) Fail-Safe. A provision designed to automatically stop or safely control any motion when a hydraulic or electrical failure occurs. The Diver Handling System shall be provided with interlocks, safety devices, and protective devices so that it will be fail-safe.
(c) Motion effects. The physical location of the handling system on board the diving ship should be such that the effects of the ship's motions on the Diving System during handling evolutions are minimized.
(d) Weight. The weight of the Diver Handling System should be minimized to limit the weight added to the support vessel and the adverse effects on its sea keeping ability.
(e) Shock mitigation. Dynamic motions of the support ship at-sea can cause shock loads to the Diving System and its personnel through the handling system. Motion compensating devices shall be considered to minimize these shock loads.

2.7 Human Engineering and Operational Design Considerations

2.7.1 Diver Handling Systems are designed to transport personnel in a restricted and hazardous environment under the direct supervision and control of support personnel. A human engineering evaluation should be conducted to ensure the ability of support personnel to control and supervise the safe and coordinated movement of the Diving System. The following are some critical areas that should be addressed in the evaluation:

(a) Hazardous exposure. Due to the nature of handling system operations, some operations will be inherently hazardous. However, hazards should be eliminated whenever possible. There should be a minimum of support personnel exposed to hazards.
(b) There should be no diver/swimmer involvement during launch and recovery of the Diving System.
(c) Coordination and control. Safe and timely operation of handling systems requires precise control and coordination of all personnel involved. The system arrangement should facilitate simplicity and require minimal supervision to attain this goal.
(d) Communication. In addition, there must be clear communications between Diving System handling support personnel, the support ship personnel responsible for manoeuvring the ship and the Diving Supervisor.

(e) Monitoring equipment status. Control and support personnel responsible for the operation of the handling system should have access to monitoring devices to enable them to evaluate the status of the equipment. This is to ensure the system is operating within its capability limits (e.g., speed, load, pressure, temperature, etc.). These factors, along with the observed sea state, can then be evaluated to determine their effect on the operating parameters of the Diving System.

(f) Manning. Minimizing the number of personnel required to operate and maintain the system should be considered.

2.8 Emergency Conditions and Reduced Operating Capability

2.8.1 The Diver Handling System shall be designed to minimize the effects of component failures. An FMEA is to be conducted to determine and resolve them. The FMEA can also be used to evaluate the system's capability to continue to operate and safely recover Diving System personnel. All handling system components shall be operable in sea states specified by the mission profile. In the event of a control console failure, an alternate or backup means of system operation is required.

2.8.2 The handling system for diving bell shall include means of safe guidance of the bell through the surface of the water, such as a moon-pool cursor or a bell cursor tower system.

2.8.3 The handling facility shall be secured against uncontrolled pay-out as a result of technical failure of the system. This normally implies that the facility should be equipped with automatically applied mechanical breaking devices providing primary and secondary protection. Furthermore the facility shall be equipped with limit switches preventing the handling of the bell / wet bell / basket / ADS outside the handling area.

2.9 Load Bearing Component Design

2.9.1 Design analyses must indicate forces, loads, shears, and moments for all structural members, welds, and connections including interaction forces with the supporting deck and ropes. Components shall be analysed considering tensile, compressive, bending, shear, and torsional loadings. Structural members shall be evaluated in accordance with requirements of *Code for Lifting Appliances in a Marine Environment, July 2019* or equivalent structural codes. (Note when using equivalent structural codes: the allowable stresses and safety factors used therein shall be revised as required to meet the safety factors specified in *Code for Lifting Appliances in a Marine Environment, July 2019 Ch 4, 2.17 Allowable stress – Elastic failure*). Analyses for rigging gear must also be included in the design documentation.

2.9.2 Calculations shall take into account the wet and dry weight of the Diving System, entrained water weight, added mass effects (if applicable), crew and payload weights, the dynamic affects due to the motion of the support ship and Diving System at sea, and the effects of the wind forces. The support ship's motions shall be analysed for the maximum operating sea conditions, sea state or swells specified in the requirements documentation. The worst-case loading due to heave, roll, pitch, or any combination thereof, shall be used in the calculations.

2.9.3 In addition to operating conditions, the Diving System is to be designed to withstand the most severe combination of motions which can occur during transit when the system is stowed on a vessel. In case of occurring the effects of green sea loading on the structure should be considered

2.10 Design Factors of Safety

2.10.1 Factors of safety for Diver Handling Systems are based on LR *Code for Lifting Appliances in a Marine Environment, July 2019*, and are related to the material used and the operating environment conditions. Relatively high safety factors are necessary, even though the materials and their properties are well known, because they are used in uncertain environments and are subjected to uncertain stresses. Material certificate will be required in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2019*.

(a) Structural and machinery components

  (i) For launch and recovery systems, the stress factors (F) for all structural and machinery components shall be according to *Table 4.2.6 Stress factor, F* of *Code for Lifting Appliances in a Marine Environment, July 2019*.

  (ii) For underwater applications, the factor of safety shall be 3 on material yield or 5 on material ultimate tensile strength; whichever is greater. The above factors of safety shall be based on the design load.

(b) Rigging and Fittings

  (i) Factors of safety for wire and synthetic rope are given in *Table 7.2.1 Factors of Safety for Rigging*. These factors shall be based on the design load of the Diver Handling System and the specified nominal breaking strength for wire rope or average breaking strength for synthetic rope.

  (ii) If galvanized wire rope is used, reduce the nominal breaking strength by 10 per cent to account for the effects of galvanizing.

Note If drawn galvanized wire is used, no reduction in breaking strength is necessary.

(iii) Rope break test. Each rope is to have a certificate of break indicating the load at which the test sample broke.

2.10.2 When used with wire or synthetic rope, the factor of safety for fittings shall be equal to or greater than the commercial rating for the Diving System design load. The main lifting wire shall be calculated using a safety factor of at least 8.0 related to the maximum safe working load.

Table 7.2.1 Factors of Safety for Rigging

Material Application	*Critical Component*	*Noncritical component*	*D/d Ratio*[1]
Wire rope standing rigging	*5*	*5*	*-*
Wire rope running rigging	*5*	*6*	*18:1*
Rotation resistant wire rope			
-Standard construction	*7*[2]	*6*	*34:1*
-Formed through a die	*6*	*5*	*18:1*
Synthetic rope[3]			
- Braided	*7*	*5*	*8:1*
-Twisted/Plaited	*7*	*5*	*10:1*
- Aramid (Kevlar)	*6*	*5*	*20:1*

Note 1. Ratio of sheave or drum diameter (D) to wire rope or synthetic line diameter (d).

Note 2. This factor of safety is used for rotation resistant wire rope supporting a free hanging load. If a guideline system is used that does not allow the load to rotate, this factor of safety can be reduced to 6. Under no circumstances shall the factor of safety for ropes be less than 6 for manned lift systems.

Note 3. When wet, the safety factor for nylon rope shall be applied to the breaking strength minus 15 per cent unless a suitable marine overlay finish is used.

2.11 Design and Testing Requirements

2.11.1 Design and testing requirements of Diver Handling Systems shall be met as stated in this section and any additional requirements of LR *Code for Lifting Appliances in a Marine Environment, July 2019*.

2.11.2 Load bearing component requirements are discussed in *Pt 5, Ch 7, 2.11 Design and Testing Requirements 2.11.4*, and cover structural, rigging, and machinery component criteria; hydraulic and pneumatic system requirements are discussed in *Pt 5, Ch 7, 2.12 Hydraulic and Pneumatic System Requirements 2.12.1*; and electrical power requirements and controls are discussed in *Pt 6 Electrical Installations and Control Engineering Systems*.

2.11.3 Design analyses for Diver Handling Systems must be based on LR *Code for Lifting Appliances in a Marine Environment, July 2019* and on recognized engineering analytical methods and standards. Loads imposed by the environmental conditions specified in the requirements documentation must be included in the analyses. The design of all load bearing and load controlling elements must be within the Scope of Certificate of diving equipment.

2.11.4 All elements of the handling system that support the weight of the Diving System when occupied by personnel shall be designed, fabricated, and maintained in accordance with the following requirements:

2.11.5 All new Diver Handling Systems must be tested prior to initial certification and operational use. In addition, all modified or extensively repaired handling systems shall be inspected and tested as required in *Pt 5, Ch 7, 2.11 Design and Testing Requirements 2.11.11*. These tests are intended to confirm the adequacy of the design, the operational characteristics, and the validity of the operating procedures. For modified or repaired systems, the purpose of these tests is to verify the adequacy of the work performed, and to ensure the handling system continues to meet its design and certification criteria.

2.11.6 All Diver Handling Systems shall have static, dynamic, and rated load tests conducted on the following occasions: after being installed on a diving ship, upon completion of an overhaul, and at intervals not to exceed 5 years. In addition, a static load test, dynamic load test, rated load test, and/or no -load test shall be accomplished, as required, after repair or replacement of system components in accordance with *Pt 5, Ch 7, 2.11 Design and Testing Requirements 2.11.12*.

2.11.7 The main handling facility shall be operable even if essential components such as a power source or a winch motor is out of action.

2.11.8 An alternative handling system shall be provided and shall comprise a dedicated system ready for immediate use, with the capability to bring the device back to the surface and into position to be connected to the chamber complex in the event of the main handling facility being out of action.

2.11.9 The alternative handling system shall comply with the same requirements for load strength as the main handling system.

2.11.10 Guide wire equipment may, in addition to functioning as an alternative handling facility, ensure a controlled movement of the device in the water and may also provide an arrangement for stopping the device in the event of failure in the primary lifting wire.

2.11.11 Test procedures for all load tests and System Operational Tests shall be submitted to LR for review and approval.

2.11.12 The following paragraphs identify the requirements for conducting static, dynamic, operational and rated load (SWL) tests. In addition, maintenance testing requirements after completing maintenance tasks are also addressed.

(a) No Load Test. No load tests are conducted to evaluate the functioning of the Diver Handling System. The Diver Handling System shall be operated through its full range of motions and directions. Check for unusual noise, vibration, or overheating in machinery and control components. Also check for proper operation of all indicator lights and gages.

(b) Static Load Test. A static load test physically verifies the structural integrity of the fully assembled Diver Handling System. Test loads may be applied with certified test weights or by mechanical devices with calibrated load measuring gages.

  (i) The static test load shall be held for a minimum of ten minutes by the brake without power to the system. (*See* Controlled Work Package for testing procedures) No evidence of structural or rigging component deformation is allowed.
  (ii) Upon completion of the static load test, the critical load bearing components and strength welds of the handling system shall be inspected to verify there is no permanent set, deformation, cracking, or other damage to any part of the structure, foundations, machinery, and reeving components. For initial certification, or if load bearing component repair or modification work was accomplished, the level of inspection shall be as specified on the drawings or in separate specifications to include MT or PT as applicable.
  (iii) End fittings on ropes included in the test shall be inspected for slippage and damage.
  (iv) Verify the system will hold the static load for one minute without power to the system.
  (v) The static load test shall be conducted when the support ship is pier-side and experiencing no significant motion. The handling system shall be tested in the position of maximum loading.

(c) Dynamic Load Test. A dynamic load test demonstrates the capability of the Diver Handling System brakes.

  (i) The dynamic load test shall be stopped at least three times in each direction to ensure proper brake operation. No speed is specified; however, the maximum speed attainable with the test load shall be used.
  (ii) During the dynamic load test, the handling system brakes shall be checked for any signs of binding, abnormal noise or vibration, and overheating. As a minimum, the following equipment parameters shall be recorded during the test: motor amperage, hydraulic fluid temperatures and pressures (including main loop, servo, and replenishing pressures), and operating speeds. In general, the following shall be verified and noted: smooth operation, and proper stopping and holding of the test weight.
  (iii) Upon completion of the dynamic load test, the handling system shall be inspected for any indications of the following: warping or permanent deformation; leaking hydraulic fluid from any component or connections; wear patterns on sheaves, ropes, and gear trains; and proper drum spooling.
  (iv) The dynamic load test shall be conducted when the support ship is pier side and experiencing no significant motion.

(d) Operational Load Test. An operational load test demonstrates the capability of the Diver Handling System to operate under the dynamic conditions of the support ship's motions at sea. The test shall demonstrate the handling system's overload capabilities and the adequacy of fail-safe components throughout its complete operating range. Care must be taken to ensure specific operating limits of the components being tested are not exceeded.

  (i) Test loads shall be moved through one complete cycle of the handling system, with all limits of its operating modes (raising, lowering, traversing, travelling, rotating, etc.) included in the test. The handling system, with the test load, shall be stopped at least three times in each direction to ensure proper brake operation.

(ii) During the operational load test, the handling system shall be checked for any signs of binding, abnormal noise or vibration, and overheating. As a minimum, the following equipment parameters shall be recorded during the test: motor amperage, hydraulic fluid temperatures and pressures (including main loop, servo, and replenishing pressures), operating speeds for all modes of operations (i.e., booming out, booming in, and/or raising and lowering, etc.). In general, the following shall be verified and noted: smooth operation, and proper stopping and holding of the test weight.

(iii) Upon completion of the operational load test, the handling system shall be inspected for any indications of the following: warping or permanent deformation; leaking hydraulic fluid from any component or connections; wear patterns on sheaves, ropes, and gear trains; and proper drum spooling.

(iv) The operational load test shall be conducted when the support ship is pier side and experiencing no significant motion.

(e) Rated Load (SWL) Test. A rated load test demonstrates the capability of the Diver Handling System to operate with its intended load at its rated speed. It also verifies that all hydraulic and electrical components operate within their specified operating limits. Test loads shall be moved completely through the handling system's full operating range, and within limits of all operating modes (raising, lowering, traversing, travelling, rotating, etc.). The system shall be capable of hoisting the Diving System at the system's rated speed when the hoist wire rope or synthetic line is on the outermost layer of the drum. The test load shall be run through at least three cycles to demonstrate proper operation. Each cycle is to be run at the specified normal operational speed of the handling system.

(f) Maintenance Testing Requirements. Conducting the full range of load tests (i.e., static, dynamic, and rated load tests) is not always necessary after completing corrective maintenance actions or some repair tasks. *Table 7.2.2 Maintenance Testing Requirements – Load Bearing Components* identifies the tests required after performing various tasks on structural, rigging, or machinery components. Some handling systems have unique components and may require additional or modified testing. The test documents for those tests shall be submitted to LR for review and approval on a case basis. The system drawings/ specifications should be consulted for further testing requirements. The tests specified in *Table 7.2.2 Maintenance Testing Requirements – Load Bearing Components* and the applicable tests specified by a drawing or specification shall be conducted for each maintenance task identified. If there is a conflict between the tests specified in *Table 7.2.2 Maintenance Testing Requirements – Load Bearing Components* and the test specified by the applicable drawing or specification, then the requirements of this document take precedence, unless specifically authorized by LR.

(g) After each installation on board, the handling system is to be tested with the static test load. In addition, a dynamic load test (braking test) is to be carried out as well.

(h) A test is to be performed to ensure that the mating, release, transfer, lowering and raising of the diving bell proceed smoothly and safely under normal and emergency operating conditions.

(i) A test is to be performed to verify that the mating device can be released and the diving bell transported only when the trunk is not under pressure.

(j) A functional test is to be performed to demonstrate that the hyperbaric evacuation system is able to convey divers under pressure from the ship or floating structure to a safe position where they can be monitored and supplied.

Table 7.2.2 Maintenance Testing Requirements – Load Bearing Components

Maintenance Task	*Test Requirements*
1. Drum or sheave repair, replacement, or modification	*Static load test*[1] *Dynamic load test* *Rated load test*
2. Hook[2] *repair, replacement, or modification*	*Static load test*
3. Main lift rope(s) replacement (wire rope or synthetic line)	*Pell test*[3] *No-load test*
4. Coupling , shaft, or bearing repair or replacement	*Dynamic load test* *Rated load test*
5.Non-load bearing shafts or bearing repair or replacement	*No-load test*
6. Gear repair and replacement (load bearing or load controlling only)	*Static load test*[1] *Dynamic load test* *Rated load test*

7. Gear bearing oil-seal replacement	*No-load test*
8. Hydraulic cylinder repair and replacement (when the cylinder is used to support the weight of the Deep Submerged Vehicle, as in the case of an A-frame and elevator)	*Static load test[1]* *Dynamic load test* *Rated load test*

Note 1. Only the repaired, replaced, or modified component needs to be statically load tested. If the affected component can be rigged such that the test load can be applied to it only, then that test would suffice for the static load test.

Note 2. "Hook" in this document is a generic term for the interface device between the Diving System and the handling system.

Note 3. All wire rope end fitting installations must be pull-tested to the static test load of the handling system, or to 40 per cent of the nominal breaking strength of the wire rope. All synthetic line eye splices shall be proof tested to the static test load of the handling system.

2.12 Hydraulic and Pneumatic System Requirements

2.12.1 Hydraulic systems shall be designed and tested in accordance with the requirements of the subsections *Pt 5, Ch 7, 2.13 System Design* and *Pt 5, Ch 7, 2.14 Relief and Counter-Balance Valves*. These requirements can also pertain to pneumatic systems.

2.13 System Design

2.13.1 Hydraulic and pneumatic systems and components shall be designed to operate the rated load at the rated speed when the differential pressure across the actuator is not more than two-thirds of the maximum operating pressure. This will ensure the handling system will operate efficiently under dynamic conditions at sea as well as when undergoing load testing.

2.13.2 Hydraulic and pneumatic systems and components shall be designed such that they are fail-safe and the brake on any winches, cranes, or elevators shall set and stop motion if there is a loss of power.

2.13.3 Additionally, the following requirements shall also be met:

(a) The maximum operating pressure shall not exceed pump or compressor and motor manufacturer's continuous ratings.
(b) Pump or compressor drive electric motor current shall not exceed nameplate rating at the design load.

2.13.4 In the case of cross hauling, such equipment shall fulfil the same requirements for strength as the rest of the handling system.

2.13.5 Umbilical shall be handled by a system compatible with the system handling the diving bell. Bell and guide-wire winches used for dry transfer into a habitat shall include a heave compensation / constant tension system.

2.13.6 Records shall be maintained of umbilical and wire cut-backs, re-termination, end-for-ending and replacements.

2.13.7 Where direct visual monitoring of the winch drums from the winch control station is not practical, TV monitoring shall be fitted.

2.13.8 Primary and emergency lighting in all critical handling areas shall be provided.

2.13.9 As a minimum, the following documents shall be submitted for review and approval:

(a) Design analyses and calculations that provide the basis for the system design, including all assumptions governing the design. The analyses must include the following when results of computer calculations are submitted: input data, summaries of input and program assumptions, output data, and summaries of conclusions drawn from the output data.
(b) Plan showing manufacturer's ratings, braking capabilities and power drive requirements for hydraulic equipment.
(c) Plan showing details on emergency source of power.
(d) Hydraulic schematic that shows:
    (i) Relief valve settings.
    (ii) Material specifications, size, and pressure ratings of all pipe fittings, valves, flexible hoses, pumps, filters, and accumulators.
    (iii) Testing and cleaning requirements.

(e) Drawings and design calculations, or a Certificate of Compliance (COC) from the manufacturer is required for each hydraulic or pneumatic cylinder to identify its burst pressure.

(f) Testing procedures.

2.14 Relief and Counter-Balance Valves

2.14.1 Relief valves and counter-balance valves require special attention and shall meet the requirements of this section. The safety of Diving System personnel depend on the proper operation of these valves. Relief valves are used in motion compensation circuits as well as for protecting the hydraulic system from over pressurization. Counter-balance valves are used to stop the Diving System from moving uncontrollably in the event of a sudden loss of system pressure.

