Rules for the Classification of Underwater Units

Effective from 1 July 2023

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GENERAL CONDITIONS

Definitions:

Administration" means the Government of the State whose flag the ship is entitled to fly or under whose authority the ship is authorized to operate in the specific case.

"**IACS**" means the International Association of Classification Societies.

"Interested Party" means the party, other than the Society, having an interest in or responsibility for the Ship, product, plant or system subject to classification or certification (such as the owner of the Ship and his representatives, the shipbuilder, the engine builder or the supplier of parts to be tested) who requests the Services or on whose behalf the Services are requested.

"**Owner**" means the registered owner, the shipowner, the manager or any other party with the responsibility, legally or contractually, to keep the ship seaworthy or in service, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2 of the Rules for the Classification of Ships or in the corresponding rules indicated in the Specific Rules.

"**Rules**" in these General Conditions means the documents below issued by the Society:

(i) Rules for the Classification of Ships or other special units.
(ii) Complementary Rules containing the requirements for product, plant, system and other certification or containing the requirements for the assignment of additional class notations;
(iii) Rules for the application of statutory rules, containing the rules to perform the duties delegated by Administrations.
(iv) Guides to carry out particular activities connected with Services;
(v) Any other technical document, for example, rule variations or interpretations.

"Services" means the activities described in paragraph 1 below, rendered by the Society upon request made by or on behalf of the Interested Party.

"**Ship**" means ships, boats, craft and other special units, for example, offshore structures, floating units and underwater craft.

"Society" or "TASNEEF" means TASNEEF Maritime

"**Surveyor**" means technical staff acting on behalf of the Society in performing the Services.

"**Force Majeure**" means damage to the ship; unforeseen inability of the Society to attend the ship due to government restrictions on right of access or movement of personnel; unforeseeable delays in port or inability to discharge cargo due to unusually lengthy periods of severe weather, strikes or civil strife; acts of war; or other force majeure.

1. Society Roles

1.1. The purpose of the Society is, among others, the classification and certification of ships and the certification of their parts and components. In particular, the Society:
(i) sets forth and develops Rules.
(ii) publishes the Register of Ships.
(iii) Issues certificates, statements and reports based on its survey activities.
1.2. The Society also takes part in the implementation of national and international rules and standards as delegated by various Governments.
1.3. The Society carries out technical assistance activities on request and provides special services outside the scope of classification, which is regulated by these general conditions unless expressly excluded in the particular contract.

2. Rule Development, Implementation and Selection of Surveyor

2.1. The Rules developed by the Society reflect the level of its technical knowledge at the time they are published therefore, the Society, although also committed through its research and development services to continuous updating of the Rules, does not guarantee the Rules meet state-of-the-art science and technology at the time of publication or that they meet the Society's or others' subsequent technical developments.
2.2. The Interested Party is required to know the Rules based on which the Services are provided. With particular reference to Classification Services, special attention is to be given to the Rules concerning class suspension, withdrawal and reinstatement. In case of doubt or inaccuracy, the Interested Party is to promptly contact the Society for clarification.
The Rules for Classification of Ships are published on the Society's website: www.tasneef.ae.
2.3. Society exercises due care and skill:
(i) In the selection of its Surveyors
(ii)In the performance of its Services, taking into account the level of its technical knowledge at the time the Services are performed.
2.4. Surveys conducted by the Society include, but are not limited to, visual inspection and non-destructive testing. Unless otherwise required, surveys are conducted through sampling techniques and do not consist of comprehensive verification or monitoring of the Ship or the items subject to certification. The surveys and checks made by the Society on board ship do not necessarily require the constant and continuous presence of the Surveyor. The Society may also commission laboratory testing, underwater inspection and other checks carried out by and under the responsibility of qualified service suppliers. Survey practices and procedures are selected by the Society based on its experience and knowledge and according to generally accepted technical standards in the sector.

3. Class Report & Interested Parties Obligation

3.1. The class assigned to a Ship, like the reports, statements, certificates or any other document or information issued by the Society, reflects the opinion of the Society concerning compliance, at the time the Service is provided, of the Ship or product subject to certification, with the applicable Rules (given the intended use and within the relevant time frame).
The Society is under no obligation to make statements or provide information about elements or facts which are not part of the specific scope of the Service requested by the Interested Party or on its behalf.
3.2. No report, statement, notation on a plan, review, Certificate of Classification, document or information issued or given as part of the Services provided by the Society shall have any legal effect or implication other than a representation that, on the basis of the checks made by the Society, the Ship, structure, materials, equipment, machinery or any other item covered by such document or information meet the Rules. Any such document is issued solely for the use of the Society, its committees and clients or other duly authorized bodies and no other purpose. Therefore, the Society cannot be held liable for any act made or document issued by other parties based on the statements or information given by the Society. The validity, application, meaning and interpretation of a Certificate of Classification, or any other document or information issued by the Society in connection with its Services, is governed by the Rules of the Society, which is the sole subject entitled to make such interpretation. Any disagreement on technical matters between the Interested Party and the Surveyor in the carrying out of his functions shall be raised in writing as soon as possible with the Society, which will settle any divergence of opinion or dispute.
3.3. The classification of a Ship or the issuance of a certificate or other document connected with classification or certification and in general with the performance of Services by the Society shall have the validity conferred upon it by the Rules of the Society at the time of the assignment of class or issuance of the certificate; in no case shall it amount to a statement or warranty of seaworthiness, structural integrity, quality or fitness for a particular purpose or service of any Ship, structure, material, equipment or machinery inspected or tested by the Society.

3.4. Any document issued by the Society about its activities reflects the condition of the Ship or the subject of certification or other activity at the time of the check.
3.5. The Rules, surveys and activities performed by the Society, reports, certificates and other documents issued by the Society are in no way intended to replace the duties and responsibilities of other parties such as Governments, designers, shipbuilders, manufacturers, repairers, suppliers, contractors or sub-contractors, Owners, operators, charterers, underwriters, sellers or intended buyers of a Ship or other product or system surveyed.

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These documents and activities do not relieve such parties from any fulfilment, warranty, responsibility, duty or obligation (also of a contractual nature) expressed or implied or in any case incumbent on them, nor do they confer on such parties any right, claim or cause of action against the Society. With particular regard to the duties of the ship Owner, the Services undertaken by the Society do not relieve the Owner of his duty to ensure proper maintenance of the Ship and ensure seaworthiness at all times. Likewise, the Rules, surveys performed, reports, certificates and other documents issued by the Society are intended neither to guarantee the buyers of the Ship, its components or any other surveyed or certified item, nor to relieve the seller of the duties arising out of the law or the contract, regarding the quality, commercial value or characteristics of the item which is the subject of transaction.
In no case, therefore, shall the Society assume the obligations incumbent upon the above-mentioned parties, even when it is consulted in connection with matters not covered by its Rules or other documents.
In consideration of the above, the Interested Party undertakes to relieve and hold harmless the Society from any third-party claim, as well as from any liability about the latter concerning the Services rendered.
Insofar as they are not expressly provided for in these General Conditions, the duties and responsibilities of the Owner and Interested Parties concerning the services rendered by the Society are described in the Rules applicable to the specific service rendered.

4. Service Request & Contract Management

4.1. Any request for the Society's Services shall be submitted in writing and signed by or on behalf of the Interested Party. Such a request will be considered irrevocable as soon as received by the Society and shall entail acceptance by the applicant of all relevant requirements of the Rules, including these General Conditions. Upon acceptance of the written request by the Society, a contract between the Society and the Interested Party is entered into, which is regulated by the present General Conditions.

4.2 In consideration of the Services rendered by the Society, the Interested Party and the person requesting the service shall be jointly liable for the payment of the relevant fees, even if the service is not concluded for any cause not pertaining to the Society. In the latter case, the Society shall not be held liable for non-fulfilment or partial fulfilment of the Services requested.

4.3 The contractor for the classification of a ship or for the services may be terminated and any certificates revoked at the request of one of the parties, subject to at least 30/60/90 days' notice, to be given in writing. Failure to pay, even in part, the fees due for services carried out by the society will entitled the society to immediately terminate the contract and suspend the service.
For every termination of the contract, the fees for the activities performed until the time of the termination shall be owned to the society as well as the expenses incurred in view of activities already programmed, this is without prejudice to the right to compensation due to the society as a consequence of the termination.
With particular reference to ship classification and certification, unless decided otherwise by the society, termination of the contract implies that the assignment of class to a ship is withheld or, if already assigned, that it is suspended or withdrawn, any statutory certificates issued by society will be withdrawn in those cases where provided for by agreements between the society and the flag state.

5. Service Accuracy

5.1. In providing the Services, as well as other correlated information or advice, the Society, its Surveyors, servants or agents operate with due diligence for the proper execution of the activity. However, considering the nature of the activities performed (see **Rule Development, Implementation and Selection of Surveyor** 2.4), it is not possible to guarantee absolute accuracy, correctness and completeness of any information or advice supplied. Express and implied warranties are specifically disclaimed.

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6. Confidentiality & Document sharing

6.1. All plans, specifications, documents and information provided by, issued by, or made known to the Society, in connection with the performance of its Services, will be treated as confidential and will not be made available to any other party other than the Owner without authorization of the Interested Party, except as provided for or required by any applicable international, European or domestic legislation, Charter or other IACS resolutions, or order from a competent authority. Information about the status and validity of class and statutory certificates, including transfers, changes, suspensions, withdrawals of class, recommendations/conditions of class, operating conditions or restrictions issued against classed ships and other related information, as may be required, may be published on the website or released by other means, without the prior consent of the Interested Party.
Information about the status and validity of other certificates and statements may also be published on the website or released by other means, without the prior consent of the Interested Party.

6.2. Notwithstanding the general duty of confidentiality owed by the Society to its clients in clause 7.1 below, the Society's clients hereby accept that the Society may participate in the IACS Early Warning System which requires each Classification Society to provide other involved Classification Societies 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 used to facilitate the proper working of the IACS Early Warning System. The Society will provide its clients with written details of such information sent to the involved Classification Societies.
6.3. In the event of transfer of class, addition of a second class or withdrawal from a double/dual-class, the Interested Party undertakes to provide or to permit the Society to provide the other Classification Society with all building plans and drawings, certificates, documents and information relevant to the classed unit, including its history file, as the other Classification Society may require for classification in compliance with the applicable legislation and relative IACS Procedure. It is the Owner's duty to ensure that, whenever required, the consent of the builder is obtained about the provision of plans and drawings to the new Society, either by way of the appropriate stipulation in the building contract or by other agreement.
In the event that the ownership of the ship, product or system subject to certification is transferred to a new subject, the latter shall have the right to access all pertinent drawings, specifications, documents or information issued by the Society or which has come to the knowledge of the Society while carrying out its Services, even if related to a period prior to transfer of ownership.

7. Health, Safety & Environment

7.1. The clients such as the designers, shipbuilders, manufacturers, repairers, suppliers, contractors or sub-contractors, or other product or system surveyed who have a registered office in ABU Dhabi; should have an approved OSHAD as per Abu Dhabi OHS Centre, or, if they do not need to have an approved OSHAD, they shall comply with TASNEEF standards and have procedures in place to manage the risks from their undertakings.

7.2. For the survey, audit and inspection activities onboard the ship, the ship's owner, the owner representative or the shipyard must follow TASNEEF rules regarding the safety aspects.

8. Validity of General Conditions

8.1. Should any part of these General Conditions be declared invalid, this will not affect the validity of the remaining provisions.

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9. Force Majeure

9.1 Neither Party shall be responsible to the other party for any delay or failure to carry out their respective obligations insofar as such delay and failure derives, directly or indirectly, and at any time, from force majeure of any type whatsoever that lies outside the control of either Party.

9.2 The Party that is unable to fulfil the agreement due to Force Majeure shall inform the other party without delay and in all cases within 7 days from when such force majeure arose.

9.3 It is understood that if such force majeure continues for more than 30 days, the Party not affected by the event may terminate this agreement by registered letter. The rights matured until the day in which the force majeure occurred remain unaffected.

10. Governing Law and Jurisdiction

This Agreement shall be governed by and construed in accordance with the laws of Abu Dhabi and the applicable Federal Laws of the UAE.
Any dispute arising out of or in accordance with this Agreement shall be subject to the exclusive jurisdiction of the Abu Dhabi courts.

11. Code of Business conduct

The **CLIENT** declares to be aware of the laws in force about the responsibility of the legal persons for crimes committed in their interest or to their own advantage by persons who act on their behalf or cooperate with them, such as directors, employees or agents.
In this respect, the **CLIENT** declares to have read and fully understood the "**Ethical Code**" published by **TASNEEF** and available in the **TASNEEF** Web site.
The **CLIENT**, in the relationships with **TASNEEF**, guarantees to refrain from any behaviour that may incur risk of entry in legal proceedings for crimes or offences, whose commission may lead to the enforcement of the laws above.
The **CLIENT** also acknowledges, in case of non-fulfilment of the previous, the right of **TASNEEF** to unilaterally withdraw from the contract/agreement even if there would be a work in progress situation or too early terminate the contract/agreement. It's up to **TASNEEF** to choose between the two above mentioned alternatives, and in both cases a registered letter will be sent with a brief sum-up of the circumstances or of the legal procedures proving the failure in following the requirements of the above-mentioned legislation.

In light of the above, it is forbidden to all employees and co-operators to:
- receive any commission, percentage or benefits of any possible kind;
- Start and maintaining any business relationship with **Clients** that could cause conflict of interests with their task and function covered on behalf of **TASNEEF.**
- Receive gifts, travel tickets or any other kind of benefits different from monetary compensation, that could exceed the ordinary business politeness.

Violation of the above-mentioned principles allows **TASNEEF** to early terminate the contract and to be entitled to claim compensation for losses if any.

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RULES FOR THE CLASSIFICATION OF UNDERWATER UNITS

Part **A B C D E**

RULES FOR THE CLASSIFICATION OF UNDERWATER UNITS

Part A
Classification and Surveys

Chapters **1 2**

CHAPTER 1
PRINCIPLES OF CLASSIFICATION AND CLASS NOTATIONS

CHAPTER 2
SURVEYS

Section 1 Survey Requirements

Section 2 Tasneef Surveys During Construction

Part A
Classification and Surveys

Chapter 1
PRINCIPLES OF CLASSIFICATION AND CLASS NOTATIONS

SECTION 1 GENERAL PRINCIPLES

1 Application

1.1 Premise

1.1.1 Where not otherwise specified, both "underwater vehicles" and "apparatuses used for underwater activity" or "systems for underwater activity" will, for the sake of simplicity, be referred to hereafter as "underwater units".

1.2 Units included and excluded

1.2.1 These Rules apply to vehicles, apparatuses and systems suitable for underwater operation or related to underwater activity, manned or unmanned, mobile or fixed, self-propelled or non-propelled, of any size.

These Rules do not apply to mobile or fixed marine platforms, for drilling or similar activity, for which reference is to be made to the specific rules.

2 Rules

2.1 Equivalence

2.1.1 Tasneef may consider the acceptance of alternatives to the requirements of these Rules, provided that they are deemed, in its sole opinion, to be equivalent to the Rules.

2.2 Novel features

2.2.1 Tasneef may consider the classification of units based on or applying novel design principles or features, to which the Rules are not directly applicable, on the basis of experi-ments, calculations or other supporting information pro-vided.

The specific limitations may then be indicated on the Certificate of Classification.

2.3 Amendments to the Rules

2.3.1 The Rules may be amended at any time and the amendments do not apply to already existing units, unless otherwise stated by Tasneef on a case-by-case basis.

3 Duties of the Interested Party

3.1 Statutory regulations

3.1.1 The classification of a unit does not absolve the Interested Party from compliance with any requirements issued by Administrations and any other applicable international and national regulations for the safety of life at sea and protection of the marine environment.

3.2 Compliance with other rules

3.2.1 Although not specifically indicated in these Rules, the relevant requirements contained in the "Rules for the Classification of Ships" (hereafter referred to as "the Rules") apply.

3.3 Assumptions

3.3.1 These Rules are based on the assumption that the design of the vehicle, apparatus or system for the underwater activity is performed by qualified technicians (with whom the responsibility for the design remains), that those units are operated in a proper manner and that the operating personnel are recognised fit for such operation by the relevant Authority or, where no legal regulations exist, are properly trained.

It is also assumed that, prior to commencing any underwater operation especially if immersion of persons is involved, the Interested Party will inform the competent Authorities, as necessary, in order to be able to plan any rescue operations with timely measures and appropriate means, already prearranged.

4 Definitions

4.1 Pilot

4.1.1 The pilot is the captain of a self-propelled underwater unit usually of small size and required to operate with the continued assistance of a supply vessel.

If the unit is not dependent on the assistance of a supply vessel, the pilot takes the usual role of the Master with regard to these Rules.

4.2 Operating Person Responsible

4.2.1 The Operating Person Responsible is the member of the crew of a non-self-propelled underwater unit (e.g. a bell) who is responsible for the operation of the unit during the mission.

4.3 Diving Superintendent

4.3.1 The Diving Superintendent is the person responsible for the maintenance and operational efficiency of the underwater units, whether self-propelled or non-propelled, manned or unmanned, as well as of the systems relevant to the underwater activity fitted on the supply vessel. He follows the activity of all units under his supervision directly from the supply vessel throughout the mission.

4.4 Duration of the underwater mission

4.4.1 The mission starts when the operating personnel enter the unit and ends when they exit from the unit into the external atmosphere.

4.5 Vehicles of major or large size

4.5.1 Vehicles of major or large size are vehicles having maximum length L of the pressure hull greater than 20 m.

4.6 Vehicles of minor or small size

4.6.1 Vehicles of minor or small size are vehicles having maximum length L of the pressure hull equal to or less than 20 m.

4.7 Isobaric or normobaric or neutrobaric pressure

4.7.1 Isobaric or normobaric or neutrobaric pressure is an absolute pressure not greater than 0,2 MPa. An isobaric operation means one carried out at isobaric pressure.

4.8 Hyperbaric pressure

4.8.1 Hyperbaric pressure is an absolute pressure greater than isobaric pressure. A hyperbaric operation means one carried out at hyperbaric pressure.

4.9 Operating time

4.9.1 Operating time is the time the unit takes, in normal conditions, to submerge, reach the working site, perform the planned underwater operations and emerge again. The operating time is calculated from when the last porthole is closed until the same porthole is reopened. See [4.4].

4.10 Decompression

4.10.1 Decompression is the slow return from hyperbaric pressure to isobaric pressure.

This treatment is to be adopted for divers after they have performed activity in hyperbaric conditions.

5 Certification that can be issued to underwater units

5.1 General

5.1.1 Underwater units may be issued with a Certificate of Classification according to the indications given in Sec 2 or with other statements of conformity specifically requested by the Interested Party. It is understood that, whatever the certification issued, the necessary checks are to be carried out on the basis of the requirements contained in these Rules.

5.1.2 *(1/7/2023)*

For modular diving systems, the following criteria applies:

- the modular system is to be assigned with a Certificate of Classification, encompassing all the modules that are part of the system;
- each module that can be operated independently from other parts of the system is to be assigned with its own Certificate of Classification;
- modules that are intended to be operated only together with other parts of the modular diving system are to be provided Certificate of Compliance to the applicable Tasneef Rules, with the same validity and anniversary dates of the Certificate of Classification of the modular system.

6 Use of underwater units

6.1 Main underwater activities

6.1.1 The most common services to which underwater units may be assigned are listed below; any services not included in the list will be given particular consideration:

a) **observation**: exploration, inspection of submerged works, construction survey of submerged arrangements, research, hydrographical surveys, oceanographic studies, spotting;

b) **work**: fishing, digging, drilling, extraction, drawing of samples from the seabed, carriage, maintenance and repair of submerged parts, building of underwater structures and plants, various installations, rescue, demolition, salvage;

c) **supply**: assistance to underwater works;

d) **tourism**: carriage of passengers (see Part E).

6.2 Weather conditions with regard to launching and hauling

6.2.1 If the diving systems are linked to a surface unit, their operation is subject to the limitations concerning weather conditions specified in the certification of the surface unit.

Launching and hauling are linked to the features of the supply unit (and, in any event, are decided by the Operating Person Responsible).

6.3 Use with continued assistance from the supply unit

6.3.1 In this case, the supply unit-underwater unit combo is considered a single operational set with regard to equipment, spare parts and living arrangements.

7 Items of class

7.1 General

7.1.1 The Certificate of Classification deals with the following parts:

a) hull structures (pressure and light shell) and relevant accessory parts such as covers and portholes;

b) propulsion system;

c) auxiliary machinery and relevant systems, if intended for essential services;

d) electrical system;

e) complete diving system, including all components and installation on board the supply unit, with regard to its operational functionality.

7.1.2 Fire protection, detection and extinction

As a rule, the requirements regarding fire protection, detection and extinction are not mandatory for classification purposes, except when Tasneef carries out surveys relevant to those requirements on behalf of an Administration.

In that case, fire requirements are considered a matter of class and consequently at class surveys compliance with those requirements is verified by Tasneef for classification purposes.

7.1.3 The Certificate of Classification does not deal with the following parts:

- types of breathing mixtures used in hyperbaric technology and their stowage conditions;
- methods of use and operation of underwater units;
- methods used by divers such as decompression stops, repetition of immersions;
- requirements of a medical nature.

SECTION 2 CLASSIFICATION NOTATIONS

1 Categories and types of underwater units

1.1 Categories

1.1.1 Premise *(1/7/2023)*

For classification purposes, units for carrying out underwater activities are assigned to the categories indicated in [1.1.2], [1.1.3] and [1.1.4].

1.1.2 Propelled underwater units

Units (vehicles, apparatuses or systems) fit to operate below the water surface or which can be used, both on the sea surface and submerged, to carry out specific underwater activities and fitted with means for their propulsion.
Notation (self-propelled underwater units): **MLS p**

1.1.3 Non-propelled underwater units

Units defined as in [1.1.2] not fitted with means for their propulsion.
Notation (underwater units): **MLS**

1.1.4 Diving support systems *(1/7/2023)*

Systems or modules operating above the water surface to support diving activities (e.g. decompression chambers, ventilation systems, etc.).
Notation (diving support): **DSU**

1.2 Types

1.2.1 Premise *(1/7/2023)*

The most common types of underwater units are listed in item [1.2].

For the purposes and within the limits of the provisions of the Tasneef Rules, underwater units may be of particulartypes, if considered so constructed and/or arranged as to be able to perform services such as those listed in Sec 1, [6.1].

Units that can perform more than one service are to comply with the requirements related to each service and to provide the operational performance necessary to shift from one service to another.

Units or Modular Diving Systems that are intended for services that are not listed in Sec 1, [6.1] may be assigned with the service notation **special service**. The classification requirements of such units are considered by the Society on a case by case basis.

An additional service feature may be specified after the notation (e.g. special service - submarine rescue system) to identify the particular service in which the unit is intended to operate. The scope and criteria of classification of such units are indicated in an annex to the Certificate of Classification.

Where units operate in manned conditions, the relevant type notation will be indicated with the letter (m) as a suffix, e.g. **Submarine (m).**

1.2.2 Vehicles and other apparatuses performing underwater activities

a) **Submersibles**
   1) Underwater units fit to sail in fresh or salt water, manned or unmanned, mainly afloat, but which are also capable of submerging, proceeding and operating underwater and re-emerging to the surface, without impairing the safety of persons on board.

      They may be required to operate in the vicinity of a supply vessel at sea or a base located ashore. Usually they are self-propelled units which, if of small size, may be towed on the sea surface during transfer voyages, if any.

      Notation: **Submersible**
   2) A particular type of submersible consists of **submersible pontoons**, which are units capable of being partially submerged so as to embark cargoes on deck and then re-emerge after the cargo has been embarked.
      Notation: **Submersible pontoon**
   3) Submersible pontoons indicated in 2) provided with arrangements and systems fit for the launching of heavy cargoes lashed on the deck, such as offshore structures, are given the additional notation "launching".
      Notation: **Submersible pontoon launching**

b) **Submarines**

   Underwater units fit to sail in fresh or salt water, manned or unmanned, mainly underwater, but which are also capable of proceeding afloat, without impairing the safety of persons on board (see also Pt B, Ch 2, Sec 1, [1.2.1] b)).

   They may be required to operate in the vicinity of a supply vessel at sea or a base located ashore or underwater.

   Usually, they are manned self-propelled units which, if of small size, may be towed on the sea surface during transfer voyages, if any.

   Notation: **Submarine**

c) **Bathyscaphes**

   Submarines capable of operating at a depth greater than 1000 m.

   Notation: **Batiscaph**

d) Mesoscaphes

Submarines capable of operating at a depth not greater than 1000 m

Notation: **Mesoscaph**

e) **Bathyspheres**

Bathyscaphes whose pressure structure is spherical.

Notation: **Bathisphere**

f) **Mesospheres**

Mesoscaphes whose pressure structure is spherical.

Notation: Mesosphere

g) **Digging units to bury underwater pipelines and cables**

Usually they are units that can be used unmanned, towed to the operation site, or embarked on a supply vessel.

Notation: **MSS**

h) **Hyperbaric Diving Bells**

Apparatuses that are usually intended to accommodate persons in a hyperbaric atmosphere.

Notation: **Hyperbaric Diving Bell**

i) **Isobaric Diving Bells**

Apparatuses similar to those defined in (h) intended to accommodate persons in an isobaric atmosphere.

Notation: **Isobaric Diving Bell**

j) **Remotely operated submarine**

They are particular types of submarines, unmanned, free moving or connected to an umbilical cable, used for surveys or for varying underwater activities, such as hull cleaning of floating units, cleaning of underwater structures, inspection of underwater structures, underwater photographs.

Notation: **ROV**

k) **High depth diving suit**

They are rigid shells having hinges at legs and arms, fitted with appliances for carrying out underwater works, which accommodate an operator.

They are permanently connected to a supply vessel.

They allow underwater work at a maximum depth of 500 m, in isobaric conditions, with underwater currents having a maximum speed of 2 knots.

Notation: **Diving suit**

1.2.3 Submerged installations

a) **Habitats**

They are submerged installations, anchored on the seabed, designed to provide a comfortable environment for underwater operators who have completed their underwater work shifts or are waiting to be moved elsewhere.

Use of these habitats is foreseen at depths not greater than 200 m.

Notation: **Habitat**

b) **Submerged laboratories**

They are arrangements provided with telescopic legs that enable the structure to rest on an uneven seabed. The lower parts of the legs are provided with long vertical blades which improve their penetration in the seabed. They may contain accommodation spaces and openings which allow the underwater operators to get out and in. In this case, if the laboratory operates in an isobaric atmosphere, it is to be provided with a decompression chamber.

Notation: **SEALAB**

c) **Submersible igloos**

They are arrangements usually anchored on the seabed, having a hemispheric shape and a diameter of about 2 m, provided with complete and efficient outfitting for at least one underwater operator.

In these igloos at least one operator can stay and survive; they are used as a refuge not far away from the working site.

In some cases they can be connected by means of a steel cable to a laboratory or a habitat and can be recovered by winding up the cable on a drum.

Other types are self-propelled (with very limited range) and are operated as true submarines, where the crew can go in or out of a suitable door.

Notation: **Submersible Igloo**

d) **Stowage reservoirs**

Reservoirs, usually spherical in shape, anchored on the seabed, also at great depths, intended to contain liquids or gases extracted from the seabed.

Notation: **Stowage Reservoir**

1.2.4 Decompression chambers

Apparatuses that can be fitted on board a supply vessel or at a base ashore and that are used for assistance to underwater operators.

Notation: **Decompression Chamber**

1.2.5 Systems for carrying out underwater activities (diving systems)

They are systems usually consisting of:

a) diving bells or other units and arrangements for carrying out underwater activities

b) decompression chamber

c) equipment and appliances for launching and hauling diving bells or other underwater units

d) systems for the production, checking and distribution of mixtures of oxygen and other gases for the supply of the breathing systems used for carrying out underwater activities, including umbilical cables.

General notation: **Diving System**

1.2.6 Modular systems for carrying out underwater activities (modular diving systems) *(1/7/2023)*

Modular systems are consisting of different underwater units or systems, operated by the same owner, each provided with its own Certificate of Classification or Certificate of Compliance, that can be employed together as a Diving System.

General notation: **Modular Diving System**

2 Certificate of Classification

2.1 General

2.1.1 *(1/7/2023)*

The units indicated in [1.2] above can be issued a Certificate of Classification in accordance with the requirements stipulated hereafter.

2.1.2 As far as the issue, filling in, validity and endorsements of the Certificate of Classification are concerned, the relevant requirements of Part A of the Rules apply, unless otherwise specified in these Rules. In particular, as far as the filling in is concerned, the following applies.

Where the main moulded dimensions are requested, the maximum dimensions of the pressure hull and those of the light hull are indicated; for the pressure hull, overall length, out-of-plating breadth and maximum depth (including turret); for light hull, the Rule dimensions of surface ships.

In the section dedicated to hull equipment, if the unit is required to always operate in the vicinity of a supply vessel, it will be indicated that it is located on the supply vessel.

The following will be specified on the Certificate of Classification:

- whether continued assistance, and at what distance, from a supply vessel is foreseen;
- if necessary, the worst weather and sea conditions in which the unit may be fit to sail, both on the sea surface and in immersion or emersion (as for the wave height to be indicated on the Certificate, see Pt B, Ch 2, Sec 1, [1.3]);
- the maximum operating depth, indicated in letters and not in numbers;
- that the operation of the unit is subject to compliance with the requirements indicated in the user manual (see [6.7]);
- that the weather and sea conditions during operations are to be such that the unit can in fact be operated;
- whether the transfer voyages are to be carried out under tow or not;
- whether the unit is self-propelled or not. In the case of self-propelled units, the main characteristics of the propulsion systems are to be indicated; in the case of non-self-propelled units, it will be indicated that "the unit is without propulsion systems";
- whether the unit is operated "manned" or "unmanned";
- whether or not the unit is operated with an umbilical cable or with another restraint from the supply vessel;
- whether the unit is provided with traction systems on the seabed (e.g. caterpillar tractor) or other similar systems enabling it to move on the seabed;
- if deemed necessary, the mechanical and chemical characteristics of the steel used for the construction of the hull (both pressure and light hull);
- the statement, if applicable, indicated in Pt B, Ch 1, Sec 1, [2.2].

2.1.3 *(1/7/2023)*

For **modular diving systems**, as defined in [1.2.6], the following information will be specified on the Certificate of Classification of the system:

- list of the underwater units or systems that are part of the modular system with the indication of the number of the Certificate of Classification or Certificate of Compliance of each unit or system, as applicable;
- list of possible configurations of the system, if more than one exists;
- indication that the operation of the system is subject to compliance with the requirements provided in the user manual (see [6.7]).

3 Conditions for classification and characteristics of class

3.1 Symbols, characteristics of class and navigation

3.1.1 The provisions indicated in Chapter 1 of the Rules apply. No navigation notation is assigned to the units indicated in [1.2.2] k), [1.2.3] and [1.2.5] c) and d).

As a rule, in most cases (especially for small size units) the navigation notation may be completed by:

- the wording "in weather and sea conditions such that the unit can operate and with continued assistance from the supply vessel";
- the indication of the operational area, if any, as well as of the navigation limitations imposed by Tasneef on the basis of the average weather and sea conditions in the geographical area where the unit is intended to operate, also taking account of the dimensions and characteristics of the unit itself.

On the Certificate of Classification, if the materials are not suitable for low temperatures (e.g. if the unit cannot operate in polar areas), the geographical operational limits are to be specified, considering the ambient conditions in which the unit operates and is manoeuvred (e.g. a diving bell that can be lowered to sea directly through a moon-pool from a warmed-up hangar may not be considered operational at low temperatures).

If the shape and dimensions of the unit are such that it is not fit to sail in any sea state, navigation for transfer under tow is not to be extensive so that favourable weather and sea conditions can be relied on. On the other hand, these conditions are also necessary for the immersion and emersion manoeuvres associated with the underwater service for which the unit is intended.

If the unit is intended to operate in fresh water, the operational area will be indicated on the Certificate of Classification.

4 Classification of systems and apparatuses for underwater work, if any, fitted on board a supply vessel

4.1 General

4.1.1 The supply vessel may be classified in accordance with the provisions of the Rules for the Classification of Ships; for the classification of systems and apparatuses relevant to the particular operation of the supply vessel, the specific requirements of the same Rules are to be applied.

At the request of the Interested Party, the systems and/or apparatuses fitted on the supply vessel, as complementary services to diving systems, may not be covered by the Certificate of Classification of the vessel; in that case, an appropriate statement will be endorsed on the certificate.

Also at the request of the Interested Party, the systems and/or apparatuses may be classified separately or together with the underwater unit to which they are fitted.

If the supply vessel is provided with a dynamic positioning system, the latter is to be tested during sea trials; otherwise it will be put out of service.

4.2 Additional class notation: DIVING SUPPORT

4.2.1 Tasneef assigns the additional class notation **DIVING SUPPORT** to supply vessels provided with diving systems complying with the provisions of these Rules and with the requirements of Part F, Ch 13, Sec 14 of the Rules for the Classification of Ships.

5 Register of ships

5.1

5.1.1 The Register of ships contains the vehicles, apparatuses and systems for underwater work provided with a Certificate of Classification.

6 Technical documentation

6.1 Premise

6.1.1 For each unit for which the issue of the Certificate of Classification is requested, the technical documentation required in the following paragraphs is to be submitted to Tasneef may also call for additional documentation, at its sole discretion, on a case-by-case basis.

The calculations and data contained in the technical documentation are to provide sufficient technical, theoretical and bibliographical references, where necessary.

6.2 General information

6.2.1 The following information is to be supplied with the request for classification:

- the building yard, the building place and, in the case of existing units, also the year of build;
- the assigned name and the former names (given in chronological order);
- any Classification Society, in addition to Tasneef, requested to issue a Certificate of Classification or, for an existing unit, which issued the Certificate of Classification (or the Authority which issued documents of fitness for the service formerly performed);
- the last period of class with the former Classification Society;
- the service for which the unit is intended;
- the requested navigation, with indication of the maximum number of persons on board, the extent of the voyages and the most severe weather and sea conditions the unit can cope with;
- whether or not the unit will be operated with the assistance of a supply vessel.

6.3 Documentation requested for units surveyed by Tasneef during construction

6.3.1 In addition to the documents requested in the specific parts of these Rules, the following documentation is to be submitted to Tasneef for examination and approval, where applicable:

a) detailed construction plans of all the structure, with indication of the scantlings, connection types and characteristics of the materials used;

b) diagrams of the apparatuses and systems installed for the on board services, including the sanitary discharge systems;

c) sufficient documentation for the checks deemed necessary;

d) detailed hypothesis and assumptions on which the design is based;

e) the calculations performed on the basis of the above-mentioned assumptions, with a view to proving the adequate strength of the structures, as well as the efficiency and functionality of the propulsion system, steering gear and various systems;

f) testing data and tests performed on prototypes or samples, if any, with pressure measures corresponding to the collapse depth and stress levels during operation;

g) calculations relevant to the stability of the unit in the various operating, navigational and manoeuvring conditions;

h) structural strength calculations showing the stress level attained with the allowable geometric variations;

Note 1: Also after checks during building and assembly, both in the pre-constructed parts and in those built, variations to the geometry of the pressure hull (see Ch 2, Sec 2, [2.7]) may be found; those defects (deviations from the circular shape or not exact alignment of the joints) may impair the resistance of the structure.

i) the user manual indicated in [6.7].

The documentation in a), b) and c) is to be submitted in triplicate, that in g) in quadruplicate (see Pt B, Ch 2, Sec 1, [1.4]).

Taking into account the requested service, Tasneef will consider the calculation assumptions and then the calculations themselves, reserving the right to call for additional calculations, even with different assumptions, if deemed necessary.

6.4 Documentation requested for units classed by an IACS Society

6.4.1 One copy (unless otherwise specified) of the documentation listed hereafter is to be supplied to Tasneef, together with the assumed hypotheses and strength calculations of the structures and stability calculations of the unit. If the unit undergoes alteration or modification works, the relevant plans are to be submitted to Tasneef for examination in triplicate, together with a single copy of the plans of the original arrangements.

Documentation to be submitted for examination:

a) copy of the Certificate of Classification (or of the documents of fitness issued by an Authority) issued by the former Classification Society, indicating the service assigned to the unit in question and the navigation in which the unit can be operated, together with any limitations such as weather and sea conditions or assistance from a supply vessel;

b) reports from the former Classification Society regarding the last class renewal survey (hull, machinery and systems);

c) survey status with indication of any outstanding recommendations;

d) lines plan;

e) construction description of the unit;

f) hydrostatic curves, including the case with the unit fully submerged;

g) general arrangement;

h) capacity plan, with indication of volumes as well as the baricentric coordinates of the various tanks and spaces;

i) midship section, with indication of the various materials of the hull, including their mechanical and chemical characteristics, confirmed by the former Classification Society or the building yard.

   Where those indications are not given, Tasneef reserves the right to decide whether to accept the materials according to the outcome of specific checks which will be selected on a case-by-case basis. The plan is also to indicate the main construction particulars, the details of the connections and procedure, the welding checks and the corrosion prevention systems. In the case of a unit intended for the burial of underwater pipelines and cables, the type of soil to be dug is to be indicated together with the cutting resistance of that soil at the surface and at the excavation depth plus one metre, as well as the maximum slope to overcome and the type of soil to be dug with indication of its compression resistance. For these particular units the maximum diameter of the pipes to be buried, the excavation depth, the shape of the trench section and the volume per hour of the soil dug are also to be indicated.

   The shape and material of the blades used are also to be indicated on the drawing of the tracks (of different size and shape in relation to the type of soil on which the unit is intended to work);

j) scantling plan (longitudinal sections and decks);

k) shell expansion (both of the pressure hull and light hull), with indication of all the openings and hull penetrations and relevant increased thickness plates around them.

   For large size units, a "Record" is to be kept containing all the penetrations of pipes and electrical cables through the pressure hull and the internal strength structures, such as watertight bulkheads;

l) framing plan (of pressure hull and light hull);

m) construction drawings and/or other documentation relevant to:

   1) (all) watertight bulkheads,

   2) access hatches, windows, portholes, transparent domes,

   3) horizontal and vertical rudders: structure of the blade and stock, with indication of the maximum speed the unit develops while navigating afloat and in immersion,

   4) other steering devices, such as thrusters; this documentation must include the function diagram or the description of the steering apparatuses,

   5) appliances for seabed supports and their connection to the hull,

   6) sterntubes, bosses, bracing of the propeller shafts, if any, and their connections to the hull,

   7) superstructures,

   8) pressure tanks,

   9) hull equipment, indicating diameter, material and ultimate tensile stress of the chains; if the anchors are connected to steel cables, the composition of the cable (number of wires, strands, and textile cores) shall also be specified; plus a copy of the testing certificates of the anchors and chains (or anchor cables) fitted on board;

n) construction drawings relevant to pressure receptacles, both internal and external to the pressure hull, indicating the maximum internal working pressure, the design pressure and the material used,

o) specification of the main engines, with indication of the builder, type and maximum continuous power and relevant rpm. Also, the year of build of the main parts of the propulsion system is to be specified,

p) diagrams and functional schemes of the:
   1) piping for fuel oil, lubricating oil and cooling water for engines,
   2) compressed air piping,
   3) piping for high and low pressure water ballast,
   4) piping for hydrodynamic control systems, where the capacity and head of the pumps and compressors are indicated, as well as the dimensions and materials of the pipes and the material in which tanks and receptacles for fluids are built,

q) construction drawings relevant to the shafting, with indication of the materials used and sealing appliances,

r) construction drawings relevant to the propellers or other propulsion devices, with indication of the materials used,

s) general diagram of the electrical system,

t) detailed diagram of the main electrical switchboard,

u) diagram of the electrical system using accumulator batteries and relevant safety arrangements, indicating the number, type and characteristics of the accumulator batteries;

v) characteristics and type of the sonar system;

w) characteristics and type of the telephone system to communicate with the surface supply vessel (underwater ultrasound telephone);

x) list of the safety means and equipment;

y) diagram and characteristics of the (main and emergency) breathing system;

z) construction drawing of the bottles containing oxygen for the breathing system, with indication of their capacity, maximum working pressure, materials used and their characteristics and relevant testing certificates;

aa) description of the systems to eliminate carbon dioxide, with indication of materials used and relevant testing certificates;

ab) diagram of the system to control contamination of the breathing atmosphere inside the unit, with relevant testing certificate;

ac) diagram of the system to control air temperature and humidity;

ad) description and type of the instrumentation relevant to all the safety arrangements (hydrogen detectors in the battery spaces, various sensors, leakage detectors, and so on);

ae) plan of the arrangements for food and potable water;

af) description of the arrangement for the system for garbage elimination;

ag) description of the system for remote control of the main and auxiliary engines;

ah) description of the systems and appliances to be used in the case of an emergency;

ai) stability calculations with the unit in the following conditions (in quadruplicate): floating, fully immerged, during immersion, during emersion and, in the case of an emergency, with one or more ballast tanks unusable due to damage (see Pt B, Ch 2, Sec 1, [1.3]);

aj) user manual (see item [6.7] below).

Tasneef reserves the right to request additional documentation, checks, surveys and tests as a consequence of the examination of the foregoing documentation and of the outcome of the required surveys.

6.5 Documentation requested for units not classed by an IACS Society

6.5.1 A copy of the same documentation is requested as for new buildings indicated in [6.3.1].

6.6 Other documentation requested

6.6.1 For each unit, whether a new or existing building, the following lists are to be filled in and supplied to Tasneef:

a) a complete list of each piece of machinery and system fitted on the unit, with indication of its main characteristics (for all the services on board);

b) a list of the special tanks on board (see Pt B, Ch 1, Sec 1, [3]), with indication of their capacity and coordinates of their centre of gravity;

c) a list of the service tanks on board (fuel oil, water, lubricating oil, etc.), with indication of their capacity;

d) a list of all the pressure receptacles, with indication of their capacity, and working and design pressure, as well as the coordinates of relevant centres of gravity.

6.7 User manual

6.7.1 *(1/7/2023)*

The user manual (or operation manual or instruction and maintenance manual) is to be kept on board the unit and/or the relevant diving support vessel, as applicable, and is to serve as information and guidance for the personnel on board in situations that may occur during the operating phases of the unit and/or the systems and for the checks that are to be carried out.

6.7.2 At each survey it is to be verified that the user manual is available on board. The manual is to include:

a) the front page, with indication of the total number of pages it consists of;

b) the contents;

c) the instructions relevant to use and maintenance of all the systems and appliances fitted on board, supplemented with particular and general diagrams. Special attention is to be given to the procedure to pump down the ballast double bottom tanks, specifying the depth at which they can be emptied by means of compressed air (see Pt B, Ch 1, Sec 8, [4.1.1]);

d) general plan with all openings and hull penetrations;

e) schematic plan of the items of machinery and systems fitted on board for the various services;

f) list of all the apparatuses and instruments fitted on board, divided according to the various services.

6.7.3 In the user manual, all the typical most significant data are to be listed as follows:

a) dimensions of the unit;
b) mechanical and chemical characteristics of the material the pressure hull is built of;
c) operative range;
d) displacement (weight in air, for small size units);
e) maximum and normal operational speed (navigating on the sea surface and in immersion);
f) maximum number of persons on board;
g) maximum operational depth (for units operating in hyperbaric conditions, such as diving bells, maximum difference between external and internal pressure);
h) data relevant to the stability cases considered in the Stability Booklet for the Master (or Pilot, for self-propelled units of small size);
i) characteristics of the propulsion system;
j) periodical checks.

6.7.4 *(1/7/2023)*

For modular diving systems, the manual is to include the following information:

a) list of all the modules that are part of the system with the indication of the main technical characteristics;
b) details of all the interfaces and connections of the underwater units that are part of the modular system;
c) list of any possible configuration of the modular system with the indication of the relevant operative instructions and limitations;
d) detailed instructions for the change of configuration of the system or replacement of a module;
e) information regarding the checks before use of the modular system.

6.7.5 In the manual, annotations are to be endorsed and pointed out stating that:

a) for any repair or modification, even if of minor scope, affecting the pressure hull or parts connected to it, prior approval from Tasneef is to be obtained. Otherwise, the unit's class will be automatically suspended;
b) for modifications causing a substantive variation to the stability characteristics of the unit, new stability calculations are to be submitted to Tasneef for examination and then a new inclining experiment is to be carried out in the presence of a Tasneef Surveyor. The necessary variations will need to be included in the Stability Booklet. Otherwise, the unit's class will be automatically suspended.

6.7.6 In addition to the requirements listed in the foregoing paragraphs, the manual is to contain information, indications and annotations for the following items:

a) information on safety (with a detailed description of the safety systems) and relevant operations, including the recovery systems also with the unit at full load, as well as the preliminary operations to be carried out prior to every mission. All the manoeuvres necessary for the manual functioning of the essential services are also to be illustrated in detail, as well as the operations to be carried out in the case of an emergency. Particular attention is to be given to the safety measures, which prevail over all the other services; therefore a lot of space is to be dedicated to explaining how the valves are to be checked, the breakers are to be closed, etc. in order to verify the correct position of levers and buttons so as to be absolutely sure of the manoeuvres necessary when manual intervention is needed;
b) indications relevant to all the service cases of the unit, including mooring in port and use in polar areas, where icing can, for instance, lock the valves;
c) information on the operations foreseen for the maintenance and overhaul intervals of the various parts; for the propulsion engines the running hours foreseen and effected between two consecutive overhauls are to be indicated. The personnel on board are to carry out the above-mentioned checks at the required intervals and record the results in the log-book;
d) indications relevant to:
    - limitations, if any, on use owing to stability,
    - speed of the sea current that can be overcome by the propulsion system,
    - maximum sea and wind force the unit can withstand on the sea surface;
    - maximum descent and/or ascent speed (it is assumed 0,3 m/s, if not otherwise specified);
e) annotations to be recorded which refer to:
    - the various operations such as launching, recovery, dry-docking,
    - in the case of large size units, filling up the trim tanks, balance tanks and the fuel reserve in the tanks.

      All filling-up relevant to the last immersion is to be reported in the immersion table, available to the Master.

      For each unit, a record of the weight movements is to be kept with indication of their horizontal distance from the vertical line passing through the centre of gravity or centre of buoyancy of the unit, so as to be able, at any time, to return to an equilibrium situation starting from an equilibrium status;
f) in the case of units having little reserve buoyancy and thus with small freeboard, the warning that the personnel shall embark or disembark only when the unit is lashed to the supply vessel and carry out the checks prior to every immersion when on board the same vessel;
g) instructions regarding first aid to injured persons (in accordance with the types of accidents that operators can have);
h) annotations regarding the drills, periodically performed by the crew, relevant to the use of safety devices and first aid appliances, as well as the instruction courses given to the personnel;
i) information on the nutritional methods, stowage and processing of food and water, as well as on the

preparation of food and treatment of rotten foods (only for large size units);

j) annotations regarding the inspections of food and potable water containers by the crew;

k) particular information for the maintenance of the oxygen system and indication of the date of the last check of the system;

l) warning that, at the beginning of every mission, a new capsule and a new container of the chemical element used to deplete carbon dioxide, as well as new filters for dust (when used), are to be fitted;

m) instructions regarding the maintenance operations to check pollution of the breathing mixture. This maintenance depends upon the type of system:
   - a system with a static check only needs the replacement of the chemical compound,
   - a system that works on the absorption and adsorption method needs maintenance of the air circulating circuit and replacement of the filters (e.g. carbon filters),
   - an absorption and adsorption catalytic system needs maintenance of fans and heaters, as well as replacement of the chemical catalyst compound and of the absorption-and-adsorption capsules;

n) information regarding the checks and maintenance program;

o) arrangements and procedures to cope with the development of gaseous chlorine (for large size units);

p) arrangements and procedures for pressurising the spaces (for large size units).

A "checklist", agreed with Tasneef, may partially or totally replace the foregoing items from (a) to (p).

7 Types of surveys

7.1 General

7.1.1 A unit is issued a Certificate of Classification only after it has undergone an admission to class survey. In order to maintain its class during its life, a unit is to undergo the following periodical surveys, according to the time schedule and methods specified in Chapter 2.

a) Class renewal survey (dealing with both hull and machinery);

b) Annual survey (dealing with both hull and machinery);

c) Intermediate survey;

d) Dry-docking survey;

e) Tailshaft survey;

f) Surveys relevant to specific systems.

   The following other non-periodical surveys are to be carried out, when due (see items (g) and (h);

g) Occasional surveys, which can separately deal with hull, machinery, electrical system and other parts;

h) Recommissioning surveys.

Lastly, periodical inspections and tests are to be carried out by the crew or appropriately designated personnel, as indicated in Ch 2, Sec 1, [6].

Part A
Classification and Surveys

Chapter 2
SURVEYS

SECTION 1 SURVEY REQUIREMENTS

1 Application

1.1 Premise

1.1.1 As far as survey requirements are concerned, those given in Sections 1, 2 and 3 apply in addition to those given in Part A of the Rules, as applicable.

1.1.2 The surveys provided in this Section can be expanded to the extent deemed necessary and, in the case of particular units, modified.

Any parts found not complying with the applicable requirements or in unsatisfactory condition are to be properly modified or, preferably, replaced, unless otherwise determined by Tasneef.

2 Survey for the assignment of class

2.1 Units surveyed by Tasneef during construction

2.1.1 For units surveyed by Tasneef during construction, class will be assigned according to the provisions of the Rules, as far as applicable and taking account of the particular requirements indicated in Sec 2. At the end of construction, the unit will be submitted to the tests indicated in Sec 3.

2.2 Units classified after construction

2.2.1 Units classed with an IACS Society

The procedure for the assignment of class is the following:

- examination by Tasneef of the required documentation (see Ch 1, Sec 2, [6.4]);
- execution of the required surveys, listed below, which may be supplemented by checks deemed necessary, considering the particular type of the unit, also taking account of the examination of the documentation referred to in the foregoing item;
- dry-docking survey, sea chests and relevant valves, propellers, tailshafts; inspection and hydrostatic test of reservoirs and/or bottles for compressed air may generally be postponed to their regular expiry date, if they are not required with regard to the work carried out during the survey for the assignment of class, provided that a copy of the reports relevant to the last survey of those parts is supplied;
- execution of the immersion test to the maximum operational depth. If the unit is used at an operational depth less than 500 m, the immersion test may not be required, if its execution is confirmed by an appropriate annotation or statement by the Society with which the unit is duly classified.

  An immersion test to a depth greater than the operational depth is not covered by the regular insurance of the pilot and crew of the unit.

Upon satisfactory outcome of the above-mentioned surveys, an Interim Certificate of Classification is issued for use as a Certificate of Classification .

The Interim Certificate of Classification can only be issued if a sufficient number of survey items, relevant to hull and machinery, have been surveyed to allow an evaluation of whether the unit is eligible to be classed for the foreseen period.

The survey for the assignment of class for a period of 5 years is to include all the survey items required; it may be carried out in more than one session and is to be completed within 12 months of commencement; any recommendations are also to be dealt with within that period, unless an earlier deadline has been given.

The survey items for the assignment of class until the expiry date of the renewal survey assigned by the former Society are:

- annual hull survey;
- survey of cofferdams;
- survey of engine room, under and above flooring;
- survey and test of bilge suctions;
- annual machinery and systems survey;
- survey of the fire protection (for units intended for the carriage of passengers) (see Ch 1, Sec 1, [7.1.2]);
- survey and test of the fire-fighting appliances with the scope of a class renewal survey (see Ch 1, Sec 1, [7.1.2]);
- survey with the scope of a class renewal survey of some parts, disassembled to the Surveyor's satisfaction, of the main engines and auxiliary machinery for the essential services of hull and machinery;
- running test of the propulsion system and essential machinery.

As far as thickness measurements are concerned, the previous thickness measurement results should be submitted, if possible. However, Tasneef reserves the right not to accept those results, either partially or totally, and to stipulate the relevant conditions.

If the unit was under the Continuous Survey System of Hull and/or Machinery for renewal survey with the former Classification Society and if that system is not kept with Tasneef as well, in addition to the previous surveys all the Continuous Survey items surveyed more than one year before the commencement date of the class period with the former Society are also to be surveyed.

The survey for the assignment of class is to be carried out in one session and is to be completed before the Interim Certificate of Classification is issued. Any recommendations are to be dealt with not later than 12 months from the commencement of the survey for the assignment of class, unless a shorter period has been given.

2.2.2 Units not classed with an IACS Society

For existing units that have never been classed by other IACS Societies, the survey for admission to class is to be a complete survey with any additional checks deemed necessary by Tasneef; the various survey items are, in terms of scope, to be not less than that indicated in the foregoing requirement [2.2.1].

As regards materials, main and auxiliary machinery, apparatuses and systems for which, as a rule, Tasneef testing is required, their acceptance is subject to submission of alternative supporting documentation issued by bodies recognised as qualified by Tasneef or, if such documentation is not available, to the execution of adequate checks and tests (including non-destructive examinations), provided that permission is granted by Tasneef.

The above requirement is a condition for classification of the unit and can give rise to recommendations which impose work to be carried out.

In any case, exhaustive running tests of machinery, systems and their components are to be performed, as requested by Tasneef Surveyors.

The Interim Certificate of Classification can be issued only after the survey has been completed in full, except for recommendations and work, if any, to be dealt with in the above-mentioned period of 12 months from the commencement of the survey, subject to the judgement and discretion of Tasneef.

2.2.3 Issue of the Certificate of Classification

The full term Certificate of Classification will be issued after the relevant survey reports have been examined.

2.2.4 Application of different rules

For the classification of existing units, national and international rules of recognised bodies may be applied. In such case, the certificate issued will specify the basis and assumptions on which the unit concerned has been classified.

2.3 Modular Diving Systems

2.3.1 *(1/7/2023)*

Modular diving systems can be assigned with a Certificate of Classification only when:

- all the underwater units that are part of the system are provided with their own Certificate of Classification issued by Tasneef, in due course of validity;
- all the underwater units that are part of the system are managed by the same owner;
- any other component, required for the operation of the modular system, which is not provided with its own Certificate of Classification is to be approved and tested by Tasneef, as applicable, and provided with a Certificate of Compliance issued in accordance with Ch 1, Sec 1,[5.1.2].

Before the assignment of the Certificate of Classification, the system will be submitted to the tests indicated in Sec 3.

2.3.2 *(1/7/2023)*

In case of automatic class suspension for overdue surveys of one or more of the modular diving system modules, the certificate of classification of the modular system maintains its validity only for the modular system configurations which do not include the module/s for which the classification is suspended.

3 Hull and machinery periodical surveys

3.1 Class renewal surveys

3.1.1 Periodicity, surveys in advance and postponements

a) For all types of units, class renewal surveys are to be carried out not later than 5 years from the previous one.

The first class renewal survey is to be carried out not later than 5 years after the date of entry into operation.

b) The Interested Party has the right to have class renewal surveys carried out in advance or delayed with regard to the regular expiry date; in any event, the expiry date of the next survey is not modified. However, advance periods and delays greater than 3 months are not allowed.

In particular cases where, at the request of the Interested Party, the scope of an annual survey is so expanded as to reach the scope of a class renewal survey, the expiry date of the subsequent class renewal survey is modified and is calculated from the date of completion of that survey.

c) The periodicity indicated in a) may be reduced, if deemed necessary by Tasneef, considering the type of unit and the service in which it is used.

d) The Continuous Survey System for class renewal survey is not allowed, for either hull or machinery.

3.1.2 Survey items to be carried out during the class renewal survey

At the first class renewal survey, the survey items listed under the following points and the pneumatic tests indicated in [3.1.3] are to be performed:

a) check of roundness of the pressure hull (at all frames and all plates in the area between frames) by measuring the local deformations (out-of-roundness);

b) all the survey items required at annual surveys (see [3.2.2]);

c) running test of all apparatuses and machinery with the unit both out of the water (if possible for small size units) and floating in the water;

d) check of the log-book, as well as inspection of all hull equipment (if fitted) and test of the relevant machinery;

e) hydrostatic test of the spaces and reservoirs subject to internal pressure (this test is required for internally accessible units, such as hyperbaric chambers, bells and the like).

The ballast tanks and pressure tanks are to be subjected to hydrostatic testing to a pressure not less than 1,5 times the maximum operational pressure, for working pressures less than 10 N/mm^2, and a pressure not less than 1,25 times the maximum operational pressure, for working pressures equal to or more than 10 N/mm^2.

For units built and not surveyed by Tasneef, for which verification calculations cannot be performed, the test pressure is not to be greater than 1,25 times the maximum working pressure;

f) hydraulic control and/or manoeuvring systems are to be subjected to a hydrostatic test (to a pressure not less than 1,25 times the maximum working pressure) and a running test; the same requirements apply to the ballast system.

The AP and BP pumps for emptying the ballast tanks, balance tanks and trim tanks are to be subjected to a hydraulic test in the workshop for the parts subject to pressure, and a running test on board. The bilge system and manometer system for depth measurement are to be hydrostatically tested;

g) the systems and appliances, if any, containing mercury or mercury mixtures, whose vapours may spread into the accommodation rooms or into the breathing mixture, are to be checked to verify that mercury or mercury vapours have not come out of the relevant containers. Those systems and appliances are not allowed to be fitted on units of new construction;

h) at alternate class renewal surveys, all the reservoirs for compressed air are to be inspected internally, by means of an endoscope or equivalent device, after the hydraulic test to verify that they are clean, dry and in good condition;

i) all the measuring instruments relevant to the safety systems are to be re-calibrated;

j) the oxygen reservoirs are to be clean, i.e. without dirt, humidity and rust, inspected externally and internally (by means of an endoscope, if they cannot be entered) and subjected to a hydrostatic test to 1,25 times the maximum working pressure and a tightness test. Where the relevant piping cannot be inspected internally, a hydrostatic test is considered sufficient.

The remaining part of the system need not be removed from the unit, but is to be protected from impacts and dust when the oxygen reservoirs are fitted and then is to be subjected to a test pressure to 1,25 times the working pressure.

All the hydrostatic tests are to be performed before coating is applied and after internal cleaning. The dripping test, as indicated in Sec 2, [5.2], is also to be performed at the working pressure.

If tightness is not complete, it is considered acceptable that the pressure in the closed circuit does not drop more than 1% in 24 hours.

From the second class renewal survey, the oxygen reservoirs are to be weighed empty and, where the weight has decreased by more than 10% with respect to the original weight, they are to be rejected;

k) the reservoirs for nitrogen, helium and helium-oxygen mixtures are to be inspected externally and internally (even by means of an endoscope) and are to be subjected to a hydrostatic test to 1,25 times the working pressure; where they cannot be internally inspected, the hydrostatic test will be considered sufficient;

l) an immersion test is to be carried out, if possible to the maximum operational depth;

m) the internal atmosphere is to be checked for pollution, verifying whether the carbon dioxide and oxygen levels are within the acceptable limits, when the expected maximum number of persons are on board;

n) a tightness test is to be performed by means of compressed air for the spaces subject to internal pressure;

o) inspection, with the necessary disassembly, of the machinery items for the essential hull and machinery services.

3.1.3 Pneumatic tests

Where, at the request of the Interested Party, some parts are subjected to pneumatic test instead of the hydrostatic test recommended by Tasneef, it is to be performed in a place where a closed circuit television system allows Surveyors to watch the parts under pressure and the manometers from a safe position outside the space containing the tested parts.

The strength test is considered satisfactorily completed after the parts tested have been kept at the test pressure for at least 1 hour while the pressure has not decreased more than 0,5% per hour (compensating for temperature variation, if any).

The test pressure is then reduced to 1,1 times the working pressure and the parts tested are to be directly checked for tightness.

The oxygen circuit may be subjected to pneumatic test by means of dry air or, preferably, dry nitrogen.

3.1.4 Class renewal surveys subsequent to the first

In addition to the requirements for the first class renewal survey, at the subsequent class renewal surveys the thickness of all the plates of the pressure hull is to be gauged by means of ultrasound methods.

Moreover, the main continuous welds of the pressure hull are to be checked by non-destructive methods. At the class renewal survey when the unit is 10 years old, and subsequent class renewal surveys, the thickness of the plates of the light hull is also to be gauged.

3.1.5 Class renewal surveys for modular diving systems *(1/7/2023)*

At all class renewal surveys, including the first, the survey items listed under the following points are to be performed:

- verification that the Certificates of Classification of the underwater units that are included in the system are in regular course of validity;
- survey in accordance with [3.1.2], or other applicable Tasneef Rules for modules not covered by the present Rules, of modules provided with a Certificate of Compliance;
- a functional test of the modular system in one representative configuration; when the possible configurations of the system may significantly differ, the Surveyor may ask to perform additional functional tests.

  The functional test of the modular system does not require the execution of an immersion test to the maximum operational depth.

In case the class certificate of one or more of the modules are not in course of validity, a condition of class will be imposed to limit the modular system configurations to those assembled with modules provided with class certificate in course of validity.

3.2 Annual surveys

3.2.1 Periodicity, surveys in advance and postponements

The relevant requirements given in Part A, Ch 2, Sec 2, [5.2.1] of the Rules apply.

3.2.2 Survey items to be carried out during annual surveys

At all annual surveys, including the first, the survey items listed under the following points are also to be performed:

a) examination of the user manual to verify that the due surveys, checks and overhauls have been carried out at the intervals provided by the Manufacturer and accepted by Tasneef. These actions are to be recorded in the log-book;

b) surveys and checks of:

   - breathing apparatuses, means of escape and life-saving appliances,
   - navigation, search and communication apparatuses,
   - batteries (with their recharge devices) and other sources of energy,
   - corrosion control systems (if fitted),
   - controls for ballast system, trim system and solid ballast release system,
   - propulsion systems,
   - hull equipment (if fitted),

c) during the above surveys, disassembly or disconnection of the various systems and circuits is not required, unless that is due as a regular procedure for checking and maintenance or the attending Surveyor has doubts about the condition of those parts. The timers recording the immersion time and the depth meters are to be re-calibrated;

d) the portholes and other similar items for external sight (see also item [6.1]) are to be examined; portholes or similar items which have scratches, both on the side subject to high pressure and on the side subject to low pressure, deeper than 0,05 mm, are to be replaced. The frames accommodating the portholes which have scratches deeper than 0,15 mm are to be replaced;

e) the local deformations (out-of-roundness) are to be checked for one frame out of three on large size units and for alternate frames on those of small size, as well as for either of the plates adjacent to the frame checked (this latter check is only to be made in those positions where no dismantling is needed);

f) in units having pressure hull of spherical shape, the sphericity is to be checked (this latter check is only to be made in those positions where no dismantling is needed);

g) a running test of the machinery items, steering system, electrical system, alarms and instruments is to be performed;

h) Tasneef reserves the right to amend the Rules relevant to the procedure of these surveys with regard to the running periods foreseen between two successive overhauls and based on the outcome of endurance and duration tests of the most stressed components;

i) an immersion test to an agreed depth is to be performed after every annual survey and a detailed report is to be given to the Tasneef Surveyor, unless he has attended the test personally;

j) all the safety arrangements are to be surveyed, i.e.

   - the system for elimination of carbon dioxide, as per [3.1.2] m),
   - the system for checking the pollution of the breathing mixture,
   - the system for checking the internal humidity and temperature,
   - the instrumentation relevant to the safety systems,
   - the system for regeneration of the breathing mixtures,
   - the system for ventilation and air conditioning,
   - the individual technical equipment for underwater operators, as required by the regulations in force,
   - the fire-fighting appliances, (see Ch 1, Sec 1, [7.1.2]).

   After the satisfactory outcome of the above survey items, a running test of the various arrangements is to be performed.

3.2.3 Annual surveys for modular diving systems *(1/7/2023)*

At all annual surveys, including the first, the survey items listed under the following points are to be performed:

- verification that the Certificates of Classification of the underwater units that are included in the system are in regular course of validity;
- survey in accordance with [3.2.2], or other applicable Tasneef Rules for modules not covered by the present Rules, of modules provided with a Certificate of Compliance, as applicable.

In case the class certificate of one or more of the modules are not in course of validity, a condition of class will be imposed to limit the modular system configurations to those assembled with modules provided with class certificate in course of validity.

3.3 Intermediate surveys

3.3.1 The relevant requirements given in Part A, Ch 2, Sec 2, [5.3] and Ch 3, Sec 4 of the Rules apply.

3.4 Dry-docking survey

3.4.1 Periodicity, surveys in advance and postponements

The first dry-docking survey is to be carried out not later than one year after the unit entered into operation.

The successive dry-docking surveys are to be carried out one year after the previous survey.

The Interested Party has the right to have any dry-docking survey carried out up to 2 months in advance and up to 4 months after the regular expiry date; in any event, the expiry date of the successive survey is not modified.

For small size units, the dry-docking survey is considered an item of the annual survey.

Tasneef has the right to require the dry-docking survey to be carried out at shorter intervals than those indicated above, where experience or particular operating conditions so recommend.

3.4.2 Survey items to be carried out at the dry-docking survey

On this occasion, all hull penetrations are also to be examined, with any dismantling deemed necessary, for instance all penetrators, i.e. hull watertight penetrations with a small diameter for the passage of electrical cables, pipes, etc.

The tightness of these penetrations may be checked by a pneumatic test with soap solution (bubble test).

In units (usually large size) used for activities where they need to be soundproof (for instance, to operate in the vicinity of acoustic-primed mines, or to closely watch sea fauna, etc.), where the hull is externally coated with ceramic material (usually tiles) attached by means of glue, the good condition of this ceramic coating is to be verified and, if some areas are missing, damaged or loose, those areas are to be replaced or, if feasible, repaired.

3.5 Tailshaft survey

3.5.1 Periodicity, surveys in advance and postponements

The first tailshaft survey is to be carried out not later than two years after the unit entered into operation.

The successive surveys are to be carried out three years after the previous survey.

The Interested Party has the right to have any tailshaft survey, after the first, up to 2 months in advance and up to 4 months after the regular expiry date; in any event, the expiry date of the successive survey is not modified.

The periodicity of tailshaft surveys may be reduced or increased with regard to that indicated above, at Tasneef's discretion, considering the operating conditions of the unit. For small size units, the tailshaft survey is considered an item of the class renewal survey.

3.5.2 Survey items to be carried out at the tailshaft survey

As a rule, the relevant requirements given in Part A, Ch 3, Sec 7 of the Rules apply.

In particular, all the sealing devices are also to be examined, if possible.

Thrusters are excluded from the scope of the tailshaft survey and are included in the scope of the class renewal survey.

For units that need to be soundproofed due to their specific operation (see [3.4.2]), which are provided with particular propellers (5 or even 7 bladed and skewed), special attention is to be paid to keeping the shape of the blades, as the characteristic of the required noiselessness may be impaired, if any repair should, even slightly, alter the original design profile.

3.6 Automation system survey

3.6.1 If machinery spaces are left periodically unattended by personnel on duty, or machinery is permanently controlled from a main centralised station, automation systems for the propulsion machinery and the machinery for essential services are to be so installed as not to reduce the global safety of the unit and to allow the machinery to properly function and manoeuvre using the traditional method in any case.

As far as automation systems not intended for essential services are concerned, it is to be checked that they are so installed as not to reduce the global safety of the unit and not to dangerously interfere with the functioning of the propulsion machinery and that of systems intended for essential services.

4 Occasional surveys

4.1 General

4.1.1 After the unit has undergone revision, repair or alteration work, it is to be verified that the efficiency, strength and safety conditions, based on which the unit was classified, have been restored.

The attending Surveyor may require a short navigation test and an immersion test to the maximum design depth; the latter test is always to be carried out if the unit has undergone structural work affecting the pressure hull. In any event, the immersion test indicated in Sec 3, [2.5.4] is to be carried out.

All the repairs, alterations and modifications approved by Tasneef, as well as all the renewals performed, are to be recorded in the user manual, so that they are known to the Surveyors attending subsequent surveys.

All the foregoing work is to be surveyed by Tasneef.

4.2 Underwater units carrying passengers

4.2.1 Underwater units carrying passengers are to undergo an occasional survey with the scope of an annual survey 3 months after they entered into operation. The first annual survey is to be performed 9 months after the aforementioned occasional survey.

4.3 Modular Diving Systems

4.3.1 *(1/7/2023)*

Modular diving systems are to undergo an occasional survey:

- in case of repairs, alterations and modifications of any component constituting part of the system;
- when the system is installed on a new diving support vessel;
- when one of the modules which are part of the system is replaced or undergo major repairs or alteration works.

5 Lay-up and re-commissioning

5.1 General

5.1.1 The relevant requirements given in Part A, Ch 2, Sec 2, [8] of the Rules apply.

6 Periodical inspections and tests carried out by the crew or technicians entrusted by the Interested Party

6.1 General

6.1.1 The main parts of the underwater units are to be inspected and tested by the personnel entrusted for that purpose at monthly intervals or according to the periodicity established by the Manufacturer.

Manned units are to be inspected and tested before every immersion, unless they perform more than one immersion in 24 hours without the need for refueling for propulsion and/or recharging the breathing mixture; in that case, the required checks and tests need only be carried out before they are put to sea at the beginning of the mission.

All unmanned units are to be inspected and tested before every launch or more often, if deemed necessary.

The above-mentioned inspections and tests are to be recorded in the user manual, with the date when they were performed and the legible signature(s) of the person(s) responsible.

The results of the inspections and tests are also to be recorded in the log-book.

Portholes are to be replaced, tested to 1,5 times the maximum working pressure and to the temperature of + 20°C, on the following due dates:

a) if there is no Manufacturer's recommendation, 3 years after they were fitted in place;
b) if there is a Manufacturer's recommendation stating that they are fit to be kept in place more than the period indicated in (a), after the lesser of the following periods corresponding to:
    - 10,000 pressurisation cycles;
    - 40,000 hours under pressure.

Each window is to be pressurised at least once after its construction, for instance during testing, before it is fitted in place. The test is to be performed with the window located in its supporting frame and may be carried out either hydrostatically or pneumatically. During the test, the window is to be kept subjected to pressure for at least 1 hour and not more than 4 hours; the depressurisation is to be made by drops not greater than 4,5 MPa/min.

During the test, the temperature is to be as close as possible to the design pressure and in any case not inferior to it by more than 2,5°C; where the test temperature should by chance exceed the design temperature, but in any case by not more than 3°C, this is not to last for more than 1 minute.

Deformations or cracks which develop after the above-mentioned test cause the window to be rejected.

As a rule, evidence is to be given that the personnel in charge have performed at least the following surveys, checks and tests:

a) monthly:
    - internal inspection of battery-pods, if external to pressure hull;
b) every 6 months:
    - check of windows with a curved surface and/or transparent domes with their parts connecting to the pressure hull (o-ring, frames, etc.);
    - checks of portholes;
    - check of hatches for internal access;
    - check of tightness of sliding telescopic devices, if any, penetrating the pressure hull [various antennas (radar, etc.), snorkel, periscopes, etc.];
c) every 12 months:
    - hydrostatic test of the double bottom and other ballast tanks;
    - check, maintenance and inspection of the vertical and horizontal rudders;
    - check, without dismantling unless repairs are needed, of all the hull penetrations (penetrators);
    - checks of the sacrificial anodes.

6.2 Immersion tests during the operation of the unit

6.2.1 An immersion test is to be performed always with the assistance of the supply vessel and in shallow waters, also in the following cases:

- after every change of weights (for instance equipment and instruments, ballast, members or number of persons of the crew);
- after the unit has been taken out of the water for repairs, painting, modifications, etc.

6.3 Inspection of the breathing apparatuses

6.3.1 The bottles for the breathing apparatuses are to be subjected to hydrostatic testing every 2 years; however, they are to be internally examined every year to verify that there is no internal oxidation.

The hydrostatic test is to be performed to 1,5 times the maximum working pressure.

Every time the breathing apparatuses are used, their efficiency is to be checked; evidence is to be given that the calibration of the breathing mixture supply devices has been performed at least annually.

6.3.2 Charging the bottles for breathing apparatuses

Charging (or recharging) the bottles for breathing apparatuses is only to be carried out by firms recognised fit to carry out this task.

SECTION 2 Tasneef SURVEYS DURING CONSTRUCTION

1 Premise

1.1 General

1.1.1 As regards the survey requirements during construction, the requirements given in this Section apply in addition to those given in Part A of the Rules, as far as relevant.

2 Pressure hull and/or hyperbaric structure

2.1 Examination of plates

2.1.1 All plates are to be examined on both surfaces and are to be smooth and free from defects.

Slight irregularities, slight incisions and the like may be removed by grinding, provided that, after repair, the plate thickness is still within the allowable limits.

All plates and all stiffeners of strength elements are to be measured by ultrasound method to assess their actual thickness.

2.2 Cutting of plates

2.2.1 Plates may be cut by oxygen cutting, by mechanical cutting or by a combination of the two procedures. For plates less than 25 mm thick, cold shearing is accepted provided that the cut edge is removed by grinding or other method for a distance of not less than 1/4 of the plate thickness, with a minimum of 3 mm.

For alloy steel plates, oxygen cutting is only accepted after adequate preheating.

The edges of cut plates are to be examined to verify that there is no splitting, cracks or other defects which might impair their use.

2.3 Forming of plates

2.3.1 Tasneef reserves the right to require tests to verify the efficiency of the systems used.

Hammer forming is not accepted.

Unless particular reasons are given, cold bending of plates is to be followed by an appropriate heat treatment, if the ratio of the internal radius after bending to the plate thickness is less than 20. That treatment may be performed after welding.

As a rule, when hot forming is used, the work is to be followed by an appropriate regeneration heat treatment to restore the mechanical properties of the different elements.

After forming and before assembly, the hemispherical (or similar shape) heads are to be subjected to an extended ultrasound check to verity that there is no scaling.

When plates are hot formed, if forming has not been performed within the appropriate temperature range, a normalising heat treatment (or another treatment suitable for the material used) is to be performed, either before or after welding.

If the forming procedures used do not cause an excessive decrease in the mechanical properties, especially resilience, the regeneration heat treatment may not be required, at Tasneef's discretion and based on evidence from the Inter-ested Party.

Tasneef may require tests to be performed on samples sub-jected to the same forming procedure and the same heat treatments, in order to verify that the above-mentioned con-ditions are complied with.

2.4 Thermal stress relieving after assembly

2.4.1 Unless there are justified reasons, after assembly a stress relieving heat treatment is to be performed.

The execution procedure of the heat treatment is to be agreed with Tasneef, especially with reference to the follow-ing parameters:

a) temperature in the oven when the piece is put into it;
b) hourly variation of the temperature (heating and cooling) and appraisal of the corresponding thermal gradients;
c) time kept at the specified treatment temperature;
d) checking devices provided for the measurement of the different temperatures.

The atmosphere in the oven is to be such that it does not cause excessive oxidation of the surface of the piece.

2.5 Partial thermal stress relieving

2.5.1 In exceptional cases, the stress relieving heat treatment need not be performed in one single phase; the treatment may be carried out:

a) either section by section after complete assembly,
b) or by heating circular bands, after welding circumferential joints.

Method a) is applicable when the oven at the disposal of the Manufacturer is of a size that cannot accommodate the whole structure; in this case, thermal stress relieving may be carried out in successive phases on the different parts that the oven can accommodate, while the remaining parts that are out of the oven are kept at a convenient temperature, for instance by means of appropriate insulating material.

Method b) is applicable when each section has been treated separately, to thermal stress relieve the welds of the longitudinal joints or of the unions of complex parts and when the stress relieving heat treatment of the whole structure cannot be performed in the oven after the welding of the circumferential joints connecting the different sections; these circumferential joints can then be locally treated by heating circular bands.

During partial thermal stress relieving, the heating appliances are to provide an as uniform as possible distribution of the temperature in the heated zone and the insulating material is to be so distributed as to avoid excessive temperature gradients in the areas close to the heated sections.

The heating and temperature control appliances and the maximum expected thermal gradients are to be submitted to Tasneef for approval.

2.6 Check of the welded assemblies

2.6.1 The accessories to be permanently connected to the pressure hull (eye bolts, supports for auxiliary machinery, etc.) are to be of such a shape as to adapt as much as possible to the surface where they are to be connected; the connecting welds are to be continuous and performed with the same precautions used for the main welds.

The accessories temporarily connected to the pressure hull, such as those used for the handling and fitting of the various elements of the hull during construction, are to be fitted and removed by a procedure to be specified by the builder; after they have been removed, the affected zone is to be ground and examined by magnetic particle inspection (MPI) or dye penetrant testing to make sure that no cracks are left.

As a rule, no welding to connect accessories is to be performed after the last stress relieving heat treatment.

2.7 Dimension check of pressure hull at the end of manufacture

2.7.1 Except where otherwise agreed between the Designer and Tasneef, the following checks are to be per-formed.

a) Check of the geometric dimensions of the cross-section of frames.

   The tolerance is ± 2%.

b) Check of the distance between frames.

   The tolerance is ± 3 mm, over an interval of 300 mm.

c) Check of the deviation of frames from the lying plane.

   For each frame, the number of points deviating from the lying plane is to be not more than 3; the tolerance of the deviation is ± 2 mm for an external diameter of the pressure shell of 2 m.

d) Check of the sphericity (or the bending) of the heads.

   It is to be performed by means of a micrometer-comparator or other appropriate device, and at least 8 points on 8 semi-circumferences (or 8 curved profiles) are to be checked.

   The tolerance is ± 2 mm over an external radius of 1 metre.

e) Check of the ovalisation of the cylindrical section of the heads.

   The following formulae are to be fulfilled, depending on the operational conditions of the unit (see Fig 1):

   - for units operating at depths not greater than 300 m:

$$\mathbf{Di}_{MAX} - \mathbf{Di}_{MIN} \le \frac{\mathbf{D}_N + 1250}{200}$$

$$\mathbf{Di}_{MAX} - \mathbf{Di}_{MIN} \le 0,01 \cdot \mathbf{D}_N$$

   where:

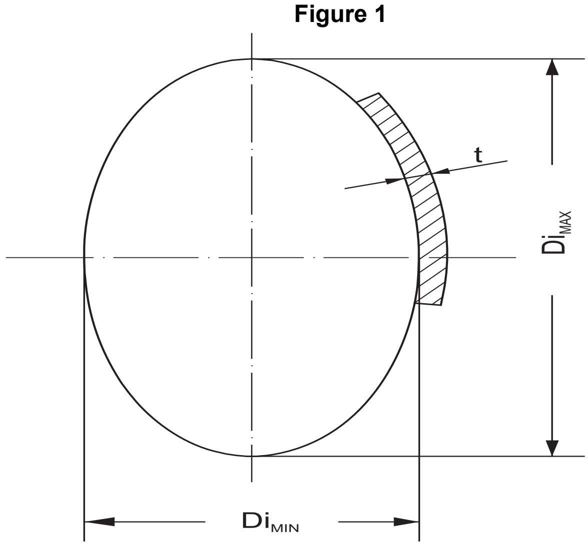
   $\mathbf{Di}_{MAX}$, $\mathbf{Di}_{MIN}$ and $\mathbf{D}_N$ are, respectively, the maximum and minimum measured values and design nominal value of the internal diameter of the cylindrical section, in mm.

   - for units operating at depths greater than 300 m:

$$\frac{200 \cdot (\mathbf{Di}_{MAX} - \mathbf{Di}_{MIN})}{\mathbf{Di}_{MAX} + \mathbf{Di}_{MIN}} \le 0,5$$

   Moreover, the maximum allowable value of the ovalisation **e**, in mm, is that found from the diagram in Fig 2, assuming as $\mathbf{L}_0$ the value of the maximum external bending radius of the head, and as $\mathbf{D}_0$ and **t** respectively, the value of the external diameter and the value of the thickness of the cylindrical section.

Figure 1



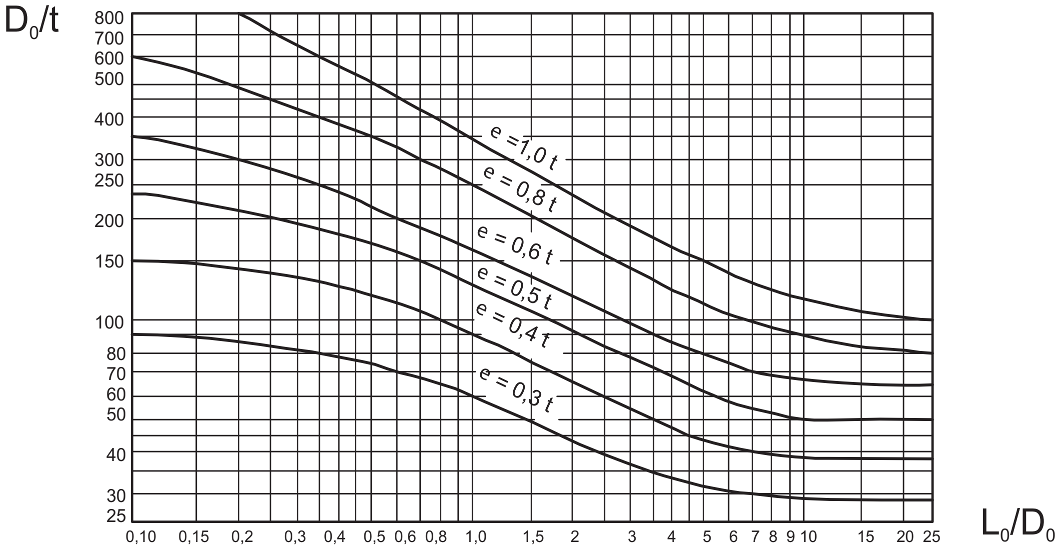
f) Check of the ovalisation of the pressure shells of spherical shape.

   The maximum allowable value of the ovalisation **e**, in mm, in a median section is that found from the diagram in Fig 2, assuming as $\mathbf{L_0}$ the value of the external radius of the shell and as t the value of the thickness of the shell.

g) Check of the cylindrical shell at the various frames.

   The maximum allowable value of the ovalisation e, in mm, in a median section is that found from the diagram in Fig 2, where $\mathbf{D_0}$ and **t** are respectively the value of the external diameter and the thickness of the cylindrical shell, while $\mathbf{L_0}$ is the length of the cylindrical section of the pressure hull.

Figure 2



The maximum allowable deviation from the theoretical circumference is:

- 3 mm over a radius of 1 m, when there are no more than 3 waves on the same section;
- 1,4 mm over a radius of 1 m, when there are 4 waves.

  More than 4 waves on the same section are not accepted.

h) Check of the ovalisation of the cylindrical coaming of the access hatch.

The following formula is to be fulfilled:

$$\frac{200 \cdot (d\mathbf{i}_{MAX} - d\mathbf{i}_{MIN})}{d\mathbf{i}_{MAX} + d\mathbf{i}_{MIN}} \leq 0,5$$

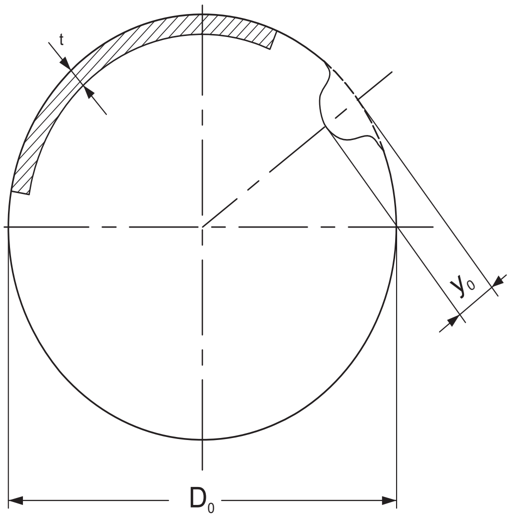
where $\mathbf{di}_{MAX}$ and $\mathbf{di}_{MIN}$ are, respectively, the maximum and minimum values measured of the internal diameter of the hatch coaming.

i) Check of the local deformations. The maximum depth $\mathbf{y_0}$, in mm, of a local deformation is to be such that it fulfils the following formula:

$$\frac{400 \cdot \mathbf{y}_0}{\mathbf{D}_0} \leq 0,5$$

where $\mathbf{y}_0$ and $\mathbf{D}_0$ are those indicated in Fig 3.

Figure 3



Where the foregoing formula is not fulfilled, the deformations may be accepted provided that further calculations based on the actual configuration of the structures give a satisfactory result.

2.8 Tolerance of deformations of the stiffeners of circular pressure hull

2.8.1 The tolerance of the deformations found in the stiffeners of the pressure hull, if they have a circular cross-section, is indicated in Fig 4, Fig 5 and Fig 6.

Figure 4

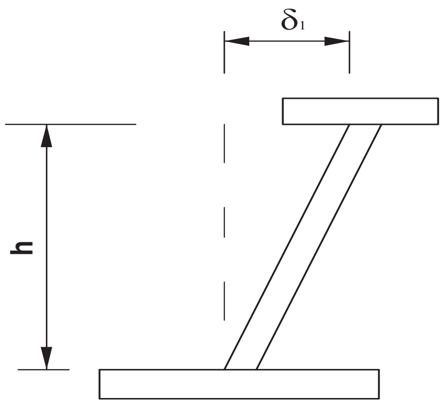


Figure 5

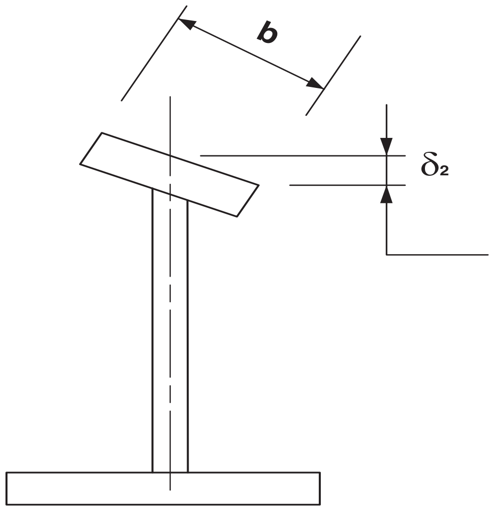
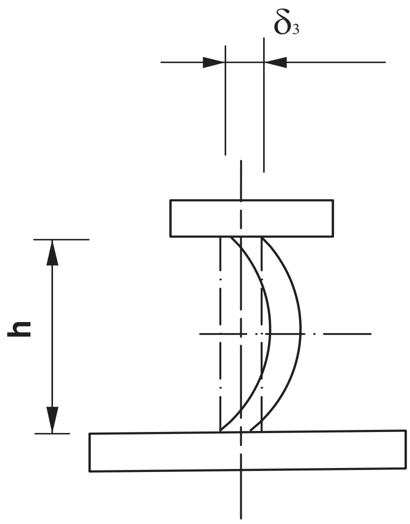


Figure 6



The deformations are to fulfil the following formulae:

$\delta_1 \leq 0,03\ h$

$\delta_2 \leq 0,05\ b$

$\delta_3 \leq 0,01\ h$

2.9 Check of welds

2.9.1 When there are justified reasons, the attending Surveyors may require any non-destructive test to be performed again, even if the submitted documentation proves that it has given a satisfactory result.

As far as the provisions not given in these Rules are concerned, the requirements for heat treatments and checks relevant to class 1 pressure vessels indicated in Part C, Ch 1, Sec 3 of the Rules apply.

Misalignments of plate joints greater than 10% of the minimum thickness, with a maximum of 3 mm of the connected plates, are not accepted; lower limits, if deemed necessary, may be required depending on the type of procedure and preparation or due to other reasons, at the discretion of Tasneef.

2.10 Construction of tanks for liquids

2.10.1 When the construction of tanks intended for liquid cargoes is completed, their net volume excluding any stiffeners is to be calculated and verified, also including the position of the centre of gravity.

That capacity and relevant coordinates of the centre of gravity are also to be indicated in the capacity plan.

2.11 Tests of double bottom ballast tanks and/or other ballast tanks

2.11.1 A hydrostatic test to 1,5 times the maximum working pressure is to be carried out.

2.12 Test of spaces for accumulator batteries

2.12.1 The spaces for accumulator batteries are to be air tested to the pressures stipulated by Tasneef based on the number and type of accumulators fitted in those spaces.

2.13 Test of watertight bulkheads

2.13.1 Every single watertight bulkhead is to be subjected to a hydrostatic or pneumatic test for strength purposes, applying to each surface separately a pressure equal to the maximum anticipated operating depth (or equal to 1,1 times the maximum operating pressure, if it is equal to 50 m or less), which is to be referred to the lower edge of the bulkhead.

When the test is performed, bulkheads are to be as complete as possible, i.e. fitted with the relevant watertight doors and sealing devices for electrical cables, shafts, piping.

2.14 Portholes made in acrylic

2.14.1 The frames accommodating the portholes are to comply with the following minimum requirements, when their opening diameter is not less than 635 mm:

- radial deformation of the porthole frame at the maximum test pressure (internal or external, as applicable): less than 0,002 $\mathbf{D_i}$, where $\mathbf{D_i}$ is the minimum internal diameter of the porthole;
- angular deformation of the porthole frame at the maximum test pressure, as indicated in the foregoing item: less than 0,5°.

3 Main engines and auxiliary machinery

3.1 General

3.1.1 Propulsion engines, machinery and apparatuses are to be installed on board under surveillance and to the satisfaction of the attending Surveyors, and tested and certified in accordance with the applicable Rules.

Any waiving or particular requirements with regard to testing may be given further to the examination of the documentation required in Pt C, Ch 1, Sec 1, [1.3].

Additional particular examinations or any waiving of the applicable Rules will be considered, case-by-case, after examining the required drawings and specifications.

3.2 Tests after installation on board

3.2.1 Main engines and auxiliary machinery are to be subjected to a working test, in accordance with the applicable requirements of the Rules (Pt C, Ch 1, Sec 15).

Particular tests may be required, at the discretion of Tasneef, following examination of the submitted documentation and further to the survey during construction.

3.3 Test of sealing devices of tailshafts

3.3.1 Given the considerable importance of the devices concerned, the Manufacturer's certificates stating the tests to which they have been subjected are to be submitted.

Tasneef reserves the right to require tests, including non-destructive examinations, to be carried out on one of the devices, after examining the above documents.

The test methods are to be agreed with Tasneef on a case-by-case basis. In any event, the test is to be performed to the pressure leading to the collapse of the pressure hull.

3.4 Calibration of the valves of sea connections

3.4.1 The test of these valves is to be carried out to a pressure not less than 1,5 times that corresponding to the design depth (see Pt B, Ch 1, Sec 1, [4.1.5]) for an operational depth not greater than 1700 m. For greater depths, the tests to which the valves are to be subjected will be stipulated case-by-case, at the discretion of Tasneef.

3.5 Tests of pumps and compressors

3.5.1 The parts of pumps and compressors under pressure are to be subjected to a hydrostatic test to a test pressure $\mathbf{P_P}$, which depends on the working pressure $\mathbf{P_E}$ as follows:

- for $\mathbf{P_E}$ less than or equal to 4 MPa:
  $\mathbf{P_P}$ = 1,5 $\mathbf{P_E}$, but in any case not less than 4 MPa;
- for $\mathbf{P_E}$ greater than 4 MPa:
  $\mathbf{P_P}$ = 1,4 $\mathbf{P_E}$.

3.6 Tests of pipelines

3.6.1 Before being installed on board, all the parts of piping, including its accessories, which during operation are subjected to a pressure greater than 1 MPa are to be hydrostatically tested to a pressure not less than 2 times the maximum working pressure.

Piping, including its accessories, which, directly or indirectly, can be put into communication with the sea, is to be hydrostatically tested to a pressure not less than 2,5 times the maximum working pressure.

After mounting, all piping is to be tested to a pressure not less than 1,5 times the maximum working pressure.

4 Electrical systems

4.1 Test of systems

4.1.1 The dielectric resistance of the electrical insulation exposed to sea water is to be tested by applying, for 1 min, an alternate current having a tension not less than 500 V.

The quality of the insulation is to be such that the current leakage does not subject the personnel and control machinery to dangerous tensions.

The test is to be performed with the coating exposed to sea water.

During the test, the apparatuses to which the cables are connected are not to be included in the part under tension if they may be damaged.

5 Oxygen system

5.1 Cleaning

5.1.1 All the components of the oxygen system are to be completely cleaned.

Valves and accessories, cleaned by the Manufacturer before delivery, are to be fitted in sealed plastic containers with the indication "degreased to be used with oxygen"; in addition, a statement by the Manufacturer is required certifying that the above-mentioned work has been performed and that the components were in good condition.

All traces of oil and grease are to be removed before oxygen is introduced into the system.

5.2 Tests

5.2.1 The system is to be so designed that it can be removed from the unit to undergo the necessary tests (and cleaning) without the need to cut the permanent or semi-permanent connections.

In semi-permanent installations, it is recommended that there should be parts which can be dismounted, so that the units are easily handled, considering the limited dimensions and poor internal accessibility. Before being fitted on board, the entire system is to be tested to a pressure equal to 1,5 times the maximum working pressure.

To reduce the danger during this test, the oxygen container is to be filled to 95% of its volume with clean water; this water is introduced through a specific inlet which is to be provided at the design stage for this purpose.

After the pressure test, the system is to undergo a tightness test to the working pressure and then it can be installed on board.

During these phases, attention is to be paid so as not to pollute the system. Thereafter the system is to be dried, put in operational condition, and pressurised with dry air or dry nitrogen to 1,1 times the working pressure.

Then the system is to be closed.

The dripping of the oxygen system, including the emergency system, is to be reduced to the minimum feasible.

At the end of construction, the dripping is to be such that the partial pressure of oxygen does not exceed 253 hPa in every space hermetically sealed for a period of at least 1 week.

After the dripping test and the measurement of the leaks, the system is to be purified and tested to make sure that any traces of the test gases, including air and nitrogen, have been removed.

6 System for elimination of carbon dioxide

6.1 Tests

6.1.1 The system, together with its double main elements, if any, is to be tested to confirm its good working order.

At least 2 tests are to be performed: one with 30% and one with 90% of relative humidity.

7 Internal atmosphere and instrumentation

7.1 Check of pollution of the internal atmosphere

7.1.1 Checks of the contamination condition of the internal atmosphere are to be performed by means of wide range analysis instruments.

7.2 Tests of instrumentation

7.2.1 All the instruments subject to pressure are to be tested to a pressure 1,2 times the maximum working pressure.

The mechanical and electrical subsystems are to be subjected to a working test for a period 1,5 times the maximum duration of the standard design mission.

SECTION 3 TESTS AT THE END OF CONSTRUCTION

1 General checks prior to sea trials

1.1 Premise

1.1.1 All the tests and checks required below are to be performed in the presence of the Surveyor entrusted with the construction survey.

1.2 Apparatuses

1.2.1 All the apparatuses are to be tested in order to verify their proper efficiency.

If fitted on board, the gyrocompass is to have performed not less than 3 hours of continuous service.

It is to be checked that all the foreseen spare parts are on board, especially those regarding the control apparatuses of the breathing system and various safety systems.

1.3 Arrangements and systems on board

1.3.1

a) All the systems are to be checked and are to be found in proper efficient condition.

b) All the valves opening and closing the various ballast tanks, as well as the remote control valves for the various circuits, are to be checked. The valves connected to shell plating are to be perfectly watertight.

c) The seating surface of the hatch giving access to the inside of the pressure hull is to be examined; it is to be clean, not corroded and its sealing gasket is to be undamaged.

d) If feasible, where they are fitted on board, all the quick release devices of the external parts of the pressure hull, such as, for instance, arms for underwater work, external net to collect samples, and external solid ballast, are to be checked.

1.4 General preliminary tests

1.4.1 The program of tests deemed necessary to carry out in order to confirm the full efficiency, functionality, strength and safety of the unit is to be agreed with Tasneef.

In any case, the following checks are required:

- check of the insulation condition of the electrical system;
- visual examination of the pressure hull.

In the case of small size units, it may be found that the pressure hull was subjected during construction in the pressure tank tower to a test pressure as indicated in Pt B, Ch 1, Sec 1, [4.1.6]. In the case of large size units, the "air pressure test" indicated in the following [1.5] is to be performed.

Before and after the above-mentioned pressure test, a check of the out-of-roundness of the pressure hull is to be carried out in a number of positions decided by the Surveyor entrusted with the construction survey.

1.5 Dock trials

1.5.1 Dock trials are to be performed for a duration deemed sufficient by the attending Surveyor. During these trials, all the systems and apparatuses of the unit are to be running.

Any damage found on this occasion will cause the tests to be discontinued. They are to be resumed from the beginning after repairs have been carried out.

The "air pressure test" is to be carried out by slightly decreasing the pressure inside the unit (a decrease of 4 hPa with respect to the external pressure is considered sufficient). If the barometric pressure inside the unit does not change for at least 2 minutes, the test is considered valid. If the internal pressure decreases, where leaks from the hull are not found, every access hatch is to be checked together with its sealing rubber gasket.

The test is to be repeated until the internal pressure shows no variation for a period of not less than 2 minutes.

Moreover, the efficiency of the mooring and warping arrangements of the unit, if fitted, is to be checked, taking account of the use, characteristics and size of the unit.

For the breathing systems and all spaces which are pressurised during service, a gas tightness test is to be performed.

These spaces are to be pressurised by means of dry air or dry nitrogen to a pressure 1,1 times the maximum working pressure and the pressure is not to decrease more than 0,5% per hour, taking account of any temperature variations.

For independent emergency breathing systems, the above pressure is not to decrease more than 0,3% per hour.

2 Sea trials

2.1 Preliminary checks

2.1.1 Sea trials are to be carried out with the assistance of the supply vessel.

Sea conditions and wind force are not to exceed those stated at the design stage; in any case, wind force is not to exceed force 4 on the Beaufort scale.

Visibility conditions are to be considered sufficient by the Master of the supply vessel.

2.2 Towing test

2.2.1 Small size units will be towed to the test site; for large size units, a 1 hour test is to be performed to verify their aptitude to be towed.

When towing exceeds 6 hours of navigation (in the case of small size units), as a rule the test is to be performed without persons on board the unit.

Prior to commencing and after finishing the towing, the bilge is to be checked in order to have further confirmation of the tightness of the unit.

During towing, the rudder is to be fastened with the blade in the longitudinal direction by means of an appropriate device and all the parts overhanging the hull that are necessary for the service of the unit, such as a net to collect samples, working arms, and drills, which will be installed in their positions before the actual tests, are to be kept, when possible, on board the supply vessel. If not removable, the above-mentioned parts are to be positioned as provided at the design stage for towing.

At the towing test it is to be verified and recorded in the user manual at what speed the unit no longer keeps the trim foreseen for surface navigation.

2.3 Floatability tests on the sea surface with the unit still

2.3.1 When the unit reaches the test site, all the connections (if fitted) to the supply vessel are to be removed, and the supply vessel is to remain as close as possible to the unit.

The bilges are to be checked once more, the rudder is to be unfastened and all the systems are to be tested.

The trim conditions and loaded cargoes are to be verified, confirming that they correspond to what is indicated in the "Stability Booklet" visaed by Tasneef.

A heeling test is to be carried out by filling the wing ballast tanks asymmetrically, as stated in the case of emergency emersion in the "Stability Booklet" (see Pt B, Ch 2, Sec 1, [1.4]).

2.4 Surface navigation trials

2.4.1 The following tests are to be performed:

- at normal speed for not less than 3 hours, on a measured course;
- at full speed ahead for not less than 1 hour, on a measured course;
- going astern, at the various possible speeds, for not less than 30 minutes altogether;
- turning circle and full astern stopping at the various speeds, in order to determine the minimum yaw radius and track reach at the various speeds;
- hauling at the various speeds, in order to verify the stability of the unit in these conditions at the maximum rudder angle.

For the above-mentioned tests, the duration, the speed reached, the sea and wind conditions, as well as the approximate angle between the direction of the wave motion and the unit route, are all to be recorded.

It is to be checked that there are no excessive vibrations in the hull and machinery components.

If the unit sails on the sea surface driven by diesel engines or diesel-electric motors, the inevitable vibrations of diesel engines may damage the electrical apparatuses, if they are not certified "impact proof", especially if badly installed; therefore, if necessary, as soon as the engines are stopped, these apparatuses are to be checked.

The parts overhanging the hull are to be positioned as provided for navigation.

2.5 Immersion tests

2.5.1 Premise

Upon completion of construction, in the case of small size units, prior to performing the immersion tests with persons on board, an immersion test without persons on board is to be performed if possible, with the unit suspended by means of steel cables fitted in positions to be agreed with Tasneef. The unit is to be immerged to increased depths up to a depth 1,1 times the maximum working depth, while strain gauges are to be fitted to the pressure hull in positions to be agreed with Tasneef in order to measure the actual stresses, which will be compared with those obtained from the calculations; in such condition, any leaks from the pressure hull may be verified by fitting appropriate sensors.

If this preliminary immersion test cannot be performed, strain gauges are to be fitted all to same in appropriate positions to be agreed with Tasneef, to be used in subsequent tests.

The site where the immersion tests are to be performed is to be agreed with the Master of the supply vessel, taking account of the distance from a shore base equipped with rescue arrangements that can be sent to the test site if necessary.

The Surveyor may attend the various tests from the supply vessel and will compare the values of the maximum depth recorded by a suitable manometer, or echo sounder, or similar writing instrument, fitted on the underwater unit with those given by the echo sounder or similar instrument fitted on the supply vessel.

The Surveyor is not obliged to participate in the immersion tests. He may be present on board isobaric units, at his own risk, and after receiving written authorisation from the Master of the supply vessel, the Master of the underwater unit and the operator responsible.