2.14.2 The following shall be accomplished for all new relief valves and counter-balance valves, and existing relief and counterbalance valves that have been subjected to repairs, modifications or corrosion that would affect the structural integrity of the valve. Prior to system operational use, they shall be:

(a) Cleaned,

(b) Seat tightness tested, and

(c) Have their cracking pressure verified.

Note Seat tightness testing and cracking pressure verification may be accomplished after installation while the system is being adjusted.

2.14.3 The duration of seat tightness tests conducted in a shop or on a test bench shall be not less than 5 minutes.

2.14.4 The duration of seat tightness tests conducted in the as-installed configuration shall be based on the time necessary for the minimum leakage to be detected at the point of observation or monitoring.

2.14.5 Acceptance criteria for seat tightness testing shall be zero leakage or that allowed in the manufacturer's specifications or approved test documents.

2.14.6 The seat tightness test shall be conducted at a pressure equal to the maximum allowable working pressure.

2.14.7 System fluid is the preferred test medium for seat tightness testing.

2.14.8 Cracking pressures shall be verified in accordance with system drawings or manufacturer's specifications. The actual cracking pressure and date verified shall be etched or stamped on a metal or plastic tag and affixed to the component.

2.14.9 Operating characteristics of relief valves and counter-balance valves shall be verified by either test bench methods or when adjusting the system during installation or maintenance.

2.15 Construction

2.15.1 The handling system must be provided with suitable means for preventing any excessive rotating of the diving bell (e.g. nonspin rope).

2.15.2 The use of fibre ropes is permitted only in special cases with the prior consent of LR.

2.15.3 Precautions are to be taken to prevent the diving bell from jarring against the ship’s hull or handling gear.

2.15.4 All interchangeable components such as blocks, hooks, shackles, masterlinks, etc. are to conform to recognised standards and must be selected with the FS=5 as a minimum factor of safety to ultimate load based on SWL, or the FS=3.33 as a minimum factor of safety to ultimate load based on design load, whichever results in higher required ultimate load.

2.15.5 The driving power of the handling system must be sufficient to lift the static test load specified in these rules. The strength of the mechanical brake must be sufficient to hold the dynamic test load specified in these rules.

2.15.6 Before assembly all interchangeable components are to be subjected to individual component load testing.

2.15.7 The rupture strength of ropes is to be verified by a full tensile breaking test.

2.16 Plans, Documents and Calculations

2.16.1 Design stress analysis, based on recognized engineering analytical methods and including environmental conditions, load plans indicating loads, shears, moments and forces for all rope members, strength welds, and connections including interaction forces with the supporting deck are to be submitted. (When the results of computer calculations are submitted, input data, summaries of input and program assumptions, output data, and summaries of conclusions drawn from the output data are to be included as part of the design analysis). In addition, the following analyses are to be submitted as applicable to the particular design features:

(a) Foundation stress analysis;
(b) Electric load and electric fault analysis including power source and power requirements;
(c) Standard wiring practice and details, including such items as cables, wires, conduit sizes and their support, cable splicing, watertight and explosion proof connections;
(d) Strain gage measurements may be required for novel designs or in association with acceptance of computer data.

2.16.2 As a minimum, the following documentation shall be submitted:

(a) Design analyses and calculations that provide the basis for the system design, including all assumptions governing the design. The analyses must include the following when results of computer calculations are submitted: input data, summaries of input and program assumptions, output data, and summaries of conclusions drawn from the output data.
(b) General arrangements showing equipment locations and the rated capacity of the system.
(c) Details showing sizes, sections, and locations of all structural members.
(d) Details of all reeving components showing sizes, safe working loads, materials, manufacturer, and part number. For synthetic rope: length, size, material, construction, average breaking strength, manufacturer, and specification (if applicable). For wire rope: length, size, construction, preformed or non-preformed, lay, finish, grade (IPS, EIPS, or traction steel), core type, lubrication, and manufacturer.
(e) Foundation and support arrangements.
(f) Structural material specifications.
(g) Drawings must show all welding proposed for the principal parts of the structure. The welding process, filler metal, and joint design are to be shown on detail drawings or in separate specifications.
(h) The areas to be non-destructively inspected and methods of inspection are to be shown on the drawings, or in separate specifications.
(i) NDT methods;
(j) Winch drum details.
(k) Type and size of bolts.
(l) Reeving diagram.
(m) Testing requirements and procedures.
(n) List of all materials and fittings, for all components. p) A description of the system with details of operating conditions
(o) Installation drawings.
(p) Construction drawings of:
    (i) Transferable equipment,
    (ii) Lifting equipment,
    (iii) Mating equipment,
    (iv) Substructure of handling gear, including winches.
(q) Detailed drawings of interchangeable components and fittings.
(r) Drawings of mechanical equipment items such a winches, drives etc.
(s) Piping and instrumentation diagrams of the hydraulic or pneumatic system as applicable.
(t) Control system diagrams and descriptions of safety equipment.
(u) Details of ratings and protection class of equipment.
(v) Details of hoisting and guide ropes.
(w) General arrangements showing equipment locations, indicating safe working loads for each system component and rated capacity for the system;
(x) Material specifications;
(y) Dimensioned weld joint details;
(z) Type and size of rivets, bolts, and foundations;
(aa) Foundation and support arrangements;
(ab) Hydraulic piping systems, materials, sizes, details of fittings, and valves and overpressure protective devices;
(ac) Electrical systems, cable, and wiring types and sizes, nominal characteristics and overcurrent protection settings of all electrical protections;
(ad) Rope sizes and data indicating material, construction, quality, and breaking strength;

(ae) Manufacturer's ratings, braking capabilities, and power drive requirements for electrical, hydraulic, and mechanical equipment;
(af) Details of emergency source of power;
(ag) A schematic or logic diagram giving the sequence of handling operations;
(ah) Operating procedures;
(ai) Procedures for operating normal and emergency electric, pneumatic and hydraulic power supplies;
(aj) List of degrees of enclosure of all electrical components;
(ak) List of materials, fittings, contacts and support for all components;
(al) Electric feeder list;
(am) Motors and battery characteristics.
(an) Operation check-off list (to include list of equipment requiring maintenance or inspection prior to each operation and verification of the existence of appropriately updated maintenance;
(ao) System description;
(ap) Electrical system description;
(aq) Hydraulic system description;
(ar) Pneumatic system description;
(as) Sea state capabilities;
(at) Maximum dynamic loads;
(au) Handling operating procedures;
(av) Liaison with support vessel;
(aw) Emergency procedures developed from system analysis for situations such as power failure, break in lifting cable, break in umbilical cord, loss of communication, etc.;
(ax) Special restrictions based on uniqueness of design and operating conditions.

Section

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

Unit Type	Fire Protection, Detection and extinction
Manned Submersible	x
Wet Submersible	x
Unmanned Submersible	x
Submersible Craft	x
Diving Bell	x
Submersible Vehicle	x
Submersible Habitat	x
Submersible Container	x
Passenger Submersible	x
Rescue Submersible	x

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to manned submersibles and diving systems and are additional to those applicable to ships and offshore installations providing operational support. Unmanned submersibles will be the subject of special consideration.

1.1.2 Whilst the requirements satisfy the relevant sections of the International Maritime Organization Code of Safety for Diving Systems attention should also be given to any relevant requirements of a National Authority exercising territorial and/or flag state jurisdiction.

1.1.3 Consideration will be given to the acceptance of the statutory requirements of National Authorities as an alternative to the requirements of this Chapter.

1.1.4 Consideration will be given to special cases where the arrangements are equivalent to those required by these Rules.

1.1.5 Consideration will be given to the acceptance of the approval of a National Authority in respect of fire insulation materials, fire-fighting appliances and items of equipment as an alternative to the relevant requirements of this Chapter.

1.2 Submission of plans and information

1.2.1 The following plans and information are to be submitted:

(a) A list of all materials required by this Chapter is to have fire-resistance properties supported by Certificates of Approval by National Authorities or Fire Test Reports by recognized independent test laboratories;
(b) A general arrangement plan showing the fire compartmentation bulkheads, decks and enclosures and location of all materials required to have fire-resistance properties;
(c) A plan showing details of construction of the fire protection bulkheads, decks, enclosures and fire doors and the protection of penetrations by ventilation ducts, pipes and electrical cables;
(d) A general arrangement plan showing the disposition of all the fire-fighting equipment including the fire main, the fixed fire-extinguishing systems and the disposition of fire-extinguishers and the types used;
(e) A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the fire-extinguishing media used and the proposed rates of application.

■ *Section 2* Definitions

2.1 Materials

2.1.1 Non-combustible material means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, according to an established test procedure. Any other material is a ‘combustible material’.

2.2 Fire test

2.2.1 A Standard Fire Test is one in which specimens of the relevant bulkheads or decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The specimen is to have an exposed surface of not less than 4,65 m^2 and height (or length of deck) of 2,44 m resembling as closely as possible the intended construction and including where appropriate at least one joint. The standard time-temperature curve is defined by a smooth curve drawn through the following temperature points measured above the initial furnace temperature:

- At the end of the first 5 minutes, 556°C
- At the end of the first 10 minutes, 659°C
- At the end of the first 15 minutes, 718°C

- At the end of the first 30 minutes, 821°C
- At the end of the first 60 minutes, 925°C

2.2.2 The fire behaviour of the chamber equipment is to be checked by reference to the relevant test certificates and symbols, as applicable.

2.2.3 A check is to be made as to whether the electrical heating systems and heaters are fitted with protection against overheating.

2.2.4 Fire alarm, detection and extinguishing appliances are to be subjected to a functional test.

2.3 Flame spread

2.3.1 Low flame spread means that the surface thus described will adequately restrict the spread of flame, having regard to the risk of fire in the spaces concerned, this being determined by achieving a Class 1 result when tested in accordance with BS 476:Pt. 7.

2.4 Fire retardant characteristics

2.4.1 Fire retardant characteristics are possessed by materials which do not flame significantly nor sustain combustion in compressed air at a pressure of 6 bar after the removal of a test flame, this being determined by an acceptable test procedure.

2.5 Divisions and spaces

2.5.1 'A Class divisions' are those divisions formed by bulkheads and decks which comply with the following:

(a) They are to be constructed of steel or other equivalent material;
(b) They are to be suitably stiffened;
(c) They are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test;
(d) They are to be insulated with approved non- combustible materials, such that the average temperature of the unexposed side will not rise more than 139°C above the original temperature, nor will the temperature, at any point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class 'A-60'	60 minutes
Class 'A-30'	30 minutes
Class 'A-15'	15 minutes
Class 'A-0'	0 minutes

(e) A test of a prototype bulkhead or deck may be required to ensure that it meets the above requirements for integrity and temperature rise.

2.5.2 Non-load bearing divisions equivalent to 'A Class' are those divisions formed by fire walls or decks which comply with the following:

(a) They are to be constructed of steel or other equivalent material;
(b) They are to have sufficient strength for the intended purpose;
(c) They are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test;
(d) They are to be insulated with approved non- combustible materials such that the temperature rise criteria stated in *Pt 5, Ch 8, 2.5 Divisions and spaces 2.5.1* are not exceeded;
(e) They are to be satisfactorily connected to supporting structural members which are capable of carrying all concentrations of loads to which they may foreseeably be subjected;
(f) A test of a prototype fire wall or deck may be required to ensure that it meets the above requirements for integrity and temperature rise.

2.5.3 Oxygen enriched atmospheres are those atmospheres in which the concentration of oxygen exceeds 23 per cent by volume or the partial pressure of oxygen exceeds 160 Torr (mm Hg) or both.

2.5.4 Diving control rooms are those spaces in which the control equipment necessary for safe performance of diving operations is centralized.

2.5.5 Enclosed spaces for diving systems or parts thereof are to be provided with a forced ventilation system capable of effecting at least 8 changes of air per hours. The air must be drawn from an area not subject to an explosion hazard.

2.5.6 Diving systems on ships and other floating structures may only be installed and operated in areas not subject to an explosion hazard.

2.6 General Fire Precautions

2.6.1 Any equipment requiring lubrication inside the chamber should be lubricated with a suitable oxygen-compatible lubricant approved for the purpose. Mineral oil or grease in an oxygen environment may cause a fire or explosion. Items introduced into the system containing mineral based oils or greases may also, under certain conditions, create an explosion when mixed with oxygen. For example, wheel chairs with greased wheel bearings. A variety of suitable and approved lubricants will be required for the differing applications within the chamber.

2.6.2 Flammable gases must be stored separately to oxygen and oxidising gases, and not in the chamber enclosure. The use of flammable agents inside a hyperbaric facility, or in proximity to any air intake, should be forbidden. Gas burners and lighters should not be permitted in the chamber area.

2.6.3 It is essential that all areas of the hyperbaric chamber, and the associated plant, are kept free of grease, lint, dirt and dust. A regular cleaning programme should be introduced and maintained. Those responsible for cleaning must be given the appropriate induction training. The chamber facility manager must approve cleaning materials.

■ *Section 3*
Pressure Fresh Water Spraying Inside Surface Compression Chambers

3.1 Requirements

3.1.1 Each compartment of a surface compression chamber is to be equipped with suitable means for extinguishing a fire in the interior by providing for the rapid and efficient distribution of the extinguishing agent to any part of the chamber.

3.1.2 The fire extinguishing system is to be designed and constructed in such a way that it can safely deal with every conceivable outbreak of fire under all the environmental conditions for which the diving system is designed. Actuation of the fire extinguishing system may not cause any unacceptable pressure change inside the chamber. The extinguishing system may be actuated by hand. It must at all times be possible to stop the extinguishing operation from the chamber and from the control room.

3.1.3 Fresh water is the preferred extinguishing agent. Extinguishing agents with a toxic or narcotic effect are not permitted.

3.1.4 Any required fixed pressure fresh water spraying or water mist fire-extinguishing system is to be designed to ensure rapid and efficient distribution of water throughout the chambers to be protected. It is to operate effectively in all hyperbaric conditions which may occur in the chamber that are capable of sustaining combustion.

3.1.5 Pressure control of the water spray is to be provided by a tracking regulator which constantly monitors the chamber pressure.

3.1.6 A water application rate of 25 litre/m^2/min of internal surface area of the chamber shell is required or 80 litre/m^2/min relevant to walking surface at ¼ of internal diameter, whichever is larger. The system is to be capable of manual operation from inside the chamber and from a continuously manned diving centre room.

3.1.7 Water spray nozzles are to provide coarse droplets of water under all pressure conditions and are to be located to provide reasonably uniform special coverage in all parts of the chamber.

3.1.8 There is to be sufficient water supply for the system to operate for one minute at the required application rate without recharging the system. It is to be possible to manually stop the discharge of the system at any time before the water supply is exhausted.

3.1.9 Where the quantity of water is required to protect more than one chamber, the quantity of water available need not be more than the largest quantity for any one chamber so protected.

3.1.10 A second fire-hose based fire-fighting system is to be provided in every hyperbaric chambers compartment. Such systems shall be better supplied through an independent pipe from nebulised stationary distribution system, alternatively a suitable pressurised/portable water extinguisher to each hyperbaric chamber compartment is to be provided (two extinguishers in large chambers and only one in each entry lock).

3.1.11 Alternative to water spray system, approved high pressure water mist system with due water capacities, securing equivalent reliable levels (extinguishing time, discharge density etc.) based on NFPA 750 or BS EN 16081 principals will be considered.

3.1.12 Upon fire-fighting system start up, the oxygen supply to the chamber is to be discontinued immediately and general safety policy provided by emergency plan shall be implemented.

3.1.13 Whenever a fire-fighting system is started, all electric systems working inside the hyperbaric chamber are to be disconnected and emergency communication and lights is to be set to work.

3.1.14 Maximum overall time from fire detection to discharge start is to be four seconds.

■ *Section 4* Fire Safety Measures for Submersibles

4.1 Materials

4.1.1 As far as practicable all materials used in the construction and outfitting of submersibles are to be non-combustible. Consideration may be given to the use of combustible materials for specific applications in order to take advantage of unique properties possessed by these materials which make them especially suitable for specific applications. The risk of fire is not to be significantly increased thereby, either intrinsically or by the provision of compensating factors.

4.1.2 As far as possible, fire loads and sources of ignition are to be avoided. Electrical heating appliances and heaters are to be fitted with protection against overheating.

4.1.3 All exposed surfaces including those in concealed or, inaccessible spaces are to have low flame spread characteristics.

4.1.4 As far as practicable all materials having surfaces exposed to oxygen enriched atmospheres are to have fire retardant characteristics in addition to any other required fire-resistance properties.

4.1.5 Materials are to be selected to minimize as far as practicable the omission of toxic and noxious combustion products.

4.1.6 Materials are to be selected with a view to minimising the danger of static charges.

4.2 Divisions

4.2.1 Machinery and equipment identified as potential sources of ignition are to be enclosed by Class ‘A-0’ divisions or equivalent non-load bearing divisions.

4.2.2 Where a submersible is subdivided into one or more spaces the divisions separating the spaces is to be Class ‘A-0’ divisions of equivalent non-load bearing divisions.

4.2.3 The fire-resistance of doors and inspection panels is as far as practicable to be equivalent to that of the division in which they are fitted.

4.2.4 Where ‘A-0’ divisions or equivalent non-load bearing divisions are penetrated by ventilation ducts they are to be fitted with fire dampers. The fire dampers are to operate automatically but are also to be capable of being closed manually from both sides of the division. It is to be possible to open fire dampers manually from the closed position from both sides of the division.

4.2.5 Special attention is to be given to maintaining the integrity of ‘A-0’ divisions or equivalent non- load bearing divisions in way of penetrations by pipes and electric cables. Transit devices containing components which release flammable or toxic gases are not to be used.

4.3 Fixed fire detection and fire-alarm system

4.3.1 A fixed fire detection and fire-alarm system of an approved type complying with the requirements of *Pt 6, Ch 1, 2.8 Earth leakage trip override facility* of the Rules for Ships is to be installed in all compartments which are not regularly occupied or in which it is unreasonable to expect a continuous watch to be maintained and inside the enclosures referred to in *Pt 5, Ch 8, 4.2 Divisions 4.2.1*.

4.3.2 The occurrence of fire must be signalled visually and audibly in at least one permanently manned control room.

4.3.3 The fire alarm may be actuated manually from the permanently manned control room or may be automatically activated by the fire detection system.

4.4 Fire-extinguishing arrangements

4.4.1 Means for extinguishing fire are to be provided in all spaces and inside the enclosures referred to in *Pt 5, Ch 8, 4.2 Divisions 4.2.1*. They are to be ready for immediate use.

4.4.2 The use of a fire-extinguishing medium which either by itself or under expected conditions of use could endanger persons inside the submersible is not permitted. The use of water inside the enclosures referred to in *Pt 5, Ch 8, 4.2 Divisions 4.2.1* is acceptable. Proposals to use other extinguishing media will be considered only where it can be shown that they will not contravene the requirements of this paragraph. CO2 and dry powder are not acceptable for use in submersibles.

4.4.3 The quantity of extinguishing media to be provided, application rates and the means of storage and application will be specially considered in each case having regard to the nature and the extent of the fire-risks in the spaces to be protected.

4.4.4 Special consideration will be given to the suitability of extinguishing equipment for use in spaces where isobaric pressure is not maintained.

■ *Section 5*
Fire Safety Measures for Diving Systems

5.1 Materials

5.1.1 As far as practicable all materials used in connection with the diving system are to be non-combustible.

5.1.2 All exposed surfaces including those in concealed or inaccessible spaces are to have low flame spread characteristics.