2.5.2 Initial tests

At the beginning, a navigation test is to be performed at "snorkel" depth, lasting not less than one hour at various speeds and hauling.

The initial immersion test is to be performed in the following conditions:

- calm sea;
- shallow water (maximum seabed 30 m, so that, in case of an emergency, the crew can get out of the unit with breathing apparatuses);
- seabed as even as possible, sandy or gravelly;
- displacement and trim in accordance with the "Stability Booklet";
- maximum distance from the supply vessel: approximately 1000 m;
- communications with the supply vessel through underwater telephone;
- duration of the first test not less than 1 hour.

Thereafter, at least 3 more immersion tests, like the initial test, are to be performed, each one lasting not less than half an hour.

At these tests, a check of the tightness of the hull, as well as heeling and trim tests, are to be carried out (by means of transfer of ballast water or shifting of weights), in order to verify the good working order of the pumps installed for those services.

The Surveyor attending these tests is to:

a) verify the sea depth in the site where the various immersion tests are performed, reading the value on the echo sounder of the supply vessel. Even if the engines of the supply vessel are not running, it is advisable to take a reading approximately every 15 min, with confirmation of the ship's position from the Master and checking the corresponding depth on the nautical chart of the zone;

b) follow the immersion of the underwater unit through the echo sounder and reading the depth, while remaining on board the supply vessel; if a writing instrument is used, a photocopy of the band containing the diagram of the depths reached by the unit at different times is to be attached to the survey report;

c) in the case of a diving bell, in addition to the provisions given in b), verify that the depth read on the instrument corresponds at least to the length of the hanging cable and umbilical cable unwound from the relevant drums.

The above-mentioned items are to be included in the survey report.

2.5.3 Immersions to intermediate depths

After the tests indicated in [2.5.2] have been satisfactorily completed, immersion tests at increasing depths up to that corresponding to 50% of the working depth are to be performed.

Those immersions are to last not less than 6 hours.

At these tests, it is to be checked that the residual air in the main ballast tanks has gone out through the air pipes; for this purpose the unit is to be heeled 2 or 3 times by approximately 5° by the bow and then by the stern. Residual air is extremely dangerous since it allows free surfaces to form and can also prevent the unit from reaching the design depth.

The readings of all the on-board instruments measuring the depth are to be compared; they are not to differ by more than 0,5%; this provision also applies with respect to the value given by the echo sounder installed on the supply vessel.

A navigation test in immersion is to be performed:

- at normal speed;
- at full speed ahead, for not less than 30 min;
- going astern at full speed, for not less than 15 min.

Turning circle tests, hauling tests and crash stop tests at the various speeds are to be performed.

All the checks are to be carried out and all the information reported, as specified in [2.4].

The outcome of the tests will be considered satisfactory if, in addition to the above-mentioned checks, the good tightness of the hull has been verified and no leaks have been found inside the hull.

Where any anomaly is found, the program of tests is to be discontinued, the anomaly is to be eliminated and the tests are to be repeated from the beginning.

2.5.4 Immersion to the maximum working depth

Gradually, increasing the immersion by 10 m at a time, the maximum foreseen working depth is to be reached, at which all the tests indicated in [2.5.3] will be performed.

The unit is to stay at that depth for not less than 1 hour, unless a shorter time is foreseen in working conditions.

During this test, all the working apparatuses external to the pressure hull, if any, such as arms and drills, are to be examined in running condition in order to verify that the unit is suitable for the service for which it will be classified.

The unit is to be brought to the surface slowly, the re-ascending angle and speed being agreed with Tasneef.

If the test at the maximum depth cannot be performed at the site due to shallow water, the operating depth of the unit is to be consequently reduced until the tests at the maximum depth have been performed.

For units with unusual structural characteristics, Tasneef reserves the right to require stress measurements by means of strain gauges; at the end of the tests, the out-of-roundness of the pressure hull will be checked again in the same positions indicated in [1.4].

2.5.5 Final immersion test

A final test of the hull and all machinery items and appliances is to be performed at the maximum foreseen working depth.

The unit is to stay at this depth for not less than 30 min.

2.5.6 Emergency emersion

Emersion tests in various simulated emergency conditions are to be performed, such as for instance:

- by the sole vertical thrust of the propellers (where possible);
- by the sole hydrodynamic thrust of the horizontal rudders (when fitted);

- by emptying the central balance tanks, the emersion tank or the "negative" tank by means of high pressure pumps;
- with one or more ballast tanks full and the corresponding tanks on the other side empty. In this case, the heeling and trim of the unit are to be verified and the residual freeboard checked.

The emersion test in emergency conditions is also to be performed from the maximum depth indicated in [2.5.5], after calibrating the appropriate automatic emersion device, if fitted. When this device is activated, the foreseen signalling buoy is also to be released.

2.5.7 Hauling down and recovery

In the case of small size units, a hauling test and a recovery test of the unit from the supply vessel are also to be performed.

3 Test of Modular Diving Systems

3.1 General

3.1.1 *(1/7/2023)*

Modular diving systems are to be tested both at dock and sea trials in all the possible configurations which are included in the Certificate of Classification and relevant user manual (see Ch 1, Sec 2 [6.7.4]).

In case of similar configurations are foreseen, Tasneef may waive the repetition of tests; in this respect, the test plan for the modular diving system is to be approved by Tasneef.

Immersion test to the maximum operational depth is not required when the same test has been already carried out on each underwater unit included in the modular system, as applicable.

RULES FOR THE CLASSIFICATION OF UNDERWATER UNITS

Part B
Hull and Stability

Chapters **1 2 3**

CHAPTER 1
HULL

Section 9 Outfitting

Section 10 Strength Checks of the Lashing System of the Unit on the Supply Ship

Appendix 1 Influence of the Shape of the Pressure Hull Cross-Section on Strength

CHAPTER 2
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CHAPTER 3
SUBDIVISION REQUIREMENTS

Part B
Hull and Stability

Chapter 1
HULL

SECTION 1 GENERAL DESIGN PRINCIPLES FOR THE HULL CONSTRUCTION

1 General

1.1 Foreward

1.1.1

a) Pressure hull scantlings reported in these Rules refer to a design life of the hull corresponding to about 18,000 working cycles, with the unit reaching the maximum allowable operating depth in each one.

b) Length L of the hull is defined as the overall length of the hull.

c) The predominant effect of hydrostatic pressure at substantial depths allows calculation simplifications, due to the fact that all other loads acting on the pressure shell can be ignored.

The following simplifying assumptions are made:

- hydrostatic pressure does not change from one point to another on the hull perimeter;
- self-weight of structures or any other concentrated load is negligible as is the influence of any stress due to longitudinal bending of the hull;
- the influence on pressure given by any local change in sea water density is negligible.

1.2 Frame spacing

1.2.1

a) For the pressure hull, the frame spacing S_R, in mm, of transverse and/or longitudinal reinforcements is generally to be assumed not higher than the following:

$$S_R = 0,2 D_0$$

D_0 being, in mm, the maximum outer diameter of the hull.

In transversely framed hulls, reinforced transverse frames are generally not required; in longitudinally framed hulls, such frames are to be fitted at a distance not greater than D_0.

With the exception of larger size units, which will be treated on a case-by-case basis, floors are generally not required.

Frame spacings higher than those mentioned above will be considered case-by-case by Tasneef.

b) For the non-structural shell, the frame spacing can be assumed equal to:

$$S_{NR} = 1,25 S_R$$

1.3 Equivalent efficiency

1.3.1 For the review of constructional plans, equivalent efficiency criteria are allowed. Therefore, Tasneef can con-sider different material and scantling distributions from those obtained with these Rules, provided that such distri-butions result in structures having longitudinal, transverse and local strength not lower than the corresponding Rule-compliant structure and according to standard practice.

Other rules or calculation and/or manufacturing criteria deemed equivalent to those indicated here may be accepted by Tasneef, which reserves the right to stipulate any conditions for such acceptance.

2 Main design principles

2.1 General

2.1.1 The pressure hull is to be designed for safe navigation of the unit while surfaced, underwater, during submersion and in all the intermediate phases, in the various working conditions (displacement, trimming and equilibrium), in still water and/or waves (see Ch 2, Sec 1, [1.3]).

Any superstructure, device, machinery or component in general and its arrangement on board is to operate continuously and withstand, without damage, static and dynamic actions deriving from the following conditions in which the underwater unit is intended to operate:

a) variation in longitudinal trim of 30°, or 7° for machinery, devices and components designed to operate only on the surface or at snorkel depth (for large size units);

b) variation in transverse trim of 15°;

c) pitch angle of 10°, at port and starboard, with respect to the longitudinal vertical plane;

d) roll angle of 45°, at starboard and port side, with respect to the longitudinal vertical plane.

The transverse section of a pressure hull having a circular shape is the one providing the highest strength with the lowest weight.

App 1 gives the criteria to be applied to evaluate the influence on the strength of the shape of the cross-section of a pressure hull when it is not circular and, in any case, to ensure an equivalent strength. The corresponding calculations are to be submitted to Tasneef for review.

2.2 External pressure

2.2.1 The external pressure P_e, in N/m², is obtained according to the following formula:

$$P_e = 10^4 \mathbf{h} \cdot \gamma$$

γ being the sea water density, in t/m^3.

For γ values, see [3.5]. During the design stage, it is to be assumed $\gamma = 1{,}025$ t/m^3 and the strength check of the structures is to be performed also at the test depth, in order to evaluate the stress level also in this condition. If necessary, the test pressure can be reduced; in such case, an appropriate remark is to be made in the "Notes" of the Certificate of Classification.

2.3 Design pressure

2.3.1 The design pressure, in N/m^2, is obtained assuming **h**, in m, equal to the depth at the lowest point of the pressure hull (in general the under-keel) and is to be considered uniformly distributed over the whole hull.

Due to the above approximation, in units having a circular cross-section pressure hull, the local stress in the web frames is given by a uniform tension or compression, for internal or external pressure, respectively.

To assume that a circular cross-section of the hull is subjected only to normal stress and not to bending is justified only when the section is considered as undeformable (see App 1).

For structures subjected to compression, as well as the compression limit (yielding), the stress limit for in-plane loading (frame tripping and plate buckling) (see [4.1]) is also to be assessed.

Plating is subjected to circumferential stresses and also to longitudinal stresses due to the axial load caused by the pressure on the heads of the pressure hull.

2.4 Absolute pressure

2.4.1 Pressure hulls designed to operate without internal atmosphere (without human occupancy on board) are to be considered subjected to the absolute pressure (hydrostatic pressure added to the above surface atmospheric pressure, assumed equal to 0,1 MPa); in such case the design pressure, in N/m^2, is given by:

$$Pa = 10^4 \mathbf{h} \cdot \gamma + 10^5$$

2.5 External ambient conditions

2.5.1 At the design stage, the following external ambient conditions can be assumed:

- Surface water temperature: -2°C ÷ + 32°C.

  For units to be classified for use in polar zones, the design sea water temperature is to be assumed equal to -5°C. In such case, the "**Polar Zone**" geographic area will be added in the navigation notation;
- deep water temperature for depth of 1500 m and above: + 1°C;
- temperature for depths between the surface and 1500 m: to be obtained by linear interpolation between +1°C and -2°C;
- air temperature: - 55°C ÷ + 60°C.

  For units with "**Polar Zone**" notation, the air temperature is to be assumed equal to -60°C;
- sea water salinity: 35 ‰.

  For the following seas, the average measured values are:

  Mediterranean Sea: 37 ‰.

  Red Sea : 43 ‰.

  Baltic Sea : 7,2 ‰.

  Where deemed necessary, values for more severe ambient conditions than those mentioned above may be required to the satisfaction of Tasneef.

2.6 Arrangement of essential parts

2.6.1 Any essential part located inside the pressure hull is to be arranged, if possible, at a distance of at least 150 mm from the outer shell of the hull, such that, in the event of damage, it will not be put out of service.

If such parts are located outside the pressure hull (for example cylinders containing O_2), they are to be adequately protected.

2.7 Shock factors

2.7.1 The resistance of structural details to bottom damage or against other obstacles in working condition is to be verified by assuming an acceleration of at least 3 **g**, except in those cases where adequate shock-absorbing arrangements are adopted.

For strength checks of structures subjected to high stress levels during launching and recovery operations, an acceleration of at least 2 **g** is to be assumed.

Shock factors arising from conditions different from the above are to be agreed with Tasneef, on the basis of docu-mentation referring to past experience.

In the case of units designed to operate in proximity to zones exposed to underwater explosions, the following parts are to be designed assuming a shock factor of at least 2,5:

- all foundations of machinery intended for essential services;
- tailshafts;
- propellers;
- rudders;
- external parts having essential safety functions.

Parts subjected to underwater shocks are not to be built in cast iron (including spheroidal cast iron).

2.8 Calculation methods

2.8.1 Calculation methods different from those described below (including "Finite Element" analysis) may be taken into consideration, provided that they are fully documented and described on the basis of equivalence criteria.

2.9 Web frames

2.9.1 The formulae expressed below for the strength check of web frames are applicable to frames fitted both inside and outside the pressure shell.

3 Special tanks of submersible units

3.1 Foreword

3.1.1 The tanks indicated in subsequent items are generally fitted on large units, self-propelled and manned (submersibles and submarines).

On smaller units, only a limited number of such tanks (if any) may be fitted, depending on the dimensions and manoeuvring methods of the unit.

3.2 Buoyancy tank

3.2.1 This tank is commonly located in the central part, approximately in way of the centre of gravity of the unit when the latter has emerged, so that, when the tank is filled, the trim is practically unaffected.

This is a pressure tank which is filled when the unit has to submerge. When it is emptied, with ballast tanks fully loaded and without manoeuvring the horizontal rudders, the unit has to surface and, due to the fact that its volume is almost equal to that of the sail, the unit comes to the surface, with the sail emerged. It is commonly fitted only in large size units.

Usually, only this tank is emptied while submerged; double bottoms (or ballast tanks), with a lighter structural arrangement, are emptied when the unit is surfacing; high pressure air is forced into the buoyancy tank, while low pressure air which is taken from outside during surfacing is forced into double bottoms.

Ballast tanks always have a near zero differential pressure, which means the external pressure is almost identical to the internal pressure.

3.3 Negative tank

3.3.1 This tank is only fitted in large size units; its volume is equal to about 3,5% of the volume of displacement at a mean draft from the under-keel corresponding to maximum displacement at full load on the surface; with such a tank, the buoyancy reserve is near zero (with such an empty tank, whatever the ballast condition, the submersible always tends to ascend).

As soon as the unit moves to emersion, this tank is emptied by means of compressed air to increase the capability to re-emerge to the surface and the depth is dynamically maintained with horizontal rudders.

This tank allows an emersion speed increase, reducing the transition time during which the unit has a zero or negative stability (see Ch 2, Sec 1, [1.5]).

3.4 Trim tanks (or balancing tanks)

3.4.1 These are tanks located at the fore and aft ends and, generally, in larger size units they are not pressure resistant.

The corresponding transfer pumps are the trim tank pumps.

In small size units these tanks are pressure resistant and replace the buoyancy and negative tanks.

These tanks are never completely filled; however, due to their small size, the corresponding free surfaces are negligible for the stability index.

3.5 Central compensating tanks

3.5.1 These are pressure tanks, used only in large size units, to compensate for any weight variation which can arise during the mission (consumption of fuel, water, food, etc.) in order to maintain the existing displacement of the unit and, consequently, the reserve of buoyancy.

They serve the trim tanks since they allow water flow-through from the fore to the central zone and from aft to the central zone.

The central compensating tank is also used to compensate for variations in the density of sea water (in the Mediterranean Sea and in the Atlantic Ocean it is assumed $\gamma = 1{,}025$ t/m^3; in the Red Sea $\gamma = 1{,}04$ t/m^3; in the Baltic Sea $\gamma = 1{,}01$ t/m^3).

In small size units, compensation and/or trim can be performed by boarding out and boarding in and/or moving some lead bars of known mass (generally 5 kg each), or by fitting spheres with positive buoyancy and sufficient strength to withstand the working pressure (generally they are made of fibreglass reinforced plastic).

3.6 End compensating tanks

3.6.1 These are pressure tanks to compensate for the boarding of weights at ends (for example manipulators, recovery bags, etc.).

They are fitted on small size work units; however, they can be replaced by lead bars as in [3.5] above.

3.7 Design of pressure tanks

3.7.1 Pressure tanks are to be designed to withstand, with the same safety factor assumed as for the pressure hull, a pressure equal to 1,2 times the design pressure of the pressure hull.

They are to be subjected, at the end of manufacturing, to a hydrostatic test pressure equal to 1,5 times the maximum operating pressure.

4 Definitions

4.1 Transverse strength of pressure hulls

4.1.1 Critical load checks

The analysis of transverse strength of a pressure hull can be assumed as that of a cylindrical shell made of stiffened plates with transverse web frames, subjected to uniform external pressure.

This implies the need for a double check of frames and the attached plates.

- A check of in-plane loading of the frame is needed due to its length in respect of the minimum radius of gyration of its cross-section.

  Compression checks of the frame are regarded as a "yielding" check; in-plane loading checks are "tripping" checks.

- The same considerations as above apply also to plates, since they directly contribute with the frame to the structure withstanding the external pressure.

  The strength check of plating with regard to axial and circumferential stress is regarded as a "yielding" check; the check concerning in-plane compression is regarded as a "buckling" check.

4.1.2 Limit pressure

Limit pressure corresponds to the pressure producing plate buckling and/or tripping of frames when subjected to in-plane loading.

Such pressure is the step before critical pressure (see [4.1.4]).

In [4.1.3] the most common causes producing deformation and subsequent structural failures are reported.

4.1.3 Buckling

a) If deformation occurs in the elastic field, and considering a constant material elasticity modulus, a virtually infinite number of buckling conditions are in principle possible for the pressure shell.

   In practice, for the case of a stiffened cylindrical shell, the following buckling modes can be taken into consideration:

   - only shell plates are subjected to deformation while the shape of reinforcements remains unchanged.

     In such a condition, the shell shows a number of inward and outward half-waves in the zone included between two contiguous frames.

     This phenomenon is known as "plate buckling" or "buckling waves" or "Von Mises buckling".

   - Both shell plates and stiffeners are subjected to deformation.

     This phenomenon is regarded as "overall instability".

     In the elastic field, on removal of external loading the phenomenon disappears: this is regarded as "elastic buckling".

     Pressure shells of the spherical shape type, highly sensitive to geometric imperfections, are subjected to "local buckling", which appears around the imperfection.

b) If deformation is produced in the plastic field, the stiffness characteristic of the structure differs from the original: this is a consequence of the non-negligible variation in resilient modulus in plasticised zones.

   When external loads are removed, the phenomenon is permanent: this is regarded as "inelastic buckling".

   The modified structure, exposed to such deformation, may sustain further deformation:

   - produced by pseudo-elastic instability in such a way that buckling appears similarly to that of the elastic field; and

   - produced by plastic hinges, in such a way that an instability pseudo-mechanism appears; this phenomenon is regarded as "plastic instability" and commonly occurs as "bellows shaped buckling" between reinforcements, also regarded as "yielding" (in such zone the external load has exceeded the yielding strength of the material and anticipates the critical pressure condition, see requirement [4.1.4]).

   Tripping of stiffeners is produced by excessive frame spacing or when the cross-section of reinforcements is insufficient.

Buckling modes that can occur on unsymmetrical pressure shells are similar to those described above.

In particular, pressure shells composed of interconnected spherical sectors are deemed to have the same behavior as individual spheres.

The most common causes of damage in pressure resistant structures can be related to:

- in spherical pressure hull: buckling;
- in cylindrical pressure hull: overall instability;
- in cylindrical sail: yielding;
- in access ways (coaming and cover): buckling;
- in outer cylindrical boxes: yielding;
- in curved-surface viewports made of acrylic resin: buckling;
- in portholes: failure due to collapse.

4.1.4 Critical pressure

This is the pressure corresponding to sudden structural collapse; the corresponding depth is the "depth to destruction".

4.1.5 Design depth (or height) and design pressure - allowable stress

The design depth or design height is the maximum operating depth of the unit, corresponding to an absolute pressure not higher than the design pressure.

The maximum allowable normal stress at the design pressure is to be assumed as the minimum of the following values.

$$\frac{\mathbf{R_s}}{1,8} \text{ or } \frac{\mathbf{R_m}}{2,7} \text{ , for ferritic and/or martensitic steels}$$

$$\frac{\mathbf{R_s}}{1,5} \text{ or } \frac{\mathbf{R_m}}{2,7} \text{ , for austenitic steels}$$

$$\frac{\mathbf{R_s}}{1,33} \text{ or } \frac{\mathbf{R_m}}{2,66} \text{ , for aluminium alloys}$$

$\mathbf{R_m}$ = minimum tensile breaking strength of material, in N/mm^2.

$\mathbf{R_s}$ = minimum yielding strength of material or the strength corresponding to a permanent deflection of 0,2% ($\mathbf{R}_{p\,0,2}$), in N/mm^2.

4.1.6 Test depth

This is the maximum depth reached during immersion tests to be performed at the end of building (see Pt A, Ch 2, Sec 3, [2.5]).

In the case of a simulated immersion test (for example by means of a tower ashore or a "depth simulator"), the test pressure is to be 1,1 times the pressure corresponding to the test depth, in sea water having salinity 35°/oo, and the duration of exposure to such pressure is to be not less than 1 hour (see also [4.1.7]).

In the case of a non-simulated test, the maximum test depth is to be at least equal to the design depth.

4.1.7 Service or working pressure - allowable stress

This is the actual pressure on the hull at maximum working depth.

The service pressure is not to exceed the test depth.

Except when specifically indicated, the maximum allowable normal stress, at working pressure, σ_{amm}, can be assumed as the minimum of the following values, in N/mm²:

a) for structures in general

$$\sigma_{amm} = \frac{\mathbf{R}_S}{0,875 \cdot \left(4,09 - \frac{\mathbf{R}_m}{\mathbf{R}_S}\right)}$$

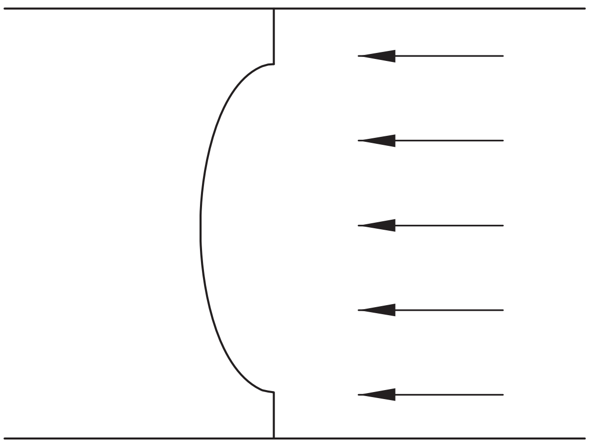
For structures, the maximum allowable ideal total stress, at working pressure σ_{ammt}, in N/mm², is in any case not to exceed 0,75 $\mathbf{R}_S$.

b) for membranes

$$\sigma_{amm} = \frac{2}{3} \cdot \mathbf{R}_S$$

As a thin shell, during operation, it is subjected only to tensile stress (not suitable to resist compression). Membranes are therefore acceptable on pressure shells subjected only to internal pressure (see Fig 1).

Figure 1



4.2 Sea depth (ground)

4.2.1 This is the vertical distance from the sea ground and the maximum elevation of sea surface reached due to the combined effects of applicable astronomical, barometric and wind-induced tide.

a) Astronomical tide is caused by attraction forces exerted by the moon and sun on oceans.

b) Barometric tide is due to the low pressure regime associated with the local presence of typhoons.

The levels achieved by barometric tide are generally lower than those achieved by other tide components. The change Δ_z, in m, of water level due to a change Δ_B, in hPa, of the barometric pressure is given by:

$$\Delta_Z = 0,0181\,\Delta_B$$

c) Wind-induced tide is caused by tangential actions of wind over the sea surface, pushing water masses toward the coasts.

The values of wind-induced and astronomical tides are generally to be obtained from tables and graphs supplied by recognised oceanographic institutes.

5 Corrosion

5.1 Protection against corrosion

5.1.1 When materials with different galvanic potential are used, measures against galvanic corrosion are to be taken.

a) For internal parts the following protection systems can be applied:
   - antioxidant coatings;
   - cathodic protection, with sacrificial anodes or powered anodes;
   - anodic protection, in the case of aluminium alloy.

b) To protect the hull, particularly in way of propellers, rudders, sail and moving components, the following can be applied to the shell:
   - sacrificial zinc anodes;
   - impressed current systems.

c) In general, considering the complementary cathodic protection systems which are always possible, coatings with a tendency to become soapy (cathodic) are to be avoided, products are to be chosen which are hard and resistant to maintenance treatments, coatings of different composition are not to be mixed, unless by special arrangements, nor are paints which are not compatible with each other (such as zinc-based paints over lead-based paints and vice versa).

Paints can be applied according to the following sequence with the indicated minimum thicknesses:
   - primer: 50÷75 µm (zinc-based paint);
   - binder: 12,5÷38 µm;
   - antifouling: 114÷140 µm (acrylic paint).

For emerging superstructures, colours contrasting with that of sea water (such as orange, yellow or red) are to be used and reflective materials and/or fluorescent paints are to be applied, in order to facilitate their identification when on the surface (including at night).

5.2 Design thickness increase

5.2.1 In defining the scantling of various structural parts, an increase in thicknesses due to generalised corrosion wastage of 0,13 mm/year is to be taken into account, in the case of ordinary or higher strength steels.

For light alloys with and without protective coating, consumption equal to 0,1 mm/year or 1 mm/year, respectively, is to be assumed.

Alternatively, or for any material not mentioned among the above, the thickness for corrosion is to be increased by 1,5 mm.

In general, for carbon steels and low alloy steels, the thickness is to be increased by 1 mm; no increase is, in general, required for austenitic stainless steels.

The above extra thickness, which accounts for corrosion, may not be required if protective coatings are applied, of the type and number of layers to be agreed with Tasneef.

6 Longitudinal strength

6.1 Application

6.1.1 As regards the provisions in [1.1.1] c), calculations of longitudinal hull girder strength are not requested for units with overall length $L < 65$ m.

For units with $L \geq 65$ m, diagrams of bending moments and shear are to be obtained for the following conditions:

a) unit floating in still water, in the various loading conditions;

b) unit completely submerged, in equilibrium trim;

c) unit lifted with hoisting devices;

d) unit lashed on supporting saddles or on keel blocks; if lashing is performed on the supply ship, dynamic loads due to ship motion and provided for by the Rules are also to be accounted for.

SECTION 2 STRENGTH CHECK OF PRESSURE SHELLS SUBJECTED TO EXTERNAL PRESSURE

1 General notes

1.1 Premise

1.1.1 Units of measurement

The units of measurement for the items reported here for the strength checks of pressure shells complying with this Section are:

- pressure (working external pressure and design pressure): N/mm^2;
- stresses: N/mm^2;
- linear dimensions: mm;
- thickness: mm;
- areas: mm^2;
- moments of inertia: mm^4.

1.1.2 General units

The following symbols apply to this Section:

P_e = external pressure;

σ_y = material yielding strength;

E = Young's modulus to be assumed equal to 2,1 x 10^5 N/mm^2 for steel in general;

ν = Poisson's coefficient, to be assumed equal to 0,3 for steel in general;

η = safety factor, to determine the allowable working condition, defined case-by-case, in the various following paragraphs.

1.1.3 Parameters of pressure shell plates

$$\vartheta = [3(1-\nu^2)]^{1/4}\,\psi$$

θ value from the above formula is expressed in radians

ψ value is defined below, in each case, in [2.1.1], [2.5.3] a), [3.2.1], [3.7.3] a).

$$\theta = \frac{\vartheta}{2}$$

$$N = \frac{\cosh(2\theta) - \cos(2\theta)}{\sinh(2\theta) + \sin(2\theta)}$$

$$H = \frac{2(\sinh\theta \cdot \cos\theta + \cosh\theta \cdot \sin\theta)}{\sinh(2\theta) + \sin(2\theta)}$$

$$K = \frac{\sinh(2\theta) - \sin(2\theta)}{\sinh(2\theta) + \sin(2\theta)}$$

In the hyperbolic functions the value of ϑ (and therefore of θ) is expressed in radians; in the trigonometric functions θ is the corresponding value converted into sexagesimal degrees.

1.1.4 Adopted formulae

The reported formulations are intended to be applied for strength checking, not for designing, allowing verification of the pressure at which the unit can operate in safety with the scantlings proposed by the Designer.

Rule thickness "t" for the shell is to be derived from formulae expressing the above-mentioned pressure.

1.1.5 General scheme for a pressure shell

Fig 1 gives a schematic plan of shapes and structural components usually applicable to a pressure cylindrical shell.

2 Cylindrical pressure shells, with circular cross-section, subjected to external pressure, with length L $\leq$ 20 m

2.1 Strength check of pressure shell plating between reinforcements

2.1.1 Plating strength

The following parameters are to be obtained, according to Fig 2 and Fig 3.

Figure 1 : Schematic plan of main structural components of a pressure shell

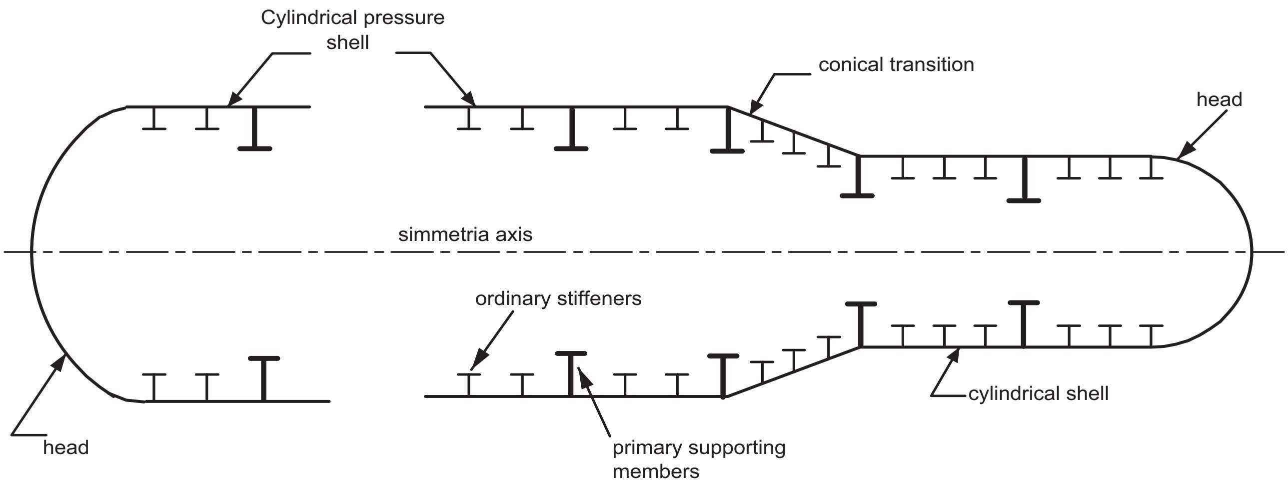


Figure 2 : Compartment length for strength check (with or without stiffeners)

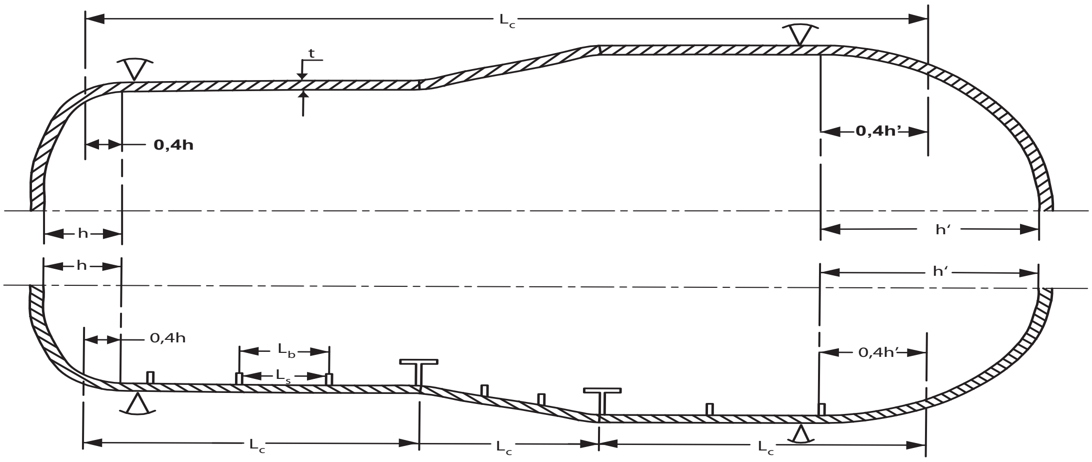
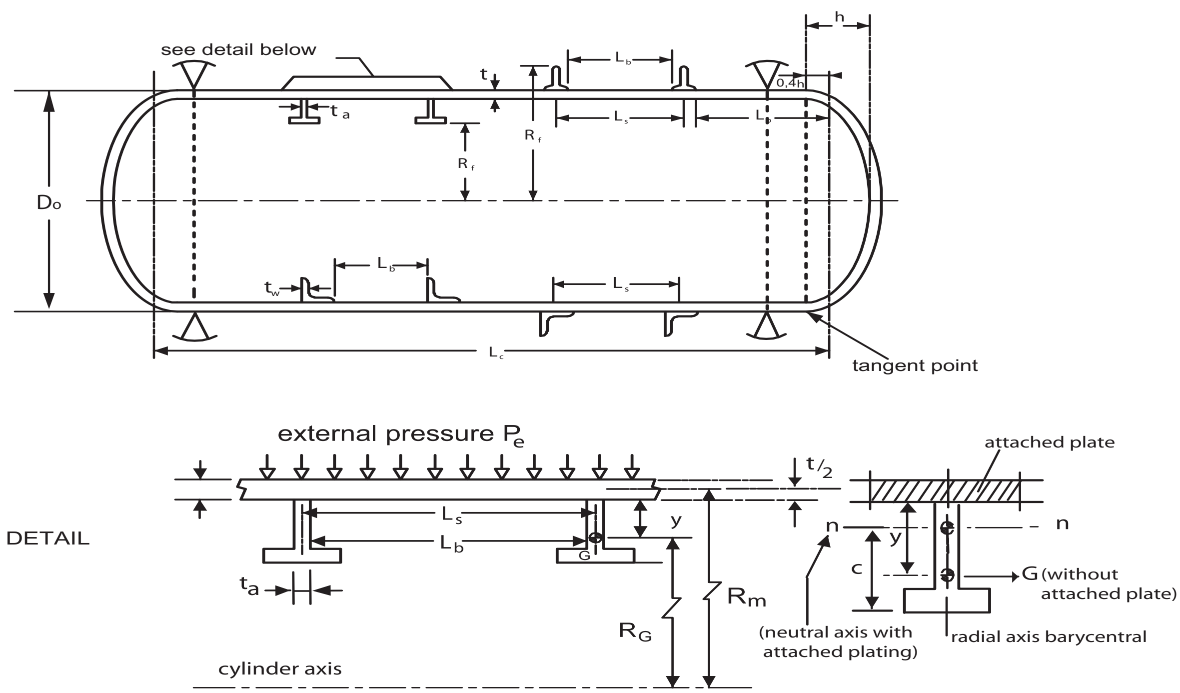


Figure 3 : Definitions



L_b = free span of plating between two adjacent reinforcements;

L_s= distance (taken parallel to revolution axis of the shell) between the centroids of two adjacent reinforcements;

S = the greater of L_b and L_s;

R_m = the average radius (at half thickness of pressure shell plate);

R_G = radius to the centroid of cross-section of stiffener (without attached plating);

t = thickness of cylindrical shell;

t_a = thickness of reinforcement web;

A_{rs} = cross-sectional area of reinforcement, without attached plating;

σ_y, E, ν, η: defined in [1.1.2].

$$\Psi = \frac{S}{\sqrt{R_m \cdot t}}$$

ψ parameter allows ϑ (and θ) in [1.1.3] to be obtained and the values for parameters N, H, K also specified in [1.1.3] to be calculated.

Moreover:

$$A = A_{rs}\left(\frac{R_m}{R_G}\right)^2$$

for reinforcements fitted outside the pressure shell;

or:

$$A = A_{rs}\frac{R_m}{R_G}$$

for reinforcements fitted inside the pressure shell.

$$F = \frac{A\left(1 - \frac{\nu}{2}\right) \cdot H}{A + t \cdot t_a + \frac{2NtS}{\vartheta}}$$

Yielding pressure for the plating of the cylindrical pressure shell, at half the distance between two adjacent reinforcements, in way of the vertical axis passing through the centroid of the reinforcement, is given by:

$$P_y = \sigma_y \frac{t}{R_m(1 - F)}$$

The Von Mises buckling pressure for the cylindrical pressure shell is given by:

$$P_b = \frac{2,42 \cdot E \cdot \left(\frac{t}{2R_m}\right)^{5/2}}{(1 - \nu^2)^{3/4} \cdot \left[\frac{S}{2R_m} - 0,45\left(\frac{t}{2R_m}\right)^{1/2}\right]}$$

The following is calculated:

$$\beta = \frac{P_b}{P_y}$$

The limit pressure of the cylindrical shell between two adjacent reinforcements is given by:

$$P_c = \frac{P_b}{2} \quad \text{if} \quad \beta \le 1$$

$$P_c = P_y\left(1 - \frac{1}{2\beta}\right) \quad \text{if} \quad 1 < \beta \le 3$$

$$P_c = 0,833 P_y \quad \text{if} \quad \beta > 3$$

Assuming:

η = 0,80

the maximum allowable working pressure for the plating is given by:

$$P_{camm} = P_c \cdot \eta = 0,80 \cdot P_c$$

2.1.2 Longitudinal limit pressure

The following parameters are to be obtained:

σ_y, ν, η: defined in [1.1.2];

t, R_m : defined in [2.1.1];

H, K : calculated in [2.1.1] as a function of ψ;

F : determined in [2.1.1];

The following is to be calculated:

μ : F / H

Limit pressure corresponding to longitudinal stress up to the yielding of reinforcements is given by:

$$P_{lim} = \frac{2\sigma_y \cdot t}{R_m\left(1 + \frac{3,464\mu K}{\sqrt{1 - \nu^2}}\right)}$$

Assuming:

η = 0,65

the maximum allowable working pressure is given by:

$$P_{limamm} = P_{lim} \cdot \eta = 0,65 \cdot P_{lim}$$

2.1.3 Unstiffened pressure shells

Plates of frameless pressure shells are to be checked using the expressions in [2.1.1], with the following changes.

The value for L_c (compartment length considered for overall instability, defined in [2.2] and shown in Fig 2 and Fig 3), is to be computed; this value is to include the axial length of any conical part adjacent to the cylindrical part(s), for each cylindrical/conical transition length without reinforcements, without any primary supporting members at their connection points (see Fig 2, upper part).

It is assumed:

$S = L_c$

F = 0

The ratio t / R_m is to be assumed such that, for each section on the cylindrical or conical part within L_c, it minimises the limit pressures P_c between reinforcements.

2.2 Span of pressure shell between primary supporting members

2.2.1 L_c is the largest distance between two primary supporting members or between the primary supporting member and head or the whole distance between two heads (in the case of a single compartment, as in Fig 3).

In heads, the length L_c is to include 40% of the height of the head (see Fig 2 and Fig 3).

2.3 Primary supporting members

2.3.1 Reinforcements adopted to decrease compartment length L_c for which the overall buckling strength is to be calculated are regarded as primary supporting members, whose scantlings are to satisfy the requirements in [2.5.3].

2.4 Overall buckling strength

2.4.1 The following parameters are to be calculated:

n : number of half-waves at structural failure; it is a positive integer, equal to or greater than two (see Fig 4), which minimises the value of pressure P_B (computed at the end of this paragraph), corresponding to the overall buckling (overall instability pressure);

E, η : defined in [1.1.2];

L_s : defined in [2.1.1];

L_c : defined in [2.2.1];

R_m, S, t : defined in [2.1.1];

L_e : width of plate attached to ordinary stiffeners equal to the lower of

$$1,5\sqrt{R_m \cdot t} \quad \text{and} \quad 0,75 \cdot L_s$$

J : moment of inertia of ordinary stiffener cross-section, with attached plating having a width equal to L_e (as defined above), about its neutral axis parallel to the cylinder axis;

$$\lambda = \frac{\pi R_m}{L_c}$$

$$A_2 = n^2 - 1$$

$$A_1 = \frac{\lambda^4}{\left(A_2 + \frac{\lambda^2}{2}\right) \cdot (n^2 + \lambda^2)^2}$$

Pressure corresponding to overall buckling of the pressure shell (overall instability pressure) is given by:

$$P_B = E\left(A_1 \cdot \frac{t}{R_m} + A_2 \cdot \frac{J}{S R_m^{\ 3}}\right)$$

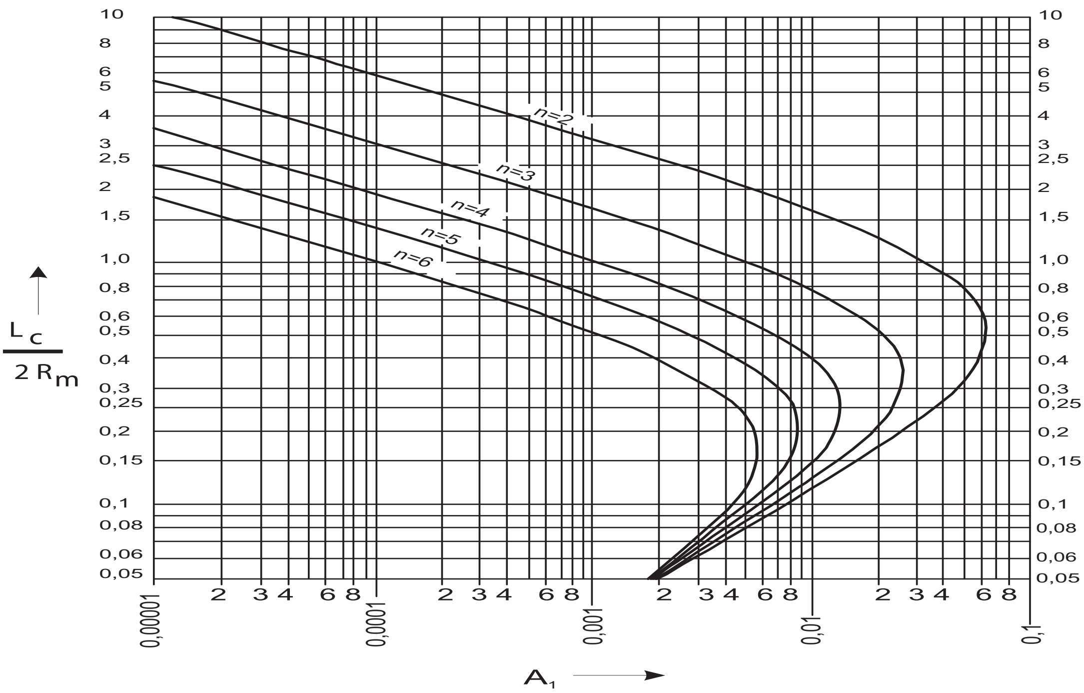
Assuming:

η = 0,50

the maximum allowable working pressure is given by:

$$P_{Bamm} = P_B \cdot \eta = 0,50 \cdot P_b$$

Figure 4 : Overall buckling strength - number of half-waves at structural failure



2.5 Reinforcements

2.5.1 General

All reinforcements are to be fitted to the shell plating by means of continuous welding.

Each reinforcing ring welded to the cylindrical shell is to comply with the following checks regarding maximum stress, tripping of reinforcement, local buckling of webs and flanges, and flexural stiffness.

These checks apply to reinforcements having symmetrical flanges (when fitted) about the web.

Different arrangements will be subject to specific review.

2.5.2 Ordinary stiffeners

a) Yielding

The following parameters are to be obtained:

σ_y, E, ν, η: defined in [1.1.2];

t, R_m : defined in [2.1.1];

ν : defined in [2.4.1];

c : distance of the stiffener flange (when fitted) from the neutral axis of the stiffener with its attached plating of width L_e as defined in [2.4.1] (see detail in Fig 3);

δ = allowable out-of-roundness, equal to 0,005 R_m (0,5% R_m);

R_f = radius to stiffener tip (either inside or outside the pressure shell, see Fig 3);

μ : defined in [2.1.2];

P_B : computed in [2.4.1];

$$P_{yf} = \frac{\sigma_y \cdot t \cdot R_f}{R_m^2\left(1 - \frac{\nu}{2} - \mu\right)}$$

$$T = \frac{\sigma_y}{P_{yf}}$$

$$V = Ec\delta(n^2 - 1)$$

$$W = P_B \cdot R^2{}_m$$

The following is to result:

$$\Delta = (T \cdot W + V + \sigma_y R_m^2) - 4 \cdot T \cdot R_m^2 \sigma_y \cdot W \geq 0$$

The yielding pressure of ordinary stiffeners of the shell, including the circumferential (hoop) and bending (from possible out-of-roundness) stresses, is to be taken as the lower absolute value from the two roots of the following expression:

$$P_{\varnothing} = \frac{T \cdot W + V + \sigma_y {R_m}^2 \pm \sqrt{\Delta}}{2T \cdot {R_m}^2}$$

Assuming:

η = 0,50

the maximum allowable working pressure is given by:

$$P_{\varnothing amm} = P_{\varnothing} \cdot \eta = 0,50 \cdot P_{\varnothing}$$

b) Stiffener tripping

The following parameters are to be obtained:

E : defined in [1.1.2];

R_m, A_{rs} : defined in [2.1.1];

ψ : distance from the ordinary stiffener's centroid of cross-section, without attached plating, to the closest face of the pressure shell plating (see detail in Fig 3);

J_y : moment of inertia of the ordinary stiffener's cross-section, without attached plating, about the radial axis through the centroid parallel to the web of the stiffener's cross-section.

The circumferential tripping stress of the reinforcements (with flange) fitted on the pressure shell plating is given by:

$$\sigma_r = \frac{E \cdot J_y}{A_{rs} \cdot R_m \cdot y}$$

The above stress is to be greater than the maximum applicable yielding strength.

c) Local buckling

The following slenderness limits are to be fulfilled in order to prevent local buckling on the ordinary stiffener's flange and web, where E and σ_y are those defined in [1.1.2]:

- Flat bars and bulb bars:

$$\frac{\text{height}}{\text{thickness}} \leq 0,3\sqrt{\frac{E}{\sigma_y}}$$

- Ordinary stiffener's web (with flange):

$$\frac{\text{web height(without flange)}}{\text{thickness}} \leq 0,9\sqrt{\frac{E}{\sigma_y}}$$

d) Required inertia

To calculate the minimum required moment of inertia for pressure shell ordinary stiffeners, the following parameters are to be determined:

P_e , E : defined in [1.1.2];

L_s , R_G : defined in [2.1.1];

D_0 : outer diameter of pressure shell (see Fig 3);

L_e : defined in [2.4.1].

The moment of inertia of an ordinary stiffener, with attached plate of width L_e, about the neutral axis parallel to the cylinder axis is to be not less than the following:

$$J_{reg} = \frac{1}{3} \cdot \frac{P_e \cdot D_0 \cdot L_s \cdot R_G^2}{E}$$

2.5.3 Primary supporting members

a) Yielding

The following parameters are to be obtained:

σ_y, ν, η, E : defined in [1.1.2];

R_m, t : defined in [2.1.1];

L_{sR} : distance (taken parallel to the shell axis) between the centroids of two adjacent primary supporting members (similarly to what is indicated for L_s in Fig 3);

L_{eR} : plate width of the pressure shell attached to the primary supporting member, equal to the lower of:

$$1,5\sqrt{R_m \cdot t} \text{ and } 0,75 \cdot L_{sR}$$

c_R : distance of the flange (if any) of the primary member to the neutral axis with its attached plating of width L_{eR} as defined above (similarly to what is indicated for c in the detail in Fig 3);

δ : defined in [2.5.2] a);

J_R : moment of inertia of the primary supporting member's cross-section, with attached plating of width L_{eR} as defined above, about the axis through the centroid parallel to the cylinder axis;

R_{fR} : radius to the primary member's tip (inside or outside the pressure shell, see Fig 3) (similarly to what is indicated for R_f in Fig 3);

L_C : distance between two adjacent primary supporting members, as specified in [2.3.1] (see Fig 2)

A_{Rs} : cross-sectional area of primary supporting member, without attached plating;

R_{GR} : radius to centroid of cross-section of primary member only (without attached plating) (similarly to what is indicated for R_G in the detail in Fig 3);

t_{aR} : thickness of primary supporting member web (similarly to what is indicated for t_a in Fig 3).

The following is to be calculated:

$$A_R = A_{Rs}\left(\frac{R_m}{R_{GR}}\right)^2$$

for members fitted outside the pressure shell;

or:

$$A_R = A_{Rs}\frac{R_m}{R_{GR}}$$

for members fitted inside the pressure shell.

Thus:

$$\psi_R = \frac{L_c}{\sqrt{R_m \cdot t}}$$

The value of ψ_R allows ϑ (and θ) and the value for the parameter N (all in [1.1.3]) to be computed.

The following is also obtained:

$$\mu = \frac{A_R\left(1-\frac{\nu}{2}\right)}{A_R + t_{aR} \cdot t + \frac{2N \cdot t \cdot L_c}{\vartheta}}$$

$$P_{yfR} = \frac{\sigma_y \cdot t \cdot R_{fR}}{R_m^{\,2}\left(1-\frac{\nu}{2}-\mu\right)}$$

$$P_{BR} = \frac{3EJ_R}{L_c \cdot R_m^2}$$

$$T = \frac{\sigma_y}{P_{yfR}}$$

$$X = 3E \cdot c_R \cdot \delta$$

$$W = P_{BR} \cdot R_m^2$$

The following is to result:

$$\Delta_R = (T \cdot W + X + \sigma_y R_m^2)^2 - 4TR_m^2\sigma_y W \geq 0$$

The yielding pressure of the primary supporting member of the pressure shell, including the circumferential (hoop) and bending (from possible out-of-roundness) stresses, is to be taken as the lower absolute value from the two roots of the following relation:

$$P_{\varnothing R} = \frac{T \cdot W + X + \sigma_y {R^2}_m \pm \sqrt{\Delta_R}}{2T \cdot R_m^{\,2}}$$

Assuming:

$\eta = 0{,}50$

the maximum allowable working pressure is given by:

$$P_{\varnothing Ramm} = P_{\varnothing R} \cdot \eta = 0,50 \cdot P_{\varnothing R}$$

b) Tripping

The following parameters are to be obtained:

E : defined in [1.1.2];

R_m : defined in [2.1.1];

A_{Rs} : defined in [2.5.3] a);

y_R : distance from the primary supporting member's cross-section centroid, without attached plating, to the closest face of the pressure shell plating (similarly to what is indicated for y in the detail in Fig 3);

J_{yR} : moment of inertia of the primary supporting member's cross-section, without attached plating, about the radial axis through the centroid, parallel to the web.

The circumferential tripping stress is given by:

$$\sigma_{rR} = \frac{E \cdot J_{yR}}{A_{Rs} \cdot R_m \cdot y_R}$$

This stress is to be greater than the maximum applicable yielding strength.

c) Local buckling

The requirement in [2.5.2] c) for ordinary stiffeners is applicable.

d) Required inertia

The following parameters are to be determined:

P_e, E : defined in [1.1.2];

L_c, R_{GR}, L_{eR} : defined in [2.5.3] a);

D_0 : outer diameter of pressure shell (see Fig 3);

The moment of inertia of the primary supporting member's cross-section, with attached plate of width L_{eR}, about the neutral axis parallel to the cylinder axis, is to be not less than the following:

$$J_{Rreg} = \frac{1}{3}\frac{P_e \cdot D_o \cdot L_c \cdot R^2_{GR}}{E}$$

2.5.4 Other primary reinforcements

The above considerations are applicable also to any other primary supporting member fitted in order to limit the compartment's length and to ordinary stiffeners within the same compartment length, with a different shape with respect to those taken into consideration in [2.5.2] and [2.5.3].

3 Cylindrical pressure shells, with conical or truncated conical shape circular cross-section, subjected to external pressure, with length L ≤ 20 m

3.1 General

3.1.1 Conical shells are to have a semi-open angle α of the cone not greater than 60°.

Conical shells having $\alpha > 60°$ will be subject to particular attention. The radial axis of all reinforcements is to be normal to the cone axis.

Conical shells fitted with ordinary stiffeners are to have reinforced rings at their ends, located as close as possible to the transition point between the conical and cylindrical parts (see Fig 2).

Local stresses and stress concentrations are to be taken into consideration in transitions between the conical and cylindrical parts.

3.2 Strength check of plating of conical pressure shell, between reinforcements

3.2.1 Plating strength

The following parameters are to be obtained; refer to Fig 5 (see also details A and B).

α = defined in [3.1.1];

L_1 = distance (taken parallel to the cone axis) between the centroidal axes of two adjacent reinforcements;

L_b = free span of the plating between two adjacent reinforcements (to be measured between the two facing faces of two adjacent reinforcements, parallel to the cone axis) (see also Fig 3);

S = the greater of L_b or L_s;

R_{m1} = mean radius (at half thickness of the conical pressure shell plate) on the minor base of the conical extension which is to be analysed;

R_{m2} = mean radius (at half thickness of the conical pressure shell plate) on the major base of the conical extension which is to be analysed;

$R_M = (R_{m1} + R_{m2})/2$ or $(R_{m2} + R_{m3})/2$, etc, depending on the conical extension which is to be analysed;

t = plate thickness of the conical pressure shell;

t_a = web thickness of reinforcement having the smallest cross-section within the conical extension which is to be considered;

A_{rs} = cross-sectional area of reinforcement having the smallest surface within the conical extension which is to be considered, without attached plating;

y = distance of reinforcement centroid (having the smallest surface within the conical extension to be considered), without attached plating, to the closest face of the plate of the conical pressure shell (see Fig 5, detail "B");

σ_y, ν, η, E : defined in [1.1.2].

The following is to be calculated:

$$\psi = \frac{S}{\sqrt{R_M \cdot t\cos\alpha}}$$

The value of ψ allows ϑ (and θ) and the parameters N, H, K in [1.1.3] to be calculated.

Moreover:

$R_{Me} = R_M + t / 2 + y$, in the case of reinforcements fitted outside the pressure shell;

$R_{Mi} = R_M - (t/2 + y)$, in the case of reinforcements fitted inside the pressure shell;

Then:

$A = A_{rs} \cdot (R_M / R_{Me})^2$, in the case of reinforcements fitted outside the pressure shell;

$A = A_{rs} \cdot (R_M / R_{Mi})$, in the case of reinforcements fitted inside the pressure shell;

$$F = \frac{A \cdot \left(1 - \frac{\nu}{2}\right) \cdot H}{A + t_a \cdot t\cos\alpha + \frac{2Nt\cos\alpha S}{\vartheta}}$$

The yielding pressure for the conical pressure shell plating, at half the distance between two adjacent reinforcements and in way of the cross-section of one of them is given by:

$$P_{yc} = \sigma_y \frac{t \cdot \cos\alpha}{R_{m2}(1 - F)}$$

The Von Mises buckling pressure for the conical pressure shell is given by:

$$P_{bc} = \frac{2,42E\left(\frac{t \cdot \cos\alpha}{R_{m1} + R_{m2}}\right)^{5/2}}{(1 - \nu^2)^{3/4} \cdot \left[\frac{S}{R_{m1} + R_{m2}} - 0,45\left(\frac{t \cdot \cos\alpha}{R_{m1} + R_{m2}}\right)^{1/2}\right]}$$

After calculating the following ratio:

$$\beta = \frac{P_{bc}}{P_{yc}}$$

the limit pressure for the conical pressure shell between two reinforcements is given by:

$$P_{limc} = \frac{P_{bc}}{2} \quad \text{se} \quad \beta \le 1$$

$$P_{limc} = P_{yc}\left(1 - \frac{1}{2\beta}\right) \quad \text{se} \quad 1 < \beta \le 3$$

$$P_{limc} = 0,833 \cdot P_{yc} \quad \text{se} \quad \beta > 3$$

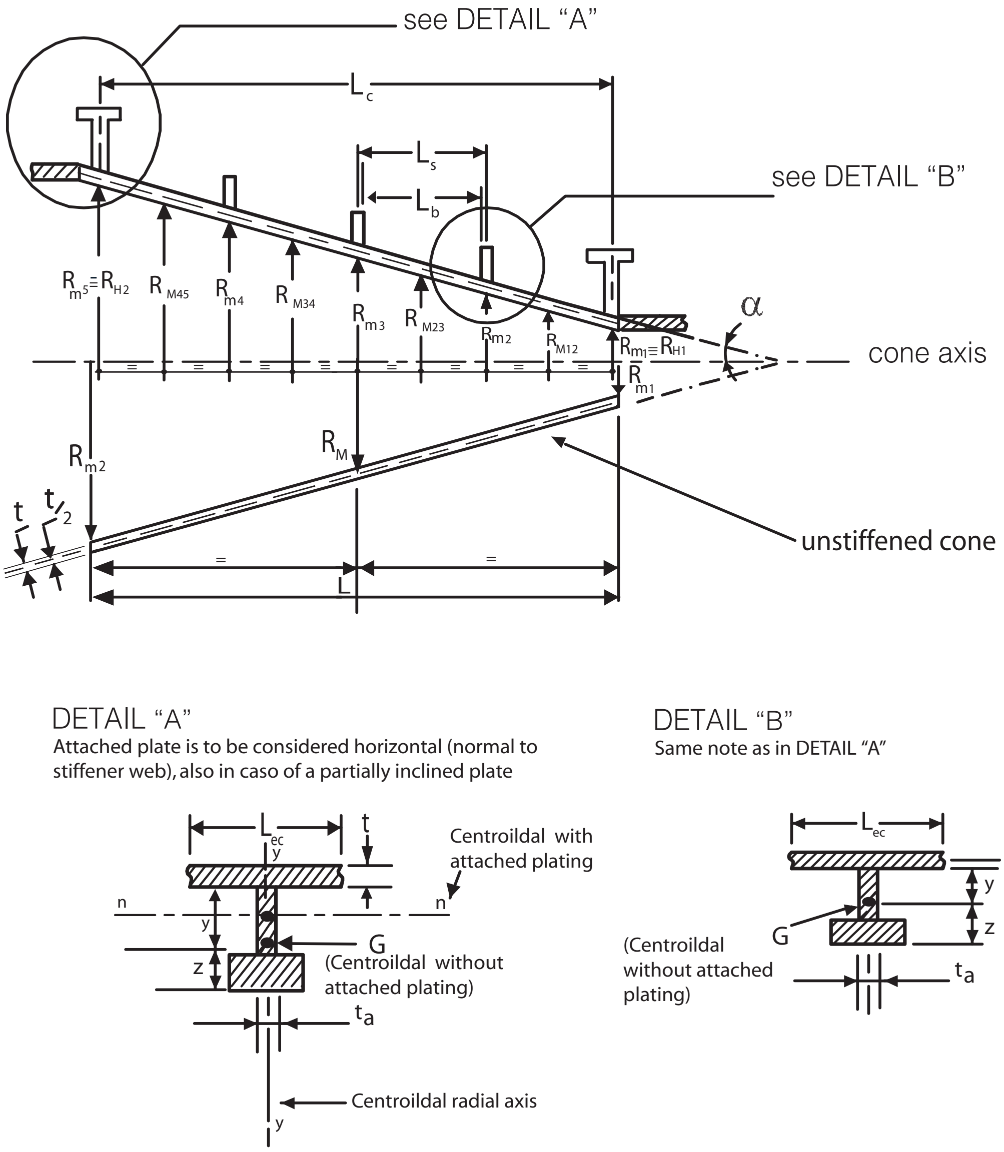
Assuming:

$\eta = 0,70$

the maximum allowable working pressure of the plating is:

$$P_{limcamm} = \eta \cdot P_{limc} = 0,70 \cdot P_{limc}$$

Figure 5 : Conical shells - Definitions



3.2.2 Longitudinal limit pressure

The following parameters are to be calculated:

σ_y, ν, η = defined in [1.1.2];

α = defined in [3.1.1];

t, R_M = defined in [3.2.1];

H, K = calculated in [3.2.1] depending on the ψ value;

F = determined in [3.2.1].

The following is to be calculated:

$\mu = F / H$

The limit pressure corresponding to longitudinal stress in the reinforcement up to yielding is:

$$P_{limLC} = \frac{2\sigma_Y \cdot t\cos\alpha}{R_M\left(1 + \frac{3,464 \cdot \mu K}{\sqrt{1-\nu^2}}\right)}$$

Assuming:

$\eta = 0{,}65$

the maximum allowable working pressure is:

$$P_{limLcamm} = \eta \cdot P_{limLc} = 0,65 \cdot P_{limLc}$$

3.2.3 Strength check completion

For each of the remaining spans of the cone, the checks in [3.2.1] and [3.2.2] are to be carried out.

3.3 Unstiffened conical pressure shells

3.3.1 Plates of frameless conical pressure shells, including those having ends stiffened by primary supporting structures (see [3.5]), are to be verified by applying the formulations in [3.2.1], determining the length L, total axial length of the cone, as shown in Fig 5.

It is assumed that:

S = L

F = 0

Furthermore, for all unstiffened cylindrical (straight) parts, close to the unstiffened conical part, without supporting structures at their transition points, the requirement in [2.1.3] on the ratio t/R_m is to be fulfilled.

3.4 Pressure shell length between reinforced structures

3.4.1 L_c is the distance between two primary supporting structures (see Fig 5) or between the reinforcing support and a head or the full length of compartment between the two heads.

In the case of a termination head, the length L_c is to include 40% of the height of the head (see Fig 2).

3.5 Primary supporting members

3.5.1 Reinforcements adopted to reduce the compartment length L_c for which the overall buckling strength is to be checked are regarded as primary supporting members, whose scantlings are to satisfy the requirements in [3.7.3].

3.6 Overall buckling strength

3.6.1 The following parameters are to be calculated:

n : number of half-waves at structural failure; it is a positive integer, equal to or greater than two (see Fig 4), which minimises the value of pressure P_{Bc} (computed at the end of this paragraph), corresponding to the overall buckling (overall instability buckling);

E, η : defined in [1.1.2];

α : defined in [3.1.1];

L_c : defined in [2.2.1];

R_{H1} : mean radius (at half thickness of the conical pressure shell plating) at the primary supporting member on the minor base of the conical extension (see Fig 5);

R_{H2} : mean radius (at half thickness of the conical pressure shell plating) at the primary supporting member on the major base of the conical extension (see Fig 5);

R_{Hm} : $(R_{H1} + R_{H2}) / 2$;

t : defined in [3.2.1];

L_{ec} : width of plate attached to ordinary stiffeners equal to the lower value of:

$$1,5\sqrt{R_{Hm} \cdot t \cdot \cos\alpha} \qquad \text{and} \qquad 0,75 \cdot L_c$$

J_c : moment of inertia of ordinary stiffener cross-section (for the one with the lowest moment of inertia among those bounded between the primary supporting structures of the conical pressure shell), with attached plating having a width L_{ec} (as defined above), about its neutral axis parallel to the cone axis;

$$\lambda = \frac{\pi R_{Hm}\cos\alpha}{L_C}$$

$$A_2 = n^2 - 1$$

$$A_1 = \frac{\lambda^4}{\left(A_2 + \frac{\lambda^2}{2}\right) \cdot (n^2 + \lambda^2)^2}$$

The pressure corresponding to overall plate buckling of the conical pressure shell between primary supporting structures (overall instability pressure) is given by:

$$P_{Bc} = E\left(\frac{t\cos\alpha}{R_{Hm}} \cdot A_1 + \frac{J_c}{L_c R_{H2}^3} \cdot A_2\right)$$

Assuming:

$\eta = 0{,}50$

the maximum allowable working pressure is given by:

$$P_{Bcamm} = \eta \cdot P_{Bc} = 0,50 \cdot P_{Bc}$$

3.7 Reinforcements

3.7.1 General

All reinforcements are to be fitted to the shell plating by means of continuous welding.

Each reinforcing ring welded to the cylindrical shell is to comply with the following checks regarding maximum acting stress, tripping of reinforcement, local buckling of webs and flanges, and flexural stiffness.

These checks apply to reinforcements having symmetrical flanges (when fitted) about the web.

Different arrangements will be subject to specific review.

3.7.2 Ordinary stiffeners

a) Yielding

The following parameters are to be obtained:

σ_y, ν, η, E = defined in [1.1.2];

α = defined in [3.1.1];

t, R_M = defined in [3.2.1];

n = defined in [3.6.1];

c = distance of the stiffener flange (when fitted) from the neutral axis of the stiffener with its attached plating of length L_{ec} as defined in [3.6.1] (see detail A in Fig 5);

δ = allowable out-of-roundness, equal to 0,005 R_M (corresponding to 0,5% R_M);

y = defined in [3.2.1];

z = distance of the centroid of the reinforcement's cross-section, without attached plating, from the end of the reinforcement (see detail B in Fig 5);

μ = defined in [3.2.2];

P_{Bc} = calculated in [3.6.1];

$R_{fc} = R_M + t/2 + y + z$, in the case of reinforcements fitted outside the pressure shell;

$R_{fc} = R_M - (t/2 + y + z)$, in the case of reinforcements fitted inside the pressure shell;

$$P_{yfc} = \frac{\sigma_y \cdot t\cos\alpha \cdot R_{fc}}{R_M^2\left(1 - \frac{\nu}{2} - \mu\right)}$$

$$Y = \frac{\sigma_y}{P_{yfc}}$$

$$V = Ec\delta(n^2 - 1)$$

$$Z = P_{BC} \cdot R_M^2$$

The following is to result:

$$\Delta = (Y \cdot Z + V + \sigma_y R_M^2)^2 - 4 \cdot Y \cdot R_M^2 \sigma_y \cdot Z \geq 0$$

The yielding pressure of ordinary stiffeners of the shell, including the circumferential (hoop) and bending (from possible out-of-roundness) stresses, is to be taken as the lower absolute value from the two roots of the following relation:

$$P_{\phi c} = \frac{Y \cdot Z + V + \sigma_y R_M{}^2 \pm \sqrt{\Delta}}{2Y \cdot R_M{}^2}$$

Assuming:

η = 0,50

the maximum allowable working pressure is given by:

$$P_{\phi camm} = \eta \cdot P_{\phi c} = 0,50 \cdot P_{\phi c}$$

b) Stiffener tripping

The following parameters are to be obtained:

E = defined in [1.1.2];

R_M, A_{rs} = defined in [3.2.1];

y = defined in [3.2.1];

J_y : moment of inertia of the ordinary stiffener's cross-section, without attached plating, about the radial axis through the centroid parallel to the web of the stiffener's cross-section.

The circumferential tripping stress of the reinforcements (with flange) fitted on the pressure shell plating is given by:

$$\sigma_{rc} = \frac{E \cdot J_y}{A_{rs} \cdot R_M \cdot y}$$

The above stress is to be greater than the maximum applicable yielding strength.

c) Local buckling

See [2.5.2] c).

d) Required inertia

The following parameters are to be determined:

P_e, E = defined in [1.1.2];

α = defined in [3.1.1];

S, t, R_M, R_{Me}, R_{Mi} = defined in [3.2.1];

$R_{MC} = R_{Me}$, in the case of reinforcements fitted outside the pressure shell;

$R_{MC} = R_{Mi}$, in the case of reinforcements fitted inside the pressure shell.

The moment of inertia of the ordinary stiffener, with attached plate of width L_{ec} (defined in [3.6.1]), about the neutral axis parallel to the cone axis, is to be not less than the following:

$$J_{reg} = \frac{1}{3}\frac{P_e(2R_M + t)S \cdot R_{MC}^2}{E \cdot \cos\alpha}$$

3.7.3 Primary supporting members

a) Yielding:

The following parameters are to be obtained:

σ_y, ν, η, E = defined in [1.1.2];

α = defined in [3.1.1];

t, RH_M = defined in [3.2.1];

L_c = length of compartment to be assumed for the overall instability check (see Fig 5);

L_{eRc} = plate width of pressure shell attached to the primary supporting member, equal to the lower of:

$$1,5\sqrt{R_{Hm}\cdot t\cdot\cos\alpha}\ \text{ and } 0,75\cdot L_c$$

c_R = distance of the flange (if any) of the primary member to the neutral axis with its attached plating of width L_{eRc} as defined above (see detail A of Fig 5);

δ = defined in [3.7.2] a);

J_{Rc} = moment of inertia of the primary supporting member's cross-section, with attached plating of width L_{eRc}, as defined above, about the axis through the centroid of the same group parallel to the cone axis;

y = distance of the centroid of the cross-section of the primary supporting member, without attached plating, to the closest face of the plate of the conical pressure shell (see Fig 5, detail A);

z = distance of the centroid of the cross-section of the primary supporting member, without attached plating, to the end of the reinforcement (see Fig 5, detail A);

$R_{fcR} = R_{Hm} + t/2 + y + z$, in the case of reinforcements fitted outside the pressure shell;

$R_{fcR} = R_{Hm} - (t/2 + y + z)$, in the case of reinforcements fitted inside the pressure shell;

R_{H2} = defined in [3.6.1];

$R_{Sx} = R_{Hm} + t/2 + y$, in the case of reinforcements fitted inside the pressure shell;

$R_{Sn} = R_{Hm} - (t/2 + y)$, in the case of reinforcements fitted inside the pressure shell;

A_{Rs} = cross-sectional area of primary supporting member, without attached plating;

$A_{Rc} = A_{Rs}\,(R_{Hm}/R_{sx})^2$, in the case of reinforcements fitted outside the pressure shell;

$A_{Rc} = A_{Rs}\cdot R_{Hm}/R_{sn}$, in the case of reinforcements fitted inside the pressure shell;

t_{aR} = thickness of primary supporting member web (see Fig 5, detail A).

The following is to be calculated:

$$\psi_{Rc} = \frac{L_e}{\sqrt{R_{Hm}\cdot t\cdot\cos\alpha}}$$

The value of ψ_{Rc} allows ϑ (and θ) and the parameter N (all in [1.1.3]) to be calculated.

The following is also obtained:

$$\mu = \frac{A_{Rc}\left(1-\dfrac{\nu}{2}\right)}{A_{Rc}+t_{aR}\cdot t\cos\alpha+\dfrac{2N\cdot t\cos\alpha\cdot L_c}{\vartheta}}$$

$$P_{yfRc} = \frac{\sigma_y\cdot t\cos\alpha\cdot R_{fcR}}{R_{Hm}^2\left(1-\dfrac{\nu}{2}-\mu\right)}$$

$$P_{BRc} = \frac{3EJ_{Rc}}{L_c\cdot R_{H2}^3}$$

$$Y = \frac{\sigma_y}{P_{yfRc}}$$

$$X = 3E\cdot c_R\cdot\delta$$

$$D = P_{BRc}\cdot R_{Hm}^2$$

The following is to result:

$$\Delta_{Rc} = (Y\cdot D + X + \sigma_y R_{Hm}^2)^2 - 4YR_{Hm}^2\sigma_y D \geq 0$$

The yielding pressure of the primary supporting member of the pressure shell, including the circumferential (hoop) and bending (from possible out-of-roundness) stresses, is to be taken as the lower absolute value from the two roots of the following relation:

$$P_{\varnothing Rc} = \frac{Y\cdot D + X + \sigma_y R^2_{Hm} \pm \sqrt{\Delta_{Rc}}}{2Y\cdot R_{Hm}^2}$$

Assuming:

$\eta = 0,50$

the maximum allowable working pressure is given by:

$$P_{\varnothing Rcamm} = P_{\varnothing Rc}\cdot\eta = 0,50\cdot P_{\varnothing Rc}$$

b) Tripping

The following parameters are to be obtained:

E = defined in [1.1.2];

J_{YRc} = moment of inertia of the primary supporting member's cross-section, without attached plating, about the radial axis through the centroid parallel to the web.

A_{Rs} = defined in [3.7.3] a);

R_{Hm} = defined in [3.6.1];

Y_{Rc} = distance of the centroid of the primary supporting member's cross-section, without attached plating, from the closest face of the pressure shell plating (similarly to what is indicated for y in detail A of Fig 5).

The circumferential tripping stress of primary members connected to pressure shell plating is given by:

$$\sigma_{Rc} = \frac{E\cdot J_{yRc}}{A_{Rs}\cdot R_{Hm}\cdot y_{Rc}}$$

The above stress is to be greater than the maximum applicable yielding strength.

c) Local buckling

The provisions of [2.5.2] c) are applicable.

d) Required inertia

The following parameters are to be determined:

P_e, E = defined in [1.1.2];

α = defined in [3.1.1];

t = defined in [3.2.1];

R_{Hm} = defined in [3.6.1];

L_c, L_{eRc}, R_{sx}, R_{sn} = defined in [3.7.3] a);

$R_{sc} = R_{sx}$, in the case of reinforcements fitted outside the pressure shell;

$R_{sc} = R_{sn}$, in the case of reinforcements fitted inside the pressure shell.

The moment of inertia of primary supporting members, with attached plate of width L_{eRc}, about the neutral axis parallel to the cone axis, is to be not less than the following:

$$J_{Rcreg} = \frac{1}{3}\frac{P_e(2R_{Hm}+t)L_c \cdot R_{sc}^2}{E \cdot \cos\alpha}$$

4 Spherical pressure shells subjected to external pressure

4.1 Plating strength

4.1.1 The following parameters are to be obtained:

σ_y, ν, η, E = defined in [1.1.2];

t = plating thickness of the spherical pressure shell;

D_o = shell's outer diameter;

$R_o = D_o/2$ shell's outer radius;

The yielding pressure for spherical shell plating is given by:

$$P_{ysf} = \frac{2 \cdot \sigma_y \cdot t}{R_o}$$

Linear buckling pressure is given by:

$$P_{bsf} = \frac{1,155 \cdot E}{\sqrt{1-\nu^2}}\left(\frac{t}{R_o}\right)^2$$

After calculating:

$$\varepsilon = \frac{P_{bsf}}{P_{ysf}}$$

the limit pressure for the spherical pressure shell is:

$$P_{limsf} = P_{ysf} \cdot \frac{0,74}{\sqrt{1+\left(\frac{P_{ysf}}{0,3 \cdot P_{bsf}}\right)^2}} \qquad \text{if} \qquad \varepsilon > 1$$

$$P_{limsf} = 0,21 \cdot P_{bsf} \qquad \text{for} \qquad \varepsilon \le 1$$

Assuming:

$\eta = 0,65$

the maximum allowable working pressure is:

$$P_{limsfamm} = 0,65 \cdot P_{limsf}$$

4.2 Ordinary stiffeners

4.2.1 In spherical shells with inner diameter $D_i \le 2500$ mm, ordinary stiffeners are generally not required.

The following parameters are to be calculated:

E = defined in [1.1.2];

t, D_o, $P_{limsfamm}$ = defined in [4.1.1];

$$L_{esf} = 0,75(D_o \cdot t)^{0,5}$$

s_{eq} = frame spacing on equatorial circumference;

D_m = diameter at neutral axis of reinforcement, perpendicular to the web of the reinforcement, with attached plating of width L_{esf} defined above.

The moment of inertia of ordinary stiffeners (that with the lowest cross-section, if different types are fitted), with attached plate of width L_{esf} defined above, about the neutral axis perpendicular to the web of the reinforcement, is to be not less than the following:

$$J_{sfreg} = \frac{0,18 \cdot D_o \cdot P_{limsfamm} \cdot s_{eq} \cdot D^2{}_m}{E}$$

4.3 Primary supporting members

4.3.1 In spherical shells with inner diameter $D_i \le 4000$ mm, primary supporting members are generally not required.

If fitted, they will be evaluated case-by-case.

5 Pressure shells composed of solids of revolution generated by a curvilinear ruler, subjected to external pressure

5.1 General

5.1.1 These are solids of revolution, commonly spherically shaped, in most cases generated by the revolution of a:

- semi-ellipse: ellipsoid;
- semi-oval: ovaloid;
- pear-shaped ellipsoid.

Such units are generally used to carry measurement instruments, aimed at assisting diving activities, unmanned, small size (a maximum overall length equal to 1000 mm), unstiffened, of the type indicated in Pt A, Ch 1, Sec 2, [1.2.5] d).

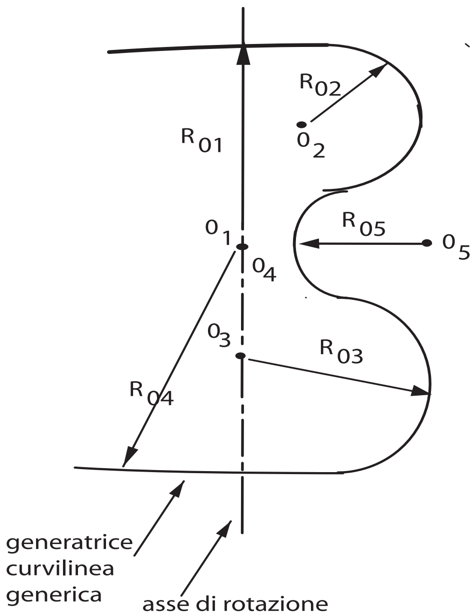
Other shapes of curvilinear solids of revolution, having a maximum overall length equal to 600 mm, find specific application in the field of scientific research.

The strength check of plating is to be carried out, on a first approximation, by applying the formulations in [4.1.1] for spherical shells, considering the maximum local external curvature radius (similarly to what is reported in App 2, [3.2.1]).

Fig 6 illustrates the above-mentioned procedure: among radii R_{01} (centred in 0_1), R_{02} (centred in 0_2), R_{03} (centred in 0_3) and R_{04} (centred in 0_4), whose centres fall within the volume of revolution, if shell thickness is constant, the one with the largest value is to be assumed in order to proceed with the check in [4.1.1]. If shell thickness is not constant, the above procedure is to be applied considering the largest curvature radius for each constant thickness part.

For shells with curvature radii like R_{05}, i.e. with the centre located outside the revolution volume, the same procedure is to be applied, but applying the requirements of Sec 7, [1.1.1], because the external pressure generates a stress field similar to that of shells subjected to internal pressure.

Figure 6



6 Spherical heads subjected to external pressure

6.1 Hemispherical heads

6.1.1 For hemispherical heads, the maximum allowable working pressure is to be obtained similarly to spherical shells, by assuming the hemisphere's outer radius R_o.

The safety factor is $\eta = 0,65$.

6.2 Ellipsoidal heads

6.2.1 For ellipsoidal heads, the maximum allowable working pressure is to be obtained as for spherical shells, by assuming an equivalent spherical radius R_{eq}, in place of R_o, corresponding to the maximum radius of the head itself, given by:

$$R_{eq} = \frac{D_o \cdot D_i}{4 \cdot h}$$

where:

D_i = inner diameter;

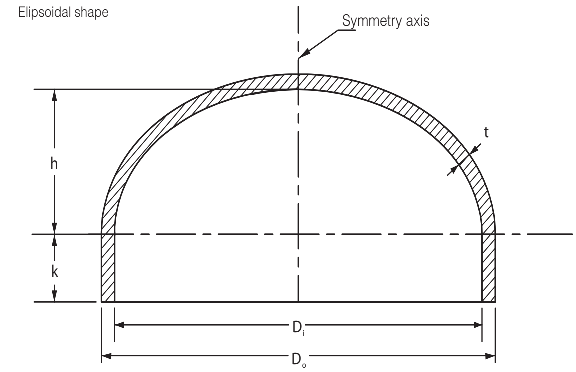
h = internal height of the head, taken from the line tangent to the cuspidal part up to the end of the cylindrical part;

D_o = shell's outer diameter.

The geometry of an ellipsoidal head is illustrated in Fig 7.

The safety factor is $\eta = 0,65$.

Figure 7 : Heads - definitions

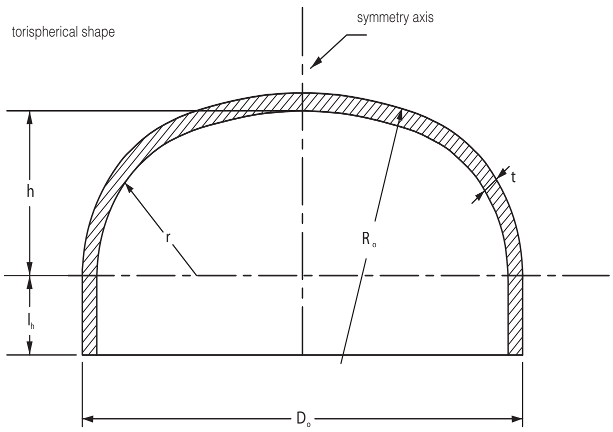


6.3 Torispherical heads

6.3.1 For torispherical heads, the maximum allowable working pressure is to be obtained similarly to spherical shells, by assuming a spherical radius R_0, corresponding to the curvature radius of the head, taken at the outer face of the plating (see Fig 8).

The safety factor is $\eta = 0,65$.

Figure 8 : Heads - definitions



6.4 Shape limitations

6.4.1 Plate thickness in hemispherical heads is to be such that:

$$0,002 \cdot D_m \le t \le 0,016 \cdot D_m$$

where D_m is the mean diameter at the base (at half thickness of the shell).

The shape limitations of ellipsoidal and torispherical heads are reported below (see Fig 7 and Fig 8, respectively), D_m being the mean diameter at the base:

Ellipsoidal heads:

$$0,002 \cdot D_m \le t \le 0,018 \cdot D_m$$

$$h \ge 0,18 \cdot D_m$$

$$k \ge 2 \cdot t$$

Torispherical heads:

$$0,002 \cdot D_m \le t \le 0,018 D_m$$

$$h \ge 0,18 \cdot D_m$$

$$k \ge 2 \cdot t$$

$$r \ge 0,06 \cdot D_m$$

$$r \ge 2 \cdot t$$

$$R_m \le D_m$$

R_m being the mean radius of the maximum curvature radius of the head.

7 Cylindrical pressure shells, with right or non-right cross-section, subjected to external pressure, with length L > 20 m

7.1 Strength

7.1.1 The transverse strength check for cylindrical pressure shells, with or without a right cross-section, of large size submarines/submersibles is to be carried out in accordance with what is stated in App 2 of this Chapter.

7.2 Weight reduction

7.2.1 Any weight reduction in the construction of the pressure shells of large size submarines/submersibles is to be carried out in accordance with what is stated in App 3 of this Chapter.

The related calculations are to be submitted to Tasneef for approval.

SECTION 3 LONGITUDINALLY FRAMED PRESSURE HULLS

1 Plating

1.1 General

1.1.1 The strength check is to be performed on the basis of the formulations reported in Sec 2 of these Rules, by assuming a frame spacing corresponding to the spacing of longitudinals.

The plate thickness to be considered in calculations is the equivalent thickness t_{eq}, in mm, given by:

$t_{eq} = t_{eff} + t_A$

where:

t_{eff} = actual thickness of pressure shell, in mm;

t_A = thickness equivalent to the sum of the areas of the cross-sections of all longitudinals, without attached plating, assumed applied over the thickness t_{eff}, in mm.

Thus:

$t_A = R_{Ae} - R_e$

in which:

R_{Ae} = outer radius of pressure shell, including the thickness t_A, in mm ;

R_e = actual outer radius of pressure shell, in mm;

$$R_{Ae} = (A/\pi + R^2{}_e)^{0,5} \text{ , in mm}$$

$$A = \Sigma_{i=1}^{n} a_i \text{ , in mm}^2$$

a_i = net area of the cross-section of the i-th longitudinal, in mm^2, without attached plating.

1.2 Longitudinal stiffeners

1.2.1 Longitudinal stiffeners are to be checked by means of direct calculation, assuming them as continuous beams supported by the frames or by reinforced portals or by transverse bulkheads, subjected to uniformly distributed load due to external pressure.

SECTION 4 OPENINGS IN THE PRESSURE SHELL

1 General

1.1

1.1.1 As applicable, the formulations in Pt C, Ch 1, Sec 3 of the Rules are to be applied.

2 Opening for "clamp"

2.1

2.1.1 This is a specific opening in the upper part of the pressure shell, having standard dimensions, for access of personnel, appliances, equipment and other devices.

It is to be connected, by means of a quick lock, to a corresponding opening in the bottom of another unit, in order to allow the transfer of personnel and goods from one unit to the other (for example from a unit in an emergency on the seabed toward the rescue unit or vice versa).

This opening is to be provided with an external flange welded to the pressure hull, and tightened by a cover plate secured by means of pre-tensioned deadbolts; watertightness is obtained by adequate gaskets in proper closing devices compressed by the cover plate subjected to pressure. At the inward side, a compensated deadlight is to be fitted, which is to be operable from both sides (see Sec 5, [1.1]).

The details of this opening (with corresponding flange), of the coupling device (having standard shape and scantling), deadlight and related compensating system are to be sent to Tasneef for review.

2.2 Structural details for coupling of hyperbaric bells and decompression chambers

2.2.1 The coupling system of hyperbaric bells with decompression chambers is to be adequate to facilitate locking and unlocking operations of the 2 units in the worst sea and weather conditions in which these units can work.

Therefore, in design calculations, the loads from a sea state corresponding to a wind intensity of at least 6 (Beaufort scale), with corresponding wave height are to be taken into account. The coupling system is to be fitted with interlock between the hyperbaric bells and the decompression chamber, in order to avoid the unwanted opening of covers. A mechanical securing device is required for hydraulically or pneumatically operated closing devices.

SECTION 5 WINDOWS AND PORTHOLES ON THE PRESSURE HULL

1 Opening and closing devices

1.1 Covers

1.1.1 Covers are to be fitted with adequate devices to be safely kept in "open" or "closed" position and are to be manoeuvred as quickly as possible both from the outside and from the inside. They are to open by rotating on hinges from inside to outside, such that the external pressure tends to keep them closed (vice versa for pressure shells subjected to internal pressure). To speed up the cover opening, dedicated devices are to be provided (for example spring-based, systems for pressurising, etc.) to equilibrate the weight of the cover in such a way that, after the unlocking of the closing devices, a light push is needed to make the cover move on its hinges.

If necessary, the cover is to be fitted with an air vent valve, manoeuvred from inside, in order to equilibrate the internal pressure with the external pressure and facilitate cover opening.

Covers are to be provided with proper securing devices that avoid manoeuvring of cleats when in open condition. Furthermore, they are to be provided with gaskets to be compressed during working conditions, in compliance with the Manufacturer's specifications.

Covers fitted on bells are to be designed in such a way that they will not be accidentally opened during operations.

The gangway is to be arranged in such a way as to allow access of personnel when the unit is free floating on the surface.

Arrangement of an inside deadlight (with inward opening), compensated, is to be adopted to avoid water leaking inside the unit.

Scantlings are to be checked, in the case of flat covers, with the following formula or with that in Sec 6, [1.5], in the case of concave covers.

For circular or oval flat covers, thickness t, in mm, is given by:

$$t = b\left(\frac{Cp}{\sigma_t}\right)^{1/2} + c$$

where:

b: lower half-diameter, in mm;

p: design pressure, in N/mm^2;

σ_t: allowable design pressure, in N/mm^2;

c: coefficient of thickness increase due to corrosion wastage (see Sec 1, [5.2]);

C: coefficient from Tab 2 as a function of ratio **a/b**, where **a** is the greater half-diameter, in mm.

In any case, the thickness calculated as above is to be not less than 10 mm.

The clear opening diameter is to be not less than 500 mm; for diver gangways, this minimum is increased to 600 mm.

Audible and visible alarms are to be arranged to indicate covers opening.

1.2 Transparent domes

1.2.1 For pressure domes, these are to be designed by means of the same methods as those adopted for pressure shells.

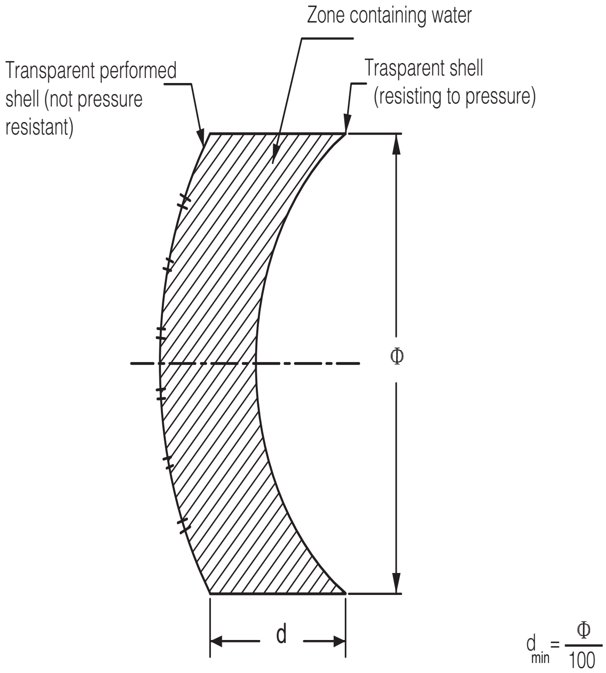
They are to be adequately protected against damage; a second shield, transparent, perforated (to allow water flowing, therefore not under pressure) can be fitted at a proper distance (see Fig 1) and/or adequate metallic shields may be fitted.

The perforated dome is to have the same curvature as that of the part to be protected; its thickness is to be not less than 5 mm.

Table 1

a/b	1	1,1	1,2	1,3	1,4	1,5	2	3	4
C	1,24	1,41	1,57	1,69	1,82	1,93	2,27	2,60	2,79

Figure 1



2 Portholes

2.1 General

2.1.1 Portholes can be built in plastic (for example in acrylic resin) or in any other material deemed suitable by Tasneef and are to be fitted within an insert having an increased thickness with respect to the plating of the pres-sure hull (according to the provisions of Sec 4 of this Chap-ter).

Furthermore, they are to be adequately protected against possible damage and scratches by adopting double port-holes (of the same thickness) separated by a void having a width equal to approximately the same thickness as the portholes and/or by protecting them by means of a metallic shield.

Scantling can be checked with formulae for flat shells fully clamped on the boundary, by assuming a safety factor on breaking strength equal to 19 or, when possible, according to the following method.

For testing procedures, refer to Pt D, Ch 1, Sec 2.

Glass and toughened glass portholes are not allowed, due to their vulnerability, after tempering, when subjected to temperature gradients.

2.2 Transparent plastic portholes

2.2.1 General

The minimum nominal thickness allowed is 5 mm. The maximum allowable stress in, N/mm², is:

$$\sigma = R_{(20)}(120 - T)10^{-3}$$

where:

$R_{(20)}$ = tensile breaking strength, assumed equal to 65 N/mm², at a temperature of 20°C;

T = design temperature of the unit, in °C (see Ch 2, Sec 1, [2.4]).

Working conditions different from those reported in Part D, Ch 1, Sec 2 of the Rules will be considered case-by-case; the use of the material in question is not allowed if:

- working pressures are greater than 140 N/mm²;
- temperatures are not within the range between -50°C and +66°C and in any case outside the testing range;
- pressurisation or depressurisation gradients are above 0,1 N/mm² per second;
- used in environments with exposure to chemical reac-tion or alteration to the material.

2.2.2 Porthole geometry

The following geometric requirements (see Fig 2, Fig 3, Fig 4 and Fig 5) are, in general, to be fulfilled:

a) flat circular portholes (see Fig 2);

b) truncated-conical portholes (see Fig 3);

c) spherical sector portholes (see Fig 4);

d) double bevelling portholes (see Fig 5).

Figure 2

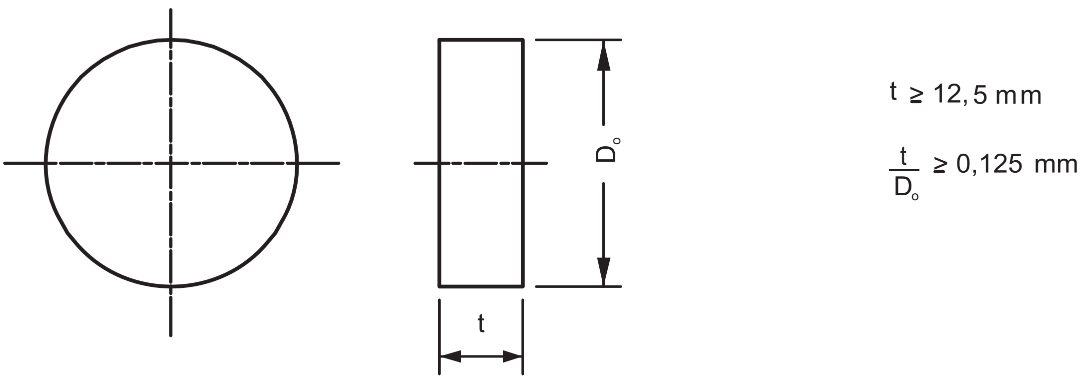
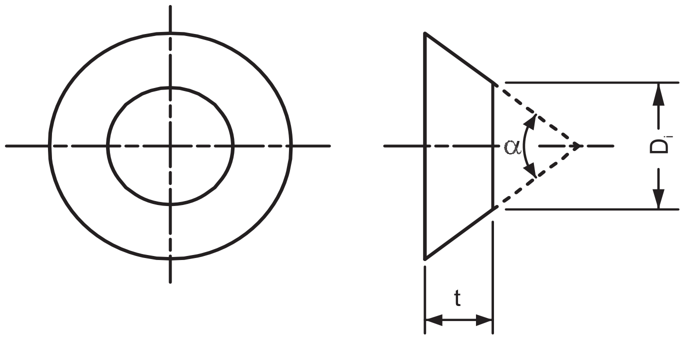


Figure 3

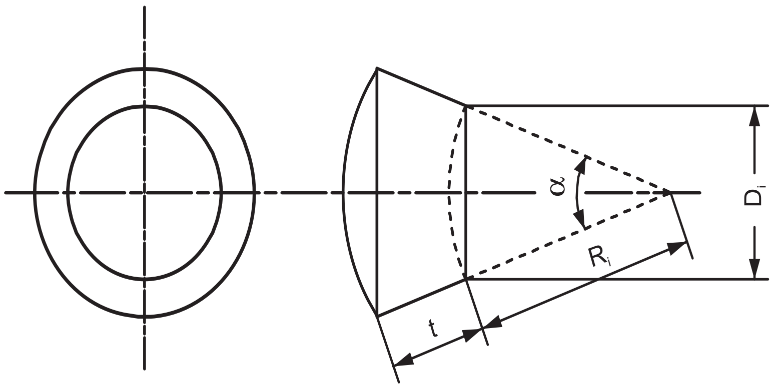


$t \geq 12{,}5$ mm

$\frac{t}{D_i} \geq 0{,}125$ mm

$\alpha \geq 60°$

Figure 4

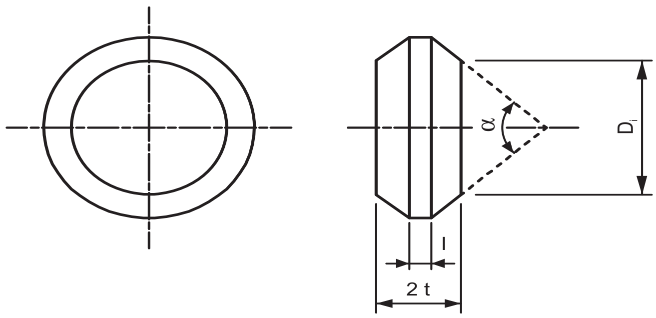


$t \geq 12{,}5$ mm

$\frac{t}{R_i} \geq 0{,}09$ for $\alpha \geq 60°$

$\frac{t}{R_i} \geq 0{,}06$ for $\alpha \geq 90°$

Figure 5



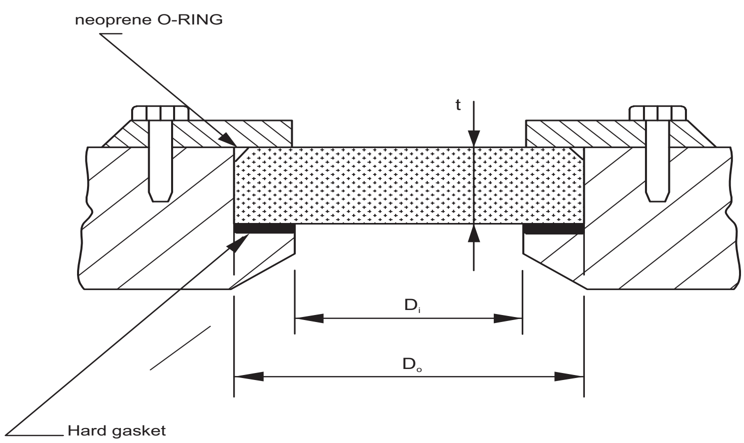
$2\,t \geq 25$ mm

$\frac{2\,t}{D_i} \geq 0{,}25$ mm

$\alpha \geq 60°$

$l \leq 0{,}5\,t$

Figure 6



2.2.3 Critical breaking pressure

The critical breaking pressure for some standard types of portholes can be derived from diagrams certified by the Manufacturer and by Tasneef, as a function of the ratio t/D_i (see Fig 3, Fig 4 and Fig 5), from which the thickness t (mm) can be obtained.

For flat portholes, D_i is that shown in Fig 6.

These diagrams are obtained by subjecting samples to a pressurisation test, with a gradient of 4,6 N/mm^2 per minute, at a temperature of 24°C kept constant through the duration of the test.

The test (see Pt D, Ch 3, Sec 1, [2.6]) is to be performed on 5 portholes and the results are accepted if the lowest breaking pressure is at least 75% of the average breaking pressure obtained on the remaining 4 portholes.

The value for the critical pressure to be assumed is the average of the 3 smallest values obtained for the critical pressures. Alternatively, the test can also be performed on five real-size prototypes, provided that these include one of the portholes actually fitted on board; the critical pressure of the latter is to be not lower than that of all the other models subjected to the test.

In any case, the critical pressure p_{cr}, in N/mm^2, is to be not lower than the product **K x p**, where **p** is the working pressure, in N/mm^2, and **K** is the coefficient given by Tab 2, Tab 3 and Tab 4.

2.2.4 Arrangement

In Fig 7 and Fig 8 two standard arrangements are shown.

a) all fillet radii R_1 in the porthole seat are to be not lower than 1 mm and not greater than 2 mm.

b) maximum clearance, for flat circular portholes, is to be:

$\mathbf{D_s} - \mathbf{D_o} \leq 0{,}005\ \mathbf{D_o}$

where $\mathbf{D_s}$ and $\mathbf{D_o}$ are diameters indicated in Fig 8.

c) For portholes with inner diameter $\mathbf{D_i} > 500$ mm, adequate devices for protection against damage are to be arranged. This protection can be:
- structures protruding for at least 50 mm beyond the external surface of the porthole;
- an external fender, protecting the porthole and able to absorb damage at a speed of 1 m/s.

Portholes with thickness not lower than 90 mm are considered adequately protected against collisions.

d) The device for watertightness of portholes is to satisfy the following requirements:
- a soft elastomeric main gasket (rubberless material) (Shore hardness ≤ 60) is to be fitted between the tightening ring and the porthole on the side exposed to pressure. Its thickness is to be sufficient to reach the initial compression indicated below;
- for flat circular portholes a secondary gasket between the porthole and the supporting seat is to be adopted. It is to be a hard gasket (Shore hardness ≥ 90) and is to be fixed to the support. Its thickness is to be not greater than 1 mm;
- water-tightening rings are to provide an initial compression of the gasket, in mm, at least equal to:

$(0{,}015\ \mathbf{D_i}\ \mathrm{tg}\ a / 2)\ \mathbf{N}$

for truncated conical portholes;

$(0{,}01\ \mathbf{R_i}\ \mathrm{sen}\ a / 2)\ \mathbf{N}$

for spherical sector portholes;

$0{,}01\ \mathbf{t} + 0{,}25$

for flat circular portholes.

For $\mathbf{D_i}$, $\mathbf{R_i}$, $\mathbf{t}$ and α see Fig 2, Fig 3 and Fig 4.

The value of **N** is given in Tab 5, as a function of the working pressure, in N/mm^2, while the relationship between Rockwell C and Shore hardness values is given in Tab 6.

2.2.5 Durability

The maximum working durability for acrylic resin portholes is equal to 10 years or, if lower, to 5000 pressure cycles.