5.1.3 As far as practicable all materials having surfaces exposed to oxygen enriched atmospheres are to have fire retardant characteristics in addition to any other required fire-resistant properties.

5.2 Structure

5.2.1 Diving Systems Installed in Enclosed Spaces

(a) Enclosed spaces on dive support vessels/offshore facilities housing diving systems are to be separated from adjacent spaces by means of A-60 class bulkheads or decks. Piping and cables essential for the operation of the diving system are to be laid in separate structural ducts insulated to the A-60 class standard.
(b) The enclosed space housing the diving facility may be subdivided into several spaces by A-0 class. There shall be no direct access between categories A machinery spaces outside of “Enclosed space”. All doors between this space and other adjacent enclosed spaces should be of self-closing type.

5.2.2 Diving Systems Installed on Open Decks

When diving systems are installed on open decks or similar structures that are directly adjacent to Category A machinery spaces, the systems are to be separated from the machinery spaces by A-60 class bulkheads or decks.

5.3 Fixed fire detection and fire-alarm systems

5.3.1 Interior spaces containing diving equipment such as surface compression chambers, diving bells, gas storage facilities, compressors and associated equipment are to be provided with a fixed fire detection and fire-alarm system of an approved type complying with the requirements of *Pt 6, Ch 1, 2.8 Fire detection alarm systems* of the *Rules and Regulations for the Classification of Ships, July 2019*.

5.4 Fire-extinguishing arrangements

5.4.1 Enclosed spaces containing diving equipment such as surface compression chambers, diving bells, gas storage facilities, compressors and associated equipment are to be provided with a fixed water deluge system or as an alternative an approved high pressure water mist system with due water capacities, securing equivalent reliable levels (extinguishing time, discharge density etc.) based on NFPA 750 principals will be considered. The system is to comply generally with SOLAS Reg. II-2/10, except that the water application rate is to be at least 10 litre/m^2/min in the spaces to be protected Nozzles are to be fitted to cool and protect the pressure vessels in the event of external fire. Where pressure vessels are situated on Open decks, fire-hoses may be considered as providing the necessary protection.

5.4.2 Portable extinguishers are to be distributed throughout the space containing the diving system. One of the portable extinguishers is to be stowed near the entrance to the space. The extinguishers are to be of approved type suitable for use on the fires likely to be encountered.

5.4.3 Each compartment in a surface compression chamber is to be protected by a pressure fresh water spraying system complying with the requirements of *Pt 5, Ch 8, 3 Pressure Fresh Water Spraying Inside Surface Compression Chambers*.

Contents

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	General Requirements	System Design	Cables and Wiring	Batteries	Hazardous Areas	Umbilical Cables	Electrical Pressure Hull Penetrators and Cable Connectors	Testing and Trials	Submersibles
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9
Unit Type									
Manned Submersible	x	x	x	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x	x
Unmanned Submersible	x	x	x	x	x	x	x	x	x
Submersible Craft	x	x	x	x	x	x	x	x	x
Diving Bell	x	x	x	x	x	x	x	x	x
Submersible Vehicle	x	x	x	x	x	x	x	x	x
Submersible Habitat	x	x	x	x	x	x	x	x	x
Submersible Container	x	x	x	x	x	x	x	x	x
Passenger Submersible	x	x	x	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x	x

Section 1
General Requirements

1.1 General

1.1.1 The requirements of this Chapter apply to submersibles, diving systems and deck decompression chambers. Attention should also be given to any relevant Statutory Regulations of the country in which the unit is to be operated.

1.1.2 The Committee will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans

1.2.1 At least three copies of the plans and particulars *Pt 6, Ch 1, 1.2 Plans 1.2.2* to *Pt 6, Ch 1, 1.2 Plans 1.2.12* are to be submitted for consideration. Single copies only are required of plans in *Pt 6, Ch 1, 1.2 Plans 1.2.13* to *Pt 6, Ch 1, 1.2 Plans 1.2.16*. Additional copies are to be submitted when requested.

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

(a) Ratings of electrical machines, transformers, batteries and semiconductor converters;
(b) All feeders connected to the main and emergency switchboards;
(c) Distribution boards;
(d) Insulation type, size and current loadings of cables;
(e) Make, type and rating of circuit breakers and fuses.

1.2.3 Simplified diagrams of interconnector circuits and feeder circuits showing:

(a) Protective devices, e.g. short-circuit, overload, reverse power protection;
(b) Instrumentation and synchronizing devices;
(c) Preference tripping;
(d) Remote stops;
(e) Earth fault indication/protection.

1.2.4 A general arrangement drawing of the electrical equipment containing at least the following information:

(a) Voltage rating of the system;
(b) Power or current ratings of electrical consumers;
(c) Switchgear, indicating settings for short-circuit and overload protection; fuses with details or current ratings;
(d) Cable types and cross-sections.

1.2.5 Calculations of short circuit current at main and emergency switchboards and, where requested, distribution boards, together with details of circuit-breaker and fuse operating times and discrimination curves showing compliance with the requirements of the *Rules and Regulations for the Classification of Ships, July 2019 Pt 6, Ch 2, 6.1 General* and *Pt 6, Ch 2, 11.6 Conductor size 11.6.2*.

1.2.6 For a diving system installed in a location where explosive gas atmospheres can occur, a drawing of the ship showing hazardous zones and spaces in and close to that location.

1.2.7 Details of electrical equipment for use in explosive gas atmospheres, including:

(a) Type of equipment;
(b) Type of protection, e.g. Ex ‘d’;
(c) Apparatus group, e.g. IIB;
(d) Temperature class, e.g. T3;
(e) Enclosure ingress protection, e.g. IP55;
(f) Certifying authority;
(g) Certificate number;
(h) Location of equipment Where uncertified equipment is permitted by the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 14 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*, details of other documentation confirming (b) to (d) may be submitted in place of those listed under (f) and (g).

1.2.8 For battery installations, arrangement plans and calculations are to show compliance with the performance requirements of *Pt 6, Ch 1, 2.2 Sources of power 2.2.2*, *Pt 6, Ch 1, 2.2 Sources of power 2.2.5*, *Pt 6, Ch 1, 4 Batteries* and *Pt 6, Ch 1, 9.5 Batteries* and the ventilation requirements of the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 12.5 Ventilation*.

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

(a) Type and manufacturer's type designation;
(b) Voltage and ampere-hour rating;
(c) Location;
(d) Equipment and/or system(s) served;
(e) Maintenance/replacement cycle dates;
(f) Date(s) of maintenance and/or replacement; and
(g) For replacement batteries in storage, the date of manufacture and shelf life; with accompanying battery replacement procedure documentation to show compliance with the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 12.7 Recording of batteries for emergency and essential services*.

1.2.10 In order to establish compliance with *Pt 6, Ch 1, 2.4 Emergency power 2.4.2*, a general arrangement plan showing the location of major items of electrical equipment, and cable or wiring routes between these items.

1.2.11 Arrangement plans of main and emergency switchboards.

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

1.2.13 In order to establish compliance with the relevant requirements of *Pt 6, Ch 1, 1.5 Design and construction 1.5.2* evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.2.14 The energy balance of the main emergency power supply systems for diving systems having their own generating plant.

1.2.15 Drawings of switchgear and generating plant.

1.2.16 Complete documentation for electric motor drives with details of control, measuring and monitoring systems.

1.2.17 Battery installation drawings with details of battery types, chargers and, as applicable, battery room ventilation or, for example for a submersible, where batteries are installed inside a pressure vessel or other container mounted on the outside of the pressure hull.

1.2.18 Details of electrical penetrations through compression chamber walls, *see Pt 6, Ch 1, 7 Electrical Pressure Hull Penetrators and Cable Connectors*.

1.2.19 Drawings and descriptions of all electrical components installed in compression chambers.

1.3 Surveys

1.3.1 Equipment is to be selected and installed in accordance with the relevant requirements of this Chapter and surveyed by the Surveyors.

1.3.2 Electrical equipment, essential for the safety of the unit and personnel, is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements.

1.4 Additions or alterations

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

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

1.4.3 When it is proposed to replace permanently installed batteries with batteries of a different type, details are to be submitted for consideration to ensure continued compliance with the relevant requirements of this Chapter.

1.5 Design and construction

1.5.1 Services essential for safety of the unit and personnel are to be maintained under emergency conditions and the safety of personnel from electrical hazards is to be assured.

1.5.2 The design and installation of all electrical equipment is to be compatible with the special conditions pertaining to marine service. In particular, equipment is to be suitable for operation under conditions of:

(a) High humidity;
(b) Hyperbaric pressure;
(c) Salt laden temperature;
(d) Vibration;
(e) Possible oxygen enrichment.
(f) Inclination of the facility.

For environmental conditions and inclination requirements pertaining to diving systems refer to *Pt 5, Ch 1, 2 Principles for design and construction of diving systems*.

1.5.3 Additional requirements for the location, installation and construction of electrical equipment are given in the *Rules and Regulations for the Classification of Ships, July 2019*,*Pt 6, Ch 2, 1.1 General* to *Pt 6, Ch 2, 1.17 Operation under flooding conditions*, which are to be complied with where applicable.

1.5.4 Equipment for services essential for the safety of the unit, and, in the case of submersibles, electrical propelling machinery and associated equipment together with services essential for propulsion, are to be constructed in accordance with the relevant requirements of this Chapter.

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

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

1.5.7 Electrical equipment for use underwater is to operate safely at the maximum design depth of the unit. Refer to IMCA D 045 “Code of Practice for The Safe Use of Electricity Under Water” for additional guidance.

1.5.8 Electrical equipment providing essential services is to be of a continuous rating.

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

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

(a) Voltage:

Permanent variations +6%, –10%
Transient variations due to step changes in load ±20%
Recovery time 1,5 seconds

(b) Frequency:

Permanent variations ±5%
Transient variations due to step changes in load ±10%
Recovery time 5 seconds

A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

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

$$THD = \left(\frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \right) 100$$

Where:

V_h = r.m.s. amplitude of a harmonic voltage of order h

V_1 = r.m.s. amplitude of the fundamental voltage.

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

(a) When supplied by d.c. generator(s) or a rectified a.c. supply:

Voltage tolerance (continuous) ±10%
Voltage cyclic variation deviation 5%
Voltage ripple 10%
(a.c. R.M.S. over steady state D.C. voltage);

(b) When supplied by batteries:

(i) Equipment connected to the batteries during charging: Voltage tolerance +30%, –25%;
(ii) Equipment not connected to batteries during charging: Voltage tolerance +20%, –25%.

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

1.5.13 Electrical conductors are to be of sufficient size for the purposes for which they are to be used. The requirements for construction, selection and testing of electrical cables are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 11.1 General* to *Pt 6, Ch 2, 11.16 Joints and branch circuits in cable systems*, which are to be complied with where applicable.

1.5.14 Effective means are to be provided so that all voltages may be cut-off from every circuit and sub-circuit, and from all equipment, as may be necessary to minimize danger.

1.5.15 Conductors and equipment exposed to a flammable or explosive atmosphere are to be constructed or protected and such special protection taken, as may be necessary to minimize danger. Compliance with IEC 60092-502: Electrical Installations in Ships – Tankers – Special Features, Clauses 5, 6 and 7, Electrical systems, Electrical equipment, and Installation, respectively, will, in general, be accepted. Where equipment can be subjected to air pressure or oxygen concentration significantly differing from normal atmospheric conditions, the suitability of that equipment for those pressures and oxygen concentrations is to be confirmed by a competent authority. Where requirements are imposed by the rules or regulations applicable to the vessel on which a diving system or deck decompression chamber can be located, the equipment is, in addition, to comply with those requirements.

1.5.16 Electrical devices in a hyperbaric chamber should not cause a risk of ignition. Information regarding this area is available in NFPA 99, section 20 and NFPA 53. In addition consideration is to be given to:

(a) Using low energy (low voltage and low current) devices;
(b) Placing the power source of the device outside the chamber or within a sealed unit;
(c) Placing the power switches of the device outside the chamber or the use of reed switches.

If in any doubt, the electrical device should not be installed in the hyperbaric chamber.

1.5.17 All electrical equipment including motor rotors and stators should meet a T5 rating (surface temperature not to exceed 100°C).

1.5.18 The quantity of material which can emit toxic fumes on overheating is to be minimized. As far as is practicable, materials used for electrical equipment, cables and accessories are not to be capable of producing excessive quantities of smoke and toxic products.

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

1.5.19 Each compression chamber compartment and each diving bell is to be equipped with a suitable normal and emergency lighting system.

1.5.20 The normal lighting system is to be so designed and installed that the intensity of the lighting inside the chamber is at least 300 lux. As far as possible, interior lighting should be free from glare. In all chambers and diving bells the normal lighting shall have a colour rendering index (CRI) of not less than 50 (to facilitate a change in skin tone).

1.5.21 The emergency lighting system is to be designed and installed in such a way that a diver inside the chamber is fully able to take readings and operate controls in every compartment.

1.5.22 Safeguards against the bursting of light fittings are to be agreed with LR in each case. Light fittings and lamps should be rated to withstand 1.3 times maximum working pressure, the use of LED lamps should be considered.

1.5.23 All electrical equipment necessary to the safe completion of the mission, including equipment that may be need during an emergency, is to be suitable for 100 per cent relative humidity, or the conditions anticipated on board the unit.

1.5.24 Electronic automation systems should comprise easily replaceable assemblies, of the plug-in type wherever possible. Standardization of units is to be encouraged and the number of assembly types is to be kept small in order to minimize the spare parts inventory.

1.5.25 Plug-in cards must be clearly marked or coded to prevent inadvertent confusion.

1.5.26 Measures must be taken to prevent condensation inside electronic units, even when switched off. Shutdown heating is recommended.

1.5.27 Wherever possible, automation equipment should be capable of operation without forced ventilation. Any cooling system used is to be monitored.

1.5.28 Components must be effectively secured. Any mechanical loading of wires and soldered connections due to vibration or jolting is to be mitigated.

1.5.29 The construction of systems and units is to be simple and straightforward. Good accessibility is to be ensured to facilitate measurements and repairs.

1.6 Bonding

1.6.1 Exposed non-current-carrying metallic parts of equipment are to be connected together and earthed to the metallic structure of the unit in such a way as to give a substantially equal potential and earth loop impedance sufficiently low to ensure correct operation of protective devices.

1.6.2 Further requirements for earthling of non-current carrying parts are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 1.12 Earthing of non-current carrying parts*, which are to be complied with where applicable.

■ *Section 2*
System Design

2.1 Systems of supply design and distribution

2.1.1 The following systems of supply and distribution are acceptable provided that adequate safeguards are taken to minimize shock hazard to divers:

(a) d.c., two-wire, insulated from earth IT System;
(b) d.c., two-wire earthed system TN-S system;
(c) a.c., single-phase, two-wire, insulated from earth IT system;
(d) a.c., three-phase,
  (i) Three-wire insulated from earth IT system;
  (ii) Four-wire with neutral solidly earthed but without hull return. TN-S system.

Note Refer to IMCA D 045 “Code of Practice for The Safe Use of Electricity Under Water” for additional guidance.

2.1.2 Earthing systems complying with IEC 61892-2:2012, Mobile and fixed offshore units – Electrical installations – Part 2: System design, section 5 and IEC 60092-502:1999, Electrical installations in ships – Part 502: Tankers – Special features, section 5 are acceptable. While both insulated and earthed distribution systems (TN-S) are permitted, systems which may result in the presence of electrical currents within the hull or unit structure return (TN-C and TN-C-S) are not permitted.

2.2 Sources of power

2.2.1 Where electric power is used for services essential for the safety of the unit and life-support systems, the arrangements of the electrical power sources and any associated transforming, storage or rectifying equipment are to be such that failure of any item of such electrical equipment will not prevent the operation of life-support systems and any equipment necessary for recovery of the unit.

2.2.2 The electrical power available from main and standby sources is, in each case, to be sufficient to ensure the operation of electrical services for essential equipment and habitable conditions, due regard being paid to such services as may have to be operated simultaneously.

2.2.3 Each source is to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system.

2.2.4 Where the source of power is totally dependent on batteries, a separate battery is to be provided for emergency life-support systems. This separate battery is to be automatically connected upon loss of the main source of power.

2.2.5 Batteries are to maintain their system voltage within the limits detailed under *Pt 6, Ch 1, 1.5 Design and construction 1.5.12*. The duration of autonomy required of each battery is to be determined by consideration of the most onerous operating conditions for which the unit is designed.

2.2.6 For a.c. systems, isolating transformers are to be provided between the main power system and the supply circuits to the unit.

2.2.7 The power supply to welding equipment is to be from an independent circuit with a clear means of isolation at a manned control station.

2.3 Power Distribution

2.3.1 Electrical distribution systems are to be so designed that a fault or failure in one circuit cannot impair the operation of other circuits or the power supply.

2.3.2 The following consumers at least are to be supplied via individual circuits equipped with all necessary safety devices and switchgear from a distribution panel supplied direct from the main switchboard of the support vessel:

(a) The diving system handling equipment on the support vessel
(b) The compression chamber and diving bell lighting system
(c) The electrical consumers of the life support systems
(d) The communication systems

2.3.3 In normal operation the emergency power distribution system may be supplied via a transfer line from the main power distribution system.

2.3.4 Distribution boards with their own individual feed circuits may not be mounted in a shared casing, i.e. each of these switchgear units must have its own enclosure.

2.3.5 Effective measures are to be taken to prevent the occurrence of vagabond voltages inside switchgear. Circuits at protective low voltage may not be routed with circuits at higher voltage in a joint conductor bundle or cable duct. Terminals for different voltage levels are to be arranged separately and are to be clearly identified.

2.3.6 Switchgear units for a connected load of 100 kW and over are to be tested at the manufacturer's works in the presence of a LR Surveyor. The test shall be performed in accordance with the Rules for Classification and Construction– Ships.

2.3.7 Switchgear units for a connected load of less than 100 kW are to undergo an internal works test of the same scope. These tests are to be certified by a Works Test Certificate issued by the manufacturer. Test certificates are to be submitted to LR not later than the trial of the diving system. For voltage ratings below 60 V, the voltage test is to be performed at a power-frequency withstand voltage of 500 V plus twice the rated voltage.

2.4 Emergency power

2.4.1 Where equipment requires an emergency source of power in order to satisfy the requirements of *Pt 6, Ch 1, 2.2 Sources of power 2.2.1* the distribution arrangements are to be such that no single failure within any switchboard or distribution board, and no single cable fault, can cause the failure of both normal and emergency supplies to the equipment.

2.4.2 Where practicable, the switchboards, distribution boards and cable routes for normal and emergency power distribution are to be physically separated so as to minimise the risk of fire or mechanical damage affecting both systems of distribution.

2.4.3 The emergency power supply must be able to simultaneously meet the requirements of at least the following items of equipment:

(a) Emergency lighting systems in compression chambers and diving bells;
(b) Emergency communication systems;
(c) Emergency life support systems;
(d) Emergency diving system handling equipment;
(e) Emergency surveillance and alarm systems.

2.4.4 In the design of the emergency power supply system, appropriate reserve capacity is to be provided to meet peak loads (e.g. caused by the starting of electric motors). In determining the necessary battery capacity, allowance is also to be made for the cut-off voltage and voltage drop of battery.

2.4.5 Diving bells are to be equipped with their own independent emergency power supply capable of meeting the power requirements of the autonomous life support system of the diving bell for at least 24 hours.

2.5 System design – Protection

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

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

2.5.2 Each circuit is to be protected against overload and short-circuit. Refer to IMCA D 045 “Code of Practice for The Safe Use of Electricity Under Water” for additional guidance.

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

2.5.4 The protection of circuits is to be such that a fault in a circuit does not cause the interruption of supplies used to provide emergency or essential services other than those dependent on the circuit where the fault occurred. For circuits used to provide essential services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety, arrangements that ensure that a fault in a circuit does not cause the sustained interruption of supply to healthy circuits may be accepted. Such arrangements are to ensure the supply to healthy circuits is automatically re-established in sufficient time after a fault in a circuit.

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

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

2.5.7 Protection for battery circuits is, where practicable, to be provided at a position external and adjacent to the battery compartment.

2.5.8 Consideration may be given to the provision of short circuit protection within the compartment where, either, the protective device is an encapsulated unit, certified as having type of protection ‘m’, or, where the batteries are of the sealed valve-regulated type and the arrangements are such that standard marine or industrial equipment is permitted within the compartment.

2.5.9 Protection may be omitted from circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

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

2.5.11 Overload protection may be omitted from the following:

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

2.5.12 Diving bells are to be equipped with an earthing and potential equalizing system. Connections for external earthing are to be provided in all chambers at diagonally opposite corners.

2.5.13 The connections between the earthing conductor and the chamber and to the ship's earth are to be made with corrosion-resistant screw unions effectively safeguarded against accidental loosening. The dimensions of the screw unions are to be compatible with the requisite cross-sections of the earth conductor to be connected and may not be used for other purposes.

2.5.14 All metal parts of electrical installations – with the exception of live components – are to be earthed. The casings of electrical equipment mounted directly against the inside wall of compression chambers and diving bells are considered to be effectively earthed only if the contact surfaces are permanently free from rust, scale and paint and the casings are fastened with at least two corrosion-resistant screws secured to prevent accidental loosening. If these conditions are not met, earthing must be effected by separate earthing conductors.

2.5.15 Earth connections must be accessible for maintenance and inspection. Wherever possible, they are to be marked. Earthing conductors in multi-core cables are to be marked green and yellow, at least at the terminals.

2.5.16 Earthing conductors are to be provided with corrosion protection compatible with their place of installation.

2.5.17 Copper earthing conductors are subject to the following minimum cross-sections:

(a) External connections on ship and water: 10 mm^2;
(b) External connections inside chambers and living compartments: 6 mm^2;
(c) Separate earthing conductors inside switchgear and casings: 4 mm^2;
(d) Earthing conductors in multi-core cables up to a conductor cross-section of 16 mm^2 must correspond to the cross-section of the main conductor subject to a minimum of 1 mm^2;
(e) Earthing conductors in multi-core cables with a conductor cross-section of more than 16 mm^2 equal to at least half that of the main conductor.

2.5.18 If other materials are used, the minimum cross-section is to be determined by the ratio of the electrical conductivity of these materials to the electrical conductivity of copper.

2.5.19 Cable sheaths and armouring may not be used as earthing conductors.

2.5.20 Electrical switches for circuits with a current rating above 0,5 A are permitted inside compression chambers and diving bells only subject to the use of additional safety features (such as pressurized enclosure in protective gas).

2.5.21 Electrical fuses may not be located inside compression chambers and diving bells. Wherever possible, fuses for the independent emergency power supply to the diving bell are to be located outside the chamber. If installed inside the diving bell, special protective measures are necessary. The fuses shall in any case be protected against intervention by the occupants of the chamber.

2.5.22 Electric motors installed inside chambers are to be fitted with an overcurrent alarm. The alarm must be activated in good time before the motor protection responds. This does not apply to those electric motors which cannot be damaged by overcurrent. For motors in the diving bell, the alarm may take place in the diving bell.

2.5.23 Devices are to be fitted which, in the event of danger, enable the power supply to all the electrical consumers in the compression chamber to be quickly disconnected. The switches needed for this purpose are to be mounted at the Central Control Position. Means must be provided to enable the disconnection separately for each chamber.

2.5.24 All unearthed distribution systems, including the groups of consumers and individual consumers supplied via isolating transformers, safety transformers, rectifiers and inverters, are to be equipped with a continuously operating insulation monitoring system. For systems using protective low voltage, an alarm must be actuated at the Central Control Position if the insulation value drops below a pre-set limit. For higher voltage systems, the insulation monitor must trip an alarm at the Central Control Position when a predetermined fault current is reached, and the system concerned must be automatically disconnected. For the electrical equipment of the diving bell, the alarm actuated by the insulation monitoring system may take place in the diving bell.

Note The current / time characteristics of insulation monitoring systems directly concerned with personnel safety must meet the requirements of diver protection. In assessing the time characteristics, account is to be taken of the response time of the insulation monitoring system and of the tripping time of the switching devices which it actuates.

2.6 Protection against short-circuit

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

2.6.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation.

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

(a) All generators, motors and, where applicable, all transformers, of the vessel from which the supply to the unit is taken, connected as far as permitted by any interlocking arrangements;
(b) A fault of negligible impedance close up to the load side of the protective device.

Consideration should be given to the impedance of the cable connections between the vessel switchboard and the unit and the possible current limiting action of the protective device at the vessel switchboard or distribution board from which the supply to the unit is taken.

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

(a) For alternating current systems at the main switchboard: 10 x f.l.c. (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, X''_d, of each generator is known, $\frac{f.I.c}{X''_d(p.u.)}$or each generator, and 3 x f.l.c. for motors simultaneously in service. The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).
(b) Battery-fed direct current systems at the battery terminals:
    (i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours, or
    (ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours and,
    (iii) 6 x f.l.c. for motors simultaneously in service (if applicable).

2.6.5 Protection against overload is to be provided by circuit breaker, overcurrent trip relay or fuse, having characteristics ensuring that cabling and electrical machinery is protected against overheating resulting from mechanical or electrical overload. Fuses of a type intended for short-circuit protection only (e.g. fuse links complying with IEC 60269-1, of type ‘a’) are not to be used for overload protection.

2.6.6 The requirements for circuit breakers are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 6.5 Circuit-breakers*, which are to be complied with where applicable.

2.6.7 The requirements for fuses are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 6.6 Fuses*, which are to be complied with where applicable.

2.6.8 The requirements for circuit breakers requiring back-up by fuse or other device are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 6.7 Circuit-breakers requiring back-up by fuse or other device*, which are to be complied with where applicable.

2.6.9 The requirements for feeder circuits are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 6.10 Feeder circuits*, which are to be complied with where applicable.

2.6.10 The requirements for motor circuits are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 6.11 Motor circuits*, which are to be complied with where applicable.

2.6.11 The requirements for the protection of transformers are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 6.12 Protection of transformers*, which are to be complied with where applicable.

2.6.12 Mains units for automation equipment must contain at least one short-circuit protection and one overload protection device.

2.6.13 The reference conductor system is to be designed to preclude circuit breaks as far as possible. This may, for example, be achieved by duplicating exposed reference conductor joints and connections.

2.7 Earth leakage protection

2.7.1 For all insulated systems, a device(s) is to be installed to continuously monitor the insulation level to earth and to operate an alarm, at a recognized control position, in the event of an abnormally low level of insulation. Refer to IMCA D 045 "Code of Practice for The Safe Use of Electricity Under Water" for additional guidance.

2.7.2 Where there is a danger of current flow through a diver's body which will exceed 10 mA a.c. or 40 mA d.c., earth leakage trip devices are to be provided and arranged to disconnect the power supply to the protected circuit in the event of the earth leakage reaching a dangerous level.

Note Guidance on assessing the magnitude of current flow and its effects is given in International Electro-technical Commission Publications IEC 60479-1:2005, Effects of current on human beings and livestock – Part 1: General Aspects and IEC 60479-1:2007 Part 2: Special aspects.

In the absence of detailed information, the current route resistance of a diver's body should be assumed to be 750 Ω for voltages up to 50 V and 500 Ω for voltages above 50 V for all applications other than electrically heated diving suits, where a current route resistance of 100 Ω should be assumed.

2.8 Earth leakage trip override facility

2.8.1 A facility to override an earth leakage trip may be provided to permit the diving operator to restore power if he considers the danger to the diver as a result of loss of power to be greater than the possible electrical hazard.

■ *Section 3*
Cables and Wiring

3.1 General

3.1.1 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC Standard stated in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2 Electrical Engineering*, *Table 2.11.1 Electric cables*, or an acceptable and relevant national standard.

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

3.1.3 Cable insulation and sheathing materials are to be flame retardant and non-hygroscopic and of a type that emits a minimum of smoke and toxic fumes when overheated.

3.1.4 Cables are to meet, at least, the requirements of IEC 60332-1-2: Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame, or an acceptable and relevant national standard.

3.1.5 The cables are also to be of low smoke emission type when tested in accordance with IEC 61034: Measurement of Smoke Density of Cables Burning under Defined Conditions.

3.1.6 Where practicable, the cables should also be of zero halogen type when tested in accordance with IEC 60754-1: Test on Gases Evolved During Combustion of Materials from Cables.

3.1.7 Exemption from the requirements of *Pt 6, Ch 1, 3.1 General 3.1.4* to *Pt 6, Ch 1, 3.1 General 3.1.6* for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

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

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

3.1.9 Cable routes within chambers are to be kept as short as possible and are to be adequately protected where there is a risk of mechanical damage.

3.1.10 Cables and cable glands which penetrate pressure chambers are to be type tested to demonstrate their suitability for the maximum pressure variations. *See Pt 6, Ch 1, 7 Electrical Pressure Hull Penetrators and Cable Connectors*.

3.1.11 Cables are otherwise to be selected and installed in accordance with the relevant requirements of the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2 Electrical Engineering*, and *Pt 6, Ch 2, 11 Electric cables, optical fibre cables and busbar trunking systems (busways)*.

3.1.12 Underwater cables and lines must be designed for an external hydrostatic excess pressure equal to 1,3 times the maximum operating depth. The pressure resistance is to be verified by pressure-testing each made-up length after the connectors have been fitted.

3.1.13 Electric umbilicals are to be routine tested in the manufacturer's works in the presence of a LR Surveyor.

3.1.14 In cables for winding on drums, no mechanical forces may be transmitted by electrical components of the cable.

■ *Section 4* Batteries

4.1 General

4.1.1 The requirements for the installation of batteries and their charging and monitoring arrangements are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 12 Batteries*, which are to be complied with where applicable. The particular requirements for batteries for submersibles are given in *Pt 6, Ch 1, 9.5 Batteries 9.5.2*.

4.2 Storage batteries

4.2.1 When installing storage batteries, the relevant provisions of the *Rules and Regulations for the Classification of Ships, July 2019 Pt 6 Control, Electrical, Refrigeration and Fire* are to be complied with.

4.2.2 In the case of battery installations equipped with a catalytic converter which ensures that at least 95 per cent of the hydrogen produced is recombined, separate ventilation of the battery room can be dispensed with. The same applies when gastight battery casings are used.

4.2.3 Batteries shall not be installed within the inner areas of chambers or diving bells.

■ *Section 5* Hazardous Areas

5.1 General

5.1.1 Where practicable, diving systems are to be located outside any designated hazardous area.

5.1.2 Where a diving system is located wholly or partially within a hazardous area, the electrical arrangements are to comply with the relevant requirements of the*Rules and Regulations for the Classification of Ships, July 2019* , *Pt 6, Ch 2, 14 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*.

5.1.3 Consideration is to be given to the safety of diving personnel during emergency conditions whereby flammable gases/ vapours extend beyond the defined hazardous areas. Electrical equipment required to remain operational under such conditions, and liable to be exposed to the flammable gases or vapours, is to be of a type suitable for use in Zone 1 and selected in accordance with the relevant requirements of the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 14 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*

Section 6
Umbilical Cables

6.1 General

6.1.1 Cables for the transmission of electrical power and signals from a surface support vessel, or structure, to a tethered submersible are to have stranded conductors and be constructed so that they are capable of being flexed. Similarly cables containing optical fibre elements shall be capable of being flexed without damaging the fibres. Evidence is to be submitted to show that the umbilical cable is able to withstand the flexing loads that will be experienced in service.

6.1.2 Umbilical cables are to have a sheath which is impervious to sea water, and be capable of operating at a pressure of twice the maximum operating depth.

6.1.3 Tensile loads are not to be transmitted by the electrical cables.

6.1.4 The design of the umbilical cable is to take account of the effect of its weight on the electrical conductors when fully extended.

6.1.5 Dielectric and insulation resistance tests are to be carried out, to verify the integrity of the insulation.

6.1.6 For details of the requirements for umbilicals comprising hoses and electric cables *see* API Specification 17E.

Section 7
Electrical Pressure Hull Penetrators and Cable Connectors

7.1 General

7.1.1 Electrical penetrators are to be arranged separately from other penetrators, they are not to impair the gas/watertight integrity of pressure vessels associated with diving systems and submersibles, even if the connecting cables become damaged.

7.1.2 Penetrator inserts and cable connecting pins should be secured so as to withstand damage from an accidental tensile load being imposed on the electrical cable. In addition a means of preventing undue stress on the cable/penetrator connection is to be provided.

7.1.3 All electrical penetrations in compression chamber walls and all plug connections are to be subjected to individual inspection by the manufacturer. A Works Test Certificate is to be issued by the manufacturer in respect of this inspection.

7.1.4 Penetrators are to be selected from LR's List of Type Approved Equipment. Alternatively, type approval certification from another IACS authority, along with full test details are to be submitted for approval.

7.1.5 Positive and negative conductors from the main and auxiliary power sources are not to pass through the same penetrator or connection in a pressure boundary and are to be spaced to prevent damaging currents. All power leads passing through a pressure boundary are to be adequately protected by circuit breakers or fuses against overload and short circuit. The circuit breakers or fuses are to be located on the power source side of the pressure boundary and are to have the ability to open the circuit quickly to prevent damage to the watertight integrity of the electrical penetration. Tests may be required to demonstrate the ability of the device to perform as mentioned above.

7.1.6 Penetrators in pressure vessels associated with diving systems must be gas and watertight. Their tightness must be guaranteed even if the connected cables are damaged or torn off.

7.2 Routine tests — Penetrators

7.2.1 All electrical penetrators are to be subjected to routine tests, which are to include the requirements of *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.2* to *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.10*. The test sequences for routine tests (also for type tests) are detailed in *Pt 6, Ch 1, 7.4 Test sequence — Penetrators*.

7.2.2 With the 'gas' side of the penetrator open-ended a helium atmosphere test sequence at not less than twice the working pressure, with a minimum of 6,9 N/mm^2, is to be applied to it. No leakage is permitted. (*See Pt 6, Ch 1, 7.4 Test sequence — Penetrators 7.4.1* f) and g)).

7.2.3 A hydrostatic pressure test sequence at not less than twice the operating pressure is to be applied to the 'wet' side of the penetrator. No leakage is permitted. *See Pt 6, Ch 1, 7.4 Test sequence — Penetrators 7.4.1*b).

7.2.4 Compression chamber wall penetrators and underwater plug connections must have been type tested in accordance with *Pt 6, Ch 1, 7.3 Type tests — Penetrators* and *Pt 6, Ch 1, 7.4 Test sequence — Penetrators* or an equivalent set of tests from another IACS authority.

7.2.5 High-voltage test (Dielectric Test) at an a.c. voltage of 1 kV plus twice the rated voltage. This test is performed at the rated frequency and is to be carried out for 1 minute in each case between all the conductors mutually and between the conductors and the casing. The test is performed in the disconnected state. The connection side of the compression chamber wall penetration may be fully wired for the high-voltage test. The sealing of the connector shells and the like is permitted where this is stipulated by the manufacturer in the relevant data sheet.

7.2.6 The test voltage for plug connections rated at more than 500 V is to be agreed with LR.

7.2.7 The insulation resistance is to be measured with an instrument using 500 V d.c. With wet plug connections, the minimum insulation resistance is also to be measured after the connection has been made once in salt water – check against manufacturer's documentation.

7.2.8 All conductors are to be subject to a high voltage test, before the release of the hydrostatic pressure on the final pressure cycle, of 1 kV a.c. plus twice the rated voltage (*see* Note) for one minute between each conductor separately and the remaining conductors together with any screen connected to the penetrator body and earth. No breakdown is permitted.

Note If no conductor is to be operated at a voltage above 60 V a.c. or 75 V d.c. the test can be carried out at 500 V a.c.

7.2.9 On completion of the tests the insulation resistance is to be measured at a voltage of at least 500 V d.c. and a resistance between conductors and between each conductor and earth of at least 5 MΩ recorded.

7.2.10 For plug and socket type penetrators continuity across the contacts is to be measured.

Note If only one side of a penetrator is to be subjected to pressure, the hydrostatic and Helium pressure tests referenced above need only be carried out on that side.

7.3 Type tests — Penetrators

7.3.1 For the purpose of type testing a program is to be submitted for consideration: The following areas should be covered:

(a) The routine tests given in *Pt 6, Ch 1, 7.2 Routine tests — Penetrators*;
(b) Temperature rise of contacts and blocking inserts;
(c) Tracking index of insulating material of blocking inserts;
(d) Pressure tests at not less than twice the working pressure, in a cyclical manner, on both the 'gas' and 'wet' side of the penetrator, followed by a temperature cycle test, and a repeat of the pressure test. (*See Pt 6, Ch 1, 7.4 Test sequence — Penetrators*a) and c));
(e) Test showing the effects of simulated rupture of the connecting cable.

7.4 Test sequence — Penetrators

7.4.1 Hydrostatic pressure and temperature tests should consist of a sequence of cycles. As an example, the following would be acceptable:

(a) Pressure test sequence — Type tests;
  (i) Conduct electrical tests as detailed in *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.5* through to *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.10*;
  (ii) Pressurize — hold for 24 hours — release to 10% of test pressure and hold for 15 minutes then reduce to zero;
  (iii) Pressurize — hold for 15 minutes — release to zero;
  (iv) Pressurize — hold for 3 minutes — release to zero;
  (v) Pressurize — hold for 3 minutes — release to zero;
  (vi) Pressurize — hold for 3 minutes — release to zero;
  (vii) Pressurize — hold for 15 minutes — release to zero. Repeat electrical insulation tests as detailed in *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.5* through to *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.10*– release to zero.
(b) Hydrostatic pressure test sequences — Routine tests;
  (i) Pressurize — hold for 15 minutes — release to zero;

(ii) Pressurize hold for 3 minutes — release to zero;

(iii) Conduct electrical tests as detailed in *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.5* through to *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.10* at end of test sequence;

(c) Temperature test sequence - – Type tests;

(i) Minus 40°C for 4 hours followed by +60°C for 4 hours, the penetrator being allowed to attain ambient temperature between cycles. Repeated 3 times. On completion of the cycling temperature tests the electrical tests as detailed in *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.5* through to *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.10* are to be repeated;

(d) X-Ray test Sequence – Type Tests;

(i) Each penetrator subjected to the above tests must be X-rayed at an accredited NDT test house before and after those tests;

(e) Destructive test sequences – Type tests;

(i) The outboard cable of each penetrator that has undergone the above tests to be cut leaving a stub approximate length 150mm;

(ii) Pressurize the penetrator under hydrostatic conditions, as in a) ii above, hold for 24 hours, release to zero;

(iii) Check for barrier leakage during and at completion of the 24 hour test. Leakage may be detected by applying absorbent tissue paper to the inboard side of the penetrator;

(f) Helium Pressure Test – Both a Type Test and a Routine Test;

(g) The penetrator shall be tested using a helium atmosphere; the pressure shall be not less than twice the working pressure and held for a period of not less than 30 minutes. A "Helium Gas Detector" shall be used to detect any leakage. A constant helium leakage reading in the 10-5 (ten to the power minus 5) range on the Helium Gas Detector, specifically 5 parts per million, is acceptable as this matches the typical Helium content of atmospheric air. The High Voltage test as prescribed in *Pt 6, Ch 1, 7.2 Routine tests — Penetrators 7.2.5* shall be carried out during the pressure hold;

(h) All conductors are to be subject to a high voltage test, before the release of the hydrostatic pressure on the final pressure cycle, of 1 kV a.c. plus twice the rated voltage (*see* Note) for one minute between each conductor separately and the remaining conductors together with any screen connected to the penetrator body and earth. No breakdown is permitted.