Table 2 : Flat circular portholes

Range of operating pressure (N/mm^2)	Range of temperature (°C)				
	≤ 10	≤ 24	≤ 38	≤ 55	≤ 66
1 - 17,0	5	6	8	10	16
17,1 - 27,2	5	6	8	10	-
27,3 - 34,0	5	6	8	-	-
34,1 - 47,6	5	6	-	-	-
47,7 - 51,0	5	-	-	-	-

Table 3 : Truncated conical and double beveling portholes

Range of operating pressure (N/mm^2)	Range of temperature (°C)				
	≤ 10	≤ 24	≤ 38	≤ 55	≤ 66
1 - 17,0	5	6	8	10	16
17,1 - 30,6	4,5	5,5	7,5	9,5	-
30,7 - 34,0	4	5	7	9	-
34,1 - 51,0	4	5	-	-	-
51,1 - 54,4	4	5	-	-	-
54,5 - 68,0	4	-	-	-	-

Table 4 : Spherical sector portholes

Range of operating pressure (N/mm^2)	Range of temperature (°C)				
	≤ 10	≤ 24	≤ 38	≤ 55	≤ 66
1 - 10,2	4	6	8	10	16
10,3 - 20,4	4	6	8	10	-
20,5 - 23,8	4	6	8	-	-
23,9 - 34,0	4	6	-	-	-
34,1 - 51,0	4	-	-	-	-

Table 5

N	Working pressure (N/mm)^2
1	1 - 17,0
2	17,1 - 34,0
3	34,1 - 51,0
4	51,1 - 68,0

Table 6

Rockwell C Hardness	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48
Shore Hardness	96	93	90	87	84	81	78	75	73	71	69	68	66	65	63	62	60	59
Rockwell C Hardness	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30
Shore Hardness	58	56	55	53	52	51	50	49	48	47	46	45	44	42	41	40	39	29
Rockwell C Hardness	29	28	27	26	25	24	23	22	21	20								
Shore Hardness	38	37	36	36	35	34	33	33	32	31								

Figure 7

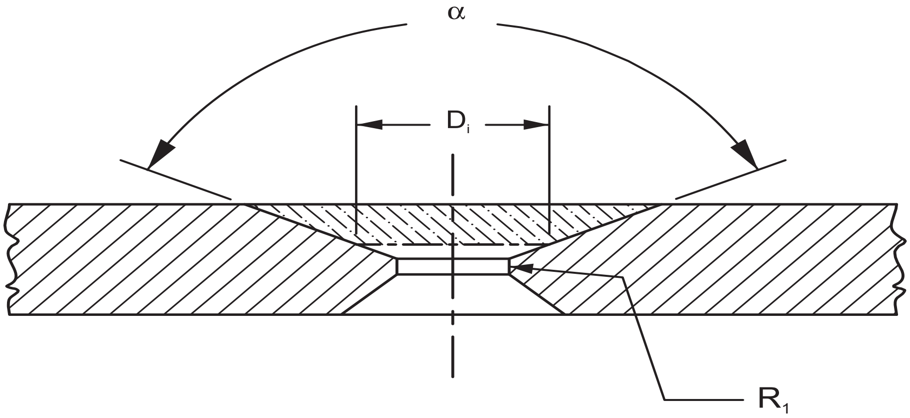
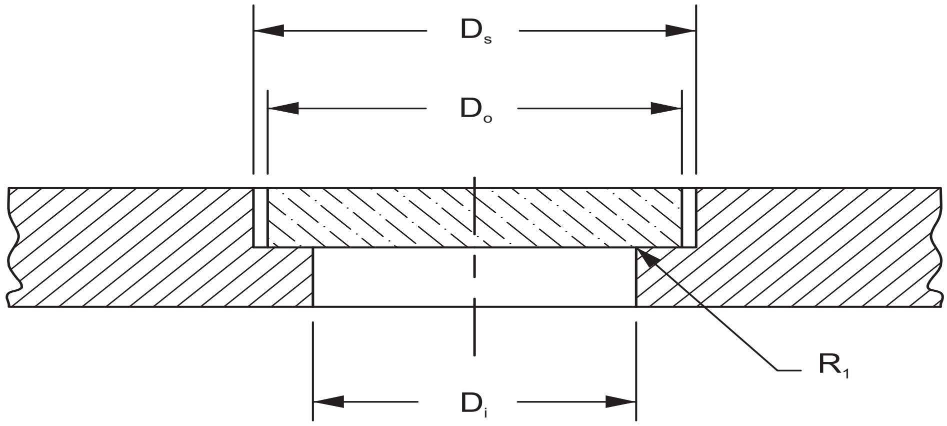


Figure 8



SECTION 6 WATERTIGHT COMPARTMENT ARRANGEMENT OF THE PRESSURE HULL

1 Transverse watertight bulkheads

1.1 Number of bulkheads

1.1.1 Units with an overall length **L** ≥ 65 m are to have at least 4 watertight bulkheads, designed to withstand a pressure corresponding to a maximum depth to which, in the case of a failure, such units can still be recovered or the rescue of personnel on board can be made so that they may still emerge with a flooded compartment.

Units with 10 m ≤ **L** < 65 m are to have at least one collision bulkhead fore and one aft of the engine room.

Self-propelled units with **L** < 10 m which operate at a distance greater than 3 miles from the supply ship are to have at least one collision bulkhead.

Self-propelled units with **L** < 10 m which operate at a distance not greater than 3 miles from the supply ship and non-self-propelled units can be arranged without a collision bulkhead.

In self-propelled units without internal watertight bulkheads, main engines, batteries and other machinery are to be fitted outside the pressure shell in which personnel can operate.

The collision bulkhead can be omitted in units with a length lower than 20 m in which personnel operate at the fore end, if a transparent dome (in acrylic material) is fitted at the fore end.

1.2 Spacing of bulkheads

1.2.1 In general, the spacing of the watertight bulkheads is to be not greater than 4 times the outer diameter of the pressure shell.

1.3 Shape of bulkheads

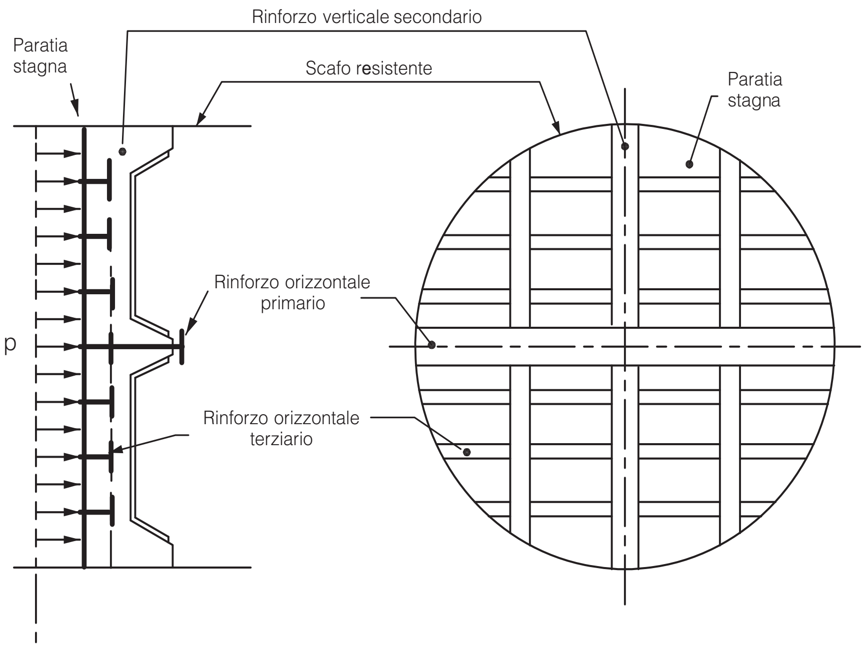
1.3.1 Internal bulkheads can be flat. End bulkheads, bounding the pressure hull, are generally convex outwards.

1.4 Flat bulkheads

1.4.1 These are generally made of plates stiffened by reinforcements: primary supporting members (horizontal stringers), secondary stiffeners (vertical reinforcements interrupted at intersections with primary supporting members) and tertiary stiffeners (horizontal ordinary stiffeners, comparable to reinforcing bars) (see Fig 1).

In calculating the reinforcement section modulus, the attached plating is to be considered, having a width equal to the lower of frame spacing and 30 times the thickness of the attached plating. For tapered reinforcements, the check is to be performed with the smallest cross-section.

Figure 1



a) Primary members

The maximum bending moment **M**, in N x mm, calculated at mid-span of primary members, is given by

$$\mathbf{M} = \frac{\mathbf{pl}^3}{489}$$

in which **l** is the gross span, in mm, and **p** is the external pressure, in N/mm^2.

The shear **T**, in N, at ends is given by:

$$\mathbf{T} = \frac{\pi \mathbf{D}^2{}_i \mathbf{p}}{1600}$$

D_i being the internal diameter (in mm) of the pressure shell, in way of the bulkhead.

b) Secondary stiffeners

They are to be assumed as beams clamped at both ends and uniformly loaded over their length for an associated width of the load equal to half of their spacing.

c) Tertiary stiffeners

They are to be assumed as beams clamped at both ends and uniformly loaded over their length.

The associated area is equal to a double triangle in square plates (see Fig 2) and to a double trapezium in rectangular plates (see Fig 3).

Figure 2

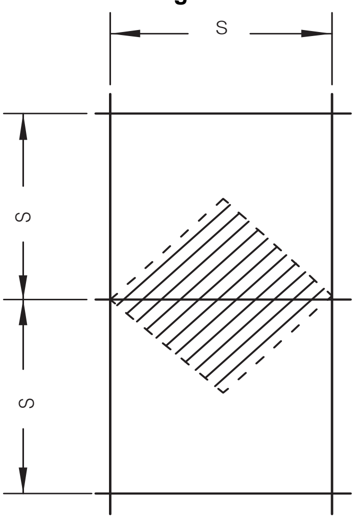
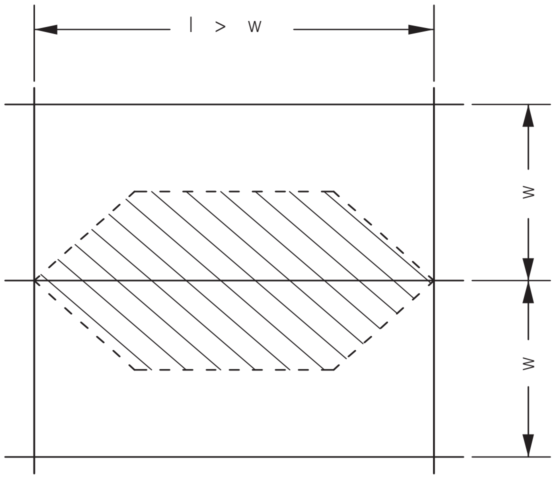


Figure 3



d) Plates

Actual maximum stress σ_{eff}, in N/mm^2, on plates is given by:

$$\sigma_{eff} = \frac{6\mathbf{K}_x \mathbf{pa}^2}{\mathbf{t}^2}$$

where:

a = length of shorter side of plate, in mm

t = plate thickness, in mm

$\mathbf{K}_x$ = coefficient to be taken from Tab 1 as a function of the ratio **b / a**

b = length of longer side of plate, in mm.

Critical plate stress, in N/mm^2, beyond which the bulkhead (also a non-watertight bulkhead) does not maintain the pressure hull's roundness, is given by:

$$\sigma_{cr} = \frac{2(1 - v/2)\mathbf{p}_e}{\beta \mathbf{t}_p}$$

where:

v = Poisson's coefficient of the material

$\mathbf{p}_e$ = working pressure, in N/mm^2

$\mathbf{t}_p$ = minimum bulkhead thickness, in mm

$$\beta = \left[\frac{12(1 - v^2)}{\mathbf{t}^2 D^2{}_0}\right]^{1/4} \text{, in mm}^{-1}$$

where **t** is the pressure hull thickness, in mm, across the bulkhead and $\mathbf{D}_0$ its maximum external diameter, in mm.

Table 1

b/a	1	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2
Kx	0,0513	0,0581	0,0639	0,0687	0,0726	0,0757	0,078	0,0799	0,0812	0,0822	0,0829

1.5 Curved bulkheads

1.5.1 These bulkheads generally have an ellipsoidal or spherical shape and are unstiffened.

The thickness, in mm, to be taken for the elastic instability check is to be determined from the formula below:

$$\mathbf{t} = \left(\frac{\mathbf{p}_{pr}\mathbf{D}_i^2}{\mathbf{KE}}\right)^{1/2}$$

$\mathbf{p}_{pr}$ = design pressure of pressure hull, in N/mm²

$\mathbf{D}_i$ = in ellipsoidal bulkheads, the internal diameter of the pressure hull in that zone, in mm.

In spherical bulkheads, the curvature radius $\mathbf{R}_i$, in mm, of the spherical head is to be adopted instead of $\mathbf{D}_i$.

K = coefficient equal to 0,3

E = Young's modulus of the material, in N/mm².

In the presence of stiffeners, their check is to be performed with the formulations in a), b) and c) of requirement [1.4.1].

The thickness **t**, in mm, to be taken for the yielding check is to be determined from the formulas below:

a) if the bulkhead profile is elliptical (major axis about twice the minor):

$$\mathbf{t} = \frac{\mathbf{p}_{pr}\mathbf{D}_i}{2\mathbf{R}_s - 0,2\mathbf{p}_{pr}}$$

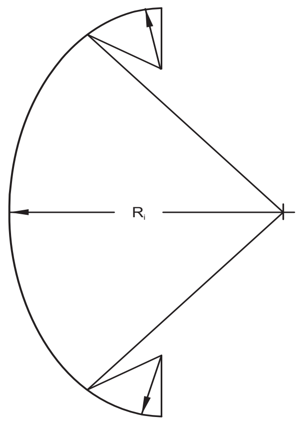
b) if the bulkhead profile is torispherical (see Fig 4):

$$\mathbf{t} = \frac{0,885\mathbf{p}_{pr}\mathbf{R}_i}{\mathbf{R}_s - 0,1\mathbf{p}_{pr}}$$

c) if the profile is spherical:

$$\mathbf{t} = \frac{\mathbf{p}_{pr}\mathbf{R}_i}{2\mathbf{R}_s - 0,5\mathbf{p}_{pr}}$$

Figure 4



2 Longitudinal watertight bulkheads

2.1

2.1.1 In submersible units the arrangement of longitudinal watertight bulkheads is not allowed.

On some large size submarines/submersibles, longitudinal watertight bulkheads having a limited extension are occasionally allowed, and their scantlings are to be checked according to the requirements in [1.4].

3 Openings in watertight bulkheads

3.1 Watertight doors

3.1.1 Watertight doors are to be provided with securing devices that avoid manoeuvring of cleats when opened.

3.2 Voice pipes

3.2.1 Voice pipes can in no case pass through watertight bulkheads.

SECTION 7 STRENGTH CHECK OF PRESSURE SHELLS SUBJECTED TO INTERNAL PRESSURE

1 General

1.1

1.1.1 For strength checks of units subjected to internal pressure (decompression chambers, etc), at a first approximation, the formulations in Sec 2 relevant to units subjected to external pressure can be applied by assuming as internal pressure the working pressure decreased by 30%.

2 Strength checks

2.1

2.1.1 For more sophisticated checks, the provisions relevant to pressure vessels reported in Pt C, Ch 1, Sec 3 of the Rules, as far as applicable, are valid.

SECTION 8 OUTER HULL

1 General

1.1

1.1.1 Scantlings of outer hulls are to be adequate to withstand the following conditions:

- impact during surface navigation (on bottom or against submerged objects);
- bottom dragging or stranding;
- bumping alongside supply ship;
- impacts, with supply ship, during launching and recovery and during lashing.

In the case of metallic or light alloy structures, thickness consumption equal to 1 mm after 10 working years is to be considered.

No consumption is to be applied for structures built in reinforced plastic; in this case the relevant provisions of the "Rules for the Classification of Ships with Reinforced Plastic, Aluminium Alloy or Wooden Hulls" are to be applied.

Any structure not covered by these Rules, for which direct calculations are to be performed, is to be verified in the most severe working conditions by assuming a safety factor equal to 2,5 with respect to the material's breaking strength.

2 Plates

2.1

2.1.1 For steel plating, the provisions in the following points (a) and (b) are to be applied:

a) If the outer hull bounds the ballast tanks, the plate thickness is to be determined as below:

   - in the case of large size units operating far from the base and without a supply ship, with the formulations in Pt B, Ch 8, Sec 3 of the Rules;
   - in small size units, 6 mm at the keel (8 mm at the skeg, if any) and 4 mm for other plates;
   - for units with **L** ≤ 6 m, in general 3 mm.

b) If the only function of the outer hull is to shield any apparatus arranged outside the pressure hull, the plating thickness is the following:

   - 8 mm, at the skeg, (false keel) if any;
   - 6 mm, for conventional keel;
   - 3 mm, for other plating.

   For materials other than steel, Tasneef will examine the thickness on a case-by-case basis, considering the mechanical, chemical and physical properties of the adopted material.

3 Stiffeners

3.1

3.1.1 Spacing of stiffeners is to be, in general, equal to that of the pressure hull.

For those parts under [2] (a), stiffener scantling is to be obtained as follows:

- with formulations applicable to tank frames in Pt B, Ch 8, Sec 4 of the Rules, in the case of large size units operating far from the base and without a supply ship;
- with formulations applicable to stiffeners of non-watertight bulkheads having the function of pillars in Pt B, Ch 4, Sec 7 of the Rules, in other cases.

For those parts under [2] b), stiffener scantling is to be obtained with the formulae applicable to stiffeners of non-watertight bulkheads not having the function of pillars in Pt B, Ch 4, Sec 7 of the Rules.

4 Arrangement of double bottom ballast tanks

4.1

4.1.1 In the case of large size units operating without a supply ship, starboard and port side compartments are to be separated by means of a watertight keelson.

Free circulation of air is to be allowed within double bottoms throughout the floors, by means of holes fitted in their upper part.

Double bottom ballast tanks are not to be fully emptied at working depth; the depth at which ballast tanks can be emptied is to be specified in the instruction manual (see Pt A, Ch 1, Sec 2, [6.7.2]).

SECTION 9 OUTFITTING

1 Hull outfitting

1.1 Buoyancy syntactic foam

1.1.1 In small size units, in order to increase buoyancy, the use of low density syntactic foam, made of hollow microspheres dispersed in a resin based matrix (polyesters), is allowed.

This material is to be certified by an independent Notified Body as having limited hygroscopic properties; water absorption of a sample, exposed to a pressure of 70 MPa for 1000 hours, is to give a weight increase not greater than 3,5 %.

This foam can also be used to fill small voids, which are neither accessible nor inspectable (small cofferdams, fins, etc.), in order to prevent any leaking of water that could increase the weight of the unit.

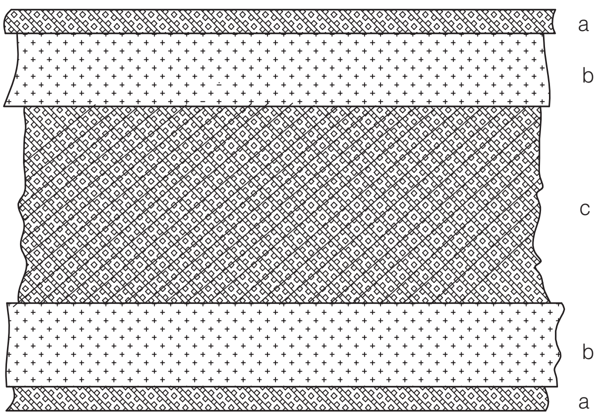
Sandwich construction is also accepted, arranged as shown in Fig 1, in which:

a = titanium alloy (minimum thickness 1 mm);

b = glass fibre reinforced plastic;

c = syntactic foam.

Figure 1



The mechanical properties of this material, certified by the Manufacturer, are to be:

- resistance to hydrostatic pressure: $\geq$ 147 N/mm^2
- resistance to axial compression: $\geq$ 112 N/mm^2
- tensile strength: $\geq$ 42 N/mm^2
- impact resistance: $\geq$ 0,08 kgf x cm/mm
- density: 0,35 $\div$ 0,45 kg/dm^3

  (higher values, in any case not above 0,7 kg/dm^3, will be considered on a case-by-case basis).

This material is to be replaced at each class renewal survey, unless appropriate tests demonstrate that it is capable of withstanding further pressurisation cycles, not having undergone a permanent compression which could have altered its volume and therefore reduced buoyancy.

1.2 Devices for towing, anchoring, overhanging or other

1.2.1 Such systems are to be fitted with a manual quick-release device.

1.3 Walking zone on deck

1.3.1 The walking zone, if any, on the deck is to be fitted with adequate anti-slip devices, in particular on units with little crew protection (handrails, stays or other).

1.4 Means for protection of crew

1.4.1 In manned units, with crew working on deck regularly, at least one longitudinal stay is to be arranged on the deck (if a single staly is fitted it should be fitted on the symmetry plane of the unit), properly supported and at a sufficient height.

1.5 Means for external protection

1.5.1 In small size units, pressure hulls and outer hulls, as well as all installations located outside, are to be protected against damage by means of tubular frames or equivalent arrangements.

If this protection is made of pipes, these are to have:

a) thickness t $\geq$ 3,5 mm and $\phi \geq$ 50 mm

b) two draining devices fitted on each extension (screw plugs at each end of the extension), in order to evacuate water entering accidentally and prevent corrosion and weight variations.

Stainless steel pipes can have free circulation.

1.6 Local reinforcement

1.6.1 In any part particularly subject to wear (for example areas exposed to sliding of anchors, chains and wires), the plate thickness is to be locally increased, over an extension and by a thickness as deemed necessary by Tasneef.

Doubler plates are not allowed.

2 Steering devices

2.1 General requirements

2.1.1 In large size units with traditional hull shapes the following steering devices are to be fitted:

- a stern vertical rudder, to change the heading both on the surface and underwater;
- two pairs of horizontal rudders, one at the fore body and one at the aft body, to change the trim during surface navigation or to facilitate ascent and descent manoeuvres.

Arrangement of "X-shaped" hydroplanes astern may be accepted (in such a way that horizontal rudders are not separated from vertical ones); these planes are inclined to 45° with respect to the traditional planes. This arrangement allows operation on vertical and horizontal hydroplanes through the use of any pair of rudders, therefore increasing the safety of navigation.

In small size units, the above-mentioned rudders can be replaced by adjustable nozzles through which a high-speed water jet or high pressure air is forced, or by side thrusters which can also be adjustable.

Dual manoeuvring systems for vertical and horizontal rudders are generally to be adopted: mechanical or electrical or hydraulic or electro-hydraulic.

Reliable manoeuvrability is required in order to reduce the risks during submersions, especially in small units operating close to the seabed or submerged installations.

Combined stress on rudder stocks and blades is to be not greater than 0,5 times the minimum yielding strength $\mathbf{R}_s$ of the material.

2.2 Vertical rudder size

2.2.1 The lateral projected area of the rudder is to be 0,013 ÷ 0,028 of the complete longitudinal fin area of the unit.

Rudder proportions are to be in compliance with those defined for surface ships in Pt B, Ch 10, Sec 1 of the Rules, assuming, instead of the actual rudder area **A**, the value $\mathbf{A}_m$ given by:

$$\mathbf{A}_m = \mathbf{A} \cdot \frac{\text{total longitudinal fin area}}{\text{longitudinal fin area in emersion}}$$

2.3 Horizontal rudder size

2.3.1 The total area of all pairs of rudder blades is to be 1/55 ÷ 1/35 of the horizontal projected area of the unit, subdivided into: 40% for the pair of aft rudders and 60% for the pair of fore rudders.

Scantlings of the rudder stock are to be related to the vertical force **F**, in N, acting on a horizontal rudder, equal to:

$$\mathbf{F} = 10\mathbf{K} \cdot \mathbf{S} \cdot \mathbf{V}^2 \cdot \sin\theta$$

where:

K = for horizontal fore rudder; 0,54 for horizontal aft rudder;

S = blade surface, in m^2;

V = maximum speed, in knots;

θ = angle of the blade with horizontal plane, in sexagesimal degrees.

The blade thickness can be obtained by assuming it as a thin shell.

Any internal webs of the blade are to comply with the provisions of Pt B, Ch 10, Sec 1 of the Rules.

3 Equipment

3.1 Units operating without assistance from the supply ship (in general with L > 20 m)

3.1.1 Anchors

Assuming Δ_{surf} as the full load displacement of the unit on the surface, in tonnes, the number of anchors to be fitted on board is to be:

- 1 anchor, if $\Delta_{surf} \leq 750$ t
- 2 anchors, if $\Delta_{surf} > 750$ t.

  The mass of each anchor, in kg, is given by:

  $P = 0{,}6\ \Delta_{surf} + 60$

If bulbs or domes containing acoustic devices or any other installations are adopted on the shell, the arrangement of a hawse on the keel can be accepted to reduce the interference between the anchor chain and these appendages; this hawse is to be fitted far from the appendages, to protect them against chain creeping, and it usually has limited plating thickness due to the efficiency of internal installations.

The lower peak of the fluke can be a flat surface in order to fit the opening in the hull and restore the hull's continuity (without necessarily being watertight).

3.1.2 Chain cables for anchors

The size of chain **d**, in mm, for anchors under [3.1.1] is given by:

$\mathbf{d} = 2{,}8\ (\Delta_{surf})^{1/3}$

For each anchor, at least 4 shots of chain are required. Chain cables can be replaced by a steel wire rope having minimum breaking strength equal to the strength of regular chains.

3.1.3 Towing and mooring lines

The (recommended) towing line should be 5 times as long as the waterline length of the unit surfacing in equilibrium trim, and have a breaking strength to Tasneef's satisfaction.

3 mooring lines are to be fitted, each 50 m long, having a breaking strength equal to ¼ of that of chain cables for regular anchors.

3.1.4 Equipment arrangement

Any arrangements of equipment, as well as the number, positioning and type of related devices (anchor windlasses, mooring winches, etc.) are to be to Tasneef's satisfaction.

3.2 Units assisted by a supply ship (in general with L $\leq$ 20 m)

3.2.1 The equipment is to be agreed with Tasneef. In small size units, 2 mooring lines are required with length and breaking strength to be agreed with Tasneef. These units are to be fitted with at least one bitt available on deck to connect towing and mooring lines.

SECTION 10 STRENGTH CHECKS OF THE LASHING SYSTEM OF THE UNIT ON THE SUPPLY SHIP

1 Foreword

1.1

1.1.1 Lashing of submersible units on the supply ship is provided, in general, only on small size units (L ≤ 20 m).

2 Lashing of unit

2.1 General

2.1.1 For strength checks, a constant cross-section ring (group web frame-attached plating) is to be considered, supported at one point and subjected to self-weight and any accelerations due to a shock factor equal to 2,5 as for outer parts of the supply ship, as per Sec 1, [2.7].

The following procedure can be applied also to non-circular rings with out-of-roundness not greater than 5% measured on the diameter at plate half-thickness; in other cases, a circular ring having radius equal to the greatest local curvature is to be considered.

The effect on the distribution of reaction forces of a wider supporting length instead of over a punctual zone is to be evaluated depending on the support type (saddles or device).

Dynamic stresses due to ship motions are to be included (Pt B, Ch 5, Sec 3 of the Rules).

In general, the following conditions, to be considered acting simultaneously, are to be assumed:

- horizontal acceleration equal to 0,5 **g**;
- vertical acceleration equal to 1 **g**;
- 30° roll angle to port and starboard (for a total of 60°);
- wind pressure equal to 25 x 10^{-4} N/mm^2 on the longitudinal total projection of the unit including its appendages.

According to Fig 1, **r** being the radius, in cm, on the neutral axis of the group web frame-attached plating, ω the current angular coordinate, increasing from **A** iclockwise, and **q** the linear weight of the ring, in N/cm, the following applies:

H = **qr**/2, , in-plane load acting on the group web frame-attached plating, in N

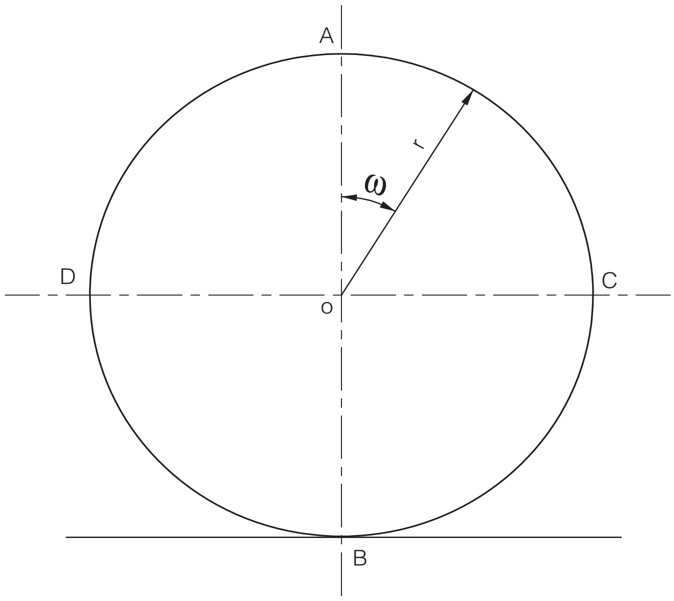
$\mathbf{M_A}$ = 0,5 $\mathbf{qr}^2$, bending moment in point **A**, in N · cm

$\mathbf{M_B}$ = 1,5 $\mathbf{qr}^2$, bending moment in point **B**, in N · cm

$\mathbf{M_C}$ = $\mathbf{M_D}$ = - 0,57 $\mathbf{qr}^2$, bending moment in **C** and **D**, in N · cm.

The bending moment is zero for ε values equal to 50° 35’, 146° 20’, 213° 40’, 309° 25’.

Figura 1



3 Lashing and supporting devices of the unit on the supply ship

3.1 General requirements

3.1.1 All devices for hauling up, mooring, towing, anchoring and lashing, to be operated on the supply ship, are to be approved, as well as the local reinforcements of the hull structures of the supply ship, where subjected to local loads induced by the arrangement of the submersible unit lashed on board, also accounting for the accelerations in [2.1] above.

Similarly, all hooks, lifting eye bolts, bitts, etc. fitted on board, as well as all details of their attachments to the hull, are to be to Tasneef's satisfaction. For strength checks of hoist-ing equipment, see Pt E, Ch 3, Sec 5, [1].

APPENDIX 1 INFLUENCE OF THE SHAPE OF THE PRESSURE HULL CROSS-SECTION ON STRENGTH

1 Foreword

1.1 Scope of analysis

1.1.1 This analysis is to be carried out when specific working operations of the submersible unit require a cross-section shape of the pressure hull other than circular; see Ch 1, Sec 1, [2.1].

1.2 Problem definition

1.2.1 In a submersible unit, especially when of large size, the main problem is to be able to withstand the elevated pressure rates underwater. Hence, the problem is essentially the transverse strength.

2 Considerations on cross-section shape

2.1 Problem examination and assumptions

2.1.1 The hollow beam shape most suitable to withstand the radial uniform pressure predominating at substantial depth is the one having a circular cross-section, as it is not subjected to a bending moment but only to tensile or compressive stresses, in the case of exposure to external or internal pressure, respectively. This is thus a uniformly stretched or compressed beam.

2.1.2 The assumption that a circular cross-section for the hull is not subjected to bending moments when exposed to uniform pressure underwater is justified only when the section is considered undeformable.

2.1.3 The point of application of stresses corresponds to the neutral axis of the web frame-attached plating group.

2.1.4 The undeformable section is adopted as a geometric condition, independent of the distribution of moments of inertia of the parts constituting the frame itself.

2.1.5 The undeformable condition is to be fulfilled by means of one of the following:

- internal framing,
- external framing,
- partly internal and external framing (sometimes bottom frames are inside and upper frames outside the shell).

2.1.6 With the increasing working depth, a calculation is to assess the amount of deformation and the deviation of stress distribution around the neutral axis due to bending moments.

Shapes are to be the most suitable to achieve an undeformable structure (to maintain uniform tension, the frame is to be a circular shape).

Sometimes, out of necessity, shapes are different from the circular one, like those close to the sterntube boss, large deck gangways, and trim tanks.

Detailed bending moment calculations are to be carried out where circular frames are fitted with appendages.

2.1.7 Deviations in stress distributions induced also by the presence of floors are to be accounted for. The following conditions are to be considered.

a) In the absence of floors, each frame is to be calculated according to its diameter in order to obtain a light construction;

b) When floors are fitted, the above-mentioned calculation is to account also for bending moments;

c) When large size floors are fitted (for example in the engine room), adequately reinforced plating is to be adopted so that the neutral axis line assumes an approximately elliptical shape at least in the zone where the section containing the floor is not too large.

3 Calculation scheme

3.1 Introduction

3.1.1 The hypothesis is made of a cylindrical body subjected to internal (or external) pressure completely free to expand or contract in every direction.

However, due to the presence of the heads, a constraint on the free deformation of the cylinder is to be considered, inducing additional stresses.

Similarly, any circular welded joint, reinforcement and transverse bulkhead as well as any local stiffener on the pressure hull gives a boundary constraint and then additional stresses.

The corresponding deformation pattern, arranged as waves, is such that only the largest wave, that is the one closest to the constraint, is appreciable.

3.2 Stability of ring subjected to external pressure

3.2.1 Since it is a non-circular ring, the bending moment is to be accounted for.

A circular pressure distribution of external pressure is assumed; thus the normal force is given by:

$N = qr$

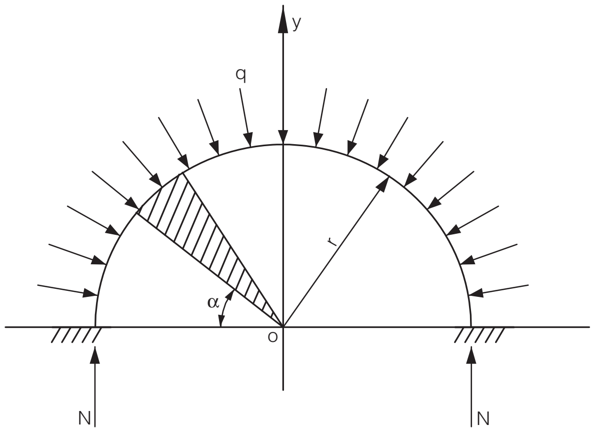
where:

q = uniform constant load from external pressure (see Ch 1, Sec 1, [1.1.1] c));

r = average radius of ring cross-section (average of the local radii at the non-circular cross-section).

The following expression comes from Fig 1.

Figure 1



$$\int_0^{\pi} qr d\alpha \cdot \sin\alpha = 2N$$

Furthermore, from the equilibrium of moments around point O, also

M = 0

The above confirms the statements in [2.1.1] and [2.1.2].

3.2.2 The deformed shape (as a closed line) is to be obtained containing the number of half-waves to the neutral equilibrium, i.e. when:

$q = q_{cr}$

q_{cr} being the critical value of q.

Critical load N_{cr} is:

$N_{cr} = q_{cr} \bullet r$

and the following is to result:

$q < q_{cr}$

and

$$\sigma_{cr} = \frac{N_{cr}}{A} < \sigma_{sn}$$

where:

A = cross-section area of web frame;

σ_n = material yielding strength.

Also:

$$q = \frac{h \cdot \gamma}{2\pi r} \quad S = h\gamma s$$

in which:

h = depth,

γ = specific gravity of sea water,

S = lateral surface of the cylinder with radius r and height equal to frame spacing $s = 2\pi r$.

For cylindrical pipes of unlimited extension (or of such a length sufficient for the central part to be insensitive to the stiffening effect of the heads) compressed by external uniform pressure, a section of unit length is compressed by a pressure P_e constituting the previously mentioned load q.

The value of q_{cr} is given by:

$$q_{cr} = (n^2 - 1)\frac{EJ}{r^3}$$

where:

n = number of half-waves, integer greater than 1;

E = defined in Ch 1, Sec 1, [1.1.2];

J = moment of inertia, about the neutral axis parallel to the axis of revolution of the pressure cylinder of the web frame cross-section with attached plating;

r = radius at the neutral axis of the web frame with attached plating (see Fig 1).

APPENDIX 2 TRANSVERSE STRENGTH CHECKS OF CYLINDRICAL SHELLS, WITH CIRCULAR AND NON-CIRCULAR CROSS-SECTION, OF LARGE SIZE SUBMARINES/SUBMERSIBLES SUBJECTED TO EXTERNAL PRESSURE

1 Premise

1.1 Reference

1.1.1 The subject of this Appendix is the implementation of the calculations in Sec 2, [7.1].

1.2 Criteria

1.2.1 The criteria presented below are to be applied for transverse strength checks of cylindrical pressure hulls, provided that the relevant provisions in Sec 2, [2.1] are taken into account.

1.3 Units

1.3.1 Refer to Sec 2, [1.1].

2 Circular cross-section pressure hulls

2.1 Plate yielding check

2.1.1 In a cylindrical shell, axial stresses σ_{EL}, in N/mm², and circumferential stress σ_{ET}, in N/mm², are:

$$\sigma_{ELMAX} = \frac{pR}{t}\left(\frac{1}{2} + 1,54\,\frac{F}{F+bt}\,\frac{\sinh\alpha l - \sin\alpha l}{\sinh\alpha l + \sin\alpha l}\,\frac{1}{1+\beta}\right)$$

$$\sigma_{ETMAX} = \frac{pR}{t}\left(1 + 1,7\,\frac{F}{F+bt}\,\frac{1,545\sinh\frac{\alpha l}{2} - \cos\frac{\alpha l}{2}}{\sinh\alpha l + \sin\alpha l} + \right.$$
$$\left. + \frac{0,455\cosh\frac{\alpha l}{2} - \sin\frac{\alpha l}{2}}{\sinh\alpha l + \sin\alpha l}\,\frac{1}{1+\beta}\right)$$

where:

p : limit pressure, equal to 2,3 times the working pressure, in N/mm², beyond which there is plate yielding;

R : outer radius of the shell in the zone under consideration, in mm;

t : shell thickness in the zone under consideration, in mm;

F : cross-sectional area of stiffeners (web frames), without attached plating, in mm²;

b : width of any attachment flange of reinforcement on the plate, in mm (see Fig 1);

l : free span between reinforcements (frame spacing is l + b) , in mm (see Fig 1);

$$\alpha = \left(\frac{m^2-1}{m^2}\,\frac{3}{R^2t^2}\right)^{1/2}$$

where $m = 1/\nu$.

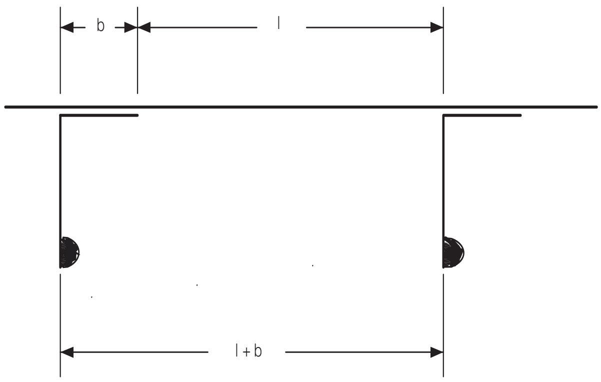
For steel, m = 10/3, therefore:

$$\alpha = \frac{1,285}{(Rt)^{0,5}}$$

$$\beta = \frac{\cosh\alpha l - \cos\alpha l}{\sinh\alpha l + \sin\alpha l}\,\frac{2t}{(F+bt)\alpha}$$

Values of σ_{ELMAX} and σ_{ETMAX} as calculated above are not to exceed the minimum yielding strength of the material.

Figure 1



More conservatively, ideal stresses (instead of actual stresses) are to be considered, given by:

$\sigma_i = \varepsilon E$

in which:

ε = unit stretch,

E = Young's modulus of the material.

Values of maximum ideal stresses, σ_{ILMAX} and σ_{ITMAX}, in N/mm², are thus:

$$\sigma_{ILMAX} = 0,85\frac{pR}{t}\left(0,235 + \frac{F}{F+bt}\,\frac{1,953\sinh\alpha l - 1,353\sin\alpha l}{\sinh\alpha l + \sin\alpha l}\,\frac{1}{1+\beta}\right)$$

$$\sigma_{ITMAX} = 0,85\frac{pR}{t}\left(1 - \frac{2F}{F+bt}\,\frac{\sinh\frac{\alpha l}{2}\cos\frac{\alpha l}{2}}{\sinh\alpha l + \sin\alpha l} + \frac{\cosh\frac{\alpha l}{2}\sin\frac{\alpha l}{2}}{\sinh\alpha l + \sin\alpha l}\,\frac{1}{1+\beta}\right)$$

The above stresses correspond to about ¾ of σ_{ILMAX} and of σ_{ITMAX}; such stresses are not to exceed the minimum yielding strength of the material.

By assuming:

$$\frac{\sinh\alpha l - \sin\alpha l}{\sinh\alpha l + \sin\alpha l} = L$$

$$\frac{\cosh\alpha l - \cos\alpha l}{\sinh\alpha l + \sin\alpha l} = M$$

$$\frac{1,545\sinh\frac{\alpha l}{2}\cos\frac{\alpha l}{2} + 0,455\cosh\frac{\alpha l}{2}\sin\frac{\alpha l}{2}}{\sinh\alpha l + \sin\alpha l} = 0$$

$$\frac{1,953\sinh\alpha l - 1,353\sin\alpha l}{\sinh\alpha l + \sin\alpha l} = P$$

$$\frac{\sinh\frac{\alpha l}{2}\cos\frac{\alpha l}{2} + \cosh\frac{\alpha l}{2}\sin\frac{\alpha l}{2}}{\sinh\alpha l + \sin\alpha l} = Q$$

the previous expressions take the form:

$$\sigma_{ELMAX} = \frac{pR}{t}\left(\frac{1}{2} + 1,54\,\frac{F}{F+bt}\,\frac{L}{1+\beta}\right)$$

$$\sigma_{ETMAX} = \frac{pR}{t}\left(1 - 1,7\frac{F}{F+bt}\,\frac{O}{1+\beta}\right)$$

and

$$\sigma_{ILMAX} = 0,85\frac{pR}{t}\left(0,235 + \frac{F}{F+bt}\,\frac{P}{1+\beta}\right)$$

$$\sigma_{ITMAX} = 0,85\frac{pR}{t}\left(1 - \frac{2F}{F+bt}\,\frac{Q}{1+\beta}\right)$$

with:

$$\beta = \frac{2Mt}{\alpha(F+bt)}$$

Values for parameters L, M, O, P, Q can be obtained from the following diagrams (see Fig 2) for values of αl in practical applications.

It is noted that, by increasing the strength of the reinforcements, that is increasing the value of F, the stresses from the previous formulae also increase and, with F large enough (for example in transverse bulkheads), stresses tend to reach their maximum levels. To avoid such a stress increase, plates are to be locally strengthened and/or frame spacing reduced in proximity to bulkheads.

2.2 Buckling check of plating

2.2.1 The critical theoretical pressure p_k, in N/mm², for plate buckling of pressure shells is:

$$p_k = \left\{\frac{(Et/n^2R)}{[1+(nl/\pi R)^2]^2} + n^2/12\cdot[1+(\pi R/nl)^2]^2\cdot \frac{m^2E}{m^2-1}\cdot(t/R)^3\right\}\frac{1}{1+0,5\cdot(\pi R/nl)^2}$$

For steel, m = 10/3, thus:

$$p'_k = \frac{\dfrac{Et/R}{n^2[(q+1)/q]^2} + 0,09156Et^3/R^3[n^2(1+q)^2]}{1+q/2}$$

where t, l and R are those defined in [2.1] above, E Young's modulus and:

q : $(\pi R/nl)^2$

n : number of half-waves, integer value that minimises p'_k

Experimental tests have allowed a correction coefficient "c" to be defined, depending on the thickness of the pressure shell plating, corresponding to:

c = 0,4 for thickness ≤ 5 mm

= 0,5 for thickness from 5 to 7 mm

= 0,6 for thickness > 7 mm.

Therefore, the critical buckling pressure is:

$p''_k = cp_k$

and, for steel:

$p'''_k = cp'_k$

For steel hulls, the approximated values reported in Tab 1 can be assumed, giving minimum buckling pressures, in N/mm².

Tab 1 already accounts for coefficient "c" as previously defined.

Tab 1 considers a value for E equal to 220,000 N/mm^2; for materials having Young's modulus E_1 different from the latter, the buckling pressure is obtained by multiplying the value from Tab 1 by the ratio E_1/220,000.

After calculating the actual and ideal stresses with the formulae in [2.1] and considering only the highest value of σ of stress for both cases, it is to be verified that:

$$\frac{\sigma p''_k}{p} \leq R_s$$

if σ is the actual normal stress;

$$\frac{\sigma p''_k}{p} \leq \frac{3}{4} R_s$$

if σ is the ideal normal stress.

If the above expressions are not fulfilled, maximum buckling pressure achievable will be p_k in way of pR_s/σ.