Note If no conductor is to be operated at a voltage above 60 V a.c. or 75 V d.c. the test can be carried out at 500 V a.c.

7.5 Routine tests — Cable connectors

7.5.1 A sample is to be pressure tested at not less than twice the working pressure. No leakage is permitted.

7.5.2 Connectors are to be subjected to a high voltage test of 1 kV a.c. plus twice the rated voltage (*see* Note) for one minute between each conductor separately and the remaining conductor, together with any screen connected to the connector body and earth.

Note If no conductor is to be operated at a voltage above 60 V a.c. or 75 V d.c., the test can be carried out at 500 V a.c.

7.5.3 The insulation resistance is to be measured to a voltage of at least 500 V d.c. and resistance between conductors and between each conductor and earth of at least 5 MΩ recorded.

7.5.4 Electrical continuity across the contacts is to be measured.

7.6 Type tests — Cable connectors

7.6.1 For the purpose of type testing a program is to be submitted for consideration. The following areas should be covered:

(a) The routine tests given in *Pt 6, Ch 1, 7.5 Routine tests — Cable connectors*;

(b) Temperature rise of contacts;

(c) Tracking index of insulating materials.

Section 8
Testing and Trials

8.1 General

8.1.1 High voltage and insulation resistance tests, in accordance with the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 21.1 Testing 21.1.2* to *Pt 6, Ch 2, 21.1 Testing 21.1.4*, are to be satisfactorily carried out on all electrical equipment, complete, or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

8.1.2 All electrical systems and equipment are to be tested before the diving system is put in service.

8.2 Trials

8.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 21.2 Trials 21.2.2* to *Pt 6, Ch 2, 21.2 Trials 21.2.7* are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be to the Surveyor's satisfaction.

8.2.2 Electrical protective devices are to be checked; in addition, an insulation test is to be performed on the electrical equipment in the compression chambers.

8.2.3 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth and, so far as is reasonably practicable;
(b) all current carrying parts of different polarity or phase; The minimum values of test voltage and insulation resistance are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Table 2.21.2 Test voltage and minimum insulation*. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

8.2.4 Tests are to be made to verify the effectiveness of:

(a) earth continuity conductor;
(b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 11.12 Installation of electric and optical fibre cables in protective casings 11.12.2*;
(c) Bonding for the control of static electricity.

8.2.5 All essential and other important items of equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

8.2.6 Voltage drop is to be measured, where necessary, to verify that this is not in excess of that specified in *Pt 6, Ch 1, 1.5 Design and construction 1.5.10* or *Pt 6, Ch 1, 1.5 Design and construction 1.5.12*, as relevant.

8.2.7 On completion of the public address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

8.3 High voltage cables

8.3.1 Where any supply is taken from a high voltage system, cabling is to be tested in accordance with the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 21.3 High voltage cables*.

8.4 Hazardous areas

8.4.1 All electric equipment located in hazardous areas is to be examined to ensure that it is of a type permitted by the Rules, has been installed in compliance with its certification, and that the integrity of the protection concept has not been impaired.

■ *Section 9* Submersibles

9.1 General

9.1.1 The electrical arrangements of submersibles are to comply with the requirements of *Pt 6, Ch 1, 1 General Requirements* to *Pt 6, Ch 1, 8 Testing and Trials* of this Chapter, as far as applicable, together with the additional specific requirements given below.

9.2 Plans

9.2.1 In addition to the details listed under *Pt 6, Ch 1, 1.2 Plans* at least three copies of the plans and particulars detailed below are to be submitted for consideration: Simplified circuit diagram of electrical propulsion system (where fitted) giving the details listed under *Pt 6, Ch 1, 1.2 Plans 1.2.3*, together with an explanation of the system giving details of the propulsion control systems and the procedures used to ensure that there is satisfactory control of the design in relation to the requirements of the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 16 Electric propulsion*.

9.3 Design and construction

9.3.1 In addition to the requirements of *Pt 6, Ch 1, 1.5 Design and construction 1.5.2*, the design and installation of all electrical equipment is to be suitable for operation over the range of inclinations though which the unit is designed to operate. Refer to *Pt 5, Ch 1, 2.2 Environmental conditions* and *Table 1.2.1 Design Angles of Inclination* and *Table 1.2.2 Environmental conditions*.

9.3.2 Passenger carrying submersibles are to be fitted with a public address system supplied from both the main and the emergency electrical systems.

9.3.3 The requirements for such public address systems are given in the *Rules and Regulations for the Classification of Ships, July 2019*, *Pt 6, Ch 2, 18.3 Public address system*, which are to be complied with where applicable.

9.4 Sources of power

9.4.1 In addition to the requirements of *Pt 6, Ch 1, 2.2 Sources of power*, the electrical arrangements are to comply with *Pt 6, Ch 1, 9.4 Sources of power 9.4.2* and *Pt 6, Ch 1, 9.4 Sources of power 9.4.3*, as applicable.

9.4.2 If the recovery of a tethered submersible is dependent on electric power supplied by the support ship or unit, a standby power source is to be provided. This is to be available in the event of failure of the main power source and is to be unaffected by any fault in the main power source or its associated equipment.

9.4.3 For tethered submersibles, the standby power source is to be automatically connected even if the umbilical cable linking the submersible to the surface is severed.

9.5 Batteries

9.5.1 In addition to the requirements of *Pt 6, Ch 1, 4 Batteries* the selection and installation of secondary batteries are to comply with *Pt 6, Ch 1, 9.5 Batteries 9.5.2* to *Pt 6, Ch 1, 9.5 Batteries 9.5.6*.

9.5.2 Battery housings mounted on the outside of submersibles are to be either a pressure vessel designed and rated to withstand 1.4 times the hydrostatic pressure at the maximum operating depth of the submersible, or a container with bladder and pressure equalisation valve or other mechanism. Alternative arrangements will be subject to special consideration. Electrical penetrators are to comply with the requirements of *Pt 6, Ch 1, 7 Electrical Pressure Hull Penetrators and Cable Connectors*. Penetrations on non-pressurised external battery housings shall have equivalent mechanical strength to those required in *Pt 6, Ch 1, 7 Electrical Pressure Hull Penetrators and Cable Connectors*, although the pressure maintaining capability may be reduced, it is advisable to use a type tested penetration compliant with *Pt 6, Ch 1, 7 Electrical Pressure Hull Penetrators and Cable Connectors*.

9.5.3 Batteries are to be fixed so as to be undisturbed at the maximum inclination of the unit. Refer to *Pt 5, Ch 1, 2.2 Environmental conditions 2.2.1*.

9.5.4 Rechargeable batteries are to be recharged on the surface, in a well-ventilated position, unless arrangements are made to avoid danger caused by gassing.

9.5.5 It is advisable to arrange for battery acid to be transported separately from the batteries, especially if very low temperatures can be expected during air freighting.

9.5.6 Where Lithium-ion batteries are to be used inside the submersible hull, a Risk Assessment using a technique selected from IEC/ ISO 31010 *Risk Management – Risk Assessment techniques,* or an alternative acceptable standard, is to be performed. The Risk Assessment is to include, but is not limited to:

- cell type;
- battery construction;
- the battery management;
- location;
- ventilation requirements;
- installation; and
- fire.

9.6 Trials

9.6.1 In addition to the requirements of *Pt 6, Ch 1, 8.2 Trials*, propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction.

Section

■ Applicable Unit Types

The following table details the unit types relevant to each section within this chapter

	General Requirements: General	Plans	Control, alarm and safety equipment	Alterations and additions	Essential features for control, alarm and safety systems: General	Control stations	Communications	Alarm systems	Safety systems	Control systems	Monitoring of parameters	Fire detection systems	Enclosures for electrical equipment	Circuitry	Control and Supervision: Isobaric chambers	Hyperbaric Chambers	Life Support Systems	Navigational Equipment	Testing and Trials: General
	Section 1.1	Section 1.2	Section 1.3	Section 1.4	Section 2.1	Section 2.2	Section 2.3	Section 2.4	Section 2.6	Section 2.8	Section 2.7	Section 2.8	Section 2.9	Section 2.10	Section 3.1	Section 3.2	Section 3.3	Section 3.4	Section 4.1
Unit Type																			
Manned Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wet Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Unmanned Submersible	x	x	x	x	x	x	x	x	x	x		x	x	x					x
Submersible Craft	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Diving Bell	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Vehicle	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Habitat	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Submersible Container	x	x	x	x	x	x	x	x	x	x		x	x	x					x
Passenger Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rescue Submersible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

■ *Section 1*
General Requirements

1.1 General

1.1.1 This Chapter applies to all submersibles and underwater systems intended to be classed and are in addition to other relevant sections of the Rules.

1.2 Plans

1.2.1 Plans and documentation required by *Pt 6, Ch 2, 1.2 Plans 1.2.2* to *Pt 6, Ch 2, 1.2 Plans 1.2.6* are to be submitted.

1.2.2 Where control, alarm and safety systems are intended for the machinery equipment as defined in *Pt 6, Ch 2, 1.2 Plans 1.2.3* the following is to be submitted:

(a) Description of operation with explanatory diagrams;

(b) Line diagrams of control circuits;
(c) List of monitored points;
(d) List of control points;
(e) List of alarm points;
(f) Test schedules which should include methods of testing and test facilities provided;
(g) Functional Safety assessment (SIL assessment):
(h) Failure Mode and Effects analysis (FMEA).

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

(a) Air compressors;
(b) Batteries and accumulators for electric and hydraulic power;
(c) Electric generating plant;
(d) Hydraulic power units;
(e) Life-support systems;
(f) Lifting gear;
(g) Steering gear and control surfaces;
(h) Thruster units;
(i) Miscellaneous machinery and equipment (where control, alarm and safety systems are specified by other sections of the Rules;
(j) Gas Sampling;
(k) Hyperbaric Monitoring and Control System.

1.2.4 Diving emergency alarm — Details of the diving emergency alarm linking the diving operation control station, the accommodation the diving office, the bridge and Offshore Installation Manager's (OIM's) office as applicable.

1.2.5 Control stations Location and details of control stations are to be submitted, e.g. control panels and consoles. Plans showing the location and details of control stations, e.g., control panels and consoles, location and details of controls and displays on each panel. Details of user interface specifications. A general arrangement plan of control rooms, showing the position of consoles, handrails, operator area, lighting, door and window arrangements. Drawing of HVAC systems including vent arrangements.

1.2.6 Fire and gas detection systems — Plans showing the system operation, the type and location of fire and gas detector heads, manual call points and the fire and gas detector indicator panel are to be submitted.

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

1.2.8 Programmable Electronic Systems - In addition to the documentation required by *Pt 6, Ch 2, 1.2 Plans 1.2.2* the following is to be submitted:

(a) System requirements specification.
(b) System integration plan, *see Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems 2.14.2*. of the *Rules and Regulations for the Classification of Ships, July 2019*.
(c) Failure Mode and Effects Analysis (FMEA), *see Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems 2.14.5*. of the *Rules and Regulations for the Classification of Ships, July 2019*.
(d) Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
(e) Hardware certification details, *see Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements 2.10.5* and *Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.3*. of the *Rules and Regulations for the Classification of Ships, July 2019*.
(f) Software quality plans, including applicable procedures, *see Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements 2.10.20*. of the *Rules and Regulations for the Classification of Ships, July 2019*.
(g) Factory acceptance, integration and sea trial test schedules for hardware and software.
(h) Details of data storage arrangements, *see Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements 2.10.10* and *Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.6*. of the *Rules and Regulations for the Classification of Ships, July 2019*.

1.3 Control, alarm and safely equipment

1.3.1 Major units of equipment associated with control, alarm and safety systems defined in *Pt 6, Ch 2, 1.2 Plans* are to be surveyed at the manufacturer's works and the inspection and testing is to be to the Surveyor's satisfaction.

1.3.2 Equipment used in control, alarm and safety systems should be suitable for its intended purpose.

1.3.3 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard, e.g. International Electro-technical Commission, Publication 51 Recommendations for indicating electrical measuring instruments and their accessories.

1.4 Alterations and additions

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

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

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

■ *Section 2*
Essential Features for Control, Alarm and Safety Systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the equipment defined in *Pt 6, Ch 2, 1.2 Plans 1.2.3* the applicable features contained in *Pt 6, Ch 2, 2.2 Control stations* to *Pt 6, Ch 2, 2.8 Fire detection systems 2.8.8* are to be incorporated in the system design.

2.2 Control stations

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

2.2.2 Control of machinery, equipment and life-support systems is to be possible only from one station at a time.

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

2.2.4 Ergonomics: Control station ergonomics to comply with all applicable rules listed in LR *Rules and Regulations for the Classification of Ships, July 2019 Pt 6, Ch 1, 3 Ergonomics of control stations*

2.3 Communications

2.3.1 A means of communication is to be provided between all control stations, the divers in each chamber compartment, the bell launch and recovery system operator, the administrative office for diving operations, the diving supervisor's accommodation and also to the bridge and OIM's office where applicable.

2.3.2 Provision is to be made at all control stations for the operation of a diving emergency alarm which is to be clearly audible in the diving operation control station, the accommodation, the diving administrative office, the bridge and OIM's office as applicable.

2.3.3 In order to co-ordinate all conversations within a submersible or chamber with more than one habitable compartment a common link with 'talk back' facility is to be provided. Where divers are working externally from, but in association with, a submersible, means are to be provided for them to be linked into the internal communications system. Helium voice unscramblers are to be incorporated, where necessary.

2.3.4 An emergency locating device, in accordance with IMO Resolution A 583 (14), is to be provided to assist personnel on the surface in establishing and maintaining contact with the diving bell or submersible while submerged.

2.3.5 A battery operated strobe light is to be fitted exterior to the hull, the battery life being not less than that of the life-support system.

2.3.6 Where the hazard analysis required by *Pt 1, Ch 2, 3.2 New Construction Surveys 3.2.2* demonstrates that there could be a requirement to locate submersibles on the surface in an emergency situation, submersibles with a low radar signature are to be provided with a radar reflector and/or transponder for use on the surface.

2.3.7 A notice is to be provided within diving bells and submersibles clearly indicating the IMO emergency tapping code.

2.4 Alarm system

2.4.1 An alarm system which will provide warning of faults in machinery, equipment and life support systems essential for the safety of diving operations and the submersible is to be installed.

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

2.4.3 Failure of the normal power supply to the alarm system is to be indicated both audibly and visually as a separate fault alarm.

2.4.4 The alarm system is to be capable of being tested during normal operations.

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

2.4.6 Any inadmissible variations in the operating parameters must actuate an automatic (visual and audible) alarm at the Central Control Position. The same shall also occur in the event of automatic switching operations in the gas and power supply systems or faults in the control and surveillance system.

2.4.7 Where the facility to provide messages in association with alarms and warnings exists, messages accompanying alarms and warnings are to describe the condition and indicate the intended response required by the crew.

2.4.8 Where the facility to provide messages in association with alarms and warnings exists, messages of different categories are to be clearly distinguishable from each other. Alarms associated with machinery, safety and control system faults are to be clearly distinguishable from other alarms (e.g., fire, general alarm).

2.4.9 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible signals and visual indications are again to operate.

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

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

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

2.5 Safety systems

2.5.1 Safety related processes shall be in accordance with the requirements of IEC 61508 'Functional safety of electrical/electronic/programmable electronic systems' or shall be realised via robust mechanical/pneumatic-logic/hydrauliclogic based protective systems.

2.5.2 Safety systems essential for the protection of diving operations, the submersible and human life are to be installed.

2.5.3 Where an external source of power is provided for its operation, the safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.5.4 In addition to electronic control and surveillance equipment, independent safety devices must be fitted which prevent a fault in one system from provoking an improper response in another system.

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

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

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

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

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

2.5.10 The safety functions of the Hyberbaric Control System are designed to ensure as a minimum, the following parameters are controlled and monitored to protect the chamber occupants:

- Monitor chamber pressure rate of change and initiate alarm, and if required take an executive action to automatically secure chamber shutoff valves.
- Monitor O2 levels and initiate alarm and if required take an executive action to secure O2 injection to the chamber.
- Monitor CO2 levels and initiate alarm.
- Internal atmospheric temperature.

2.6 Control systems

2.6.1 Control systems are to be stable throughout their operating range.

2.6.2 All equipment for the automatic surveillance and control of diving system operating parameters is to be designed and constructed so that it works properly under the design and environmental conditions specified for the diving system.

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

2.6.4 Failure of the power supply to a safety system is to operate an audible and visual alarm in the control room(s).

2.6.5 Control systems should be designed to 'fail safe'.

2.6.6 Control systems are to be designed such that normal operation of the controls cannot endanger life or induce detrimental effects within machinery or equipment.

2.6.7 It must be possible to check the function of important indication lamps, alarms, and control and safety systems during operation.

2.6.8 Automatic surveillance and control equipment must be capable of being switched to manual operation at all times.

2.6.9 Automation equipment must be compatible with the operating conditions of the diving system.

2.6.10 The central control position is to be equipped with indicating instruments for the following parameters:

(a) Pressure of connected breathing gas receivers/bottles.
(b) Pressure downstream of pressure reducers.
(c) Oxygen content in supply lines to:
  (i) Umbilicals;
  (ii) Chamber compartments;
  (iii) Breathing masks in chambers.

2.6.11 For monitoring and controlling the diving system, a central control position is to be provided at which all important data relating to the chambers and the operating states of the ancillary equipment are displayed and where the chamber pressures can be controlled and the gases distributed to the various chambers.

2.6.12 Diving systems are to be so arranged and equipped that centralized control and the safe operation of the system can be maintained under all weather conditions.

2.6.13 The central control position is to be fitted with controls for at least the pressurization and pressure control for each compression chamber compartment capable of independent operation and for each diving bell.

2.6.14 At the central control position, controls are to be grouped to allow all the control needed for the operation of the diving system, including CCTV monitoring and communications equipment, from one location.

2.6.15 All items of surveillance and control equipment are to be clearly inscribed and identified.

2.6.16 Indicating instruments and synoptic displays are to be designed and inscribed in such a way that they can be read quickly and clearly.

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

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

2.6.19 Arrangements are to be such that satisfactory control may be affected with the system of remote or automatic controls out of action. This may be achieved by manual control or redundancy arrangements within the control system.

2.6.20 Only those items of equipment may be installed at the central control position which are essential to the operation of the diving system and do not impair its surveillance and control.

2.6.21 The central control position is to be separated from the other spaces in the ship or floating structure by bulkheads and decks of type "A"-60.

2.6.22 The central control position is to be equipped with separate ventilation system, the intake duct of which must be routed from an area not subject to an explosive hazard.

2.6.23 Instruments for the surveillance, control and operation of the diving system are to be grouped and arranged in the Central Control Position in accordance with the principles of safety technology and ergonomics.

2.6.24 The Central Control Position is to be equipped with suitable HMI showing compression chamber parameters for the surveillance of each manned compression chamber compartment and each diving bell *Table 2.2.1 Operating parameter to be monitored*.

2.6.25 The integral operation of automation systems must be designed to take account of the lags and time constants of the units and elements making up the system (e.g. by allowing for the length and cross-section of piping systems and the response times of gas analysers).