Figure 2

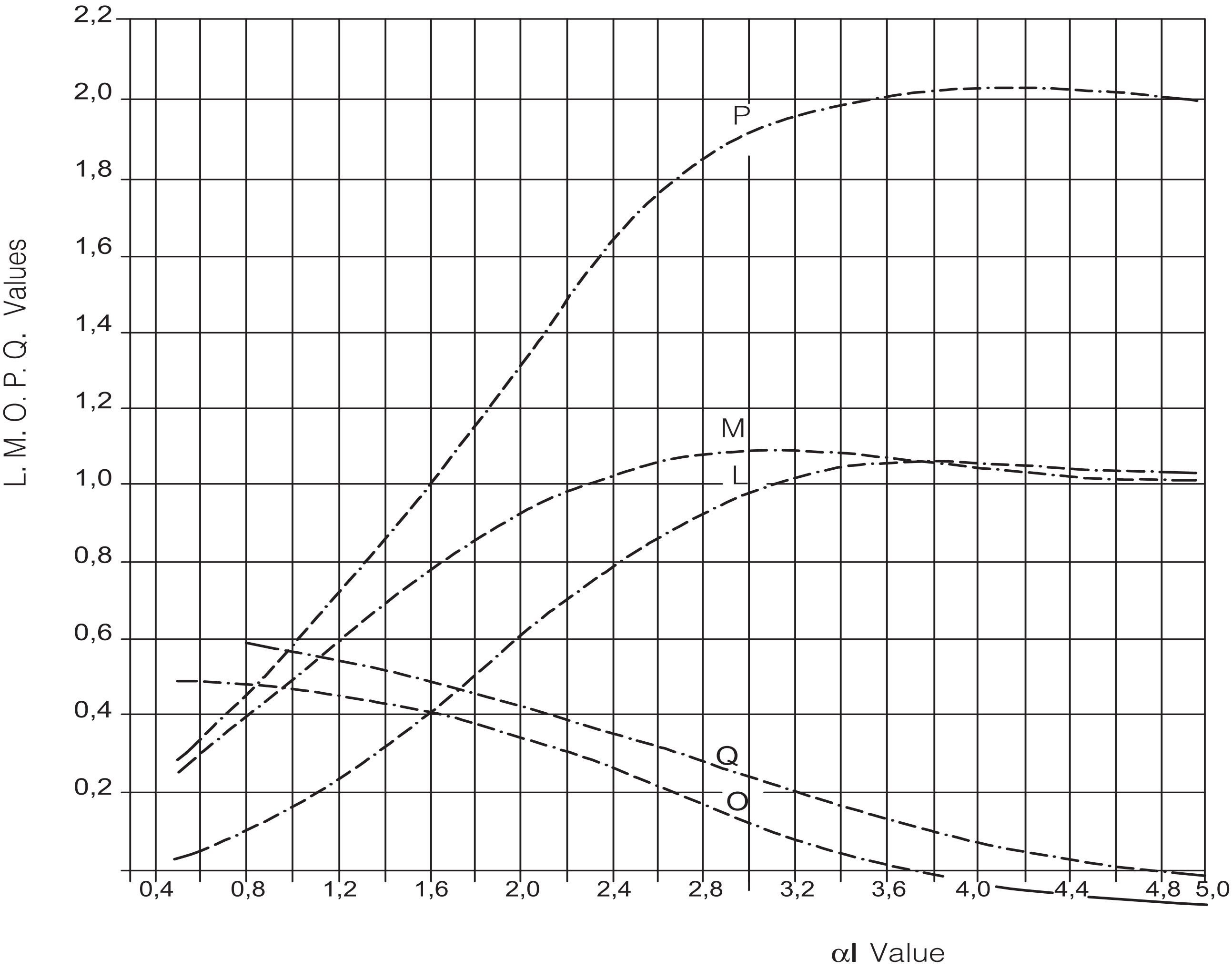


Table 1 : Minimum pressure p'''_k , in N/mm^2, for different values of outer radius R of the shell, in mm, as a function of shell thickness t, in mm, and of free span “l” between reinforcements, in mm

Values of p'''_k for R = 1250 mm

t \ l	400	500	600	700	800	900	1000
8	1,48	1,17	0,94	0,78	0,68	0,60	0,55
9	2,02	1,58	1,28	1,26	0,93	0,31	0,72
10	2,69	2,09	1,65	1,37	1,20	1,04	0,94
11	3,42	2,66	2,09	1,73	1,51	1,33	1,20
12	4,26	3,31	2,61	2,18	1,88	1,66	1,50
13	5,21	4,06	3,22	2,68	2,31	2,04	1,84
14	6,32	4,92	3,92	3,25	2,81	2,48	2,22
15	7,60	5,91	4,72	3,91	3,37	2,94	2,63
16	9,02	7,04	5,60	4,64	4,00	3,50	3,10
17	-	-	6,56	5,46	4,69	4,08	3,62
18	-	-	7,60	6,34	5,45	4,76	4,20
19	-	-	8,74	7,31	6,27	5,46	4,80
20	-	-	9,94	-	7,13	6,22	5,48

Values of p'''_k for R = 1500 mm

t \ l	400	500	600	700	800	900	1000
8	1,14	0,89	0,71	0,58	0,51	0,45	0,49
9	1,54	1,21	0,96	0,79	0,70	0,60	0,54
10	2,04	1,60	1,26	1,03	0,91	0,80	0,71
11	2,61	2,04	1,61	1,32	1,16	1,01	0,90
12	3,28	2,54	2,02	1,66	1,45	1,26	1,13
13	4,05	3,14	2,50	2,06	1,78	1,56	1,38
14	4,93	3,81	3,04	2,51	2,15	1,88	1,68
15	5,93	4,60	3,65	3,07	2,65	2,25	2,01
16	7,03	5,44	4,31	3,53	3,02	2,64	2,37
17	8,24	6,36	5,04	4,14	3,52	3,08	2,76
18	9,57	7,2	5,85	4,80	4,10	3,58	3,20
19	-	-	6,70	5,51	4,72	4,14	3,68
20	-	-	7,64	6,31	5,39	4,72	4,20
21	-	-	6,66	7,22	6,14	5,35	4,75
22	-	-	9,80	-	6,95	6,06	5,36

Values of p'''_k for R = 1750 mm

t \ l	400	500	600	700	800	900	1000
10	1,62	1,26	1,00	0,82	0,72	0,62	0,56
11	2,10	1,64	1,28	1,06	0,93	0,82	0,72
12	2,62	2,05	1,62	1,34	1,17	1,02	0,90
13	3,25	2,55	2,00	1,65	1,43	1,25	1,10
14	3,96	3,10	2,44	1,99	1,72	1,51	1,34
15	4,78	3,73	2,92	2,38	2,04	1,78	1,60
16	5,70	4,42	3,46	2,80	2,40	2,10	1,88
17	6,69	5,16	4,04	3,28	2,80	2,46	2,20
18	7,76	5,96	4,67	3,80	3,25	2,84	2,54
19	8,93	6,86	5,34	4,35	3,72	3,26	2,90
20	10,24	7,78	6,08	4,97	4,26	3,73	3,30
21	-	-	6,92	5,70	4,86	4,22	2,73
22	-	-	7,87	6,47	5,55	4,82	4,22

Values of p'''_k for R = 2000 mm

t \ l	400	500	600	700	800	900	1000
10	1,37	1,05	0,83	0,69	0,60	0,52	0,47
11	1,74	1,36	1,09	0,90	0,76	0,68	0,60
12	2,16	1,70	1,36	1,12	0,97	0,85	0,76
13	2,66	2,09	1,67	1,38	1,18	1,03	0,92
14	3,23	2,53	2,01	1,66	1,43	1,26	1,11
15	3,90	3,02	2,39	1,97	1,70	1,48	1,31
16	4,66	3,57	2,82	2,32	2,00	1,75	1,54
17	5,54	4,21	3,32	2,72	2,34	2,05	1,82
18	6,53	4,88	3,87	3,20	2,73	2,38	2,12
19	7,58	5,62	4,46	3,68	3,14	2,74	2,44
20	8,70	6,56	5,10	4,22	3,60	3,14	2,78
21	9,90	7,32	5,80	4,81	4,09	3,55	3,15
22	-	-	6,54	5,40	4,61	4,02	3,55
23	-	-	7,34	6,05	5,17	4,50	3,98
24	-	-	8,22	6,74	5,77	5,03	4,43
25	-	-	9,14	7,48	6,42	5,60	4,93
26	-	-	10,15	-	7,10	6,18	5,44

Values of p'''_k for R = 2250 mm

t \ l	400	500	600	700	800	900	1000
10	1,16	0,91	0,71	0,59	0,51	0,45	0,40
11	1,50	1,16	0,91	0,75	0,65	0,57	0,51
12	1,88	1,46	1,14	0,94	0,82	0,72	0,64

Values of p'''_k for R = 2500 mm

t \ l	400	500	600	700	800	900	1000
10	1,01	0,77	0,61	0,50	0,43	0,38	0,34
11	1,30	1,00	0,78	0,65	0,56	0,49	0,44
12	1,66	1,28	0,99	0,82	0,70	0,61	0,54

13	2,32	1,80	1,41	1,16	1,00	0,87	0,78	13	2,05	1,56	1,22	1,00	0,87	0,77	0,67
14	2,83	2,18	1,71	1,41	1,22	1,07	0,95	14	2,48	1,91	1,47	1,20	1,04	0,91	0,81
15	3,41	2,62	2,04	1,68	1,45	1,28	1,13	15	2,98	2,28	1,76	1,44	1,25	1,10	0,96
16	4,06	3,11	2,42	1,97	1,75	1,49	1,33	16	3,54	2,68	2,09	1,70	1,46	1,28	1,13
17	4,79	3,66	2,84	2,31	1,99	1,75	1,55	17	4,18	3,18	2,44	1,97	1,70	1,50	1,32
18	5,60	4,26	3,30	2,70	2,31	2,04	1,80	18	4,88	3,70	2,84	2,30	1,98	1,73	1,53
19	6,48	4,90	3,81	3,10	2,65	2,32	2,07	19	5,64	4,25	3,26	2,64	2,28	1,99	1,76
20	7,45	5,62	4,36	3,54	3,04	2,67	2,36	20	6,48	4,86	3,74	3,04	2,60	2,27	2,00
21	8,51	6,38	4,96	4,05	3,46	3,02	2,68	21	7,41	5,48	4,26	3,48	2,96	2,56	2,28
22	9,67	7,20	5,60	4,58	3,92	3.42	3,02	22	8,42	6,17	4,83	3,97	3,36	2,90	2,57
23	-	8,15	6,30	5,18	4,43	3.85	3,38	23	9,46	6,92	5,44	4,46	3,78	3,28	2,89
24	-	-	7,04	5,81	4,97	4,30	3,77	24	10,56	7,78	6,10	4,98	4,23	3,66	3,24
								25	-	6,80	5,56	4,71	4,09	3,60	
								26	-	-	7,53	6,15	5,21	4,53	4,01
Values of p′′′$_k$ for R = 2750 mm								Values of p′′′$_k$ for R = 3000 mm							
t \ l	400	500	600	700	800	900	1000	t \ l	400	500	600	700	800	900	1000
10	0,88	0,67	0,53	0,43	0,38	0,34	0,29	10	0,79	0,60	0,47	0,40	0,33	0,29	0,28
11	1,14	0,88	0,68	0,55	0,48	0,42	0,37	11	1,02	0,78	0,60	0,51	0,43	0,37	0,33
12	1,44	1,09	0,85	0,68	0,60	0,53	0,46	12	1,29	1,00	0,76	0,63	0,54	0,45	0,42
13	1,80	1,35	1,05	0,85	0,75	0,65	0,57	13	1,60	1,22	0,94	0,78	0,67	0,58	0,52
14	2,19	1,66	1,28	1,04	0,91	0,79	0,69	14	1,95	1,48	1,14	0,94	0,80	0,70	0,62
15	2,63	1,97	1,53	1,25	1,08	0,95	0,84	15	2,34	1,79	1,37	1,10	0,96	0,84	0,74
16	3,13	2,37	1,82	1,47	1,28	1,13	1,00	16	2,79	2,11	1,62	1,33	1,14	0,99	0,87
17	3,68	2,77	2,14	1,73	1,49	1,31	1,18	17	3,30	2,49	1,90	1,54	1,33	1,15	1,02
18	4,31	3,24	2,49	2,00	1,73	1,52	1,37	18	3,87	2,90	2,21	1,80	1,54	1,34	1,18
19	5,00	3,74	2,86	2,31	1,99	1,76	1,56	19	4,48	3,30	2,54	2,07	1,78	1,54	1,36
20	5,74	4,26	3,27	2,61	2,27	1,98	1,78	20	5,16	3,78	2,90	2,35	2,04	1,77	1,56
21	6,55	4,84	3,72	3,02	2,58	2,26	2,00	21	5,90	4,38	3,30	2,68	2,31	2,02	1,76
22	7,43	5,48	4,21	3,42	2,92	2,54	2,23	22	6,71	4,92	3,72	3,00	2,61	2,28	1,99
23	8,37	6,14	4,73	3,84	3,27	2,84	2,48	23	7,58	5,53	4,19	3,40	2,93	2,55	2,24
24	9,36	6,82	5,29	4,03	3,65	3,15	2,73	24	8,54	6,24	4,70	3,81	3,27	2,86	2,50
25	-	7,78	5,88	4,77	4,05	3,48	3,00	25	9,56	6,94	5,27	4,26	3,64	3,15	2,78
								26	10,64	7,68	5,88	4,77	4,05	3,50	3,08
								27	-	-	6,52	5,28	4,47	3,88	3,41
								28	-	-	7,20	5,84	4,93	4,26	3,75
								29	-	-	7,93	6,44	5,41	4,66	4,11
								30	-	-	8,68	7,02	5,91	5,10	4,49
Values of p′′′$_k$ for R = 3250 mm								Values of p′′′$_k$ for R = 3500 mm							
t \ l	400	500	600	700	800	900	1000	t \ l	400	500	600	700	800	900	1000
14	1,72	1,28	1,00	0,82	0,72	0,61	0,55	14	1,60	1,18	0,92	0,76	0,65	0,54	0,50
15	2,10	1,55	1,20	1,00	0,86	0,72	0,65	15	1,93	1,44	1,11	0,89	0,77	0,67	0,60
16	2,51	1,84	1,42	1,17	1,02	0,88	0,77	16	2,32	1,70	1,31	1,06	0,92	0,80	0,71
17	2,98	2,14	1,67	1,38	1,20	1,03	0,90	17	2,74	2,00	1,54	1,25	1,08	0,93	0,82

18	3,49	2,52	1,95	1,61	1,40	1,21	1,04	18	3,19	2,34	1,80	1,45	1,25	1,06	0,96
19	4,04	2,92	2,25	1,86	1,60	1,38	1,20	19	3,70	2,70	2,07	1,68	1,43	1,24	1,10
20	4,65	3,36	2,58	2,13	1,84	1,58	1,36	20	4,24	3,13	2,38	1,92	1,64	1,42	1,25
21	5,30	3,84	2,94	2,42	2,08	1,78	1,55	21	4,83	3,52	2,71	2,18	1,86	1,60	1,42
22	6,02	4,38	3,34	2,72	2,35	2,01	1,75	22	5,50	3,95	3,05	2,46	2,10	1,80	1,60
23	6,81	4,92	3,76	3,10	2,64	2,28	1,98	23	6,20	4,48	3,45	2,80	2,36	2,04	1,82
24	7,66	5,56	4,25	3,46	2,96	2,55	2,22	24	6,98	5,02	3,88	3,14	2,65	2,29	2,04
25	8,60	6,16	4,75	3,87	3,38	2,82	2,48	25	7,86	5,60	4,32	3,50	2,95	2,55	2,28
26	9,65	6,82	5,30	4,34	3,64	3,13	2,75	26	8,84	6,25	4,82	3,90	3,29	2,84	2,49
27	-	7,60	5,88	4,76	4,01	3,45	3,04	27	9,94	6,92	5,34	4,34	3,64	3,14	2,78
28	-	-	6,50	5,26	4,40	3,80	3,30	28	-	7,70	5,90	4,78	4,00	3,46	3,05
29	-	-	7,17	5,79	4,84	4,17	3,66	29	-	-	6,50	5,28	4,40	3,80	3,33
30	-	-	7,87	6,34	5,26	4,51	4,00	30	-	-	7,12	5,80	4,81	4,16	3,62
31	-	-	8,60	6,88	5,72	4,91	4,34	31	-	-	7,82	6,36	5,32	4,53	3,92
32	-	-	9,38	7,46	6,20	5,34	4,70	32	-	-	8,50	6,95	5,80	4,92	4,22
Values of p'''_k for R= 3750 mm								Values of p'''_k for R = 4000 mm							
t \ l	400	500	600	700	800	900	1000	t \ l	400	500	600	700	800	900	1000
14	1,47	1,10	0,84	0,69	0,59	0,50	0,45	14	1,35	1,01	0,77	0,62	0,54	0,46	0,41
15	1,77	1,31	1,01	0,82	0,71	0,62	0,54	15	1,64	1,22	0,92	0,74	0,64	0,56	0,51
16	2,11	1,56	1,20	0,98	0,83	0,71	0,64	16	1,96	1,44	1,10	0,87	0,76	0,66	0,60
17	2,49	1,85	1,41	1,14	0,98	0,85	0,75	17	2,32	1,70	1,29	1,03	0,89	0,77	0,69
18	2,92	2,14	1,64	1,34	1,14	0,99	0,87	18	2,68	2,00	1,50	1,21	1,04	0,90	0,79
19	3,38	2,49	1,90	1,54	1,31	1,13	1,00	19	3,14	2,30	1,74	1,40	1,19	1,04	0,91
20	3,89	2,85	2,17	1,76	1,50	1,30	1,14	20	3,62	2,64	2,00	1,61	1,36	1,18	1,04
21	4,44	3,26	2,47	2,00	1,71	1,47	1,29	21	4,12	3,01	2,28	1,84	1,55	1,34	1,18
22	5,06	3,70	2,80	2,26	1,93	1,67	1,45	22	4,71	3,38	2,58	2,08	1,77	1,52	1,33
23	5,72	4,18	3,16	2,54	2,17	1,88	1,63	23	5,31	3,82	2,91	2,35	1,98	1,69	1,49
24	6,44	4,67	3,54	2,85	2,43	2,10	1,82	24	5,98	4,30	3,28	2,65	2,22	1,89	1,66
25	7,24	5,21	3,95	3,18	2,71	2,34	2,03	25	6,68	4,78	3,66	2,95	2,48	2,12	1,85
26	8,11	5,82	4,40	3,53	3,00	2,58	2,25	26	7,45	5,33	4,05	3,28	2,74	2,34	2,06
27	9,04	6,46	4,87	3,92	3,32	2,86	2,49	27	8,26	5,90	4,51	3,64	3,04	2,60	2,27
28	-	7,11	5,38	4,32	3,65	3,15	2,74	28	9,13	6,52	4,98	4,02	3,34	2,86	2,50
29	-	8,00	5,93	4,75	4,00	3,44	3,00	29	-	7,16	5,50	4,42	3,66	3,13	2,76
30	-	-	6,52	5,16	4,37	3,75	3,28	30	-	-	5,98	4,84	4,01	3,43	3,00

2.3 Web frame check

2.3.1

Transverse structures are considered. The formulae for tripping and yielding checks of web frames are, respectively:

$$p_{ko} = 3\frac{m^2}{m^2-1}\frac{EJ}{R_B^2 \cdot R}$$

$$p_c = \frac{F+bt}{R_B}R_S$$

where:

p_{ko} : critical tripping load for unit length, in N/mm, to be considered over the peripheral length of the stiffener with plate width as wide as the attachment flange. If the attachment flange does not exist or if the frame is outside the pressure hull, the frame alone is to be considered;

p_c : critical yielding load for unit peripheral length of the stiffener (considered similarly to p_{ko}), in N/mm;

J : moment of inertia of stiffener as defined above about the neutral axis parallel to the frame ring axis, in mm^4;

R_B :

R, F, b and t are defined as in [2.1];

R_S : minimum yield stress of material, in N/mm^2.

Since, for steel, m=10/3, the tripping load for the unit length of the stiffener is:

$$p_{ko} = \frac{3,3EJ}{R^2{}_B \cdot R}$$

For frames fitted on plating by means of attachment flanges, the total hydrostatic load of one frame, equal to:

Q = p (b + l)

is to be distributed for one fraction, equal to [b/(b-l)], on the frame itself and the other fraction on the part of the adjacent plate of width "l"; hence, due to the greater flexibility of the plating, part of its load is transferred into reinforcements which, therefore, will need to be checked for yielding for a load equal to the partial load, independently of the buckling of the shell.

In such a case, the total radial load p_t, in N/mm, on the whole reinforcement is given by:

$$p_t = pb\left(1 + \frac{0,85\beta}{1+\beta}\,\frac{F}{bt}\right)$$

where p is the external pressure, in N/mm^2.

For:

$p_t < p_{ko}$

the tripping check of the web frame is fulfilled. To fulfil also the yielding check, the value of p_{ko} is to be such that the maximum ideal stress is:

$$R_s = \frac{p_{ko} \cdot R}{F + bt}$$

where:

$$p_t \leq p_{ko}\frac{\sigma_{IDMAX}}{R_s}$$

2.4 Other hull structures

2.4.1 For any hull structure not specified in this item [2], the scantlings of the same part prescribed in the other items of this Chapter 1 are to be applied. It is to be noted that the stress of the external plating σ_{EL} (see [2.1]) increases by increasing the web frame's cross-sectional area F; therefore, in way of transverse bulkheads, the plate thickness is to be increased (in general, to allow for an increase of 3 ÷ 4 cm^2 in area F, a plate thickness increase of 0,5 mm is sufficient).

3 Non-circular cross-section pressure hulls

3.1 Foreword

3.1.1 The method described below is to be adopted whenever more sophisticated calculation procedures also accounting for the provisions in App 1 are not applied.

3.2 Strength of plates

3.2.1 The formulations reported in item [2] can be applied by considering the local curvature radius: at a first approximation, a circular cross-section cylinder with radius equal to the maximum local curvature radius, as illustrated in Fig 3, can be considered, in which:

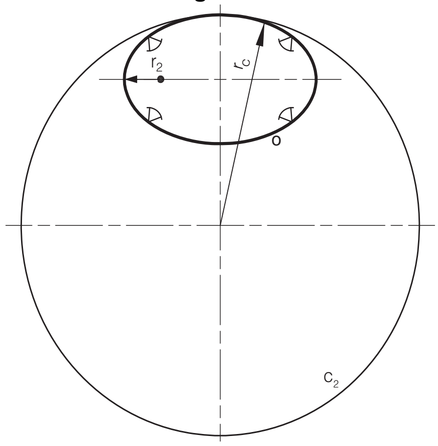
r_c : maximum curvature radius;

o : cross-section (oval for the case in Fig 3) of the pressure cylinder;

c_2 : circular cross-section of the pressure cylinder.

In a more sophisticated calculation, the thickness of part "o" with radius r_2 can be recalculated with the above-mentioned formulae.

Figure 3



In any flat parts of the hull, formulae relevant to flat shells, with proper boundary conditions, can be adopted.

3.3 Strength of web frames

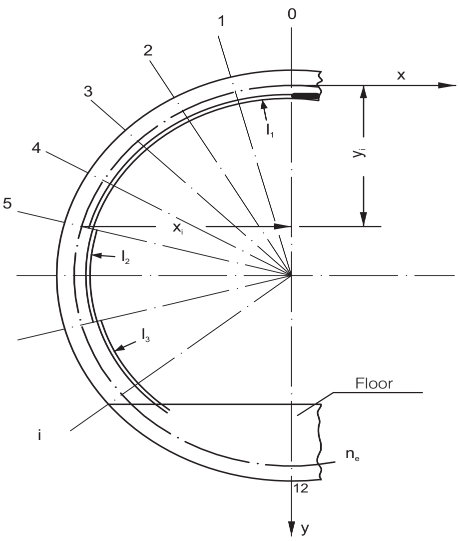
3.3.1 Even if the calculation scheme reported here is relevant to a just about circular cross-sections (see Fig 4), however, this method is also applicable to non-circular cross-sections or to variable section stiffeners.

For symmetrical sections, calculations need only be performed for one half.

The cross-section in examination has frame of variable inertia (see Fig 4). Assume I_1, I_2 and I_3 the moments of inertia of cross-sections of frame with attached plating (having a width equal to the lower of the frame spacing and 30 times the plating thickness), and <<n_e>> the neutral axis of the frame with attached plate; if the neutral axis line has discontinuities (in way of changes on the moment of inertia of the frame), the position-envelope is to be traced for all the frame length in such a way as to have a continuous line.

The neutral axis is to be subdivided into a number of equal extensions and the various calculation points are to be numbered starting from the intersection of the upper part of the trace of the symmetry plane with the neutral axis (point O). If the web frame extends up to the lowermost point, this is the last calculation point (generally number 12).

Figure 4



Tab 2 is to be filled in, such that for every calculation position:

h_t : height of web frame cross-section, including the flange and without the attached plate, in cm

MS : Simpson's multiplier (see Tab 2)

I : moment of inerti I_i, in cm^4, as defined above

J : the lowest of the I_i, already defined, in cm^4

X : horizontal distance of the calculation position from the vertical axis y, in cm

Y : vertical distance of the calculation position from the horizontal axis x, in cm

$$Y_G = \frac{\sum \frac{MS}{I} JY}{\sum \frac{MS}{I} J} \quad \text{, in cm}$$

$Y - Y_G$: algebraic sum, with its sign.

$$\rho^2 = X^2 + (Y - Y_G)^2$$

$\frac{MS}{I} J\rho^2(Y - Y_G)$ = algebraic product whose sign depends on that of ($Y - Y_G$)

$\frac{MS}{I} J(Y - Y_G)^2$ = algebraic product always positive

In the last column of Tab 2, in cells without a slash, the sum of all the values of the corresponding row is to be calculated.

Then Tab 3 is to be filled in, where for every calculation position:

$$b' = \frac{\sum \frac{MS}{I} J\rho^2(Y - Y_G)}{2\sum \frac{MS}{I} J(Y - Y_G)^2} \quad \text{, in cm}$$

$$i_o^2 = \frac{\sum \frac{MS}{I} J\rho^2}{\sum \frac{MS}{I} J} + b'^2$$

$i_o^2 - r_1^2$: to be considered with its sign;

p_3 : product, in kg/cm, of assumed depth, in cm, by mass density of sea water, in kg/cm^3, by frame spacing, in cm;

Q_1 : compression load, in N;

A_1 : cross-sectional area of web frame with attached plating, in cm^2;

σ_c : compressive stress, in N/cm^2;

M : bending moment with sign depending on the sign of ($i_o^2 - r_1^2$), in Ncm;

Z_o : section modulus of frame cross-section, with attached plating, about the flange of frame, in cm^3;

Z_S : section modulus as defined above, about the attached plating, in cm^3;

σ_b : bending stress, with its sign depending on the sign of M, in N/cm^2;

σ : total stress in N/cm^2 equal to the sum of σ_b and σ_c, where σ_b is:

- positive for compressive stress (as for σ_c);
- negative for tensile stress.

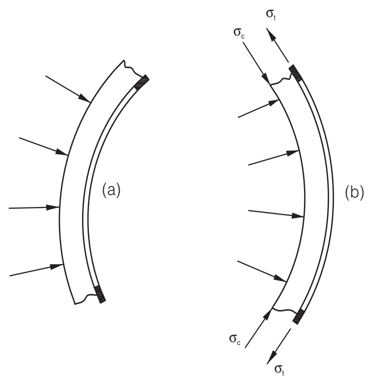
In the case of external pressure, the circular structure tends to ovalise so that, when frames are fitted inside the pressure hull (see Fig 5), the plating is subjected to compression while the flanges of the stiffener are subjected to tensile stress.

In the case of Fig 5, the flange is subjected to tensile stress so that, for the computation of σ, the σ_b relevant to the flange is to be subtracted from the σ_c while the one relevant to the attached plating is to be added.

If σ_b is negative, the previous criteria will have to be applied by making a summation.

The contrary of the above will be required in the case of web frames fitted outside the pressure hull.

Figure 5



(a) undeformed hull subjected to external pressure
(b) deformed hull subjected to external pressure

Table 2

Position No.	0	1	2	3	4	5	6	7	8	9	10	11	12	Σ
h_t, in cm														\
MS	1/2	2	1	2	1	2	1	2	1	2	1	2	1/2	\
I, in cm^4														\
$\frac{MS}{I}J$														
X, in cm														\
Y, in cm														\
X^2, in cm^2														\
$\frac{MS}{I}JY$, in cm														
$Y - Y_G$, in cm														\
$(Y - Y_G)^2$, in cm^2														\
$p^2 = X^2 + (Y - Y_G)^2$, in cm^2														\
$\frac{MS}{I}J\rho^2$, in cm^2														
$\frac{MS}{I}J\rho^2(Y - Y_G)^2$, in cm^2														
$\frac{MS}{I}J(Y - Y_G)^2$, in cm^2														

Table 3

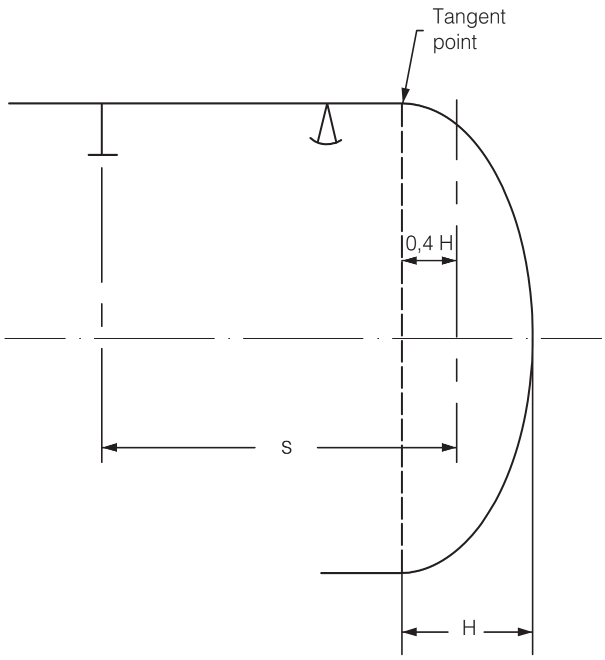
Position No.	0	1	2	3	4	5	6	7	8	9	10	11	12
$d = (Y - b') - Y$, in cm													
d^2, in cm^2													
$r_1^2 = d^2 - x^2$, in cm^2													
$i^2_0 - r_1^2$, in cm^2													
r_1, in cm													
$Q_1 = 10\ p_3 r_1$, in N													
A_1, in cm^2													
$\sigma = \dfrac{Q_1}{A_1}$, in cm^2													
$M = 10\ (i^2_0 - r_1^2\ p_3)$, in Ncm													
Z_0, in cm^3													
Z_S, in cm^3													
$\sigma_b = M/Z_0$, in N/cm^2													
$\sigma_b = M/Z_S$, in N/cm^2													
$\sigma = \sigma_b + \sigma_c$ in N/cm^2													

4 Frameless pressure hulls

4.1

4.1.1 In general, pressure hulls without web frames are not allowed. However, in such case, the same procedures for the strength check as those for framed hulls could be applied by assuming, for the frame spacing, the distance between the heads or the transverse bulkheads or the reinforced members, where the value of "s", for the end parts, is that defined in Fig 6.

Figure 6



APPENDIX 3 LIGHTWEIGHT PRESSURE HULLS

1 General

1.1

1.1.1 To design a lightweight pressure hull (see Sec 2, [5.2]), the criteria in article [2] are to be applied.

A compromise solution between the theoretical result and a practical design is to be adopted.

2 Procedure

2.1

2.1.1 Based on App 2 [2.3] it follows that, for each R value, one value can be obtained for the thickness and one for the frame spacing so as to produce the hull with the lowest weight and the same strength.

2.1.2 A graphical solution can be adopted as described below.

A Cartesian plane is to be produced, having in the ordinate the weight for unit length (N/m) of the pressure shell (plates + frames) calculated from the constructional plans, and in the abscissa the frame spacing (mm); different curves, one for each plate thickness t (mm), are obtained (t1<t2<t3<….<t8, etc), and each corresponding to one particular pressure hull configuration.

For each point of the above curves, the critical pressure p (N/mm^2) is to be calculated and the points having equal pressure ($p_1<p_2<$ …..$<p_4$, etc.) are to be connected; in this way the curves of the weights per metre length corresponding to various critical pressures are obtained.

Fig 1 shows typical curves; such curves have two minimum points: one, the absolute minimum, corresponds to frame spacing too small to be practical, while the other, the relative minimum, corresponds to frame spacing that is too large, which would require excessive plate thickness and too large frame scantling.

Between the two above-mentioned points, the practicable application for frame spacing, in general ranging between 500 and 800 mm, is to be identified.

For frame spacing higher than the value at the relative minimum, the weight increases considerably and reaches its maximum in the case of a non-framed cylindrical pressure shell.

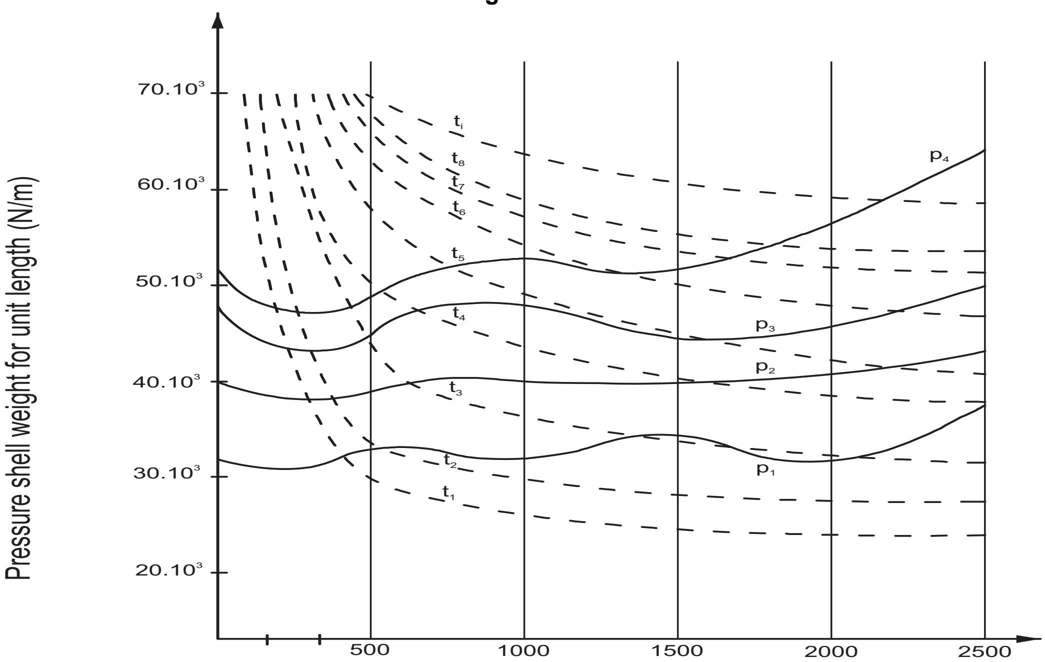
The lightest solution, having a lower frame spacing, implies a greater number of frames and thus a substantial increase in the number of welds required.

3 Summary

3.1

3.1.1 By adopting a free span of the plating which, in compliance with the requirements of the arrangement, is the closest to that with the lowest weight, the lightest possible solution is achieved or, in the case of a fixed weight, one capable of withstanding a higher external pressure.

Figure 1



Part B
Hull and Stability

Chapter 2
STABILITY

SECTION 1 GENERAL REQUIREMENTS

1 Introduction

1.1 Foreword

1.1.1 For what is not specified in this Section, the requirements of Part B, Chapter 3 of the Rules, as far as applicable, are valid.

1.2 Definitions

1.2.1

a) A fully submerged body is in stable equilibrium condition when the buoyancy equals the displacement and also when the centre of mass is located underneath the centre of buoyancy and aligned on the same vertical.

b) Δ_{surf} and Δ_{sub} being, respectively, the displacement of the unit on the surface and underwater, the reserve buoyancy can be defined as follows:

as a percentage:

$$\frac{\Delta_{sub} - \Delta_{surf}}{\Delta_{sub}} \cdot 100 \quad (\%)$$

or in tons:

Δ_{sub} - Δ_{surf}

Submersibles have reserve buoyancy equal to or greater than 20%, submarines lower than 20%.

c) Equilibrium trim: a unit on the surface or underwater is said to be in such a condition when, with standard loading and engines stopped (propellers at rest), it is in equilibrium between buoyancy and weight and also when the centre of buoyancy C and mass G are aligned on the same vertical, with the unit in horizontal trim.

To obtain such a condition, trim tanks (aft and fore) and central compensating tanks are used and, since the reserve buoyancy has to be eliminated, the negative tank, if any, is to be filled (see Ch 1, Sec 1, [3.3]).

d) Equilibrium water: this is the amount of water shared between the compensating tanks and the trim tanks, corresponding to the difference between the reserve buoyancy and the standard ballast water (contained in double bottoms and in the buoyancy tank - see Ch 1, Sec 1, [3.2]).

e) Blowing trim or breaking surface (rigged to diving): this condition applies when, opening the kingston valves and the air vents of ballast tanks, the kingston valves of the buoyancy tank are also opened but its air vents are not; a small amount of water flows into this tank compressing the air up to a pressure equal to the value of hydrostatic pressure at corresponding depth. When air vents are opened, the unit submerges.

1.3 General design conditions and stability criteria

1.3.1 Adequate stability is to be provided, both underwater and on the surface, as well as in all intermediate and emergency conditions.

While on the surface, the transverse metacentric height is to be similar to that required in surface ships.

Lower values can be accepted in small size units, provided that the centre of mass is always located under the centre of buoyancy. However, actual metacentric height (ρ - a) is to be equal to or greater than 0,04 D, D being the outer diameter of the pressure hull, in m.

In any case, (ρ - a) > 0 is always to result up to a transverse trim of 75°.

If manned navigation on the surface is required, a freeboard deemed acceptable by Tasneef is to be granted and adequate protection of gangways is to be provided.

1.3.2 *(1/7/2023)*
In small size units, adequate negative buoyancy is to be provided (to be obtained only by means of thrusters, because positive buoyancy must always exist in any working condition) for any unit involved in work on the seabed, in such a way that it is transversely stable even when lying on ground having an inclination of 25° with respect to the horizontal.

Furthermore, the centre of mass is to be in such a position that sufficient stability is granted when:

a) the unit is on the surface in waves of height equal to the intended navigation and operative conditions, when surfaced with open hatches, as stated in the class certificate in accordance with Pt A, Ch 1, Sec 2, [3.1.1]; if not otherwise specified, the significant wave height is to be assumed not less than 2,5 times the height of the hull (from keel to weather deck).

Unprotected openings when the unit is operating in surface are to be at a height of not less than one meter above the reference wave height in all the foreseeable loading conditions when surfaced.

b) roll angle is $\leq$ 45°, port and starboard.

It is also to be ensured that:

- in static condition for the unit, longitudinal shifting of weights or equipment within the unit does not produce a trim variation greater than 5°;
- in any self-propelled unit, a zero buoyancy condition is achievable in immersion, at any speed of the unit and in any possible working condition;
- if ballast items or any other part dismountable from the hull exist, their attachment to the hull is adequately designed and their abandonment

possible with a longitudinal and/or transverse trim of at least 10°;

- habitats (with at least 3 legs) are stable on ground with an inclination of at least 25° with respect to the horizontal;
- fully equipped ballasted bells have a negative buoyancy equal to at least 3000 N, with a diver on board and without water in the gangway trunk;
- fully equipped non-ballasted bells have a positive buoyancy equal to at least 2000 N, with the maximum allowable number of divers on board and with the gangway trunk filled with water;
- the weight of a diver fully equipped and with fully charged breathing cylinders is assumed equal to 1000 N;
- the centre of mass of bells is located underneath the centre of buoyancy, both in normal and in emergency conditions.

1.3.3 In large size units, the percentages of the equilibrium trim displacement on the surface to be achieved from the equilibrium water and from the permanent ballast are to be specified.

Load and position (frames) of permanent ballast are to be specified together with the indication of the partial centroidal coordinates (for every zone where such ballast is fitted) as well as of the coordinates of the total centre of mass of the ballast.

1.3.4 When a unit not in motion and without dynamic actions (at rest) submerges, its Δ_{sub} is not equal to its "in air" weight P, but lower; Δ_{sub} becomes equal to P by means of the "equilibrium system".

If $P < \Delta_{sub}$, the buoyancy S is positive and in such case the unit always tends to emerge. In units where $S > P$ is always verified (in this case immersion can be achieved only dynamically), the value of:

$S = V_{c\ sub} \cdot \gamma$

$V_{c\ sub}$ being the volume of displaced water of the unit completely submerged, can be calculated assuming:

$\gamma = 1\ t/m^3$ (fresh water).

1.4 Stability calculations

1.4.1 Four copies of the trim and stability booklet with Instructions to the Master containing data related to the stability test, carried out with the unit on the surface and completely submerged, attended by a Tasneef Surveyor and including the necessary information on the following conditions for the unit, where applicable, including the equilibrium polygon (see [1.6]) and the calculations under Ch 2, App 1, [3.3], are to be submitted, together with the required diagrams and capacity plan:

- dry lightweight condition, corresponding to the unit on the surface, with the complete hull, outfitting, arrangements and plants for the specific service for which it is intended to operate. The following are not to be considered: movable weights of any type and, in particular, fluid circulating in the hull and engine room; high pressure air in cylinders and/or pressure vessels, as well as any equilibrium water; crew with their personal effects;
- surface navigation at full load, in towed condition;
- surface navigation at full load, in departure condition;
- surface navigation at full load, in arrival condition;
- blowing trim (rigged to diving);
- in immersion, at an intermediate depth between surface and maximum operating depth.

  Due to the fact that in this condition the stability index "a" is valid both for transverse and longitudinal inclinations, the critical condition generated by longitudinal shifting of even small loads, due to the relevant values of righting levers, is to be assessed;
- at maximum operating depth;
- lying on the seabed, both flat and on a plane transversely inclined at an angle of 25° (see Part B, Ch 2, Sec 2, [1.2] and [1.3]);
- in working condition on the seabed;
- during loading of weights (rock samples, etc.) on the seabed;
- during immersion and emersion phases, with particular consideration of free surfaces, to assess whether, as far as practicable, when the centre of gravity and the centre of buoyancy of the unit coincide, there is still shape stability (see [1.5]).

  In large size units, stability during fast ascension is to be checked with the unit subjected to a heeling moment (generated by an existing transverse trim due, for instance, to shifting of a weight or to unsymmetrical water charging).
- in zero stability condition;
- in equilibrium trim, on the surface;
- in equilibrium trim, underwater;
- during emergency emersion, including the condition with lateral ballast tanks unsymmetrically loaded, by assuming that more than one lateral tank on the same side is filled, due to a failure in the corresponding discharging system;
- on the surface during the release of weights from the unit;
- lying on the seabed, transversely inclined due to current pressure (see Sec 2, [1.4]).

Depending on the type and service of the unit, Tasneef may stipulate additional conditions.

For each condition, the diagram of static transverse stability is to be obtained (see [2.3]).

In the case of loading or shifting of weights in underwater navigation, the longitudinal static stability is also to be accounted for (see [2.4]).

1.5 Metacentric height of submerged units

1.5.1 Completely submerged bodies have only weight stability (transverse and longitudinal metacentric radii are zero) and thus the distance "a" from the centre of buoyancy to the centre of gravity applies to both the transverse and longitudinal inclinations.

In stability checks, the metacentric method can be applied for angles in no one case greater than 10° (value usually not exceeded during normal operating conditions).

For inclination angles α greater than 10°, the following rule can be applied for the surface stability moment:

$$M = \Delta_{surf}[r(1 + 0,5\,tg^2\alpha) - a]\sin\alpha$$

where Δ_{surf} is the displacement of the unit on the surface and r is the metacentric radius.

If possible, the units are to be designed such that, during immersion, when the centre of buoyancy C and the centre of gravity G coincide, there is still shape stability; if this is not possible, it is to be verified that the condition with zero stability has a limited duration (in any case not greater than 20 seconds).

There can also be the case of negative stability during immersion and/or emersion phases; this can be accepted by Tasneef, such transient condition being of extremely short duration (not more than 10 s), by considering that the unit submerges, not only statically but also dynamically, in this way better dealing with such unstable conditions.

A remark is to be made in the trim and stability booklet with instructions to the Master stating that, during transitions with zero or negative stability, any steering is to be avoided.

Ballast tanks are to be positioned as low as possible and are to have a shape such that, when they are filled, the centre of gravity G decreases faster than the increase in the centre of buoyancy.

The stability index "a", in m, is to be decreased according to the standard correction for free surfaces, for the factor ε, in m, given by:

$$\varepsilon = \frac{\sum_{i=1}^{n} \omega_i I_i}{\Delta_{sub}}$$

where:

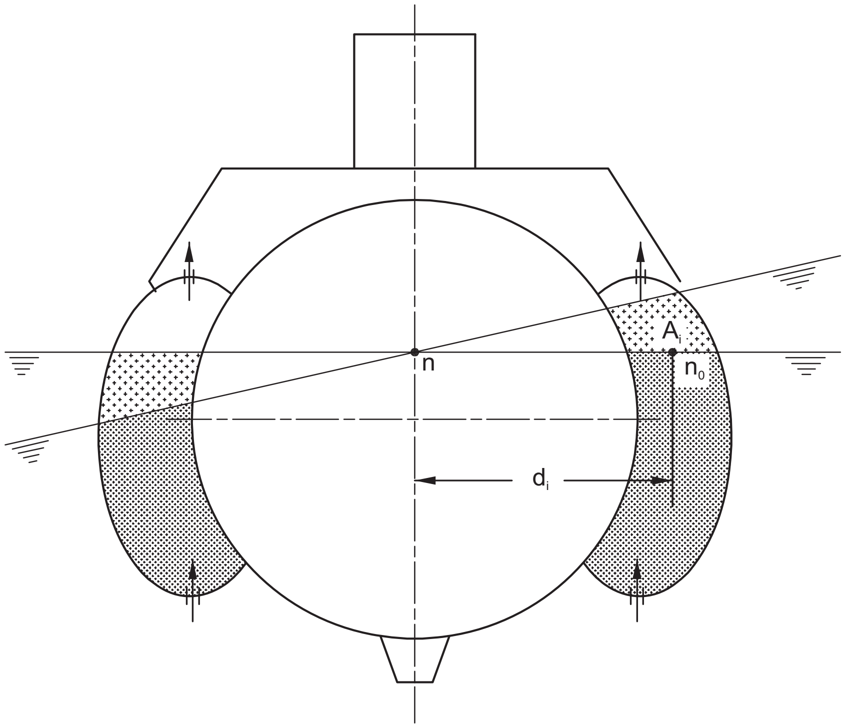
- n : number of tanks;
- Δ_{sub} : displacement of the unit in immersion, in t;
- ω_i : density of the fluid inside the i-th tank, in t/m³;
- I_i : moment of inertia of the free surface of the i-th tank, about the axis of rotation (longitudinal or transverse depending on which stability is to be assessed), in m⁴.

  For the computation of I_i it is to be taken into account that for lateral compartments, if filling valves are closed, it should be possible to calculate the moments of inertia I_i about their centroidal axes; however, during immersion, such valves are generally open, the lateral compartments communicate with the sea and thus the effect of the fluid is to be determined by calculating the moment of inertia of free surfaces about the axis of rotation of the unit (see Fig 1):

$$I_{i(n)} = I_{i(no)} + A_i\, d^2_i$$

- $I_{i(n)}$: moment of inertia of the free surface of the fluid in the i-th tank (assumed horizontal) about the longitudinal trace axis "n", in m⁴;
- $I_{i(no)}$: moment of inertia of the above-mentioned free surface about the centroidal longitudinal axis of rotation having trace n_o, of the same tank, in m⁴;
- A_i : area of the above-mentioned free surface, in m²;
- d_i : distance between n and n_o axes, in m²;

Figure 1



1.6 Equilibrium polygon

1.6.1 This is a polygon, generally of non-regular shape, provided by the Designer of large size new buildings.

It is particularly useful during the design phases and is used in operational phases to determine the equilibrium trim, with changes of working depth (generally seawater density varies) and of the weights fitted on board.

The main aspects related to the procedures for the assessment of equilibrium polygons are reported in App 1.

2 Diagrams

2.1 Immersion phase

2.1.1 The determination of the stability index "a" during the immersion phases would be an extremely hard task if all influencing effects were taken into account. In fact the unit, as well as progressively increasing its displacement, submerges with a speed and an acceleration which will decrease only at full submersion.

Furthermore, the aerodynamic effects of air flowing out of tank vents and the hydrodynamic effects due to water flowing in double bottoms make the theoretical solution complex.

In practice, it is deemed sufficient to determine stability in such phase while ignoring all the above-mentioned marginal effects.

It is recalled that, with increasing depth, compression of the hull increases and, accordingly, due to the increased contraction of its volume, buoyancy decreases and the unit tends to descend with increasing speed (the depth can be maintained dynamically by means of the horizontal rudders or statically by means of the equilibrium system). Such condition is much more important in the case of large size units.

Calculations are to be made by assuming the unit in equilibrium trim on the surface so as to draw the diagrams exemplified in Fig 2.

In this figure:

LC : building line, defined as the intersection of the upper face (or of the tangent on the inner face in the lower end point) of the garboard strake with the vertical trace of the symmetry plane (see Fig 3 and 4, in which tg is the tangent in A_L to the internal face of the garboard strake of the pressure hull);

WL : waterline of the unit in equilibrium trim on the surface;

t : time, in s, between the various depths, from WL to complete immersion, during which tank filling is carried out. In general, time intervals of 1 or 2 seconds are to be adopted (in any case without exceeding 10% of the time needed for the complete immersion phase). For each of the above time intervals, the amount of water which has flowed into double bottoms and/or tanks (see Part C, Ch 1, Sec 3, [2.6]) is to be determined; hence, new displacement, draught and then the new position of the centre of buoyancy C, centre of gravity G and metacentre M, as well as the value of ε (see [1.5]) referred to the actual free surface in the various compartments are to be updated.

T : mean draughts from LC, in m;

z : ordinates from LC, in m;

C : curves of ordinates of centres of buoyancy;

G : curves of ordinates of centres of gravity;

M : curves of ordinates of transverse metacentre;

α : curves of factors ε of free surfaces (see [1.5]);

A : effective stability index.

Where the α curve is on the left side with respect to the G curve, then A<0 and in points where the α curve intersects the G curve A=0.

In order to draw the diagrams in Fig 2, in addition to hydrostatic curves, sounding tables are also to be available for each tank, giving at any filling the corresponding volume.

Figure 2

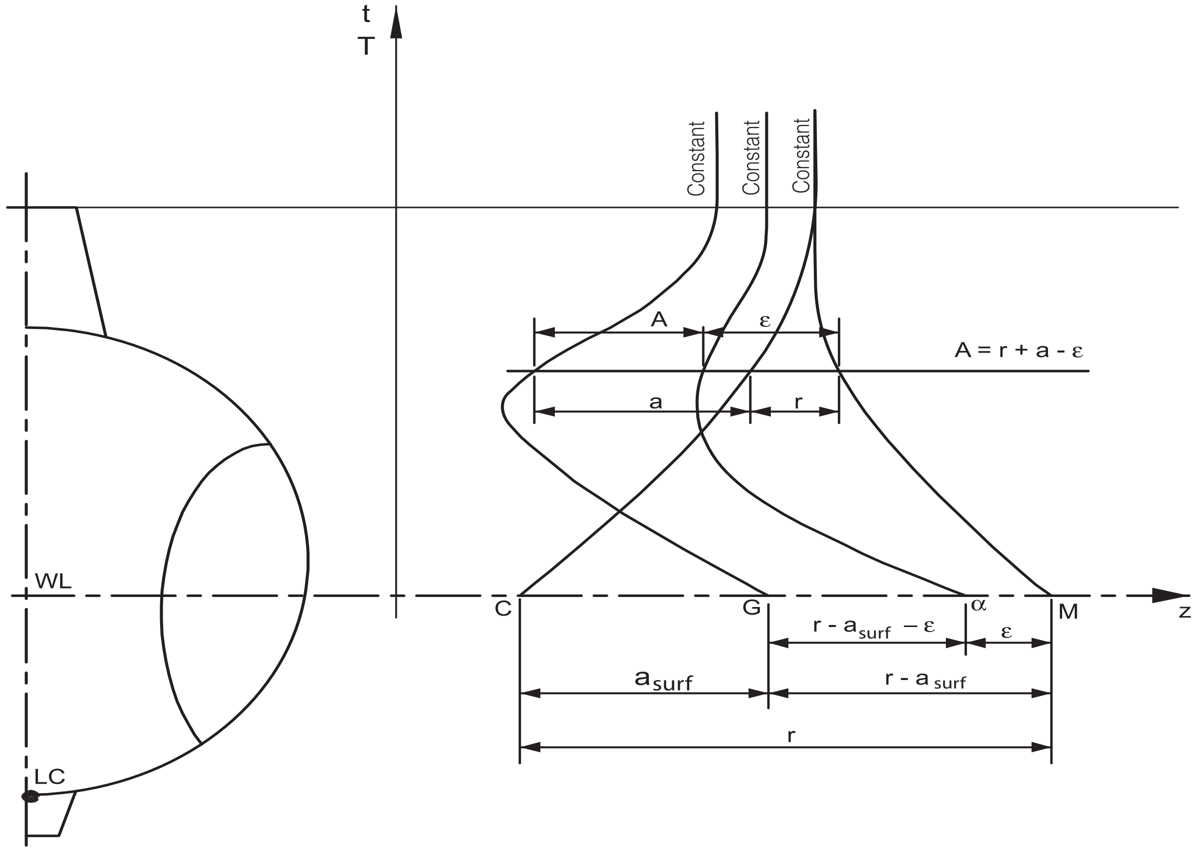


Figure 3

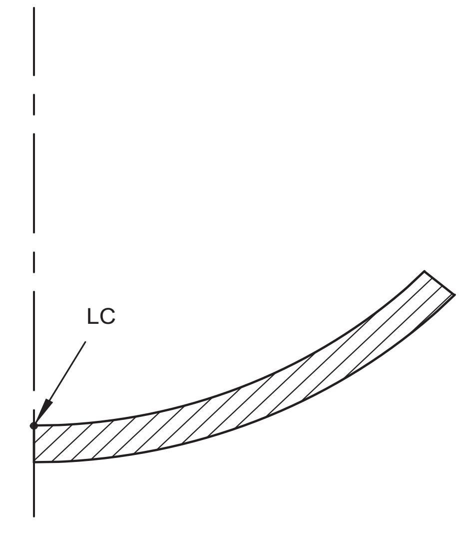
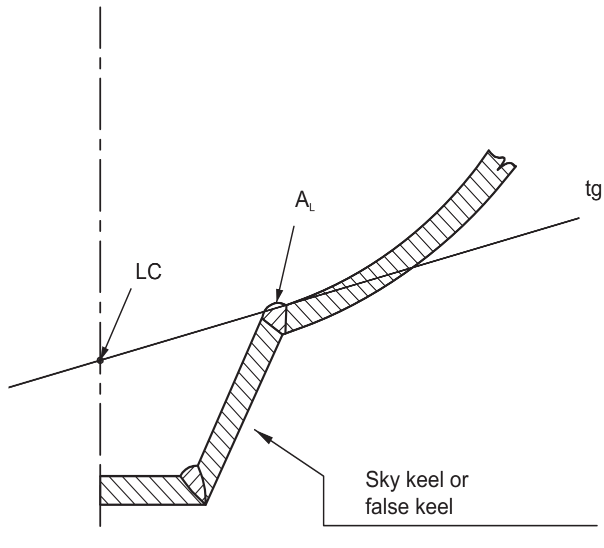


Figure 4



2.2 Emersion phase

2.2.1 The conditions are approximately the same as those during the immersion phase, but somewhat more critical because the manoeuvre has a longer duration; however, the presence of compressed air above the free surfaces of tanks during emptying offsets the free motions of the water in such compartments and gives better stability.

In the instruction manual (see Pt A, Ch 1, Sec 2, [7.8]), specific remarks are to be provided for the emersion phase, especially if performed with high pressure air, in order to prevent any overturning moment that can originate because of the pressure opposing immersion, due to small transverse rolls, especially during quick emersions by fast emptying of ballast tanks.

One of the forces of such moment is the resistance given by the horizontal surface of the unit, mainly of the deck, directed downward; the other force is the buoyancy applied to the centre of gravity of the unit (lower than the deck) on account of the expelled ballast water.

2.3 Static transverse stability diagrams

2.3.1

a) When the unit is on the surface, it behaves like a surface unit. By putting in the ordinates the projection to the transverse plane of stability moments and in the abscissas the transverse inclination angles, a diagram is obtained which is usually irregular due to the changes in the waterline (especially in small size units with several external appendages).

b) When the unit is in immersion, the stability moment is given by:

   $M = D_{sub}\ a_{sub}$ sen q

   The diagram has sinusoidal behaviour with a maximum for inclination θ of 90°; the overturning angle is θ = 180°.

   To draw stability diagrams during the immersion phase, it is necessary to relate to defined instants of such phase. In general, reference is made to defined instants during filling of ballast tanks, by considering, for example 1/8, 1/4, 1/2, 3/4 and 7/8 of complete filling; for each of them the cross curves are obtained and the stability diagram is traced.

2.4 Static longitudinal stability

2.4.1

a) When the unit is on the surface, for angles β not greater than 10°, the stability moment M_e is given by:

$$M_e = \Delta_{surf}(R - a)\sin\beta = \Delta_{surf} R \sin\beta$$

   R being the longitudinal metacentric radius.

b) When the unit is in immersion, the stability moment M_i is given by:

$$M_i = \Delta_{sub} a \sin\theta$$

For specific units having a length comparable to the breadth, longitudinal stability checks are to be performed.

SECTION 2 STABILITY IN TYPICAL WORKING CONDITIONS

1 Intact stability calculations

1.1 Longitudinal shifting of a weight

1.1.1

a) When the unit is on the surface, the trim angle β is given by:

$$\sin\beta = \frac{py}{\Delta_{surf} \cdot R}$$

in which, further to the symbols already defined, p is the shifted weight and y is the corresponding longitudinal displacement.

b) When the unit is in immersion, the trim angle θ is given by:

$$tg\theta = \frac{py}{\Delta_{sub} a_{sub}}$$

1.2 Unit lying on the seabed

1.2.1 Laying the unit on the seabed by a negative buoyancy is equivalent to loading a weight p (greater than the difference between displacement and buoyancy) in a point A (application point of the resultant for which the displacement has exceeded the buoyancy). In F (point of contact with the seabed) there is a reaction -p (see Fig 1).

If displacement, buoyancy, p and reaction -p are all on the same vertical, the unit remains aligned; if, on the other hand, the unit inclines by an angle α, the stability moment will be:

$$M = (\Delta_{sub} a_{sub} - pz)\sin\alpha$$

Until $\Delta_{sub} a_{sub} > pz$, the unit tends to stay upright; if $\Delta_{sub} a_{sub} = pz$, i.e. if M = 0, the unit remains inclined at an equilibrium position; if $\Delta_{sub} a_{sub} < pz$, the unit continues to roll until it lies on one side.

If the unit is lying on the seabed vertically, by increasing the width of the skeg keel (false keel) the stability also increases; for this purpose, skeg keels are to have a width equal to at least 30% of the outer diameter of the pressure hull.

In fact, in Fig 2 it can be seen that if the skeg keel has a semi-width:

$$\overline{OA} = a$$

the moment opposing transverse inclination is:

$$M_r = a \cdot |p|$$

If the semi-width of the skeg keel becomes:

$$\overline{OB} = b$$

the moment opposing transverse inclination is:

$$M'_r = b \cdot |p|$$

from which:

$$M'_r > M_r$$

Figure 1

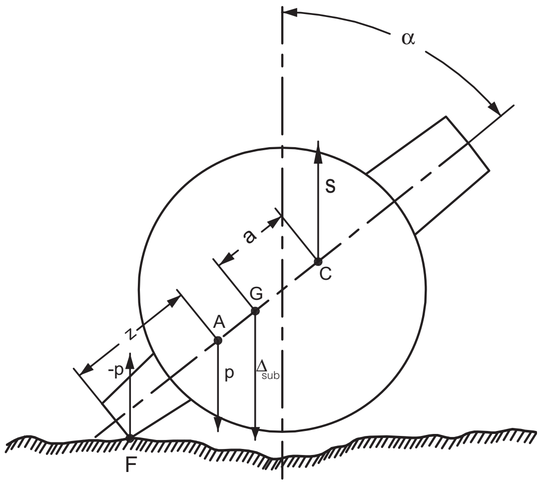
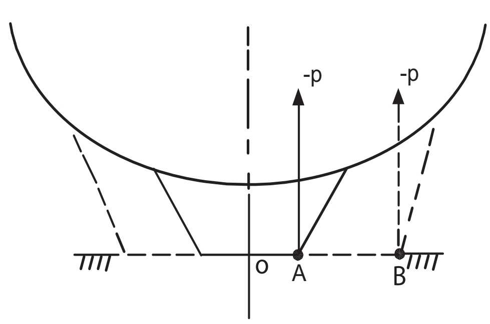


Figure 2



1.3 Unit eccentrically lying on the seabed

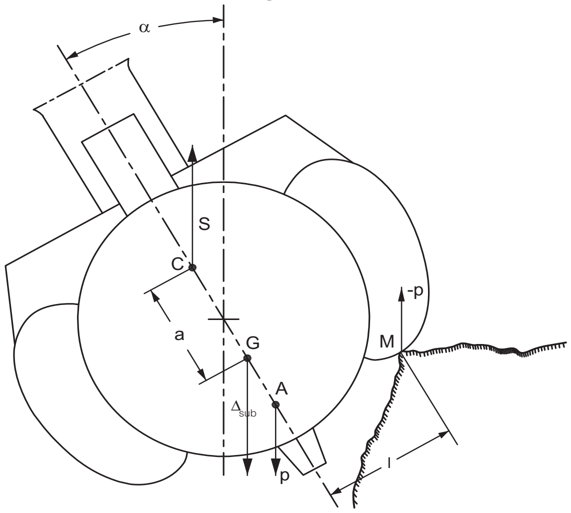
1.3.1 p and A are again the force and its application point as defined in [1.2] (see Fig 3). l is the distance from the point of contact and the symmetry plane of the unit, inclined by an angle α.

The stability moment is given by:

$$M = (\Delta_{sub} a_{sub} \cdot \Delta t - pl)\sin\alpha$$

and the same considerations as in [1.2] above apply.

Figure 3



1.4 Unit lying on the seabed and inclined by a pressure N, in kN/m², acting on the longitudinal area, due to a current speed V, in m/s

1.4.1 S being the longitudinal area, in m^2, and h the height, in m, of the centre of longitudinal area above the underkeel of the unit in upright condition, the inclining moment, in kNm, is given by:

$M = NSh$

where:

$N = 0{,}5\ V^2\gamma$

with γ the density of sea water, in $t\backslash m^3$.

Again considering the case in point [1.2], the transverse inclination angle is given by

$$\sin\alpha = \frac{M}{\Delta a_{sub} - pz}$$

Data regarding the speed (modulus, direction and distribution with the distance from the seabed) of currents in the operational zones of the unit are to be obtained, as far as possible, from reliable statistical records.

Design current speed is given by the vector sum of individual current components:

$$\vec{V}_c(Z) = \vec{V}_m(Z) + \vec{V}_v(Z) + \Sigma_i \vec{V}_i(Z)$$

where:

- $\vec{V}_c(Z)$: resultant speed of current at distance Z from the seabed, in m/s;
- $\vec{V}_m(Z)$: speed of current component at a distance Z from the seabed due to the tide, in m/s;
- $\vec{V}_v(Z)$: speed induced by current component at a distance Z from the seabed due to wind, in m/s;
- $\vec{V}_i(Z)$: speed of the i-th current component at distance Z from the seabed due to other causes, in m/s.

Since the unit is lying on the seabed, the distance Z to be computed is the distance of the underkeel from the centre of the longitudinal area, with the unit in upright condition.

If reliable data regarding the distribution of the current speed with the distance from the seabed are not available, the following laws can be adopted:

$$\vec{V}_m(Z) = \vec{V}_m(H)\left(\frac{Z}{H}\right)^{1/7}$$

$$\vec{V}_v(Z) = \vec{V}_v(H)\frac{Z}{H}$$

where:

- $\vec{V}m(H)$, $\vec{V}v(H)$: current speed due to tide and wind at sea surface in still water, in m/s;
- Z : distance of the seabed from the point where the current's speed is to be evaluated, in m.

Speed $\vec{V}_v(H)$ in open water, whenever reliable records are not available, can be calculated by the following law:

$$\vec{V}_v(H) = 0{,}01 \cdot \vec{V}_{10c(N)}$$

where $\vec{V}_{10c(N)}$ is the continuous speed of the wind, with return period of N years, measured at a height of 10 m above the still water sea level.

The value of $\vec{V}_v$ (H) is to be assumed, in any case, equal to or greater than 1 m/s.

APPENDIX 1 EQUILIBRIUM POLYGON

1 Foreword

1.1

1.1.1 This Appendix develops what is stated in Sec 1, [1.4.1] and [1.6].

It provides shipyards and Designers with the procedures to be followed and considerations for drawing the equilibrium polygon.

2 Equilibrium trim in immersion

2.1 Definitions

2.1.1 A submersible unit fully submerged is in **equilibrium trim** when its weight P is equal to the buoyancy S and when its centre of gravity G is in the same longitudinal position (on the same vertical) as the centre of buoyancy S, such that the trim angle is zero.

In reality, there can be small differences between weight and buoyancy and between longitudinal positions of C and G.

The use of horizontal rudders during underwater navigation can help to reduce such differences.

If the unit underwater is to be kept "dead" or in "silent trim" it is then important that S = P exactly.

Δ_{sub} being the displacement in immersion, $P < \Delta_{sub}$ on the surface and water is to be introduced in the **ballast tanks** in order to submerge and achieve **equilibrium trim**.

It is possible to have either **light** or **heavy** loading conditions on the surface corresponding to small or large amounts of **variable ballast (equilibrium water)**, which is to be already in place when the unit is still on the surface, in such a way that, after the **main ballast tanks** are filled, the unit will be in an equilibrium condition with zero trim while underwater.

A submarine/submersible which is correctly designed for weight, buoyancy and tank capacity of the above-mentioned **variable ballast** will always be ready to submerge (equilibrium trim on the surface), irrespective of the actual weight variations; it will immerge and achieve equilibrium trim with main ballast tanks fully loaded.

2.2 Weight distribution for the study of equilibrium in immersion

2.2.1 Elements contributing to weight, to be considered for the study of the equilibrium in immersion of submersibles/submarines, are shown in the graphs in Fig 1 and Fig 2 and are defined in the following.

a) **Displacement in immersion (Δ_{sub})**

This is the weight of water displaced by the whole shell of the unit, decreased by the weight of the volume of water bounded in any space that can be flooded (like cofferdams between pressure hull and the false deck).

Δ_{sub} is defined by the hull geometry more than by the actual weight of the unit.

For a given condition of the unit, Δ_{sub} changes only with the density of the sea water. The weight is then to be adjusted to accommodate Δ_{sub}.

b) **Lightweight**

This is the sum of the weights constituting the unit.

This is a fixed weight to be determined at the end of building.

c) **Permanent ballast**

This constitutes the "margin" with respect to the estimated weight.

During the design of a unit, the weight of water displaced while the unit is immersed is calculated in excess with respect to the weight in immersion, by a large "margin".

Part of this margin generally needs to be compensated for due to inaccuracies in weight and displacement estimation or due to unexpected arrangements. When loading is completed, any residual margin is to be loaded in the form of permanent ballast to obtain equilibrium in immersion. Permanent ballast is part of the lightweight.

Most commonly lead is adopted for permanent ballast due to its elevated density and low corrosion.

d) **Load to submerge**

This is the load to be added to the lightweight, including permanent ballast, to lead the unit to equilibrium trim in immersion.

By assuming that there were not any changes in the unit's geometry and weight, the load to submerge only varies when there is a gradient in sea water density.

e) **Standard fuel oil tanks**

These tanks contain fuel oil for main and auxiliary machinery, and are fitted with a sea water compensation system, such that they are always full of fuel oil or sea water.

f) **Main ballast tanks**

These tanks are filled for the unit to submerge and emptied to re-emerge.

They are fitted with air vents in their upper part, which are opened in order to allow water filling, and openings for flooding, in their bottom, fitted with (Kingston) valves, connected with the compressed air plant for emptying.

g) **Fuel oil/ballast tanks**

These tanks can be used either to contain fuel oil or main ballast.

When they are used as fuel oil tanks, they can be compensated so that they can be regarded as standard fuel oil tanks (see point e).

When the fuel oil has been fully consumed, their use can be modified for ballast for emersion and submersion purposes.

This switching of use reduces the displacement on the surface (Δ_{surf}) and increases the reserve of buoyancy until new fuel oil is introduced.

This tank type is not fitted on nuclear submarines, due to the small amount of fuel oil to be kept on board.

h) **Residual water (not removable)**

This is the water contained within the main ballast and in fuel oil/ballast tanks; it is located below the uppermost point of the openings for flooding and cannot be expelled by the immersion manoeuvre.

i) **Water seal in fuel oil/ballast tanks**

This is the water layer existing above the uppermost point of the openings for flooding and below the lowermost point of the compensation water pipe.

This layer is maintained when these tanks are used as standard fuel oil tanks, in order to prevent fuel oil flowing through the openings for flooding during rolling of the unit.

Therefore, when one of these tanks contains fuel oil at its nominal capacity, it will contain, starting from the top: fuel oil, water seal, residual water.

j) **Water ballast for immersion**

This is the water introduced at the start of the immersion phase and which is expelled to obtain the re-emersion of the unit.

When the fuel oil/ballast tanks are used as standard fuel oil tanks, the amount of ballasting for immersion corresponds to the capacity of the main ballast tanks and is introduced above the residual water.

When, on the other hand, the fuel oil/ballast tanks are used as main ballast tanks, water ballast for immersion corresponds to the main ballast tanks' capacity plus the capacity of the fuel oil/ballast tanks and is introduced above the residual water.

Some submersible units are fitted with one tank, approximately located in way of 0,5L, regarded as the **buoyancy tank**, which is considered as being part of the ballast necessary for immersion and that is expelled for emersion. The emersion tank can only be partially filled in immersion when the unit is at full load.

This tank has a volume almost equal to that of the pressure resistant part of the turret and is fitted in way of the turret itself; this tank can be emptied while the unit is immersed, in order to achieve positive buoyancy in the event of damage to the upper part.

k) **Standard loading condition on the surface**

This is the value of Δ_{surf} when the fuel oil/ballast tanks are used as main ballasting.

l) **Maximum loading condition on the surface**

This is the value of Δ_{surf} when the fuel oil/ballast tanks are used as standard fuel oil tanks.

m) **Reserve buoyancy**

This is the displacement of the volume of the part of the hull above the waterline on the surface, minus the volume of any space available to be flooded.

n) **Variable load**

This is formed by the following items: crew with their personal effects, stores, stocks kept in storerooms, weights of any type (even explosives, depending on the service of the unit), passengers, drinking water, feed water store (for some types of units), distilled water for batteries and accumulators, cooling fluid store for reactor (in nuclear submarines), lubricating oil, oxygen, hydraulic oil store, content of the sanitary tanks and of the systems for emptying hygienic-sanitary plants, fuel oil.

Variable load in "standard loading" and "maximum load" conditions is identical, except for the fuel oil contained in fuel oil/ballast tanks, which is present in the maximum load condition.

o) **Variable ballast**

This is sea water ballast continuously adjusted to compensate for changes in variable loads or variations in sea water density.

Variable ballast water is transported in tanks fitted at the fore and aft ends, named **trim tanks**, and amidships, named **compensating tanks** or **auxiliary tanks**; these tanks allow a constant adjustment of the longitudinal inclining moment (trim moment) and of weight.

Some units with conventional (diesel-electric) propulsion are fitted with **variable fuel oil tanks**: these are not compensated but are of a size such that the load of fuel oil introduced is almost equal to the weight increase occurring when fuel oil in compensated tanks is replaced by sea water.

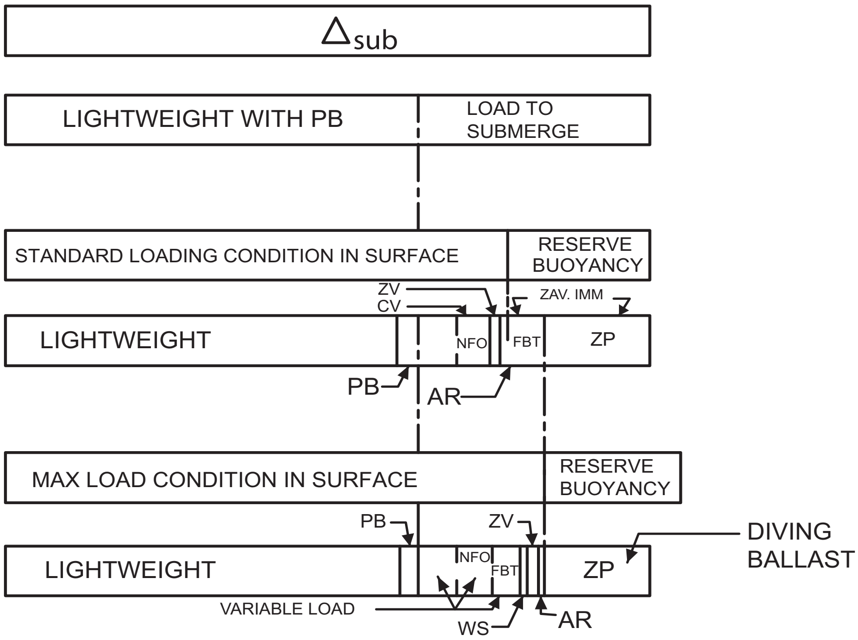
By consuming fuel oil from the "variable fuel oil tanks" in a way that the residual percentage in these tanks is the same as that remaining in the compensated tanks, the weight of all contents of all the fuel oil tanks will be kept almost constant.

"Variable fuel oil tanks" are fitted with pipes that allow cross transfer of fuel oil and transfer to the compensated tanks.

This transfer generates an increase or decrease in the weight of the unit each time the compensation water is either introduced or removed from the standard fuel oil tanks.

Due to their variable capacity, these fuel oil tanks are considered part of the variable ballast rather than part of the variable load.

Figure 1 : Weight distribution of submarine with conventional (diesel-electric) propulsion



PB =permanent ballast (P_b)

SPFC = surface

AR = residual water

Zv = variable ballast

CV = variable load

NFO = standard fuel oil tanks

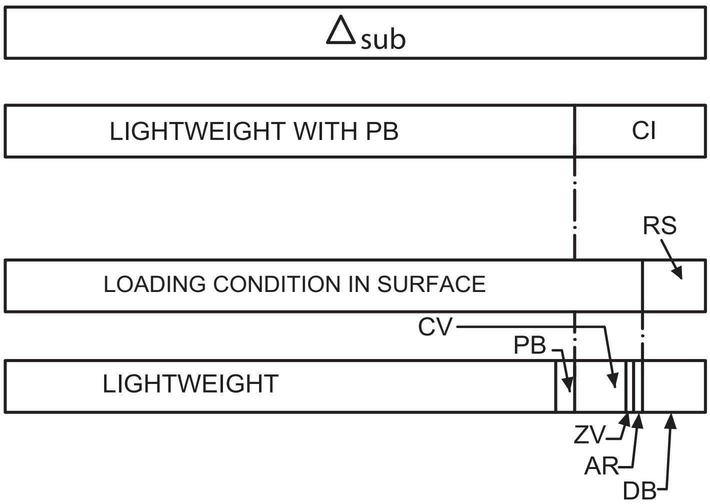
FBT = fuel oil/ballast tanks

ZP = main ballast tanks

ZAV. IMM = diving ballast

WS = water seal in fuel oil/ballast tanks

Figure 2 : Weight distribution in a nuclear propulsion submarine



PB = permanent ballast (P_b)

CI = load to submerge

SPFC = surface

RS = reserve buoyancy

CV = variable load

DB = diving ballast

AR = residual water

ZV = variable ballast

2.3 Relationships among items contributing to the "weight"

2.3.1 In order to obtain equilibrium conditions underwater, each of the graphs in Fig 1 and Fig 2 is to represent the same weight and, for each one, the centre of gravity is to be found in the same longitudinal position.

Two additional relationships can be obtained from the vertical subdivisions in Fig 1 and Fig 2:

a) reserve buoyancy is equal to the ballast water needed for immersion and the longitudinal position of their centres of gravity has to coincide;

b) load to submerge Q, which corresponds to:

$Q = \Delta_{sub}$ - (lightweight + permanent ballast)

is also equal to:

Q' = variable load + variable ballast + residual water + diving ballast

and, in the maximum load condition on the surface:

$Q'' = Q'$ + water seal in fuel oil/ballast tanks.

Furthermore, the centre of gravity of the load for immersion has the same longitudinal position as the centre of gravity resulting from the various terms of the above-mentioned sum.

These necessary relationships are to be achieved by performing variations of weight and longitudinal position of the centre of gravity of permanent and variable ballasts.

In order to save space, variable ballast tanks are sized to accommodate only the possible modifications in the variable load plus the variation of Δ_{sub} caused by changes in the sea water density.

Permanent ballast (Pb), due to less space needed per unit mass, is adopted for the necessary corrections, further to the capacity of variable ballast tanks.

In general, changes to the permanent ballast (Pb) are performed in the shipyard, to compensate for variations in the lightweight or in the displaced volume of the unit immersed, while variable ballast is used to compensate for possible sea variations.

2.4 Diving trim

2.4.1 During surface navigation, a submersible/submarine is usually maintained at a **diving trim**, meaning that the weights are positioned on board in such a way that, after completing filling of the main ballast and of any of the fuel oil/ballast tanks used as main ballast, the unit will immerse in an equilibrium condition, with the load of the unit equal to the weight of the displaced water of the immersed body and with G at the same longitudinal position as C.

It can be seen in Fig 1 that the load and the inclining longitudinal moment of the unit on the surface at a "diving trim" are to be equal to the difference between the values of Δ_{sub} and the reserve buoyancy, and that the reserve buoyancy corresponds, as far as load and position of the centre of gravity are concerned, to the load to submerge.

Since the volume and the trimming moment, both of Δ_{sub} and of the load to submerge, depend only on the shape of the unit, the draught on the surface in "diving trim" in both standard and maximum load conditions is governed by the hull geometry.

Diving trim is maintained during navigation by the adjustment to the variable ballast water (equilibrium system).

When variable fuel oil tanks are fitted (see [2.2.1] or [1.2]o)), the fuel oil in these tanks can also be adjusted.

When the immersed unit proceeds at very low speed, variable ballast can be either introduced, discharged outside or longitudinally shifted to other tanks, until any longitudinal inclination is removed as well as any tendency for it to increase or decrease.

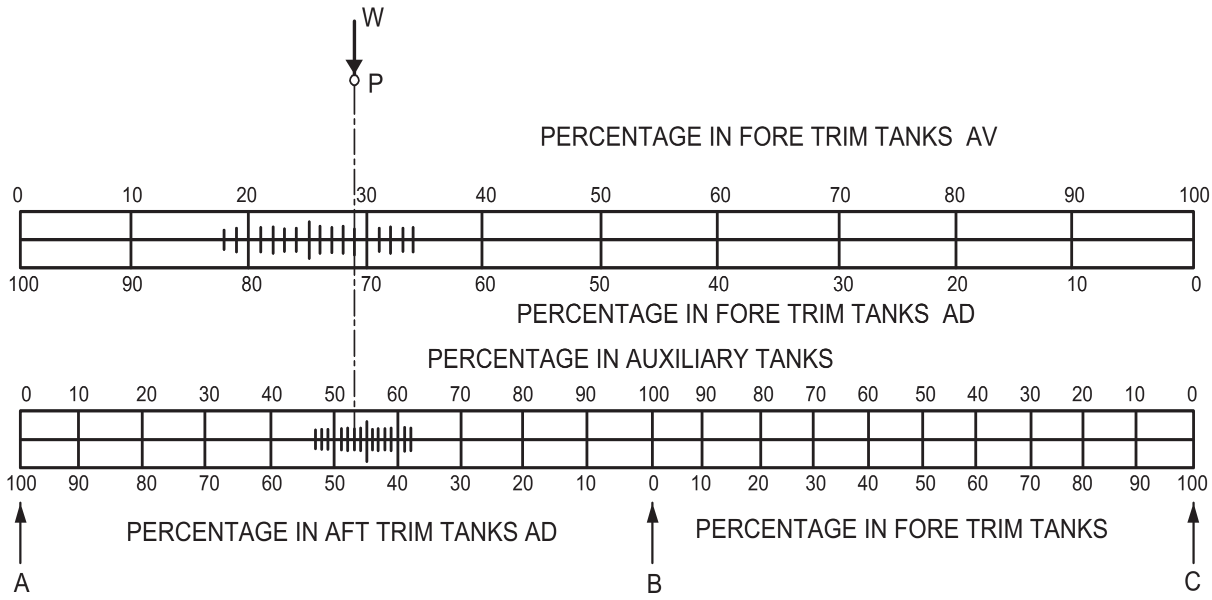
Among such correction attempts, the proper amount and positioning of variable ballast is achieved by recording all weight variations (like those due to replacing fuel oil with sea water, garbage expulsion, emptying of sanitary tanks by means of compressed air) and by compensating for such weight variations by means of variable ballast.

In addition to the above-mentioned weight fluctuations, sudden substantial weight variations can also occur underwater, due to the possible expulsion of heavy weight, which will require immediate compensation.

This can be achieved by introducing, simultaneously with this expulsion, a mass of water equal to that of the expelled load.

The diagram for checking the trimming moment, shown in Fig 3, is useful to evaluate the weight variation to be introduced to the variable ballast to compensate for a change in the variable load.

Figure 3 : Diagram of inclining longitudinal moment of a submersible/submarine



A = position of centre of gravity - aft trim tanks

B = position of centre of gravity - central balance tanks (or auxiliary tanks)

C = position of centre of gravity - fore trim tanks

When a weight W is added at longitudinal position P, by reading the scale indications on the diagram, in way of point P, the load percentage W can be obtained that is to be removed from the aft trim tanks and from auxiliary tanks, or from either of the trim tanks (fore and aft), to compensate for the added load; in general, each trim tank (fore and aft) is longitudinally subdivided into two equal parts, to also compensate for transverse inclinations.

In this diagram, points A, B and C are positioned, respectively, in way of the centres of gravity of the aft trim tanks, auxiliary tanks and fore trim tanks. The scales are constructed by subdividing the distances from A to B, from B to C and from A to C in 100 equal parts, as represented in Fig 3.

By way of example for use of the diagram, if 10,000 N are introduced at point P, according to Fig 3 there will not be any change in loading or in the longitudinal position of G of the unit, if:

a) 2900 N of water are expelled from the fore trim tanks and 7100 N are expelled from the aft trim tanks, or

b) 5300 N are expelled from the auxiliary tanks (or central balance tanks) and 4700 N are expelled from the aft trim tanks.

2.5 Equilibrium conditions

2.5.1 Since the variable ballast is to be adjusted to compensate for any fluctuation in the density of the sea water and in the variable load, it is necessary to evaluate the magnitude of possible variations of both loads and the longitudinal inclining moment of these items in order to properly size the variable ballast tanks. In order to allow the diving trim to be achieved with any possible fluctuation of the density of the sea and of the variable load and in order to provide variable ballast tanks large enough to compensate for such variations, it would be necessary to evaluate the lightest loading condition in the event of maximum sea water density, maximum load condition in the event of minimum sea water density, as well as any condition with maximum longitudinal inclining moment at fore and aft, for both high and low sea water density cases.

According to the above, variable ballast tanks too large for practical applications would be required, when the available space is always limited.

Assuming extreme conditions, which are quite improbable, are ignored, the sizes of variable ballast tanks can be maintained within practical ranges.

In calculating the displacement of the unit on the surface, the specific volume of sea water is to be assumed equal to 0,975 m^3/t (γ = 1,025 t/m^3) and the normal fluctuations from this value are normally negligible, producing a very small change in draught.

A small displacement change for a submarine in immersion, for example of 10 t, would translate into an unacceptable imbalance between weight and buoyancy.

Even if 10 t is a small percentage of Δ_{sub}, a small variation in the density of sea water will be sufficient to produce such unbalancing.

It is known that specific volume of sea water ranges, on average, between 0,971 m^3/t (γ = 1,020 t/m^3) and 0,971 m^3/t (γ = 1,030 t/m^3).

Extreme variation in variable ballast to compensate for such an effect would occur if the unit started to immerse in sea water having light density, filling the main ballast and the fuel oil/ballast tanks, and afterwards went, when immersed, in sea water having a high density.

It is common to assume that such an extreme condition, or its opposite, does not occur and that the diving ballast has the same density as that where the submersible/submarine operates.

On the basis of this assumption, the amount of variable ballast needed for the fluctuation of sea water density is equal to Δ_{sub} minus the diving ballast, in m^3, multiplied by the variation of the density of sea water.

For example, if Δ_{sub} = 4000t and the diving ballast is 500 t, the variable ballast to counter this effect is:

$$(4000-500)[t]\cdot 0,975\left[\frac{m^3}{t}\right]\cdot\left(\frac{1}{0,971}-\frac{1}{0,981}\right)\left[\frac{t}{m^3}\right]=$$

$$=3500[t]\cdot 0,975\left[\frac{m^3}{t}\right]\cdot(1,030-1,020)\left[\frac{t}{m^3}\right]=$$

$$=3500[t]\cdot 0,975\left[\frac{m^3}{t}\right]\cdot 0,01\left[\frac{t}{m^3}\right]=\ 34t$$

In order to assess the additional variation in variable ballast needed to compensate for changes in variable load, calculations for a number of "equilibrium conditions" are to be carried out, representative of heavy load conditions in low density sea water, light weight conditions in high density sea water and conditions with heavy loads fore and aft in both high and low density sea water.

For the evaluation of the load on board in any particular condition, experience and user friendliness of operational procedures are necessary to decide the amount of the various items contributing to variable load (variable load distribution) if large size variable ballast tanks are to be avoided.

Conditions with heavy load at fore and aft ends do not necessarily imply heavy loads.

The term "heavy fore" for example, means that loads at fore end are heavy, while loads at aft end are light.

In a unit carrying the majority of variable loads in the fore part, the "heavy aft" condition could be, in reality, quite light.

In "heavy aft" condition, the amount of dry load, for example, would be assumed equal to zero in the fore part, while a full load of such items should be assumed in the aft part.

As for the cases of heavy and light load conditions, it is advisable to assess two "heavy fore" conditions and two "heavy aft" conditions, one with a high percentage of fuel oil on board in which only the fuel oil of the fuel oil/ballast tanks at the "heavy" end has been consumed, and the other which occurs later when all fuel oil in the fuel oil/ballast tanks and in standard fuel oil tanks at the "heavy" end has been consumed.

The "heavy fore" and "heavy aft" conditions not necessarily being heavy or light, computations for both cases of sea water having "heavy" and "light" densities are to be performed.

The final result of the calculations in equilibrium condition is the value of the load and longitudinal inclining moment of the "variable ballast necessary for balancing", which means the required variable ballast, in relation to the assumed load and the density of sea water, in order to bring the unit to the "trim ready to submerge on the surface" (equilibrium trim on the surface) and to the equilibrium in immersion (equilibrium trim in immersion).

As indicated in Fig 1 and Fig 2, the "variable ballast necessary for balancing" can be obtained by subtracting the sum of the load and trimming moment of the variable load from the value of the load to submerge.

Fig 1 and Fig 2 also show that the load to submerge can be found by subtracting the load and the trimming moment in lightweight with permanent ballast (Pb) from the value of Δ_{sub}.

Two sets of values for the load to submerge can be obtained using values of Δ_{sub} with 0,981 m^3/ t and 0,971 m^3/t.

The load condition adopted to immerse in water having low density is the condition with heavy load; the one to immerse in water having high density is the light condition; both of them are used for "heavy fore" and "heavy aft" conditions.

Two sums of the variable load are required for "heavy fore" and "heavy aft" conditions, in such a way that the density of the diving ballast corresponds in any case to that used for Δ_{sub}.

2.6 The equilibrium polygon

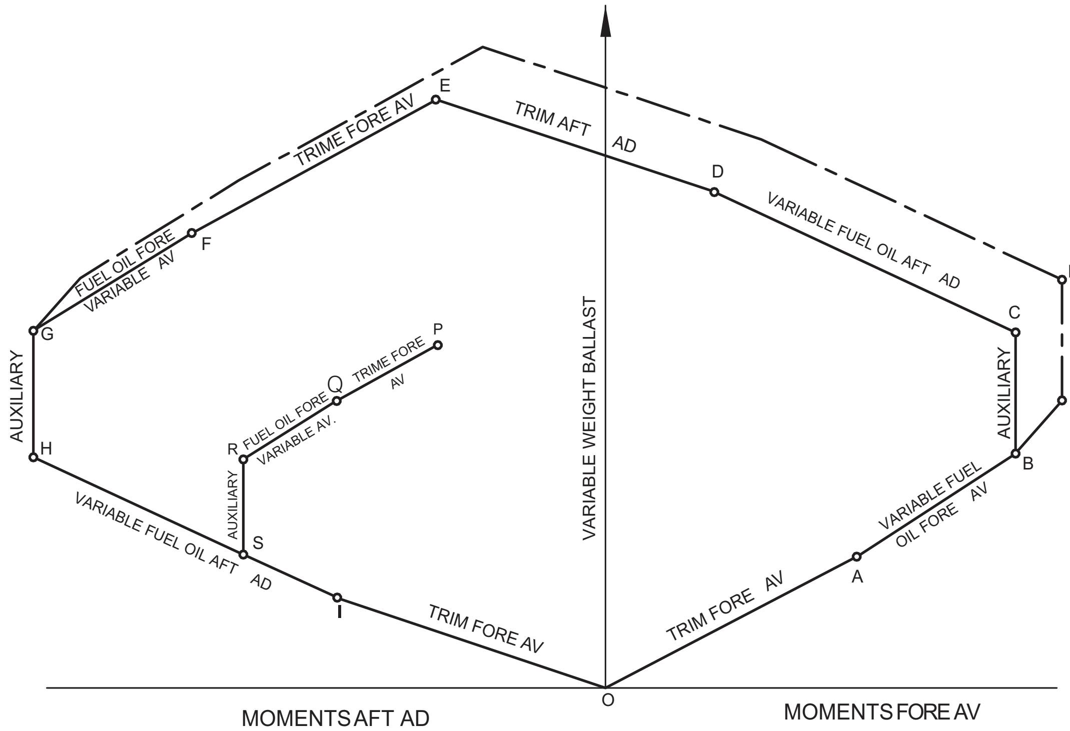
2.6.1 The equilibrium polygon of a typical diesel-electric propulsion submarine shown in Fig 4 is a tool to graphically represent the overall behaviour of the load and longitudinal inclining moment that can be obtained by adjusting the variable ballast.

The load of the variable ballast is reported in the ordinates, while the longitudinal inclining moment about the reference transverse plane used for equilibrium conditions is reported in the abscissas.

Each of the edges of the polygon represents the effect following filling of one of the variable ballast tanks.

This polygon is constructed by adding, algebraically and in sequence, loads and trimming moments of each of the variable ballast tanks, starting from the fore end, considering the largest number as possible of tanks and proceeding toward the aft end; subsequently, the process is repeated, starting from the aft end and moving to the fore end.

Figure 4 : Equilibrium polygon



Each of these sums is reported in Fig 4, where the line $\overline{OA}$ represents the load and the trimming moment obtained when the fore trim tank is full; the line $\overline{AB}$ represents only the effect due to the filling of the fore fuel oil tank after the fore trim tank has been filled, and so on until point E is reached, corresponding to the load and longitudinal inclining moment obtained when all variable ballast tanks have been filled.

The same point E is reached, through an opposite process, by reporting the various steps of the summation starting from the aft tank and proceeding toward the fore end.

The load of each of the variable ballast tanks is assumed equal to the net capacity of each tank at the specific volume of 0,975 m^3/t.

This volume is applied to the variable fuel oil tanks even if they contain fuel oil, because the transfer of 0,975 m^3 of fuel oil from a variable ballast fuel oil tank to a standard fuel oil tank would force 0,975 m^3 of sea water, or one tonne, overboard.

The load variation is assumed to occur at the position of the variable fuel oil tank, even though for a short time a small variation will also occur due to the unknown position of the standard fuel oil tank to which the fuel oil is transferred.

The dashed and dotted outer line in Fig 4 highlights the effect of also considering the negative tank as part of the variable ballast.

This is a tank located fore of the centre of buoyancy and usually empty during emersion and immersion, which is filled as soon as immersion is started, with the aim of speeding up the unstable transitory phase of the immersion.

This manoeuvre is such that the unit exceeds its own Δ_{sub} by a few tonnes and induces a descent angle (trim different from 0), both effects being suitable for a quicker immersion.

The negative tank is emptied when the unit reaches the desired depth, and equilibrium is replaced.

If necessary, in order to obtain very "light" equilibrium conditions, the negative tank can be considered part of the variable ballast.

Variable ballast can be adjusted in a way that its load and trimming moment correspond to the coordinates of each point bounded within the equilibrium polygon.

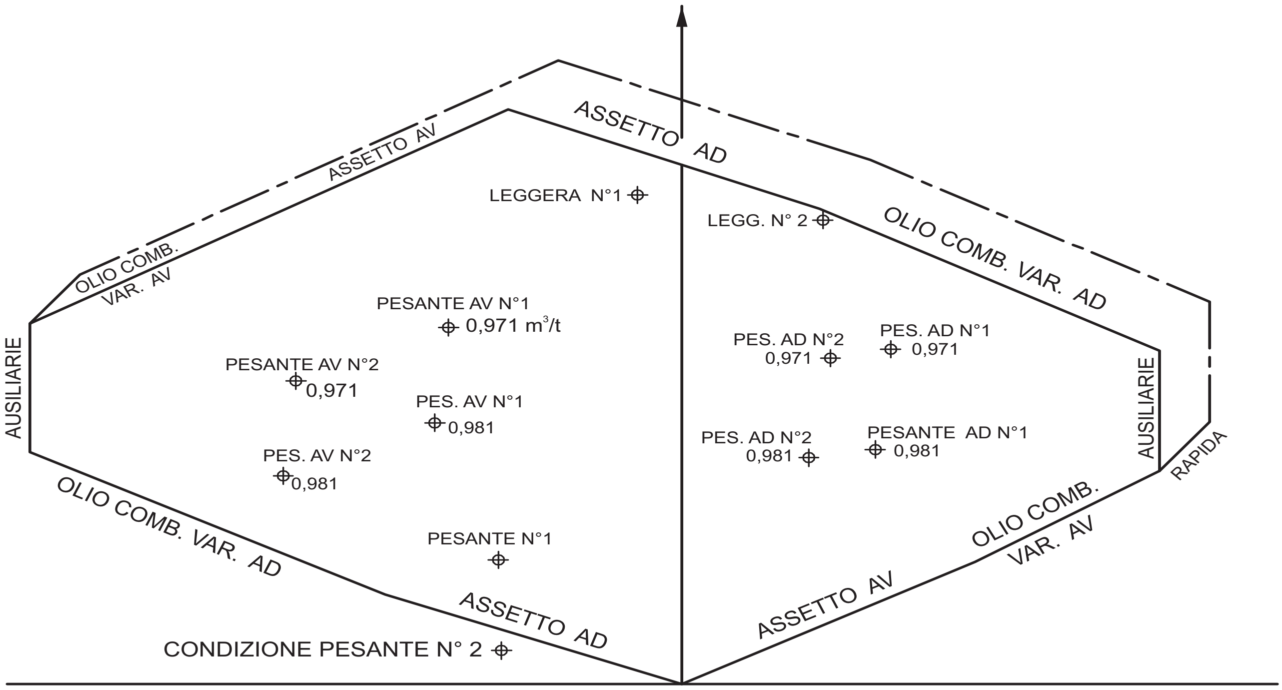
For example, point P in Fig 4 can be obtained by filling the aft trim tank (moving from point O to point I), part of the aft variable fuel oil tank (moving from I to S), then part of the auxiliary tanks, the fore variable fuel oil tank and the fore trim tank.

Segment $\overline{SR}$ is parallel to $\overline{HG}$ and is not longer than $\overline{HG}$, $\overline{RQ}$ is parallel to $\overline{GF}$ and not longer than $\overline{GF}$, $\overline{QP}$ is parallel to $\overline{FE}$ and not longer than $\overline{FE}$.

The above is only one of several ways to obtain point P.

Fig 5 is the equilibrium polygon of Fig 4, in which the load and longitudinal inclining moment of the variable ballast needed to equilibrate the various indicated equilibrium conditions are shown.

Figure 5



It results immediately from Fig 5 that the unit cannot immerse in equilibrium in "heavy condition No. 2" in light sea water and that all the other conditions can be obtained without the use of a negative tank, even if quite a small margin exists in the case of "light condition No. 2".

2.7 Permanent and variable ballast adjustment

2.7.1 Under the conditions shown in Fig 5, it is evident from Fig 1 and Fig 2 that, if that part of the permanent ballast (Pb) were removed, the amount of variable ballast needed would increase and "heavy condition No. 2" in Fig 5 would rise to the inside of the polygon.

Furthermore, if a few load blocks were shifted astern without any variation of the permanent ballast total load, the above-mentioned point would move horizontally to the right to the inside of the polygon in Fig 5. All other points in Fig 5, corresponding to equilibrium conditions, would move, in both cases, for the same length and in the same direction.

The above demonstrates that all points can be shifted, either fore or astern, upwards or downwards, or in any combination therof, by adjusting the permanent ballast (Pb).

Of course, there are practical limitations to the shifting of loads; moreover, their removal could be precluded for transverse stability reasons.

In the case of Fig 5, it is evident that the set of points corresponding to equilibrium conditions is beyond the capacity of the variable ballast tanks and variable fuel oil tanks, but the whole group of points can be enclosed by the polygon which includes the negative tank effect.

If the submersible unit is already built, the complete loss of efficiency of the negative tank in immersion, in light condition and in high density sea water, could be accepted and in "light condition 2" it would be acceptable to move in the area representing this negative tank effect.

Otherwise, it would be prudential to consider enlarging the width of the polygon.

In such situation, the equilibrium polygon is useful to decide which tank or tanks need to be increased.

It is evident from Fig 5 that no improvement would derive from increasing the capacity of the aft variable fuel oil tank or aft trim tank, since this would only widen the polygon on the left-hand side.

The greatest advantage, per unit ton of capacity increase, would be obtained by enlarging the size of the auxiliary tanks, but if this were not practical, it would be effective to increase both fore trim tank and variable fuel oil fore tank.

2.8 Stability at high depth

2.8.1 While weight and buoyancy forces can be brought almost close to equilibrium when a unit is submerged, many submersibles/submarines do not have inherent stability with respect to depth, because when the unit descends or ascends, no force is generated to allow the unit to go back to the original depth.

The case can occur in which water at greater depths is appreciably "heavier" than that close to the surface, due to differences in temperature and salinity that allow the unit to stay at the interface if its weight is greater than its displacement in "lighter" water, but lower than its displacement in "heavier" water.

In any case, unless any other forces are applied, like for example by operating the horizontal rudders or using a lifting system, many submersible units could either ascend to the surface or descend to the seabed.

In the common submersible unit, the sea pressure on the hull tends to induce an unstable condition.

The loss in buoyancy due to hull compression exceeds the buoyancy gain due to compression of sea water and the consequent small increase in density.

The net result is that buoyancy decreases when the unit descends and increases when the unit ascends.

The effect of sea water pressure would be enhanced if a partially filled tank existed communicating with the sea, since the air inside the tank would expand and compress immediately after any depth variation, by ejecting water while the unit ascends or introducing it while the unit descends.

On some very stiff hulls, this effect is reversed, since the effect of hull compression is smaller than the effect of compression of sea water when density increases.

This translates into a small gain of buoyancy when the unit descends, a small reduction when it ascends, and consequently a smaller stabilising effect.

3 Equilibrium trim in immersion

3.1 Fundamental principles

3.1.1 The equilibrium trim in immersion follows from the experimental determination of the load and of the inclining longitudinal moment of the "load to submerge" as defined in point [2].

In theory, the load to submerge could be obtained, as shown in Fig 1 and Fig 2, by subtracting the lightweight with permanent ballast (Pb), as determined from stability tests, from the calculated value of Δ_{sub}.

However, Δ_{sub} cannot be computed with accuracy due to the various appendages in the dead-works.

Furthermore, the load to submerge thus determined would represent a small difference between two large terms and this would expose it to a greater error than that of the case of direct determination.

It is thus common practice to obtain the load to submerge experimentally, with a list of all weights on board included in the load to submerge, taken when the unit is in underwater equilibrium.

The load to submerge is adopted, as discussed in point [2], as a basis to calculate the variable ballast to balance the unit in the various equilibrium conditions which, alternatively, define the optimum load and location of the permanent ballast (Pb).

3.2 Actions to obtain the equilibrium trim in immersion

3.2.1 The unit is led to full immersion in a zone without heavy currents or sudden density changes.

Variable ballast is to be accurately placed at a point to bring the unit to equilibrium trim in immersion.

The unit is to stay at rest for a sufficient time to ensure that neither a longitudinal inclination, nor any appreciable tendency to ascend or descend occurs.

While the unit is in equilibrium underwater, a sample of sea water is taken, preferably by a water circulation system which is working, and the density of water is measured.

A complete list of the weights and trimming moments of any elements [different from the permanent ballast (Pb)] that exist on board and do not contribute to the lightweight is to be produced.

As for the case of the stability test, this list is to be based on a detailed definition of the lightweight condition.

Total load and inclining longitudinal moment resulting from this list represent the "load to submerge" and the inclining longitudinal moment related to the actual sea water density as measured accordingly.

3.3 Report on equilibrium trim in immersion

3.3.1 Calculations performed for the assessment of the report on equilibrium trim in immersion result in a change in the load to submerge associated with the density of sea water in which the unit is operating, relating it to specific volumes 0,981 m^3/t, 0,975 m^3/t, and 0,971 m^3/t.

As recalled in point [2], these values represent the range of fluctuation of the specific volume of sea water and are applied for the calculation of equilibrium conditions, where even small variations in specific volume are important.

The value of 0,975 m^3/t is used for stability calculations, like for surface ships.

When the stability test and checking of the trim in immersion have been completed, the loads and trimming moments of the unit in lightweight and with permanent ballast (Pb) and the load to submerge are known.

In theory, the sum of these items should correspond to the volumetric terms to calculate Δ_{sub}, but small differences are to be expected due to inaccuracies in the calculations with each of the 3 values of the specific volume.

It is usually deemed that Δ_{sub} and the trim in immersion, through the stability test performed with the unit immersed, are more accurate than those obtained through volumetric calculations.

Values of the "load to submerge" referred to the different values of sea water density are to be obtained as follows:

a) Δ_{sub} and its inclining longitudinal moment, when the equilibrium trim in immersion is reached, are obtained by adding the load and trimming moment of the unit in lightweight with permanent ballast (Pb), assessed through the stability test, to the load to submerge, assessed through the trim in immersion;

b) Δ_{sub} and its inclining longitudinal moment at 0,981 m^3/t, at 0,975 m^3/t or at 0,971 m^3/t are obtained by multiplying the load and trimming moment calculated in a) by the ratio of 0,981 m^3/t, 0,975 m^3/t or 0,971 m^3/t to the actual value of sea water specific volume;

c) the "load to submerge" and its inclining longitudinal moment at a specific volume of sea water of 0,981 m^3/t, 0,975 m^3/t and 0,971 m^3/t are obtained by subtracting the values of the lightweight with permanent ballast (Pb) from Δ_{sub} at such specific volumes.

A single copy of the assumed hypotheses and calculations performed, at the design stage, related to equilibrium trim in immersion, is to be submitted to Tasneef.

Part B
Hull and Stability

Chapter 3
SUBDIVISION REQUIREMENTS

SECTION 1 CALCULATIONS RELEVANT TO SUBDIVISION REQUIREMENTS AND DAMAGE STABILITY

SECTION 1 CALCULATIONS RELEVANT TO SUBDIVISION REQUIREMENTS AND DAMAGE STABILITY

1 Introduction

1.1 Foreword

1.1.1 General requirements for subdivision arrangements and damage stability are not mandatory for class, except in those cases where Tasneef carries out supervision on behalf of the relevant Administration.

In such case, these provisions are considered standard class Rules and therefore compliance is checked by Tasneef during class surveys.

1.2 General notes

1.2.1

a) In units with subdivision arrangements, damage stability calculations can be performed with the same criteria adopted for surface ships, considering the flooding of one compartment at a time.

b) In large size units intended for carriage of passengers, the above-mentioned calculations are to be carried out considering two adjacent compartments flooded at a time.

c) Working units, in general of small size, are not subdivided; some of these units have a subdivision with watertight doors to be put in communication with the sea (to allow the passage of divers) or with a "clamp" (which gives access to a watertight subdivision) used to connect the unit to another unit: in this case, the calculations are to be performed assuming the flooding of this compartment .

RULES FOR THE CLASSIFICATION OF UNDERWATER UNITS

Part C
Machinery, Systems and Fire Protection

Chapters **1 2 3 4**

CHAPTER 1
MACHINERY AND RELATIVE SYSTEMS

Appendix 3 Flooding and Emptying of Double Bottoms and Ballast Tanks of Units Whose Length Is More Than 20 M

CHAPTER 2
ELECTRICAL INSTALLATIONS

Section 3 Installation

Section 4 Tests

Section 5 Additional Requirements for Diving Systems

CHAPTER 3
AUTOMATION SYSTEMS

Section 1 General Principles

Section 2 Additional Requirements for Diving Systems

CHAPTER 4
FIRE PROTECTION, DETECTION AND EXTINCTION

Part C

Machinery, Systems and Fire Protection

Chapter 1

MACHINERY AND RELATIVE SYSTEMS

SECTION 1 MAIN MACHINERY AND AUXILIARY MACHINERY FOR HULL AND MACHINERY SERVICES

1 Propulsion plants and machinery in general

1.1 General

1.1.1 Part C, Ch 1 of the Rules is to be applied to plants and machinery, in addition to the requirements of these Rules, as far as possible and reasonable.

However, on a case-by-case basis, Tasneef reserves the right to permit possible deviations from the above-mentioned Rules or to make additional requests in relation to special characteristics of proposed systems.

In particular, proposed solutions will be examined case-by-case for watertight penetration through the resistant hull of rotating shafts, manoeuvring systems, electrical cables, etc. Watertight elements on the above-mentioned penetrations are to be certified by the relevant Manufacturer as suitable for the collapse depth of the resistant hull.

Auxiliary machinery of significant importance for the unit's safety (e.g trim and ballast pumps) is to be redundant.

All machinery and systems are to be designed and constructed in order to operate continuously and adequately with an inclination, in any direction, of up to 22° 30'. For particular operational needs, a greater value of the inclination may be required.

No damage or operational difficulties are to occur at transient inclinations, in any direction, whose angle is double the above-mentioned one.

All safety and emergency systems are to be designed to operate continuously with any inclination of the unit in any direction.

In units of small dimensions, propulsion engines may be located outside or inside the resistant hull.

a) Engines located outside the resistant hull.

   They are to be watertight at their external working pressure.

   The seals of tailshafts are to be approved by Tasneef.

b) Engines located inside the resistant hull

   If deemed necessary, a closed circuit cooling system, depending on the installed power and ventilation system of the engine room, is to be provided.

   To maintain the electrical insulation resistance of machinery above the requested limit, an electric heater may be provided for windings.