2.6.26 Automation equipment must be capable of reliable operation under the conditions of voltage and frequency variation stated in the Rules for Classification and Construction, of Ships.

Table 2.2.1 Operating parameter to be monitored

Parameter	Compression chamber compartments	Diving bell
Pressure or depth[1]	X	X[2]
Temperature[1]	X	
Humidity	X	
O2 partial-pressure[1]	X	X
CO2-partial pressure	X	X

Note 1. These parameters are to be displayed continuously

Note 2. The pressure or depth inside and outside the diving bell is to be indicated

2.7 Monitoring of parameters

2.7.1 An on-line system shall be used for recording of diver, ADS, bell, habitat and chamber parameters.

2.7.2 Sensors for depth monitoring shall be located on the bell and on the diver.

2.7.3 The following parameters shall be measured, displayed and logged on a continuous basis:

(a) Time;

(b) Divers/ADS depth;
(c) pO2 and pCO2 in the divers/ADS breathing gas;
(d) Hot water temperature and flow to the bell;
(e) Bell internal and external pressure;
(f) Bell internal pO2, pCO2 and temperature;
(g) Chamber internal pressure, humidity, pO2, pCO2 and temperature;
(h) ADS O2 supply bottle pressure;
(i) ADS suit temperature, pressure and humidity;
(j) Habitat internal and external pressure;
(k) Habitat internal pO2, pCO2 and temperature;
(l) Continuous video camera monitoring of compartments by the dive control station personnel.

2.7.4 For diving deeper than 185 msw the following parameters shall in addition be measured, displayed and on a continuous basis:

(a) Hot water temperature at the divers suit;
(b) Bell hot water temperature and flow to the diver at the bell.

2.7.5 The following substances shall be monitored and logged on a routine basis:

(a) Potentially toxic gases in the hyperbaric environment;
(b) In habitat when welding: CO, Ar, NOx, O3, fumes, dust (not required on-line);
(c) Bacterial growth/content in all critical places.

2.7.6 The following parameters are to be logged/recorded on a continuous basis:

(a) pO2 and pCO2 in the divers/ADS breathing gas;
(b) Audio recording of the communication between divers and control room.

2.8 Fire detection systems

2.8.1 Fire detection systems including central fire detection stations, fire detectors and the wiring of the detection loops require the approval of LR.

2.8.2 Fire detection systems must be so constructed that any fault, e.g. supply failure, short-circuit or wire breakage in the detection loops, or the removal of a detector from its base triggers a visual and audible signal at the central fire detection station.

2.8.3 Fire detectors are to be suitable for the atmospheric conditions in which they are deployed having regard to considerations such as humidity saturation and oxygen enriched atmospheres. Evidence to demonstrate that the detectors are suitable for the application is to be submitted.

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

2.8.5 When it is intended that a particular loop or detector is to be temporarily switched off, this state is to be clearly indicated. Reactivation of the loop or detector is to be performed automatically after a pre-set time.

2.8.6 Fire detector heads are to be of a type which can be tested and reset without the renewal of any component.

2.8.7 In the event that a fire is detected, audible and visual fire-alarms are to operate in the diving control room, within all interconnected chambers and locks and at the submersible’s control position as applicable.

2.8.8 For power supplies, *see Pt 6, Ch 2, 2.6 Control systems*, *Pt 6, Ch 2, 2.3 Communications* and *Pt 6, Ch 2, 2.4 Alarm system*.

2.9 Enclosures for electrical equipment

2.9.1 All items of electrical equipment belonging to a diving system are to be encased or sealed in a suitable enclosure compatible with their nature, location and protection class.

2.9.2 The enclosures of electrical equipment installed inside compression chambers and diving bells or operated in water must have been approved by LR.

2.9.3 Pressure-tight electrical equipment enclosures inside compression chambers and diving bells are to be subjected to external pressure test of 1,5 times the maximum working pressure of the chamber. Enclosures mounted on the outside of diving bells are to be tested at 1,4 times the design pressure of the diving bell.

2.10 Circuitry

2.10.1 Signalling equipment and control systems with a safety function must be designed on the failsafe principle, i.e. faults due to short-circuit, earthing or circuit breaks shall not be capable of provoking situations hazardous to personnel and/or the system. In this respect, a single failure criterion is to be assumed. The failure of one unit, e.g. due to short-circuit, shall not result in damage to other units.

2.10.2 In stored-program control systems, the electrical characteristics of the signal transmitters shall conform to the safety requirements for instruction and control devices. This means principally

(a) Activation at H level, i.e. by energization across NO contacts.
(b) Deactivation at L level, i.e. by deenergization across NC contacts

The requirements of *Pt 6, Ch 2, 2.3 Communications 2.3.1* are unaffected.

2.10.3 Instruction and control units for safety functions, e.g. emergency stop buttons, shall be independent of stored-program control systems and shall act directly on the output unit, e.g. the STOP solenoid.

2.10.4 Stored-program control systems should be reactionless and, in case of fault, should cause no malfunctions in program-independent safety interlocks or stepped safety circuits for fixed subroutines.

2.10.5 Freely accessible potentiometers and other units for equipment trimming or operating point settings must be capable of being locked in the operation position.

2.10.6 Interfaces with mechanical switchgear must be so designed that the operation of the system is not adversely affected by contact chatter.

Conductive tracks forming part of circuits which extend outside the enclosure housing the circuit boards must have qualified short-circuit protection, i.e. in case of an external short-circuit only the safety devices provided may respond without destroying the conductive tracks.

2.10.7 The equipment shall not be damaged by brief overvoltage in the ship's power supply, due for example to switching operations. The design is to allow for overvoltage equal to approximately 2,5 times the rated voltage and lasting 1 ms. Where systems are supplied by static converters, it may be necessary to make allowance for periodic voltage pulses lasting about 0,5 ms. The pulse amplitude depends on the converter type and is to be investigated in each case.

■ *Section 3*
Control and Supervision

3.1 Isobaric chambers

3.1.1 The compartments of compression chambers are to be fitted with pressure and temperature gauges which can be read from inside. Diving bells are to be equipped with instruments indicating the internal and external pressure and the pressure of the independent gas supply. In addition, the diving bell is to be equipped with an autonomous unit for monitoring the oxygen and CO2 levels.

3.1.2 Means are to be provided to maintain atmospheric pressure by regulating the oxygen supply as the carbon dioxide is absorbed, an atmospheric pressure gauge is to be fitted to indicate that atmospheric pressure is being maintained within the chamber.

3.1.3 Provision is to be made for the automatic release (with manual override) of accidental pressurization in order to limit ‘high internal to low external chamber’ differential pressure to two atmospheres. Account is to be taken of the delay time for the operation of the release.

3.1.4 Simple analysers of the chemical gas absorption type are to be carried as spot check devices for atmosphere sampling on service voyages.

3.1.5 Pressure gauges connected directly to the compression chamber system are to be fitted with a shutoff valve.

3.2 Hyperbaric chambers

3.2.1 All chambers which have variable pressure control are to be provided with means to change their internal pressure from the outside of the chamber. Where necessary, means to change their internal pressure may also be provided within the chamber and/or from adjacent compartments.

3.2.2 Where dual controls are fitted for changing the chamber pressure the external control is to override any internal controls.

3.2.3 In the case of airlocks the pressure controls are to include the selection of the correct gas mixture within the chamber at any time.

3.2.4 For safety interlocks associated with the prevention of unintentional or uncontrolled loss of pressure via mating systems, food and equipment locks and sewage systems, *see Pt 5, Ch 6, 2.1 General 2.1.10*.

3.2.5 In addition to the instrumentation required for isobaric chambers a means of determining the rate of change of pressure is also to be provided. On submersibles where decompression schedules require the use of pure oxygen, the oxygen dump system is to be adequately instrumented to enable proper control of partial pressure to be maintained.

3.3 Life-support systems

3.3.1 Where the life-support systems of a submersible or chamber can be controlled from more than one chamber a full set of the instrumentation required by *Pt 6, Ch 2, 3.3 Life-support systems 3.3.2* to *Pt 6, Ch 2, 3.3 Life-support systems 3.3.4* is to be provided in each chamber.

3.3.2 Pressure gauges are to be fitted showing the pressure drop across pressure reducing valves, filters and absorbers, together with the pressure within all gas storage bottles, or within the discharge rail where two or more bottles are on line.

3.3.3 A pressure recorder is to be provided in the life-support systems to divers.

3.3.4 Means of ascertaining the humidity and temperature of all chambers is to be provided.

3.3.5 A wide-band toxic contamination level indicator is to be available, and is to be used during trials to check that there is no buildup of toxic vapours in any chamber. With the exception of chambers used for welding it need not be carried on normal service voyages. The toxic contamination limit (threshold limit value) is to be in accordance with National Regulations.

3.3.6 The make-up of breathing gases within hyperbaric chambers is to be regularly monitored and the content of all relevant breathing gas constituents is to be displayed in the diving control room. Means are to be provided to enable the diving control room superintendents to verify satisfactory performance of the analyser.

3.3.7 Throughout the entire operating period, the oxygen analysing system must give a reading accurate to ± 0,015 bar partial oxygen pressure or equivalent to 0.1% full scale reading surface equivalent.

3.3.8 Throughout the entire operating period the CO2 analysing system must give a reading accurate to ± 0,001 bar partial CO2 pressure or equivalent to 1% full scale reading surface equivalent.

3.3.9 In addition, autonomous instruments for monitoring the oxygen and CO2 levels are to be provided in diving bells and the living compartments of compression chambers.

3.3.10 Where gases other than air, helium-oxygen mixtures or He/N2/CO2 mixtures are used for diving operations, the instrumentation required shall be agreed with LR in each case.

3.3.11 A system is to be provided for analysing the chamber atmosphere for impurities such as CO, NO, NOx and hydrocarbons. Test tubes may be recognized for this purpose.

3.4 Navigational equipment

3.4.1 Navigational equipment is to be at least in accordance with the 1982 International Maritime Organisation Publication 979 82.07E Performance Standards for Navigational Equipment.

3.4.2 For underwater navigation, heading information is to be provided at the steering position by means of a magnetic compass or a gyro compass.

3.4.3 In addition to watches carried by the crew and divers, a clock with movable segments showing the working time and operational time remaining available is to be fitted. This clock is to be self-contained and not reliant on the electrical supply.

3.4.4 A depth indicator accurate to ± 1,0 per cent at target maximum diving depth is to be provided. The indicator is to be graduated in meters to the maximum operating depth plus 20 per cent. In built test facilities or shut off cocks for easy replacement and testing are to be provided. A quick-read table for conversion of the scale for density and temperature correction is to be available. The depth indicator is not to be affected by pressure changes within the chamber.

3.4.5 The instrument indicating the pressure in the compression chambers and diving bells must be accurate to ± 0,25 per cent of the whole scale with a maximum deviation of 30 cm water column. All other pressure reading shall be accurate to ± 1 per cent of the whole scale.

3.4.6 Where a hazard analysis required by *Pt 1, Ch 2, 3.2 New Construction Surveys*, demonstrates that the submersible may be required to operate in waters deeper than its maximum operating depth a second independent depth indicator complying with *Pt 6, Ch 2, 3.4 Navigational equipment 3.4.4* is also to be provided. In addition a depth alarm is to be fitted and arranged to operate before the maximum operating depth is exceeded.

3.4.7 A speed and distance indicator is to be provided for mobile submersibles.

3.4.8 Suitable heel and trim or attitude indication is to be provided.

3.4.9 Suitable meters are to be provided to indicate the state of charge of the submersible's batteries.

3.4.10 Where an echo sounder is used in more than one role, e.g. for obstacle avoidance in the ahead, upward or downward zones, clear visual indication of the direction of the beam is to be given. If of the recording type, the direction is to be recorded.

■ *Section 4*
Testing and Trials

4.1 General

4.1.1 Before a new Installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be based on the approved test schedules list as required by *Pt 6, Ch 1, 1.2 Plans 1.2.2*.

4.1.2 Two copies of the alarm and control equipment test schedules signed by the Surveyor and builder are to be provided on completion of the survey. One copy is to be submitted to LR and the other is to be made available at subsequent Periodical Surveys.

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■ *Section 1* Contingency Plans

1.1 Hazards

1.1.1 It is the responsibility of Owners of ships and offshore installations to provide Contingency plans for the protection of divers or crews of submersibles when under pressure while on board against hazards such as:

(a) In respect of fixed installations — irreparable damage to life-support systems, fire, explosion or blow out.
(b) In respect of ships — irreparable damage to life-support systems fire, explosion, collision, stranding, loss of watertight integrity or reserve stability.

1.2 Basic protection

1.2.1 Persons under pressure remain at greater risk while in a Hyperbaric Evacuation Unit whether consisting of a rescue chamber installed in a lifeboat or a chamber which is self-buoyant. It is to be noted that self-propelled hyperbaric lifeboats are generally considered the most appropriate method of evacuation of divers in an emergency. Other methods of hyperbaric evacuation will be subject to special consideration. Consequently every effort should be made in the design of a ship or offshore installation to maximize fire protection by fire-resisting bulkheads and fire-fighting installations and in the case of Ships to minimize risk of foundering or capsize by extensive Subdivision.

1.2.2 A potentially dangerous situation can arise if a floating unit, from which saturation diving operations are being carried out, has to be abandoned with a diving team under pressure. While this hazard should be reduced by pre-planning, under extreme conditions consideration may have to be given to hyperbaric evacuation of the divers. The hyperbaric evacuation arrangements should be studied prior to the commencement of the dive operation and suitable written contingency plans made. Where, in the event of diver evacuation, decompression would take place in another surface compression chamber the compatibility of the mating devices should be considered.

1.2.3 Once the hyperbaric evacuation unit has been launched the divers and any support personnel may be in a precarious situation where recovery into another facility may not be possible and exposure to seasickness and accompanying dehydration will present further hazards. It is therefore necessary that diving contractors ensure that any such contingency plans include appropriate solutions. It should be emphasised that hasty or precipitous action may lead to a premature evacuation situation which could be more hazardous in the final analysis.

1.2.4 In preparing the contingency plans the various possible emergency situations should be identified taking into consideration the geographical area of operation, the environmental conditions, the proximity of other vessels, and the availability and suitability of any onshore or offshore facilities. The facilities for rescue, recovery and subsequent medical treatment of divers evacuated in such circumstances should be considered as part of the contingency plan. In the case of unattended hyperbaric evacuation units not having an attended crew, consideration should be given to providing equipment to transfer the tow line to an attendant vessel before launch of the hyperbaric evacuation unit. Such an arrangement would enable the unit to be towed clear immediately after launching.

1.2.5 Copies of contingency plans shall be available on board the parent vessel, ashore and in the evacuation unit.

1.3 Training schedule

1.3.1 While LR does not lay down a specific training Schedule or certificate format, it is considered that sub-sections *Pt 7, Ch 1, 1.3 Training schedule 1.3.2* to *Pt 7, Ch 1, 1.3 Training schedule 1.3.7* may be of assistance to operators.

1.3.2 The crew, and in particular the pilot, for every submersible should be fully informed about, and be fully aware of, the design capabilities of the submersible Once trials and experience have verified and expanded the operator’s knowledge of the submersible’s service capabilities, this knowledge Should be recorded for the benefit of Subsequent users.

1.3.3 Operating and maintenance instructions Should be so written and produced that it will normally be Possible for Properly trained personnel to undertake routine operations and maintenance Without the need to consult additional literature, except for navigational purposes.

1.3.4 Pilot and crew should also have a full knowledge of diving procedure emergency procedure and, on certain submersibles of decompression tables and the use of pressurized access chambers, and in this respect it is recommended that experience as a scuba diver is an advantage.

1.3.5 Pilots and crews of wet submersibles Should Possess recognized diving qualifications.

1.3.6 Detailed knowledge is required of the effects of buoyancy, heel and trim, equipment handling, underwater television sonar, hydraulics, electrics together with the medical effects of gas mixtures. In addition, the pilot should have experience of navigation by dead reckoning.

1.3.7 Periodic training exercises should be carried out to test the operation of the hyperbaric evacuation system and the efficiency of the personnel responsible for the hyperbaric evacuation of the divers. Such training exercises should not be carried out with divers under pressure in the hyperbaric chamber, but should be carried out at each available opportunity.

■ *Section 2* Life Support and Safety

2.1 General

2.1.1 An additional/ emergency life support package shall be provided for connection to the hyperbaric evacuation unit (HEU). The contractor shall ensure that the equipment is properly maintained and ready for use at all times during saturation diving operations.

2.1.2 The Life Support Package (LSP) shall be kept at a suitable location from where it can reach the HEU within reasonable time. Risk analysis shall be performed for verification. Compatibility of the LSP to the HEU shall be verified.

2.1.3 Procedures for use of the LSP shall be included in the contingency plan and shall be available with the LSP and inside the HEU.

2.1.4 Relevant emergency procedures shall be available in the HEU chamber, the HEU control and with the LSP.

2.1.5 Means should be provided to maintain all the occupants in thermal balance and in a safe and breathable atmosphere throughout the environmental operational envelope for air temperature, sea temperature and humidity with the maximum and minimum number of divers likely to be carried. In determining the duration and amount of life-support necessary consideration should be given to the geographical and environmental conditions, the O2 and gas consumption and CO2 generation under such conditions, the heat input or removal and the emergency services that may be available for the decompression of the divers. Gas losses as a result of using toilet facilities which discharge to outside the hyperbaric evacuation unit and medical lock operation should be taken into account in determining the amount of gases required. The effects of hypothermia and hyperthermia should be considered and the effectiveness of the arrangements provided should be established as far as is reasonable and practicable under all conditions envisaged. However in no such case should the duration of the unit’s autonomous life-support endurance be less than 72 hours.

2.1.6 In addition to any controls and equipment fitted externally, compression chambers should be provided with adequate controls within for supplying and maintaining the appropriate breathing mixtures to the occupants, at any depth down to the maximum operating depth. The persons operating the chamber, whether they are within or outside it, should be provided with adequate controls to provide life support. As far as practicable, the controls shall be capable of operation without a diver having to release his/her safety harness.

2.1.7 Two separate distribution systems should be provided for supplying oxygen to the compression chamber. Components in the system should be suitable for oxygen service.

2.1.8 Adequate equipment should be provided and suitably situated to maintain oxygen and carbon dioxide levels and thermal balance within acceptable limits for the life support duration.

2.1.9 In addition to any instrumentation necessary to be provided outside the compression chamber suitable instrumentation should be provided within the chamber for monitoring the partial pressures of oxygen and carbon dioxide and be capable of operation for the duration of the available life-support period.

2.1.10 Where it is intended that divers may be decompressed within the hyperbaric evacuation unit, provision should be made for the necessary equipment and gases including therapeutic mixtures, to enable the decompression process to be carried out safely.

2.1.11 An adequate supply of food and water should be provided within the evacuation chamber. In determining in particular the amount of water to be provided, consideration should be given to the area of operation and the environmental conditions envisaged.

2.1.12 A breathing system should be provided with masks which exhausts to the external environment sufficient for all the occupants under pressure.

2.1.13 Provision should be made external to the hyperbaric evacuation unit and in a readily accessible place for the emergency service connections as per IMCA D-051. Any supplementary connections required by the end user should be mounted on a separate plate to the 12 emergency connectors in order to minimise any possible confusion. The connections should be clearly and permanently marked and be suitably protected.

2.1.14 In hyperbaric evacuation units designed to pass through fires the breathing gas bottles and piping systems and other essential equipment should be adequately protected. In addition thermal insulation should be non-toxic and suitable for this purpose.

2.1.15 First Aid equipment, sickness bags, paper towels, waste disposal bags and all necessary operational instructions for equipment within the compression chamber should be available within the chamber, on board the parent vessel and ashore.

2.2 Gas and Power Supplies

2.2.1 Any capsule/chamber designed for escape/rescue should be self-contained and carry sufficient provisions, fuel, breathing gas and power supplies to enable the full diving complement to exist for a minimum period of 72 hours, without outside assistance. The chamber should be mounted in and connected to a properly equipped lifeboat, which complies with the requirements of the relevant National Regulations.

2.2.2 The consumables such as fuel, gas and power supplies are to be kept fully charged whilst the complex is manned and under pressure. The power supplies should be sufficient for heating, cooling, scrubbing the atmosphere and for systems providing communication with HEU as designated in the Specification with both minimum and maximum number of persons on board.

2.2.3 All electrical equipment and installation including the power supply arrangements should be designed for the environment in which they will be required to be operated and designed to minimise the risk of electrical capacity depletion as result of fault, fire or explosion, electric shock, the emission of toxic gases and of galvanic action. Electrical equipment within the compression chamber should be designed for hyperbaric use, high humidity levels and marine application.

2.2.4 Power supplies required for the operation of life-support systems and other essential services should be sufficient for the life-support duration. The battery charging arrangements should be designed to prevent overcharging under normal or fault conditions. The battery storage compartment should be provided with means to prevent over-pressurisation and any gas released should be vented to a safe place.

2.2.5 Each compression chamber should be provided with a source of lighting sufficient for the life-support time and be of such luminosity to allow the occupants to read gauges and operate essential systems within the chamber.

2.3 Safety harness

2.3.1 For the safety of personnel a safety harness is to be provided for each person of the full diving complement.

■ *Section 3* **Launching**

3.1 Launch method

3.1.1 As persons under pressure are substantially at risk once they have left their on board habitat, arrangements for the safety of the launching crew should be such that they can defer launching until it is quite certain that launching will ultimately be necessary, and even then not before the last possible moment.

3.1.2 In the case of fire or irreparable damage to life-support systems, the ability to transfer a hyperbaric evacuation unit by crane direct to another vessel is desirable, If reliance is placed on this means of evacuation in the case of fire, then there must be available a second crane or other means of transfer, such that it is very unlikely that both will be rendered ineffective by the fire which is necessitating evacuation.

3.1.3 For ships, ‘Float Off’ is acceptable as an alternative to davit launching provided reliance can be placed on an alternative means of evacuation in the case of fire or irreparable damage to life-support systems.

3.2 Launch mechanisms

3.2.1 Means should be provided for the safe and timely evacuation and recovery of the unit and due consideration should be given to the environmental and operating conditions, the dynamic snatch and impact loadings that may be encountered. Where appropriate the increased loading due to water entrapment should be considered. Where the primary means of launching depends on the ship’s main power supply then a secondary and independent launching arrangement should be provided.

3.2.2 The launch mechanism should be such that the capsule/chamber can be disconnected from the diving system. Gas systems and normal power supply are to be readily detachable and holding down arrangements suitable for easy disconnection. The launch mechanism should also be capable of recovering the capsule chamber to enable it to be reconnected to the diving system.

3.2.3 All the arrangements should be capable of being disconnected by either one of the following methods, as laid down in the specification:

(a) From within the capsule/chamber without the aid of external personnel;
(b) By external personnel.

3.2.4 Release mechanisms and lowering equipment should also be able to be triggered from within the capsule/chamber and should not rely on external power sources from the installation being available. Gravity systems should be fitted with an override mechanism so designed that the capsule/chamber and its occupants are protected from shock on entry into the water.

3.2.5 Lifeboat type HEU’s should carry an attendant for release and otherwise comply with all rules relevant to lifeboats.

3.2.6 ‘Float Off’ type HEU’s must have a quick release arrangement such as explosive bolts to be operated only when it seems likely that once afloat the HEU will not again contact the ship.

3.2.7 HEU’s shall be capable of being launched in situations where normal power supply is unavailable.

3.2.8 If the power to the handling system fails, brakes should be engaged automatically. The brakes should be provided with manual means of release and control.

3.2.9 The launching arrangements provided should be designed to ensure easy connection or disconnection of the hyperbaric evacuation unit from the surface compression chamber and for the transportation and removal of the unit from the ship under the, same conditions of trim and list as those for the ship’s other survival craft.

3.2.10 Where a power actuated system is used for the connection or reconnection of the hyperbaric evacuation unit from the surface compression chamber then a manual or stored power means of connection or disconnection should also be provided.

Section 4
Buoyancy and Stability

4.1 Surface conditions

4.1.1 Hyperbaric evacuation units designed to float should be provided with adequate stability for all conditions of operation and envisaged environmental conditions and be self-righting. In determining the degree of stability to be provided, consideration should be given to the adverse effects of large righting moments on the divers. Consideration should also be given to the effect equipment and rescue personnel required to be placed on the top of the system, to carry out a recovery from the sea, may have on the stability of the hyperbaric evacuation unit.

4.1.2 Buoyancy and stability on the surface should be such that the capsule/chamber will have self-righting characteristics together with a reserve buoyancy of not less than 10 per cent of its total buoyancy. The connections on the capsule/chamber for towing and lifting should be well emerged above the equilibrium water plane of the capsule/chamber and lifting must be possible from a single point by the HRV's own slinging arrangements without requiring special spreaders or other gear not likely to be available in a vessel with a suitable crane. In meeting these objectives the beneficial effect of any auxiliary buoyancy, which is provided by buoyancy bags, or by other buoyancy which is flammable or otherwise prone to damage, should be disregarded.

4.1.3 In cases where the buoyancy, which is afforded by the pressure hull and the rigid watertight external appendages of the capsule/chamber, does not fulfil the objectives of *Pt 7, Ch 1, 4.2 Protection against damage 4.2.1*, the necessary additional buoyancy should be provided by additional buoyancy units securely connected to the structure of the capsule/chamber. The additional buoyancy units should be nonflammable and of adequate strength for the maximum depth of submerges which may occur.

4.1.4 Consideration should be given to the use of buoyancy bags, or other suitable alternatives as a means of augmenting freeboard, trim and stability over the standard defined by *Pt 7, Ch 1, 4.2 Protection against damage 4.2.1* and thereby improving the visibility of the capsule/chamber and the accessibility of the towing and lifting connections. All attachments between the buoyancy bags and the capsule/chamber should be carefully designed for the loads involved. It should be ensured that the towing and lifting attachments remain accessible and the self-righting characteristics are maintained under any situation where one or more of the buoyancy bags are damaged.

4.1.5 Towing attachment points should be so situated that there is no likelihood of the hyperbaric evacuation unit being capsized as a result of the direction of the tow line. Where towing harnesses are provided they should be lightly clipped or secured to the unit and so far as is possible be free from snagging when pulled free.

4.1.6 Where hyperbaric evacuation units are designed to be placed on board a rescue vessel, the unit should be designed as to permit it to remain in an upright position and attachment points should be provided on the unit to enable it to be secured to the deck.

4.1.7 Hyperbaric evacuation units provided on ships required to have fire protected lifeboats should have a similar degree of fire protection.

4.2 Protection against damage

4.2.1 The exterior of the pressure hull and the external equipment of the capsule/chamber should be equipped with a suitable arrangement of fenders to provide protection against damage when the capsule chamber is afloat.

4.3 Blow out conditions

4.3.1 Consideration should also be given in the specification to the possibility of aeration of the water, reducing density under blow out conditions where the diving system is fitted in an installation where blow out could occur.

■ *Section 5* Evacuation Systems

5.1 General

5.1.1 With reference to the "Guidelines and Specifications for Hyperbaric Evacuation Systems", Resolution A.692 (17) of 6 November 1991, the IMO Code of Safety for Diving Systems, Resolution A.831 (19) of 23 November 1995 and IMCA D 052 stipulates for diving systems installed on board ships or offshore platforms an evacuation system enabling divers in saturation to be rescued in the event of them needing to abandon the ship or the platform.

5.1.2 Depending on the local, geographical and other service conditions, different kinds of evacuation systems are conceivable, including:

(a) Hyperbaric self-propelled lifeboats;
(b) Towable hyperbaric evacuation units;
(c) Hyperbaric evacuation units, which may or may not be towable, suitable for offloading onto an attendant vessel;
(d) Transfer of the diving bell to another facility;
(e) Transfer of the divers from one diving bell to another when in the water and under pressure;
(f) Negatively buoyant unit with inherent reserves of buoyancy, stability and life support capable of returning to the surface to await independent recovery.

5.1.3 Where a self-propelled or towable hyperbaric evacuation system permanently connected to the diving systems is provided, the requirements of *Pt 7, Ch 1, 8 Design and Construction* are to be complied with.

5.1.4 The means provided for access into the compression chamber should be such as to allow safe access to or from the surface compression chambers. Interlocks should be provided to prevent the inadvertent release of the hyperbaric evacuation unit from the surface compression chamber whilst the access trunking is pressurised. The mating flange should be adequately protected from damage at all times, including during the launch and recovery stages.

5.1.5 Arrangements should be provided to enable an unconscious diver to be taken into the unit.

5.1.6 Compression chamber doors should be so designed as to prevent accidental opening while pressurised. All doors should be so designed that, where fitted, the locking mechanisms can be operated from both sides.

5.1.7 Arrangements should be provided to allow the occupants to be observed. If viewports are provided they should be situated so that risk of damage is minimised.

5.1.8 Where decompression of the divers after hyperbaric evacuation is intended to be carried out in another surface compression chamber, then consideration must be given to the suitability of the mating arrangements on that surface compression chamber. Where necessary a suitable adapter and clamping arrangements should be provided.

5.1.9 A medical lock should be provided and be so designed as to prevent accidental opening while the compression chamber is pressurised. Where necessary, interlock arrangements should be provided for this purpose. The dimensions of the medical lock should be adequate to enable essential supplies, including CO2 scrubber canister to be transferred into the compression chamber, and be of such dimensions as to minimise the loss of gas when the lock is being used.

■ *Section 6* Communications

6.1 General

6.1.1 If breathing mixtures containing helium or hydrogen are used, a self-contained primary communications system fitted with an unscramble device should be arranged for direct two way communication between the divers and those outside the compression chamber. A secondary communication system should also be provided.

6.1.2 In addition to the communication system referred to in *Pt 7, Ch 1, 6.1 General 6.1.1* a standard bell emergency communication tapping code should be provided which meets the requirements of that specified in the Supplement to the IMO

Code of Safety for Diving Systems resolution A.583 (14). Copies of the tapping code should be permanently displayed inside and outside the evacuation unit.

6.1.3 Hyperbaric evacuation units designed to be water borne should be provided with a strobe light and radar reflector.

6.1.4 Hyperbaric evacuation units designed to be placed on the seabed to await independent recovery should be provided with a strobe type light and an acoustic transponder. The transponder should be suitable for operation with a diver held interrogator-receiver which will be retained on board the parent ship. The equipment provided should meet the requirements of that specified in the Supplement to the IMO Code of Safety for Diving System-resolution A.583 (14).

■ *Section 7* Recovery

7.1 General

7.1.1 Aids to assist recovery should be considered, generally, in accordance with *Pt 5, Ch 7 Lifting Appliances*.

7.1.2 Adequate foot grips and handgrips should be fitted to the exterior of the capsule/chamber to enable access, by rescue personnel, to the towing and lifting connections.

7.2 Towing and lifting points

7.2.1 As rescue craft may not carry suitable lifting gear it is recommended that all towing and lifting points should be of a commonly used type and suitable for the loads involved. The tow hawser and lifting strop should be readily available to the rescue craft.

7.2.2 The towing and lifting arrangements shall be certified in accordance with statutory requirements applicable to the Flag State giving considerations to the geographic area of operation, expected sea states and terms of delivery.

7.3 Life-support system connections

7.3.1 All life-support system connections should be of a standard type and size to facilitate supply from the rescue craft. Such connections are to be adequately protected from possible damage and readily accessible as per IMCA D-051.

7.4 Control and monitoring

7.4.1 Control and monitoring of the HEU(s) compression chamber environment shall be from the outside and it shall be possible to lock materials in and out. When connected to the chamber complex on board the work-site, the control and monitoring shall be performed from the saturation control room.

■ *Section 8* Design and Construction

8.1 General Design Principals

8.1.1 The design and construction of the hyperbaric evacuation system should be such that it is suitable for the environmental conditions envisaged, account being taken of the dynamic, snatch, horizontal or vertical loads that may be imposed on the system and its lifting points particularly during evacuation and recovery.

8.1.2 Facilities for saturation diving shall be equipped for adequate work-site evacuation of all divers under pressure.

8.1.3 The pressure chamber of the hyperbaric evacuation system shall be so designed that all the divers in the diving system can be rescued simultaneously at maximum operating depth. At least one seat with safety harness is to be provided for each diver. The seating or other arrangements provided should be designed to provide an adequate degree of protection to the divers from impact collisions during launch, while the unit is afloat and during recovery. Where the chamber is intended to be occupied for more than 12 hours arrangements for the collection or discharge of human waste should be provided. Where discharge arrangements are provided they shall be fitted with suitable interlocks.

8.1.4 The arrangements and instructions should be provided externally to enable the hyperbaric evacuation unit to be recovered safely. The instructions should be located where they will be legible when the hyperbaric evacuation unit is floating.

8.1.5 The pressure chamber is to be equipped with a supply lock.

8.1.6 The connection flange of the pressure chamber is to be so designed that it is also able to mate to a different system.

8.1.7 The pressure chamber is to be fitted with viewports in such a way that, wherever possible, all the occupants can be observed from outside.

8.1.8 The pressure chamber is to be provided with the necessary connections to enable the internal pressure, temperature, gas composition and humidity to be maintained.

8.1.9 The pressure chamber is to be adequately lit.

8.1.10 The hyperbaric evacuation system is to be so designed that its behaviour in a seaway corresponds to that of an enclosed lifeboat.

8.1.11 The system must be self-propelled and capable of navigation or must be provided with means (e.g. suitably equipped ancillary boat) enabling the hyperbaric evacuation system to be towed away quickly after launching.

8.1.12 The hyperbaric evacuation system must be equipped with its own life support system enabling the pressure, temperature, humidity and gas composition in the pressure chamber to be maintained for at least 72 hours. The life support systems are to be provided with connections for external supply and surveillance.

8.1.13 The hyperbaric evacuation system must be equipped with the controls needed to maintain a safe environment for the divers.

8.1.14 The hyperbaric evacuation system must be equipped with a communication system for talking to the divers.

8.1.15 The hyperbaric evacuation system is to be equipped with its own power supply capable of keeping the electrical installations in operation for at least 72 hours.

8.1.16 The hyperbaric evacuation system is to be provided with lifting attachments enabling it to be hoisted by a standard ship's crane.

8.1.17 The hyperbaric evacuation unit should be capable of being recovered by a single point lifting arrangement and means should be provided on the unit to permit a surface swimmer or other person to hook on or connect the lifting arrangement.

8.1.18 The hyperbaric evacuation system must be constructed of materials suitable for their intended use, which are at least flameretardant and must be equipped with a water spray system for cooling the surface in the event of fire.

8.1.19 The mating system of the hyperbaric evacuation system must be designed to permit rapid and safe connection and disconnection.

8.1.20 The design and testing of the handling system must confirm to Rules and Regulations for life saving appliances, lifting appliances and, where applicable, to the relevant national regulations.

8.1.21 The handling system must be capable of safely launching the hyperbaric evacuation system and, where applicable, of effecting also the retrieval and mating operations.

8.1.22 Hyperbaric evacuation systems should not be located in Zone 0 or Zone 1 hazardous areas and high fire risk areas should be avoided as far as is reasonably practicable.

8.1.23 Components in the hyperbaric evacuation system should be so designed, constructed and arranged as to permit easy inspection, maintenance, cleaning and, where appropriate, disinfection.

8.1.24 In the design of pressure vessels including accessories such as doors, hinges, door landings, closing mechanisms, penetrators and viewports, the effect of rough handling should be considered in addition to design parameters such as pressure, temperature, vibration, operation and environmental conditions. In general, piping penetrations through the chamber should have isolating valves on both sides.

8.2 Control and Monitoring

8.2.1 The HEU shall be capable of maintaining an acceptable environment for a minimum of 72 hours or until the personnel can be brought to safety. It shall be capable of sustaining vital functions even if primary HEU power supply is not available.

8.2.2 An HEU shall withstand the stresses it may be subjected to in connection with handling, and shall have equipment enabling safe and efficient handling out of the water. It shall be equipped with lifting appliances/towing arrangements corresponding to the relevant recovery procedures.

8.2.3 Operational procedures for HEU(s) shall contain information regarding limitations in launching, towing and lifting operations, etc. relevant to different weather conditions.

8.2.4 The HEU shall have its own propulsion facility, which shall be capable of functioning for at least 72 hours. It shall be reasonably powered and strengthened for its size and mass when fully equipped and manned. It shall further contain equipment for oral communication with other craft, e.g. a two way marine VHF radiotelephone.

8.2.5 The emergency connector panel shall be provided in accordance with IMCA D-051.

8.2.6 In case the HEU crew has to leave the HEU, it shall be possible to secure the chamber system in a way that makes it possible for the divers inside to take over the control of O2 make-up and gas supply.

8.2.7 Detectors, sensors, and continuous sampling devices that operate both audible and visible alarm should be provided to warn personnel of high or low oxygen concentration.

8.3 Electrical Systems

8.3.1 Service definitions

(a) Essential services are defined as those services that are required to be in continuous operation for maintaining the hyperbaric evacuation system's functionality with respect to safety of diver and crew of the lifeboat
(b) Emergency services. Examples of equipment and systems for emergency services include:

- condition monitoring of emergency batteries
- emergency lighting
- emergency communication
- emergency life support systems including carbon dioxide removal (unless manual systems are used), gas analysis and temperature monitoring
- Alarm systems for the above emergency services.
- The required minimum operating time for Emergency services is considered to be 72 hours.

8.3.2 Power supply systems

(a) Two mutually independent and self-contained electric power supply systems are to be provided on board the HEU defined as:

- a main electric power supply system supplying all essential consumers
- An emergency electric power supply system supplying emergency consumers.

(b) Electrical equipment within the decompression chamber shall also be designed for oxygen-enriched atmospheres. Reference is made to:

- NFPA53M (National Fire Protection Agency) "Manual on Fire Hazards in Oxygen-Enriched Atmospheres 1990",
- AODC 035 "Code of practice for the safe use of electricity underwater", and
- AODC 062 "Use of battery operated equipment in hyper-baric conditions”.

8.4 Propulsion Machinery (SPHL)

8.4.1 **Lifeboat propulsion**

(a) Every lifeboat shall be powered by a compression ignition engine. No engine shall be used for any lifeboat if its fuel has a flashpoint of 43°C or less (closed cup test).
(b) The engine shall be provided with either a manual starting system, or a power starting system with two independent rechargeable energy sources. Any necessary starting aids shall also be provided. The engine starting systems and starting aids shall start the engine at an ambient temperature of -15°C within 2 min of commencing the start procedure unless, in the opinion of the Administration having regard to the particular voyages in which the ship carrying the lifeboat is constantly engaged, a different temperature is appropriate. The starting systems shall not be impeded by the engine casing, seating or other obstructions.
(c) The engine shall be capable of operating for not less than 5 min after starting from cold with the lifeboat out of the water.
(d) The engine shall be capable of operating when the lifeboat is flooded up to the centreline of the crank shaft.

(e) The propeller shafting shall be so arranged that the propeller can be disengaged from the engine. Provision shall be made for ahead and astern propulsion of the lifeboat.

(f) The exhaust pipe shall be so arranged as to prevent water from entering the engine in normal operation.

(g) All lifeboats shall be designed with due regard to the safety of persons in the water and to the possibility of damage to the propulsion system by floating debris.

(h) The speed of a lifeboat when proceeding ahead in calm water, when loaded with its full complement of persons and equipment and with all engine powered auxiliary equipment in operation, shall be at least 6 knots. Sufficient fuel, suitable for use throughout the temperature range expected in the area in which the ship operates, shall be provided to run the fully loaded lifeboat at 6 knots for a period of not less than 24 h.

(i) The lifeboat engine transmission, and engine accessories shall be enclosed in a fire-retardant casing or other suitable arrangements providing similar protection. Such arrangements shall also protect persons from coming into accidental contact with hot or moving parts and protect the engine from exposure to weather and sea. Adequate means shall be provided to reduce the engine noise so that a shouted order can be heard. Starter batteries shall be provided with casings which form a watertight enclosure around the bottom and sides of the batteries. The battery casings shall have a tight fitting top which provides for necessary gas venting.

(j) The lifeboat engine and accessories shall be designed to limit electromagnetic emissions so that engine operation does not interfere with the operation of radio life-saving appliances used in the lifeboat.

(k) Means shall be provided for recharging all engine starting, radio and searchlight batteries. Radio batteries shall not be used to provide power for engine starting. Means shall be provided for recharging lifeboat batteries from the ship’s power supply at a supply voltage not exceeding 50 V which can be disconnected at the lifeboat embarkation station, or by means of a solar battery charger.

(l) Water-resistant instructions for starting and operating the engine shall be provided and mounted in a conspicuous place near the engine starting controls The engine and transmission shall be controlled from the helmsman’s position.

(m) The engine and engine installation shall be capable of running in any position during capsize and continue to run after the lifeboat returns to the upright or shall automatically stop on capsizing and be easily restarted after the lifeboat returns to the upright. The design of the fuel and lubricating systems shall prevent the loss of fuel and the loss of more than 250 ml of lubricating oil from the engine during capsize.

(n) Air cooled engines shall have a duct system to take in cooling air from, and exhaust it to, the outside of the lifeboat. Manually operated dampers shall be provided to enable cooling air to be taken in from, and exhausted to, the interior of the lifeboat.

(o) Diesel engines for drive of electrical generators on board self-propelled hyperbaric evacuation units shall be built, equipped and installed to comply with the relevant Rules for Classification of Ships in addition to the requirements of this section as applicable.

■ *Section 9*
Fire Protection and Extinction

9.1 General

9.1.1 Materials used in the construction and installation should so far as is possible be non-combustible and non-toxic.

9.2 Internal Fire Protection

9.2.1 A fire extinguishing system should be provided in the hyperbaric evacuation unit which should be suitable for exposure to all depths down to the maximum operating depth.

9.2.2 A fire extinguishing system should be provided in the hyperbaric evacuation unit which should be suitable for exposure to all depths down to the maximum operating depth as per *Pt 5 Main and Auxiliary Machinery, Systems and Equipment* of these Rules and:

(a) The enclosure area, between a lifeboat shell and the chamber, shall be equipped with manually actuated portable fire extinguishers with such a layout as to cover the complete area and expected types of fire.

(b) The portable fire-extinguishing equipment shall be of an approved type suitable for extinguishing oil fires as required in the *LSA Code - International Life-Saving Appliance Code – Resolution MSC.48(66) 4.4.8 Lifeboat equipment*

9.3 External Fire Protection

9.3.1 In hyperbaric evacuation units designed to float and which may be used to transport divers through fires, consideration should be given, where practicable, to providing and external water spray system for cooling purposes.

■ *Section 10* Other Requirements

10.1 General

10.1.1 In all other aspects these chambers shall comply with the requirements of these Rules.

10.2 Surveys

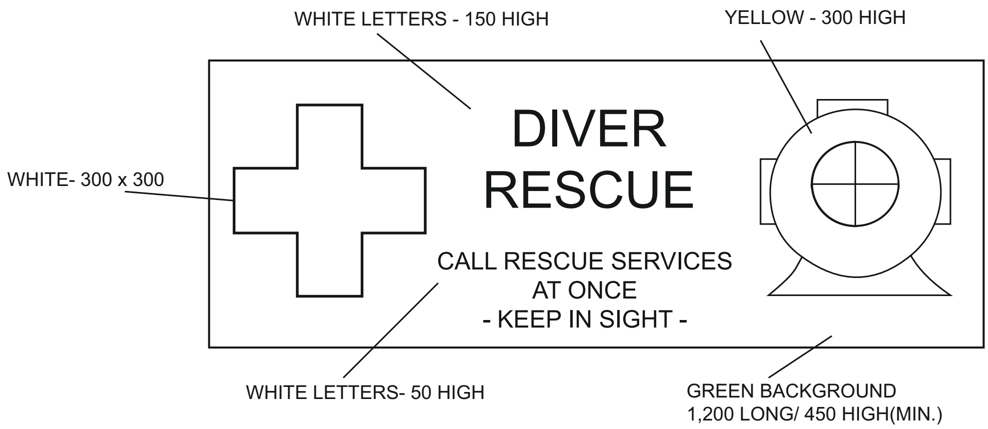
10.2.1 Each hyperbaric evacuation system should be subject to following surveys, which are to be carried out by an LR Surveyor:

(a) An initial survey before being put into service. This should comprise a complete and thorough examination of the hyperbaric evacuation system, equipment, fittings, arrangements and materials including functional tests which should be such as to ensure they are suitable for the intended service and in compliance with these Guidelines and Specifications.
(b) A survey at intervals specified by the administration but not exceeding two years.
(c) An annual inspection within 3 months of each anniversary date of the survey to ensure that the hyperbaric evacuation system, fittings, arrangements, safety equipment and other equipment remain in compliance with the applicable provisions of the Guidelines and Specifications and are in good working order.
(d) Where a hyperbaric evacuation system complies with the provisions of these Rules, as applicable, and has been duly surveyed it may be recorded on the supplement to the Cargo Ship Safety Equipment Certificate Safety Equipment Record of Inspection as providing the Life-Saving Appliances and arrangements for divers in compression.

10.3 Markings and information to be provided on hyperbaric evacuation units

10.3.1 Dedicated hyperbaric evacuation units should be coloured International orange and be provided with retro-reflective material to assist in their location during hours of darkness.

10.3.2 Each hyperbaric evacuation unit designed to be water borne should be marked with at least three identical signs as shown in *Figure 1.10.1 Hyperbaric Evacuation Unit Marking*. One of these markings should be on the top of the unit and clearly visible from the air and the other two, on either side, mounted vertically and as high as possible and capable of being seen while the unit is afloat.



Note: Dimensions in millimetres

Figure 1.10.1 Hyperbaric Evacuation Unit Marking

10.4 Name Plate

10.4.1 Where applicable the following should be clearly visible and readily available whilst the unit is afloat.

(a) Towing arrangements and buoyant tow line.
(b) All external connections, particularly for the provision of emergency gas, hot/cold water and communications.
(c) Maximum gross weight of unit in air.
(d) Lifting points.
(e) Name of the parent ship and port of registration.
(f) Emergency contact telephone, telex and facsimile numbers.

10.4.2 Warning Information - Where appropriate every hyperbaric evacuation unit should be permanently marked in two separate locations with the following information and these markings should be clearly visible while the unit is afloat. “Unless Specialised Diving Assistance is available:

(a) Do not touch any valves or other controls.
(b) Do not try to get occupants out.
(c) Do not connect any gas, air, water or other supplies.
(d) Do not attempt to give food, drinks or medical supplies to the occupants.
(e) Do not open any hatches”.

10.5 Maintenance and testing

10.5.1 The availability of any evacuation system provided is dependent on the regular testing and maintenance of the system. A planned maintenance and testing programme should be devised with the responsibility of carrying out the maintenance tasks being allocated to specific crew members. A maintenance and testing schedule should be available for recording the execution of the tasks and signatures of the persons allocated the tasks. Such schedules should be maintained onboard and be available for inspection.

Contents

Overall Design Requirement for One-man Submersible Atmospheric Diving Suit System (ADS systems)

■ *Section 1* General

1.1 Design basis

1.1.1 Requirements for one-man atmospheric diving suits and supporting equipment are to be as listed below and in accordance with the remaining requirements of these Rules:

(a) one-man submersible atmospheric diving suits shall normally consist of a pressure hull and an exostructure;

(b) the pressure hull and the exostructure shall be:

- so designed that all loads to be exerted on the structure are taken into account. These shall include the most severe loads imposed in normal conditions together with loads resulting from several conditions occurring simultaneously. The planned maximum operating depth and the collapse depth shall be specified;
- the pressure hull joints between moving pressure boundary components of the limbs are to provide a pressure tight seal under all normal operating conditions and have a fail-safe design that, in the event of primary seal failure, will engage a secondary seal that will maintain the integrity of the pressure boundary and will prevent leakage;
- designed where practicable, so that all pipe systems penetrating the pressure hull will be provided with two isolating valves, primary and secondary readily accessible to the Operator, with the primary valve to be immediately inboard of the penetration. Where this is not practicable, all components of the system between the hull penetration and the primary isolating valve shall be designed for an internal pressure of not less than that equivalent to the collapse depth;
- Oxygen cylinders located on board of the ADS are to be stored outside the human occupancy pressure boundary of the ADS. There are to be at least two banks with separate penetrations entering the pressure boundary. These penetrations should be positioned so as to minimise the possibility that a single incident would cause failure of both penetrations. Oxygen pressure is to be externally regulated, such that high pressure Oxygen does not enter the human occupancy pressure boundary of the ADS. The human occupancy pressure boundary of the ADS is to be provided with a pressure relieving device to prevent the internal pressure from rising more than 100 mbar above 1 atm;
- fitted with a lifting point and external structural members capable of withstanding the stresses that may be experienced in service condition in accordance with the LR *Code for Lifting Appliances in a Marine Environment, July 2019*;
- equipped with at least one alternative lifting point to which attachments may be secured to raise the ADS unit to the surface in an emergency.

■ *Section 2* **Power supply**

2.1 General requirements

2.1.1 One-man submersible atmospheric diving suits shall be:

(a) provided with a source of power capable of maintaining normal services for a period adequate for the service envisaged and including the minimum life support requirements set out in Section 5 below;
(b) equipped with means of propulsion adequate for the service envisaged.

2.1.2 Where electrical power is used, the suit shall be:

(a) fitted with equipment compatible with the special conditions pertaining to marine service, where practicable all equipment shall be continuously rated;
(b) provided with adequate electrical protection;
(c) fitted with effective means of isolating all poles or phases from every circuit and sub-circuit as may be necessary to minimise shock hazard;
(d) fitted with circuits which do not use hull return;
(e) provided with an earth leakage measuring device;
(f) fitted with gas control safeguards, where applicable, on the compartments containing the power source.

■ *Section 3* **Auxiliary systems**

3.1 General requirements

3.1.1 Atmospheric diving suits shall, where appropriate:

(a) contain valves, gauges and such other equipment as are necessary to control the propulsion and auxiliary systems, including any fuel supply and exhaust systems;
(b) contain such valves, gauges and other equipment as are necessary to control the depth, attitude, and rate of descent and ascent without inducing resonant or unstable motions;
(c) The ADS is to be provided with an emergency surfacing system, be fitted with jettisonable weights or other means, suitably protected against inadvertent operation, to achieve positive buoyancy in an envisaged emergency. This system is to permit the ADS to ascend to the surface when disconnected from its tether/umbilical. The system is to provide positive buoyancy sufficient to ascend to the surface from any operational depth. Emergency surfacing system activation is to require at least two positive manual actions for operation and is to be independent of electrical power. Emergency ascent calculations (addressing the net positive buoyancy provided and the resultant ascent rate) are to be submitted for review and approval. The emergency surfacing system is to operate properly under all anticipated conditions of heel and trim;
(d) be fitted with valves or other fittings to enable manipulators, grasping or anchoring devices and jettisonable equipment to be released in a planned or envisaged emergency;
(e) the ADS is to be configured such that it will automatically and naturally assume a normally upright or comfortable position, when not influenced by the pilot’s body motion or thrusters;
(f) the ADS stability analysis, test procedures and test results are to be submitted for approval;
(g) be fitted with an umbilical capable of maintaining services and of sufficient strength for its intended service;
(h) be equipped with an internal release, suitably protected against inadvertent operation, for severing or releasing the umbilical cable.

■ *Section 4* Buoyancy and Stability

4.1 General requirements

4.1.1 One-man submersible atmospheric diving suits shall, where appropriate, have sufficient buoyancy and stability to enable a properly trained person to operate it in all sea states and conditions for which it is intended.

4.1.2 Instructions showing operating procedures shall be provided for each suit in intended service conditions together with emergency procedures. The instructions shall take into account the fully submerged and transient submerging and surfacing conditions together with a full buoyancy condition. The effects of releasing any jettisonable devices either individually or in combination shall be taken into account.

■ *Section 5* Life Support

5.1 General requirements

5.1.1 One-man submersible atmospheric diving suits shall be provided with the on-board emergency means of life support to maintain the occupant in a safe and breathable atmosphere for a minimum period of 24 hours.

5.1.2 One-man submersible atmospheric diving suits shall:

(a) Contain adequate equipment to maintain a safe and breathable atmosphere in the Operator's compartment. Where electrical power is used, the equipment shall be capable of functioning whether or not the main electrical power source of the suit is operable;

(b) contain monitoring devices to test the atmosphere in the Operator's compartment;

(c) The ADS is to be provided with the following instrumentation for monitoring the life support conditions within the human occupancy pressure boundary of the ADS:

- (i) Oxygen analyser;
- (ii) Carbon Dioxide (CO_2) analyser;
- (iii) temperature measurement device;
- (iv) suit internal pressure gauge.

In addition to the above instrumentation, displays or gauges are to be provided to show the breathing gas storage cylinder supply high pressure and regulated low pressure supply to the human occupancy pressure boundary of the ADS;

(d) at all times carry emergency supplies of food and water to sustain the occupant for the period of 24 hours or as specified by the administration;

(e) contain the minimum of flammable and toxic materials, *see Pt 5, Ch 6 Environmental Conditions*;

(f) the ADS is to be provided with the appropriate equipment to generate, monitor and maintain suitable life support conditions inside the human occupancy pressure boundary;

(g) the ADS is to be designed so that the concentration of O_2 (Oxygen) will be kept within the limits of 19,8 to 22,0 per cent by volume;

(h) the ADS is to be designed so that the concentration of CO_2 (Carbon Dioxide) will never exceed 0,5 per cent by volume referenced to standard temperature and pressure except in emergency conditions, *see also Pt 8, Ch 1, 6.1 General requirements 6.1.5*;

(i) The ADS designer is to specify the normal ADS mission duration (including working and resting periods) as well as the reserve duration, along with the associated metabolic parameters that are applied to each of these durations. The normal life support system is to have sufficient life support capacity for the anticipated maximum mission duration, including consideration of the metabolic workload(s). The anticipated maximum mission duration is to be defined by the ADS designer, but is not to be less than 6 hours. The normal life support system is to include two independent Oxygen banks (supplies) and piping systems. One of the two independent Oxygen banks is to have sufficient Oxygen capacity to support the anticipated maximum mission duration. The remainder of the Oxygen capacity in the two independent banks (after considering the anticipated maximum mission duration) is to be sufficient to support the reserve mission duration as defined in these Rules. The normal life support system is to include at least one Carbon Dioxide (CO_2) removal system. The scrubber of the CO_2 removal system is to have sufficient absorbent material capacity to support the anticipated maximum mission duration as well as the emergency duration defined in these Rules. The CO_2 removal system may consist of a powered blower type circulation system or a lung-powered arrangement using an oral-nasal mask or a full-face mask.

■ *Section 6*
Emergency Life Support

6.1 General requirements

6.1.1 The ADS is to be provided with an on-board emergency life support capacity.

6.1.2 The reserve life support capacity is to be sufficient for a duration that is consistent with the emergency rescue plan but is not to be less than 24 hours (over and above the anticipated maximum mission duration).

6.1.3 Actuation of internal controls intended for emergency operation is to be fully manual.

6.1.4 For emergency operation, the CO_2 removal system is to be capable of being used in a lung-powered mode using an oral-nasal mask or a full-face mask.

6.1.5 Under emergency conditions, the CO_2 removal system is to be capable of maintaining the concentration of CO_2 below 1,5 per cent by volume.

■ *Section 7*
Communications

7.1 General requirements

7.1.1 One-man submersible atmospheric diving suits shall be fitted with suitable equipment as is necessary for the submersible suit to communicate with its parent craft when on the surface and when submerged. Equipment using through water communication methods shall have a minimum range of twice the maximum operating depth of the suit under the expected operational conditions.

7.1.2 Where main communications are transmitted through the umbilical, emergency through water means of communication shall also be provided.

■ *Section 8*
Navigation and position indication

8.1 General requirements

8.1.1 One-man submersible atmospheric diving suits shall be:

(a) fitted with an efficient compass;
(b) provided with an adequate means of visual look-out ahead of the suit;
(c) fitted with such gauges or instruments to provide a continuous read-out of depth to the Operator;
(d) fitted with a visual means of position indication for use on the surface, including highly visible paint, and strobe light;
(e) fitted with a sonic location device with frequency of 37.5KHZ as per *IMO Resolution A.831(19) – Code of Safety for Diving Systems, 1995 – (Adopted on 23 November 1995)*, to provide position indication in an emergency when submerged.

Section 9
Supporting Equipment: Launch and Recovery System

9.1 General requirements

9.1.1 One-man submersible atmospheric diving suits shall be so constructed as to be capable of use in association with a lifting gear system which enables the suit to be lowered into and recovered from the water with adequate safety factors for the intended service.

9.1.2 If wires or ropes are incorporated for hoisting or lowering any submersible suit, these shall have safety factors based upon the proven or calculated breaking strength of the wire or rope.

9.1.3 The ADS is to be provided with primary lifting lugs or attachments designed to support the entire weight of the ADS including the weight of the equipment, supplies and pilot within the ADS. They are to be designed for forces of at least 2g vertical (1g static plus 1g dynamic), 1g transverse and 1g longitudinal, unless otherwise determined by the designer, acting simultaneously under the most severe loading condition. Where appropriate, the increased loading due to other applicable loads such as added mass including flooding of the compartment and drag are to be also considered.

9.1.4 Additional lifting lugs or attachments are to be provided for emergency recovery of the ADS. The emergency lifting lugs or attachments are to be designed for lifting and raising the ADS to the surface under the heaviest emergency condition following an accident.

9.1.5 The lifting gear system shall be subjected to static and dynamic load tests.

Section 10
Tests

10.1 Tests and test dive

10.1.1 The human occupancy boundary of ADS is to be subjected to a hydrostatic proof test as per *Pt 3, Ch 1, 12.1 General 12.1.2.(e)*.

10.1.2 Each ADS is to be subjected to a test dive to the design depth in the presence of the Surveyor. The test dive is to be conducted with the ADS manned to verify proper operation of the joints and controls at depth.

10.1.3 Where the depth of water available is less than the design depth, both the rated depth (depth reached during test dive) and the design depth will be indicated in the record.

10.1.4 Each ADS is to be subjected to manned functional test in the presence of the Surveyor. The functional test is to demonstrate satisfactory performance of life support systems, position control and steering systems, electrical systems, and other items required for safe operation of the ADS. The testing may be conducted at shallow depths or test tanks.

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