   Heating of windings through electrical resistance may be requested in order to maintain machinery insulation at a high level.

   Devices such as a "Snorkel" may be installed for explorative navigation at limited depth.

1.2 Shaft lines and propellers

1.2.1 Shaft lines and propellers are to comply with Pt C, Ch 1 of the Rules for the Classification of Ships.

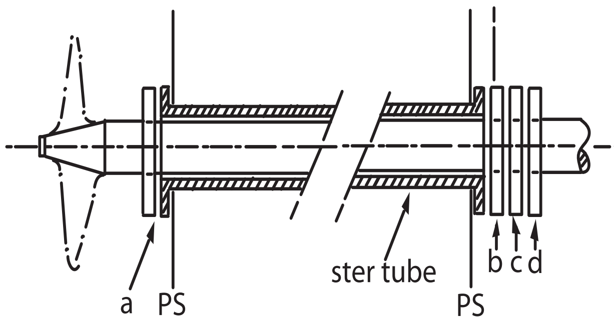
In addition, propellers are to be particularly protected from potential impact on the seabed or against immersed obstacles (structures).

An ordinary and a reserve seal are to be provided in way of the sterntube on units of large dimensions.

In addition, an emergency seal is to be provided forward of the above double seals, to be utilised in the case of underwater maintenance work on the above-mentioned seals. An additional emergency seal of mobile type is to be provided.

The required seal installation is shown in Fig.1.

Figure 1



a : ordinary seal

b : reserve seal

c : emergency seal

d : emergency seal of mobile type.

1.3 Drawings and specifications

1.3.1 In addition to the requirements for the different components in Part C, Ch 1 of the Rules, the following are to be submitted:

- details of all monitoring and safety devices adopted to avoid failure of the most stressed components. Where possible, the documentation of destructive tests and/or endurance tests performed on these components is to be attached;
- torsional, lateral and axial vibration calculations of the propulsion system as requested in Pt C, Ch 1, Sec 9 of the Rules, independently of prime mover power;
- arrangement and details of "Snorkel" type devices, if any;
- diagrams of interconnection and location of batteries suitable for the different unit speeds. The type of batter-

ies and their electrical characteristics are to be specified;

- drawing of the arrangement of machinery intended for all services on board.

1.4 Special type propulsion plants

1.4.1 Tasneef reserves the right to accept propulsion plants of non-conventional type on board underwater vehicles, upon examination of the submitted documentation, shop and on-board tests and satisfactory results of the checks which are deemed necessary case-by-case.

The above refers, in particular, to the following types of engines:

a) hydrogen peroxide engines (H_2O_2).

Pure hydrogen peroxide, or hydrogen peroxide solution in different concentrations (in general not more than 85%), is to be stored in vessels of pure aluminium or aluminium alloy without copper or steel lined with synthetic resins.

Density, temperature and pressure are to be indicated on the vessels containing the product.

The regulatory device is to be described in detail. At different power rates, the regulatory device is to introduce the requested parts of hydrogen peroxide, pure water and fuel oil in the plant, with a margin of less than 0,8% with respect to the theoretical quantities fixed at the design stage. This is in order to achieve a thermal load which can be sustained by the engine.

Specific information concerning the catalyst (in general, potassium permanganate) is to be provided.

b) closed circuit engines

Constructional and functional details of the control valve are to be sent to Tasneef for examination. The valve controls the pressure in the exhaust gas circuit and is to maintain the required pressure in the circuit itself allow-ing the discharge of gases in excess outside the circuit.

Complete additional information is to be provided concerning the mixture used by the engine (it consists of exhaust gases, oxygen and fuel oil in proportions which change with power, so that the thermal load is sustained by the engine).

The necessary oxygen is to be stored in vessels and/or high pressure bottles. It is also to be specified how unutilised exhaust gases are expelled or collected in suitable pressure vessels.

c) nuclear energy propulsion plant for units of large dimensions.

Units with this type of propulsion plant will be specially considered by the Society.

d) Fuel cell propulsion plant

The type of fuel cell is to be specified:

- AFC (Alcaline Fuel Cell)
- PAFC (Phosphoric Acid Fuel Cell)
- MCFC (Molten Carbonate Fuel Cell)
- SOFC (Solide Oxide Fuel Cell)

In the case of an AFC plant, it is to be specified if it utilises:

- hydride
- H_2 liquid;
- H_2 liquid and battery (hybrid solution).

In the case of a PAFC plant, it is to be specified if it utilises:

- hydride;
- H_2 liquid;
- liquid and battery (hybrid solution).

Addidionally, the use of reformer and methanol is to be specified for AFC or PAFC.

In addition, it is to be specified if the plant is also intended for auxiliary services.

Detailed information is to be provided on the main subsystems forming the "system of fuel cells", such as:

- "electrochemical section": block of single cells assembled in one or more packages, specifying the type of electrolyte used.
- "fuel treatment section" (reformer): to transform used fuel (natural gas, hydrocarbons or light alcohols) into a gas rich in hydrogen. This section is not necessary if hydrogen is provided as fuel.
- "conditioning system for electrical power": to convert direct current produced by fuel cells into a variable frequency and current according to users' requests,
- "system for control and recovery of heat": it is to remove the heat produced by the cell, in order to maintain the operational temperatures at constant levels; to ensure the heat necessary for cold starting of the entire system; to provide the heat required for the operation of the fuel conditioning section, by utilising the thermal content of gas from cells; and to regenerate heat, if its use is possible and convenient.
- "control system": to automatically control the system and to ensure the operational coordination of different sections of the system.

The main characteristics of the module are to be communicated as follows:

- nominal power (kW)
- nominal voltage of the cell (V)
- current density (mA/cm^2)
- active surface (cm^2)
- number of cells per electrochemical module (stack)
- number of stacks per module
- nominal voltage of the module (V)
- nominal current of the module (A)
- efficiency (considered average efficiency of the cell) (%)
- thermal efficiency (kcal/kWh)
- H_2 consumption (mol/kWh)
- O_2 consumption (mol/kWh)
- weight (N);
- volume (m^3)
- working pressure (N/mm^2)
- working temperature (°C)
- dimensions and weight of heat exchangers (m^3/kW and N/kW, respectively).

The storage system is to be indicated for:

- hydrogen (pressurised, in the form of hydride, liquefied),
- pure oxygen (pressurised, liquefied).

All proposed solutions are to be detailed for safety purposes.

SECTION 2 BATTERIES FOR PROPULSION

1 Introduction

1.1 General

1.1.1 Part C, Ch 2, Sec 7 and Sec 11 of the Rules are to be applied to batteries, in addition to the requirements of these provisions, as far as possible and reasonable.

2 Batteries

2.1 Type of batteries

2.1.1 Batteries may be of the lead-acid or nickel-cadmium alkaline type. Other types may be accepted if they are of satisfactorily proven design (e.g. silver-zinc, zinc-cadmium) and/or after examination of the documentation considered necessary by Tasneef.

2.2 Installation of batteries within the resistant hull (generally for units of large dimensions)

2.2.1 Batteries are to be located in chosen spaces in relation to the distribution of weights necessary to obtain the required trim. They are to be located in the lowest possible position to improve the unit's stability. The number and weight of the elements are to be specified with the addition of their location (frame); the coordinates of the centre of gravity of each element (relative to different zones where they are located) and the total centre of gravity are to be indicated.

In addition, drawings of the supporting structures and their connection to the hull are to be sent for approval.

Batteries are to be located where they are not exposed to environmental conditions which may impair performance or accelerate deterioration. Therefore, the battery room is to comply at least with the following requirements:

- it is to be kept adequately dry
- it is to be adequately ventilated and insulated
- it is to be protected by paint resistant to the corrosive action of acid
- "no smoking" signs are to be put up.

The room is to be closed by a water and gas-tight deck with water and gas-tight access manholes. It is to be easily and readily accessible; the access manholes are to have coamings of suitable height in order to avoid water entering the room. Drainage systems are to be provided.

The passage of salt water or fuel oil pipes through the room is to be avoided as far as possible.

Elements are to be connected in series by copper bars, whose section depends on the maximum current intensity; this occurs during the first rapid charge period or during the discharge of maximum current load.

If batteries are stored in different rooms, these rooms are to be separated by water and gas-tight bulkheads.

2.3 Installation of batteries outside the resistant hull (generally for units whose length is 20m or less)

2.3.1 Batteries are to be stored in watertight containers, suitable to withstand external pressure and efficiently protected against impacts.

A compensation tank of sufficient capacity to refill the batteries with liquid is to be fitted.

If necessary, non-return valves are to be provided on the upper part of the container in order to allow the discharge of gases into the sea.

Each container is to be equipped with a drainage system.

The passage of pipes and electrical cables through the battery containers is to be avoided.

2.4 Lead-acid storage batteries

2.4.1 Specific requirements are given in App 1.

2.5 Nickel-alkaline storage batteries

2.5.1 Specific requirements are given in App 2.

SECTION 3 PUMPS, PIPING AND FITTINGS FOR HULL AND MACHINERY

1 Introduction

1.1 General

1.1.1 Pt C, Ch 1, Sec 10 of the Rules is to be applied, in addition to the requirements of these provisions, as far aspossible and reasonable.

2 Systems and their arrangement

2.1 General

2.1.1 All piping is to be considered class I.

2.1.2 The Manufacturer is to communicate the list of essential systems for manoeuvre and safety by sending, for approval, the relevant diagram, with indication of all the necessary elements for review and in particular the maximum working and design temperatures and pressures,as well as the type and mechanical and chemical characteristics of the materials used.

2.1.3 The drawings of all passages of piping through theresistant hull are to be sent for approval. However, these passages are to be limited and the use of stuffing box typedevices is to be avoided as far as possible.

2.1.4 Essential services are to have dual controls, one ofthem manual if possible.

2.1.5 The parts of the piping exposed to salt water are tobe protected by special paint and/or linings.

2.1.6 Piping and its fittings which may be directly or indirectly connected to the sea are to be dimensioned withthe same safety coefficient requested for the resistant hull.

2.1.7 *(1/7/2023)*
All piping passing through the pressure hull is to be equipped with 2 consecutive and easily accessible valves, one which is fail set type (based on a FMEA analysis agreed with Tasneef) and the other which is manually operated; both valves are to be located within the pressure hull and the first one secured directly to the shell plating. If this is not possible, the part between the passage through the hull and the first valve is to be designed for an inner pressure equal to the collapse pressure of the resistant hull.

Pumps, valves, cocks and other fittings are to be located in an easily accessible position. They are to be distinguished by marks indicating their function and the circuit they serve; all valves and cocks are to be equipped with an "open/closed" indicator and they are to be protected from impacts.

2.1.8 Circuits installed outside are to be conveniently protected from impacts. Where possible, pumps and vessels are to be installed inside the resistant hull.

2.1.9 All piping and associated fittings are to be distinguished by a colour code; the relative code is to be displayed on board where it is visible to the crew. Persons concerned may colour either the entire piping or limited stripes. In particular, piping is to be coloured next to valves, connections, intersections, joints, equipment, bulkheads and in any other positions where this is deemed necessary.

Generally, the colours used are indicated in Tab 1 for piping relative to different on-board services, except for breathing service (see Sec 4, [1.1.1] c)).

An arrow indicating the direction of the flux may be required to be added. If so, it is added on the piping next to the distinctive colour and it is painted in black or white in order to contrast with the colour of the piping.

Table 1

COLOUR	PIPING AND FITTINGS
Green	Water
Silver-grey	Steam and overheated water
Brown with pink stripe	Mineral oils, vegetable oils, liquid fuels
Yellow ochre	Different gases (in gaseous or liquid state, provided that they differ from those in Sec 4, [1.1.1] c)
Violet	Acids and alcohols
Light blue	Air
Black with yellow stripe	Other liquids

2.1.10 Flexible hoses will be considered case-by-case; however, they are to be reduced to a minimum.

The use of metallic or other material for high pressure flexible hoses will be specially considered by Tasneef.

2.1.11 Fittings are not to be arranged on piping unless they are suitably fixed to the hull, especially if vibrations are appreciable.

2.1.12 See also Sec 4 concerning piping and valves relative to systems and arrangements for underwater work.

2.1.13 See Pt A, Ch 2, Sec 2, [3.6] for tests on piping.

2.1.14 Vessels containing liquids whose possible leakage may harm the atmosphere in the unit are not to be located in normally attended spaces.

2.2 Thickness of piping subjected to external pressure

2.2.1 The minimum thickness is to be calculated with the formula used for the resistant hull, assuming as design pressure that corresponding to the design depth of the unit.

Any inner pressure is not to be considered, except in particular cases when it is ensured that the inner pressure is never nullified.

In any case, the minimum thickness is to be the greater of t_1 and t_2, which are determined by the following two formulas:

$$t_1 = 2,5 \cdot R \cdot \left[\frac{p}{E}(1-\nu^2)\right]^{1/3} + C$$

$$t_2 = \frac{3pR_o}{\sigma_{yamm}}$$

where:

p	:	external pressure (N/mm^2);
R	:	average radius (at 1/2 thickness of the pipe) (mm)
E	:	elasticity module of the material (for steel, E= $2,1 \times 10^5$ N/mm^2);
R_o	:	external radius of the pipe (mm);
ν	:	Poisson coefficient (for steel, ν = 0,3);
σ_{yamm}	:	allowable stress in relation to the material yield point (N/mm^2);
C	:	0,00 for smooth pipes
	:	1,25 for threaded pipes (also partially threaded) whose external diameter $D_o = 2R_o \leq 15$ mm.

2.3 Materials

2.3.1 The Manufacturer's certification concerning the material's resistance to salt water is to be presented; however, Tasneef will decide the survey intervals, on a case-by-case basis, in order to ascertain absence of corrosion, pitting, cracks, galvanic corrosion, etc.

Grey cast iron is not allowed; spheroidal cast iron with a ferritic matrix may be used if the fluid temperature does not exceed 300°C and in parts which are not subjected to underwater shocks (see Pt B, Ch 1, Sec 1, [2.7]).

Bronze accessories are not allowed when design pressures are greater than 1,5 N/mm^2.

Piping made of copper or copper alloy is to be seamless drawn or manufactured using other methods acceptable to Tasneef.

First and second class copper piping is to be seamless drawn.

Piping made of plastic is allowed for:

- sanitary drainage to the bilge, without any possible communication with the sea
- the trim and ballast system, without communication with the sea
- the draining system without communication with the sea, provided that the presence of corrosive liquids is impossible
- other systems, in the opinion of Tasneef.

All piping valves and fittings connected to or penetrating through the resistant hull are to be constructed of ductile material whose elongation is not less than 15%.

2.4 Hydraulic systems

2.4.1 For units of large dimensions, the different users of hydraulic systems are to be roughly divided into vital, normal and steering users and they are to be normally activated by different systems. They are related to the following services:

- vital users: they are related to essential services of the unit and, in particular, they are for manoeuvring in case of an emergency or unit failure;
- normal users: they differ from vital users and steering users
- steering users: they are related to main and auxiliary steering systems (vertical and horizontal rudders).

Vital users are to be able to be activated also by the system of normal users and steering users are to be able to be activated also by the systems of vital users.

2.5 Compressed air systems

2.5.1 In units of large dimensions, the high pressure compressed air system is to be provided with a group of bottles for emergency emptying of the double bottoms at maximum operational depth: the compressed air is to be led directly to the double bottoms.

In general, the air quantity available on board, in litres at a pressure of 20 N/mm^2, is to be ten times the displacement in immersion expressed in tonnes.

2.6 Means for flooding double bottoms and ballast tanks

2.6.1 Filling of double bottoms and ballast tanks is done by utilising the water head between the sea waterline and the sea suctions.

Air vent pipes are to be arranged in the upper part of the above-mentioned spaces. Specific requirements for units of large dimensions are set out in App 3.

2.7 Emptying systems for double bottom and ballast tanks

2.7.1 Emptying may be done by pumps and/or by compressed air. Emptying by compressed air can be done at high or low pressure.

It is to be clearly stated in the user manual that double bottoms are not to be emptied by compressed air at great depths (except in an emergency); at such depths only resistant tanks are to be emptied, i.e. only emersion tanks and, if fitted, rapid tanks. The depth at which the double bottom can be emptied by compressed air is to be specified in the user manual.

Air pressure is to be regulated by suitable reduction valves before being sent to different users.

Additional requirements for units of large dimensions are set out in App 3.

2.8 Bilge

2.8.1 In small units which are designed to operate with the continuous assistance of a support ship, bilge systems need not be fitted on condition that equivalent means for drainage are provided. Such means can be portable.

Where the construction of a longitudinal bilge well is foreseen on the bottom of the resistant hull (see Fig 1), the maximum length "l" of the arch of the hull which is not supported by the frame is obtained from the diagram in Fig 2, where:

D_o : external diameter, in mm,

t : thickness of plate of the resistant hull, in mm,

L : overall length of the resistant hull, in mm.

Figure 1

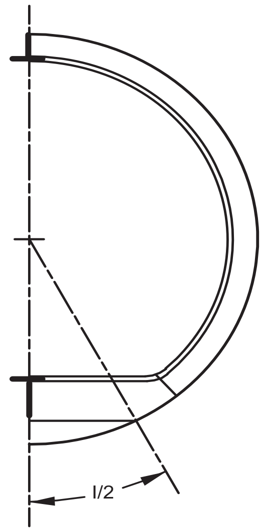
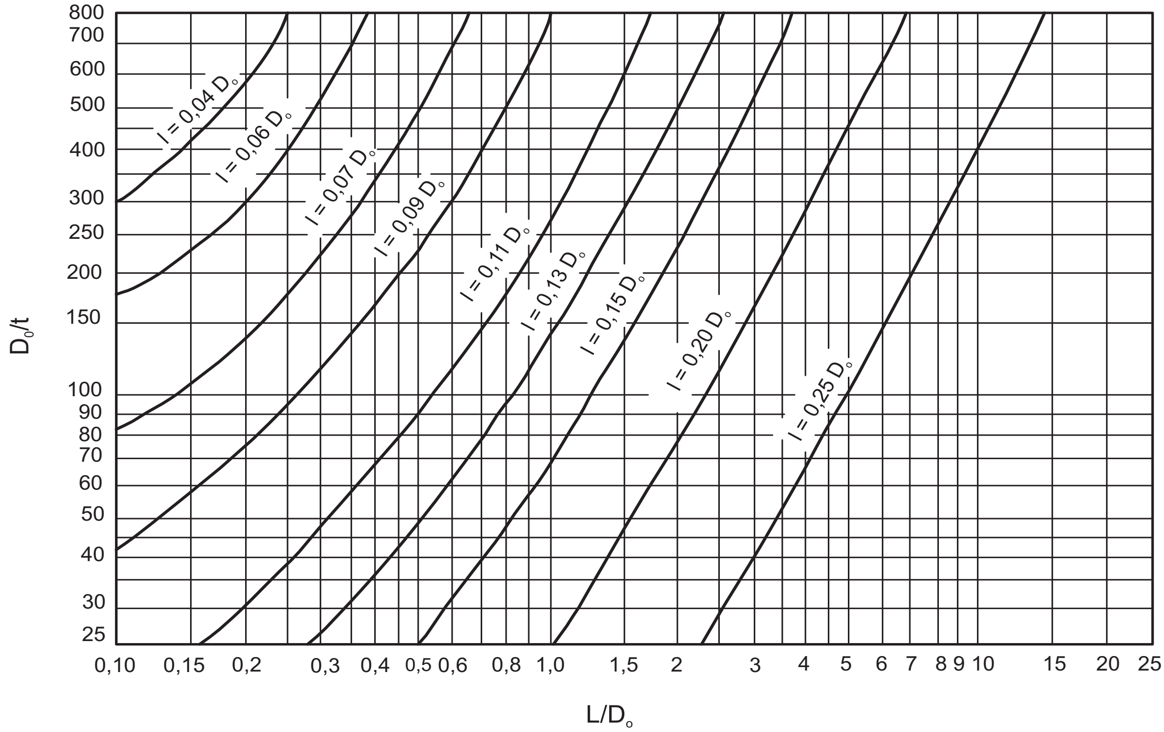


Figure 2



SECTION 4 BREATHING SYSTEM

1 General

1.1

1.1.1

a) It is assumed that the air breathed in an isobaric environment is composed of the following elements:
- N_2 = 79% ± 0,5% (in volume),
- O_2 = 21% ± 0,5% (in volume) (23% in weight),
- CO_2 (max) = 300 ÷ 450 ppm,
- CO(max) = 10 ppm,
- vapours of non-toxic oil (max) = 1 mg/m^3,
- vapours of toxic oil (max) = 1 ppm,
- steam = 0,5 g/m^3,
- NO_2 + NO (max) = 0,5 g/m^3,
- solid particles, dust etc. = residual whose dimensions are less than 5 µm verified by filtering 5 dm^3 of air through a filter which passes solid particles whose dimensions are not greater than 5µm

b) Pipes and associated accessories for different gases of the breathing systems are generally to be distinguished by the colours indicated in Tab 1.

Table 1 *(1/7/2023)*

Gas	Valves and piping	Bottles
N_2	Grey with black stripes or completely black	Grey with white stripes or completely black
O_2	White	Black with white stripes or completely white
NO	Light blue	Light blue
He	Brown	Brown
H_2	Red	Red
CO_2	Grey	Grey
O_2 + He	White and brown	Brown with white stripes
Air	White and black	White and black

When a bottle contains 2 or more gases mixed with each other, the head is to indicate the colours of the gases divided into alternate segments. Each bottle is to be marked with the name and chemical formula of the content or the percentage of components in the mixture. The code of the above-mentioned colours is to be displayed on board in a suitable position where it can be easily consulted.

Flexible hoses with quick couplings can be used on board the support ship in order to permit substantial flexibility in distribution operations.

c) the type of lubrication oil of breathing mixture compressors is not to make the mixture unsuitable for breathing.

Vegetable oil is to be used for breathing air compressors; the use of mineral oil is not allowed.

2 Oxygen system - Consumption and characteristics of the gas

2.1 General

2.1.1 The oxygen consumption per person is assumed to be 1,14 l/min at 20°C and 0,1 MPa in working conditions; air consumption is 20 times greater than this, under the same conditions.

However, the quantity provided, including the amount for emergencies, is to be enough for the duration of the entire mission, plus 72 hours. Tasneef may waive this requirement, partially or totally, taking into account the type of unit as well as the brevity and low hazard level of the mission. The following oxygen consumption can be considered to estimate particular design conditions:
- person who is sleeping 0,25 l/min
- person who is sitting 0,30 l/min
- person who is standing 0,40 l/min
- person who is walking slowly 0,60 l/min
- person who is walking slowly on the (muddy) seabed 1,1 l/min
- person who is swimming at 0,5 knots 0,80 l/min
- person who is swimming at 0,85 knots 1,4 l/min

For units equipped with diver-lock-out, at least 72 breathing hours are to be foreseen for each person who remains in transfer-lock.

In emergency conditions, oxygen consumption per person can be reduced to 26 l/h, but it is to be borne in mind that, when tense, a person consumes 1,5 l/min of oxygen.

Oxygen quantity which is already in the rooms at the beginning of the mission is not to be considered for supplying purposes.

The oxygen content in each room is not to be more than 22% in volume, at the pressure of 0,1 MPa, in order to reduce fire hazards.

As an indication, the main oxygen characteristics are given below:
- boiling temperature θ_e = -182,96 °C

- critical temperature ϑ = -118,8 °C
- critical pressure p_c = 5,03 MPa
- density (at 0°C and 0,1 N/mm^2) δ = 1,43 kg/m^3

Pure oxygen inhalation is not harmful provided that it happens at atmospheric pressure and not for a long time (not more than 8 h).

2.2 Oxygen stowage

2.2.1 Oxygen without traces of hydrocarbons or flammable gases may be stowed in suitable vessels as follows:

a) in a gaseous state, compressed.

Each compressed gas bottle is to be equipped with a pressure gauge located on the supply line and with a valve upstream of the pressure gauge. The valve is to have an "open/closed" indicator.

These bottles are to be fitted with a suitable valve in order to introduce clean water for hydrostatic testing.

Suitable devices are to be provided on the delivery line of the bottle stacks, for sampling, to ascertain non-contamination of stored gases.

O_2 bottles are to be housed in well-ventilated rooms and far from ignition sources.

Bottles usually utilised for other combustible gases (such as acetylene, methane, etc.) are not to be used for O_2 (or for mixtures whose O_2 percentage is greater than 25%). This also applies to piping and associated fittings.

If O_2 bottles are located outside the resistant hull, there are to be at least two and they are to be stored in different positions and the penetrations of the associated piping are to be kept separate. In addition, the bottles are to be able to support not only the inner pressure but also the maximum operating pressure of the underwater unit when inner pressure equals zero.

Moreover, their scantling is to satisfy the rules in force relating to pressure vessels.

b) In a liquefied state, at low temperature.

The vessels are to be thermally insulated and insulated trays are to be fitted where leakages may damage the unit structure.

2.3 Oxygen distribution

2.3.1 All parts of the system are to be designed considering a safety factor equal to 4 in respect of ultimate strength, in the design conditions.

a) Piping

Materials are to be compatible with pure oxygen.

For $p \geq 7$ MPa, Cu and Ni alloys are to be used; for $p<7$MPa the use of Cu is acceptable. For $p<0,7$ MPa, other metallic materials with high resistance to oxidation may be used.

In underwater units of large dimensions, high pressure piping for oxygen or gas mixtures is not to cross accommodation or machinery spaces, as far as possible. If necessary, it is to be suitably screened by strong protection.

Piping for gas mixtures whose O_2 percentage is greater than 25%, in volume is to be considered as pure oxygen piping.

b) Connections

Connections are, if possible, to be without thread.

Threaded fittings may be used where they are deemed to be essential. They are to be of approved type.

Welded or brazed fittings are acceptable, also for high pressure parts, provided that they are duly examined by means of non-destructive tests.

Fittings are to be of Cu and Ni alloy if $p \geq 7$ MPa; if $p<$ 7MPa, Cu is accepted.

c) Valves

All valves are to be certified by the Manufacturer that they are suitable for use with oxygen at the foreseen design pressure.

For $p \geq$ 7 MPa, parts of valves are to be made of Cu and Ni alloy (brass valves are acceptable for bottles).

Valves are to allow oxygen flow variation of 0,2 l/min; flow indicators are to be arranged for the automatic and/or manual control of the system.

If a failure of the system may expose the flow indicator to dangerous pressure, a safety valve or an equivalent safety device is to be located upstream of the flow indicator.

Spindle slow opening valves are to be installed on high pressure oxygen systems.

d) Notes of a general nature

Any traces of grease or oil are to be removed from components intended to come into contact with oxygen: the above-mentioned substances become easily flammable and sometimes explosive when they are in contact with this gas.

Fluorocarbon compounds may be used for lubricating parts in contact with oxygen.

Oxygen piping is to be protected by a 15 µm filter in order to prevent contamination.

2.4 System control

2.4.1

a) Manual controls

The easiest way of manual control is the periodical opening of an oxygen system's valve in order to restore the atmosphere in a room, when the oxygen partial pressure becomes too low, according to the instructions in the user manual.

This system is not acceptable if this is not auxiliary to an automatic system.

The above-mentioned method of manual control is acceptable if a flow control valve and a flow indicator are fitted on the system.

If a pressure regulator is used, a manual bypass is to be fitted in case the regulator fails in "closed" position.

b) Automatic control

When these systems are used, the system design is to include a careful evaluation of safety in respect of fire hazards of an electrical nature.

In the case of failure of the automatic control, manual control of the system must be possible. Any deficiency in the automatic control system is to generate a signal.

O_2 partial pressure is to be continuously monitored. Type approved portable O_2 analysers are to be used for continuous measurement of the oxygen concentration in the air or in other gases.

3 Carbon dioxide

3.1 General

3.1.1 *(1/7/2023)*

Carbon dioxide breathed out by each person in working conditions is to be calculated on the basis of the reference operative profile taking into account the percentage of time at work and time in rest; when the reference operative profile is not available, the Carbon dioxide can be assumed to be 25 l/h, at 20°C and 0,1 MPa; alternative calculation methods may be accepted when supported by appropriate technical background.

The value of admissible partial pressure of carbon dioxide is 5 hPa in normal operating conditions; in emergency conditions, the partial pressure of carbon dioxide is not to exceed 20 hPa.

During the design of the breathing system, it is to be anticipated that the carbon dioxide quantity to be eliminated is at least 20% more than the amount which can be produced inside the unit. The length of the stay is to be considered equal to the planned duration of the mission increased by 72h.

The breathing system is to be made of materials which are non-combustible, non-toxic, non-corrosive and non-reactive with carbon dioxide. Nor are they to be reactive with substances used as absorbers (e.g. if the use of alkaline absorbers, such as LiOH and KO_2, is foreseen, Al is not to be used unless it is adequately covered).

Solid absorbers are to be in grain or without dust. Spare absorber materials are to be stowed in inert and hermetically closed spaces (Al vessels are not to be used for alkaline absorbers) in order to prevent any deterioration. Some absorbers have an expiry date stamped by the supplier.

Absorbers in capsules, located in suitable positions, may be utilised.

A gauge is to be fitted to continuously indicate the percentage of carbon dioxide in the rooms; alternatively, a visual alarm is also acceptable.

3.2 Chemical products utilised for carbon dioxide elimination

3.2.1 Carbon dioxide, in both isobaric and hyperbaric activities, can be eliminated by the chemical absorbers listed below, which cannot be regenerated.

a) hydrated lithium (LiOH)

Contact with skin and eyes is to be avoided, insofar as it is highly irritant.

The reaction of carbon dioxide elimination by hydrated lithium is strongly exothermic, therefore the unit's air conditioning system is to be designed to keep the inner temperature within fixed limits.

At low temperatures, soda-lime is more efficient (see c) below).

b) potassium dioxide (KO_2)

Contact with water and with the skin, especially if it is greasy, is to be avoided.

The reaction of carbon dioxide elimination by potassium dioxide is not exothermic.

c) grained soda-lime (NaOH + CaO)

Its efficiency decreases at low temperatures.

d) other products can be considered on the basis of satisfactory experience of previous service (e.g. absorbers containing barium mixture and quicklime).

The calculation of carbon dioxide absorption is shown in Tab 2. Calculation is performed using a filter of soda-lime and a filter of lithium hydroxide.

Table 2

Absorber	Soda-lime	Lithium hydroxide
(1) Volume of filter V [dm^3] (1)	7,2	7,2
(1) Density γ [kg/dm^3] = k	0,887	0,448
Quantity of product Q $Q = \gamma V$ kg	6,38	3,23
(1) Real absorption (kg $C0_2$/kg of product) A = 0,245	0,245	0,46
Absorbed CO_2 quantity C = A x Q = 1,56 kg	1,56	1,4
(2) Absorbed CO_2 volume $C_1=C/(\gamma(CO_2))$ [dm^3]	821	779
(1) Value given by the Manufacturer **(2)** At 0°C and 0,1 MPa, carbon dioxide density $\gamma(CO_2)$ equals 1,97 kg/m^3.		

In units of small dimensions at least 6 CO_2 absorber elements are to be available, each sufficient for at least 4 hours, and they are to be replaceable when the unit is immersed.

For units operating in hyperbaric conditions, spare absorbers are to be available. They are to be sufficient to allow final decompression of divers to isobaric pressure.

3.3 Elimination of carbon dioxide through regeneration systems

3.3.1 The system is used only in units of large dimensions and it is to be able to continuously provide suitable atmosphere for living by:

a) maintaining the oxygen concentration at constant and satisfactory level;

b) keeping the carbon dioxide concentration below a tolerable limit.

A solid absorber (molecular filter) eliminates carbon dioxide from an airstream which can be regenerated with the addition of oxygen. This stream is not to contain dust or humidity.

A carbon dioxide vessel with an outboard discharge, equipped with suitable valves, is to be fitted. It is to be possible to discharge this gas from it when the inner pressure of the said vessel is greater than the hydrostatic external pressure.

Washing liquids, such as monoethanolamine (mEA), diethanolamine (dEA), silicic clay (zeolite), etc., may be utilised instead of solid filters. They are not allowed to be used in hyperbaric applications.

If mEA is used, active coal filters are to be located at the exit of regenerators, in order to prevent the concentration of this product exceeding 1% in inner atmosphere.

The maximum acceptable level of mEA is given by the following values (values greater than these cause eye irritation, sometimes with irreversible damage):

- for exposure of 1 h: 50 ppm;
- for exposure of 24 h: 3 ppm;
- for exposure of 90 days: 0,5 ppm.

c) removing any "odours" typical of cohabiting in a restricted space, by means of a suitable deodorising additive.

In this system, opening and closure of the air circulation is to be possible; automatic control is not required but a visual signal is prescribed indicating whether or not the system is working.

In units of large dimensions, two ducts are to be fitted, one for ventilation and the other for air extraction (air which can be recirculated once purified, at the desired temperature and set degree of humidity).

Two valves are to be fitted where these ducts pass through watertight bulkheads.

Filters for dust are to be installed.

All spaces are to be efficiently ventilated in order to avoid build-up of toxic or flammable gases and formation of explosive mixtures, as well as to permit good utilisation of regenerating installation of breathing mixtures.

Stale air, aspirated by the ventilation circuit, is to pass through the regeneration station.

The efficacy of the regeneration station is to be verified for maximum and minimum physiologically acceptable humidity rates in normal working conditions.

When the unit is on the surface, ventilation is to be provided through a duct safely protected from splashes and fitted with devices suitable to prevent water entering.

4 Contamination of breathing mixture

4.1 General

4.1.1 Contaminants are unavoidable (such as metabolic contaminants, etc.) and avoidable (such as those from Hg, etc.). Their possible presence is to be evaluated together with the devices foreseen for their elimination, which generally use the following products:

- soft activated carbon
- hydrate lithium
- soda-lime and other alkaline-earthy elements
- activated aluminium, saturated by potassium permanganate.

4.2 Contaminating gas

4.2.1 In addition to CO_2 (see [3]), the following gases may be present in the breathing mixture:

a) Carbon Oxide

This gas may originate from different circumstances: it may come from different types of combustion, from a great part of slow oxidations, from the ageing of rubber fittings, from galley ovens, from the use of glazed pots, from cigarette smoke (which contains about 3% of CO), etc.

b) Ozone (O_3)

In isobaric atmosphere, this can only be present in exceptional cases: electric discharge due to poor insulation (in the presence of humidity), discharges from ultraviolet devices.

The gas essentially causes eye irritation.

c) Nitrogen Oxides (NO and NO_2)

These gases may be produced by: electric discharge, sparks, combustion, etc.

Nitrogen monoxide is about 5 times less toxic than dioxide, but it is naturally oxidised once in contact with the atmosphere and it becomes dioxide. This oxidation depends on the concentration of nitrogen monoxide: oxidation is relatively slow below 50 ppm.

Concerning tolerated limits related to toxicity, only nitrogen dioxide is considered. This gas causes marked irritation only in the case of lengthy and continuous exposure at high concentrations.

The above-mentioned contaminating gases are to be eliminated by using absorbent products described in [4.1.1] and their generation is to be limited as far as possible.

5 Humidity and temperature control systems

5.1

5.1.1 A suitable humidity and temperature control system for inner atmosphere is to be arranged.

If there are no means suitable to maintain humidity and temperature within the limits fixed in the system's design, the operational time of the vehicle may be limited instead of arranging drying filters. This limitation will be noted in the user manual.

6 Air conditioning system

6.1

6.1.1 In units of large dimensions, if installed, the air conditioning system is to ensure the required heating or cooling of air, according to seasonal and environmental conditions, and the appropriate degree of humidity.

It is to be able to operate with the unit on the surface, at snorkel depth and in immersion.

The conditioning system fans are to be anti-sparking type (Ch 4, Sec 1).

7 Emergency breathing devices

7.1

7.1.1 Emergency breathing devices are to be used in the case of breathing system failure. They consist of a self-contained air breathing apparatus for each person on board plus one, or of a fixed emergency system equipped with breathing nozzles for each person on board plus one.

APPENDIX 1 LEAD STORAGE BATTERIES WITH ACID ELECTROLYTE

1 Discharge regime

1.1

1.1.1 It is necessary to provide diagrams indicating the complete variation of the capacity of an element in relation to different intensity of discharge, in order to calculate the duration of the batteries and, therefore, the operating range of the unit.

When the capacity of an element or battery is determined, it is necessary to correct the effectively measured capacity at average temperature of electrolyte during discharge, with the capacity of the conventional temperature of 20°C, with the formula:

$$C_c = C[1 - \alpha(t - t')]$$

where

C_c : capacity referred to the conventional temperature, expressed in Ah;

C : effectively measured capacity, expressed in Ah;

t' : conventional temperature (20°C);

t : average temperature of electrolyte, expressed in °C;

α : 0,08, for discharges up to1 h,

: 0,07, for < 1 h discharges ≤ 3h,

: 0,06, for < 3 h discharges ≤ 5h,

: 0,05, for < 5 h discharges ≤ 10h,

: 0,04, for 10 h < discharges ≤ 20h

The volume of electrolyte is to be specified for each 100 Ah of capacity, as well as its density at the beginning and at the end of the discharge.

Density of electrolyte is to be referred to the temperature of 15°C; if the temperature is greater the density is to be corrected, during the reading, by plus or minus 0,7 g/cm3 for each degree more or less than 15°C, respectively.

Control of the density of electrolyte is to be mentioned in the user manual since it is an operation of maximum importance for the good conservation of batteries and it is to be done according to the deadlines stipulated by the Manufacturer.

Density m of electrolyte is generally measured in Baumé degrees (bè); the correspondence between density in Baumé degrees and in g/cm^3 is given by the following relationships:

For liquids heavier than water

$$m\ (\text{in Bè}) = 145 - \frac{145}{m\ (\text{in g/cm}^3)}$$

$$m\ (\text{in g/cm}^3) = \frac{145}{145 - m\ (\text{in Bè})}$$

For liquid less heavy than water

$$m\ (\text{in Bè}) = \frac{140}{m\ (\text{in g/cm}^3)} - 130$$

$$m\ (\text{in g/cm}^3) = \frac{140}{m\ (\text{in Bè}) + 130}$$

The diagram of discharge and charge of batteries is to be shown in the user manual.

Angles of maximum operational inclination are to be considered in order to avoid leakage of electrolyte from elements.

A convenient provision of distilled water is to be provided in order to restore the water level in the elements.

In units of small dimensions, batteries are to be stored in separate rooms if they are within the resistant hull. The room is to be gas-tight and it is to be able to be ventilated during charging. It is to be equipped with devices suitable for removing hydrogen which forms during the discharge.

2 Calculation of number of elements

2.1

2.1.1 There is a well-defined link between the discharge capacity of batteries, the number of elements which compose the battery and the characteristics of speed and range of the unit.

It is to be possible to distribute energy for the cruise speed range and energy for the full-speed range from the same battery. Therefore, there is a compromise between the said characteristics in order to properly satisfy them from only one battery.

The chosen type of battery will be more suitable for speed and range requirements, the nearer n1 and n2 are to each other. They are calculated by the following formulae:

$$n_1 = \frac{T_1'' \cdot F_{1_{sub}}}{\eta_1 C_1 V_1}$$

$$n_2 = \frac{T_2'' \cdot F_{2_{sub}}}{\eta_2 C_2 V_2}$$

where:

n_1 and n_2: number of elements of necessary batteries to obtain F_{1sub} and F_{2sub}, respectively

F_{1sub} : engine power, expressed in W, necessary for maximum depth v_1

F_{2sub} : engine power, expressed in W, necessary for cruise speed in depth v_2

C_1 and C_2: capacity, expressed in Ah, of discharge regimes corresponding to powers F_{2sub} and F_{2sub}, respectively, for duration of discharge T_1'' and T''_2, expressed in seconds

η_1 and η_2: efficiency of electric motors of power F_{1sub} and F_{2sub}, respectively. It can be considered that they are between 0,92 and 0,85, with the trend to assume greater values when motors operate at maximum load

V_1 and V_2: average voltage, expressed in V, during the said discharges. For discharges up to 1h, these voltages may be considered to vary between 1,7V and 1,8V; for discharges greater than 1h and up to 20h, a value of 1,9V can be assumed.

The previous formulae are to be corrected in order to consider the energy that batteries supply for auxiliary services; detailed calculations are to be sent to Tasneef for examina-tion. However, it can be deemed, as a first approximation, that auxiliary services increase the power F_{1sub} by 2-4% and the power F_{2sub} by 15-20%.

3 Charge

3.1

3.1.1 Charging is to be done according to the following procedure:

a) ventilation of the room for at least 15 minutes;

b) it is to be verified that electrical insulation satisfies the following relationship:

$$R_g = R_m\left(\frac{E}{V_p + V_n} - 1\right) > 1\,M\Omega$$

where:

R_g : ground resistance, expressed in Ω;

R_m : measured resistance, expressed in Ω;

E : voltage at terminals of battery, expressed in V;

V_p : voltage between positive pole and ground, expressed in V;

V_n : voltage between negative pole and ground, expressed in V.

If $R_g \leq 1$ M Ω,, the battery is not to be charged.

c) To control the state of charge, a Baumè densimeter can be used (see [1] and Tab 1).

Table 1

Bè	γ (g/cm³)	State of charge
33,3	1,3	max
31,1	1,275	max
28,4	1,245	About 3/4
25,5	1,215	About 1/2
22,0	1,18	About 1/4
15,5	1,12	discharge

4 Maintenance

4.1

4.1.1 The following requirements are of a general nature:

a) Introduction of extraneous substances in batteries is to be avoided. Very noxious substances are: iron dust or iron fragments, chlorine, ammonia, copper and nitric acid.

b) Only sulphuric acid and chemically pure water (distillate) are to be used for filling up elements.

Water is to be contained in clean portable containers made of glass or suitable vinyl material.

These containers are not to be used to contain other products. The maximum acceptable percentage of impurity in water volume is the following:

- suspended particles : traces
- solid particles 0,01%
- CaO and MgO: 0,004%
- Fe+FeO (including Fe_2O_3 or FeO_2 or Fe_3O_4): 0,0005%
- Cu: 0,00025%
- Cl: 0,0005%
- Ni: 0,0002%
- organic or volatile particles 0,0051%
- ammonia salts (with group NH_4): 0,0008%
- nitrite (with group NO_2): 0,0005%
- nitrates (with group NO_3): 0,001%.

The analysis of electrolyte is to be carried out at intervals prescribed by the battery Manufacturer and the maximum acceptable percentages (in weight) of impurity are:

- Fe: 0,012%
- Cu: 0,005%
- Cl: 0,012%
- As: 0,0001%
- Sb: 0,001%
- Nitrites (with group NO_3): 0,002%
- Mn: 0,00006%
- Ni: 0,001%

The presence of perchlorate, NH_4, Pt and particles in suspension is not accepted in any percentage.

c) Electrolyte is to have the density prescribed by the Manufacturer (it is generally between 1,2 and 1,28 kg/dm^3, according to the temperature, which is to be specified).

It is recalled that a greater value of density of electrolyte is equivalent to a greater capacity, but it causes greater wear of elements.

d) During charging, the temperature is not to exceed 45°C; if this occurs, the value of the charging current is to be reduced.

e) Before charging, the correct battery connection to the charge device is to be checked.

f) Good insulation and cleaning of batteries are to be ensured.

5 Materials

5.1

5.1.1

a) Lead for the preparation of dusts and positive plates is to be pure, soft, of first melting (density 11,33 ÷ 11,44 kg/dm^3; melting temperature 325 ÷ 334 °C).

The maximum allowable percentage of impurity is not to exceed 0,05% (99,95% of Pb), whereas the maximum allowable percentages of single elements constituting the impurity are:

- Fn, Mn, Sb: 0,01%
- Cu, Pt, Ag, Ni, Co: 0,005%
- As: 0,03%
- Zn, Bi: 0,02%.

Lead of second melting, i.e. that obtained from the fusion of old storage plates or from sludge recovered from batteries, is not usable for the preparation of dusts or of positive plates because it has a different physical state in respect of lead of first melting, even after elimination of all impurities. It may be used for the construction of negative plates, provided that the percentage does not exceed 72,5%.

b) Antimony is not to contain more than 1% of impurity and it is to be completely free from As, Zn, Bi, Cu, Ag and Fe. Antimony with a maximum percentage of 10% is to be used.

c) Sulphuric acid is to satisfy the following conditions of impurity (the maximum acceptable tolerances are indicated below):

- Fe e Mn: 0,01%
- N_2: 0,01%
- Cl: 0,002%
- As: 0,005%
- Zn: traces
- H_2S (hysdrogen sulphide): traces
- H_2SO_3 (sulphurous acid): traces.

APPENDIX 2 NICKEL BATTERIES WITH ALKALINE ELECTROLYTE

1 Features

1.1

1.1.1

a) Duration

Nickel Alkaline batteries last longer than other secondary elements of similar performance.

They have a great resistance to deterioration from both the chemical and mechanical viewpoints.

b) Maintenance

They do not require periodical recharge or other maintenance operations during periods of inactivity at ambient temperatures.

Open elements produce small gas quantities in normal operations with a suitable charge device and they seldom require to be filled up.

Tight elements do not require any maintenance except for the recharge and they can work in all positions.

c) Performance at low temperatures

At low temperature, their performance is higher than the other common batteries. They can supply energy and they can be charged at temperatures below zero, until the freezing point of electrolyte.

The influence of the level of charge or discharge on the concentration of electrolyte and its point of freezing is negligible.

d) Voltage

Nickel Alkaline batteries produce exceptionally constant voltage during charge at normal speed.

Tight elements may be recharged at slightly higher voltage than that generated during the discharge.

2 Maintenance

2.1

2.1.1 In non-tight batteries, electrolyte is to be filled up to the requested level by periodical addition of distillate water, in order to compensate for losses due to natural vaporisation and water electrolyse. In the case of nickel-cadmium batteries, this loss is very small, provided that the voltage of the charge device is suitable. It is occasionally necessary to check the electrolyte in order to verify the degree of carbonation due to prolonged contact with the atmosphere but, if necessary, it can be replaced. In some cases, special elements are fabricated; they contain a greater quantity of electrolyte: this increases the weight and dimensions but reduces maintenance.

It is necessary to discharge and short-circuit the elements of nickel-iron when it is anticipated that they will remain inactive for a long period of time.

Tight elements do not need maintenance, whereas semi-tight elements sometimes need some attention, but always a reduced amount.

3 Salient properties of some nickel batteries with alkaline electrolyte

3.1

3.1.1

a) Open elements:

1) Elements of nickel-cadmium with pocket electrodes.

   They can be considered for all applications where high capacity is necessary and where problems of space and maintenance are not present. They maintain the charge in an excellent way.

2) Elements of nickel-iron with sealed cylindrical positive electrodes.

   Their life is very long when the discharge is total and regular also at high ambient temperature; in any event their efficiency at high regimes is not less than that of other elements with pocket electrodes.

   They can be considered for applications where problems of space do not exist, the ventilation is good and regular maintenance is possible.

3) Elements of nickel-cadmium with sintered plate electrodes.

   They can be discharged at very high regimes; in conditions of rapid discharge they have higher efficiency than any other alkaline battery. In addition, they can withstand the rapid charge. They should be utilised when it is necessary to have a high instantaneous current from a low capacity battery.

b) Tight elements

Advantages of tight elements are reduced maintenance and limited dimensions; however, it is necessary to avoid excessive recharge. Tight elements may be permanently connected and in this manner they are used in applications requiring low power.

1) Tight elements with compressed plate electrodes.

   They are suitable for applications requiring low current intensity and where it is not important to maintain the charge for very long periods.

2) Tight elements with sintered plate electrodes.

Although they are recommended for low power, these elements can supply high intensity currents for short periods without loss of efficiency.

c) Semi-tight elements.

The advantage of these elements compared with completely tight elements is that they can have greater dimensions even if outflow of the electrolyte is impossible and they have fewer limitations concerning the charge regimes.

However, they do require maintenance, albeit less than that required for open elements. Semi-tight elements can be considered for all types of portable devices where the necessary current intensity is greater than that achievable using completely tight elements.

APPENDIX 3 FLOODING AND EMPTYING OF DOUBLE BOTTOMS AND BALLAST TANKS OF UNITS WHOSE LENGTH IS MORE THAN 20 M

1 Flooding systems

1.1

1.1.1

a) The cross-sectional area A [m^2] of sea water inlets is to be calculated by means of the following relation:

$$Q = 4,45\varphi \cdot A \cdot T \cdot h_m^{0,5}$$

where:

Q = volume of the compartment [m^3]

T = fixed time [s] to fill up the compartment (in general 30 s in order to reduce to a minimum the critical phase of stability)

φ : outflow coefficient, to be assumed as:

- for circular sea inlets $\varphi = 0{,}50 \div 0{,}55$;
- for square or rectangular sea inlets: $\varphi = 0{,}60 \div 0{,}65$.

In larger compartments, 2 sea inlets are to be arranged: in this case, the above-mentioned values of φ are to be reduced by 12%.

h_m : average head [m] between the inner level of the compartment and the sea waterline during the filling phase. In order to calculate h_m, it is necessary to have the ullage tables of different compartments and the buoyancy curve up to the full immersion of the unit.

The following graphic-analytic method allows sufficiently reliable results to be obtained. The method supposes the existence of proportionality between the volume of water entering the considered compartment Q_x after the time T_x and the differential volume (V_{sub}-V_x) relative to the over-immersion of the unit after the time T_x. The proportion is expressed by:

$$\frac{Q}{V_{sub} - V^{surf}} = \frac{Q_x}{V_{sub} - V_x}$$

$$Q_x = Q\frac{V_{sub} - V_x}{V_{sub} - V^{surf}}$$

Therefore, in way of immersion ix, to which the buoyancy volume V_x corresponds, Q_x can be determined by the preceding formula and, once Q_x is known, the corresponding value h_x is obtained from the considered compartment's ullage table.

In Fig 1, the symbols have the same meaning as specified above and additionally:

WL : surface waterline of the unit

C.A. : flooding compartment

S : flooding compartment's ullage table

V : buoyancy volume.

Repeating the process for different depths between isurf and i_{sub}, it is possible to draw the curve in Fig 2, where the averaged line gives the value of hm.

b) The total cross-sectional area As [m^2] of air vents is not to be less than:

$A_s = 0{,}165$ A

where A is the total cross-sectional area A [m^2] of relevant sea water inlets.

In the user manual it is to be specified that the control of air vents is simultaneous: air vents are to be opened before the sea inlets so that ballast tanks fill up at the same time; otherwise the unit can list and in such case tanks on the listed side tend to fill even more.

The valves are to be protected against impacts.

2 Emptying systems

2.1

2.1.1 The compressed air system is to have two independent circuits which can be connected to a single tube through shut-off valves.

A compressor capable of filling the compressed air tanks and/or bottles is to be fitted on units which are designed to operate without a support ship.

Figure 1

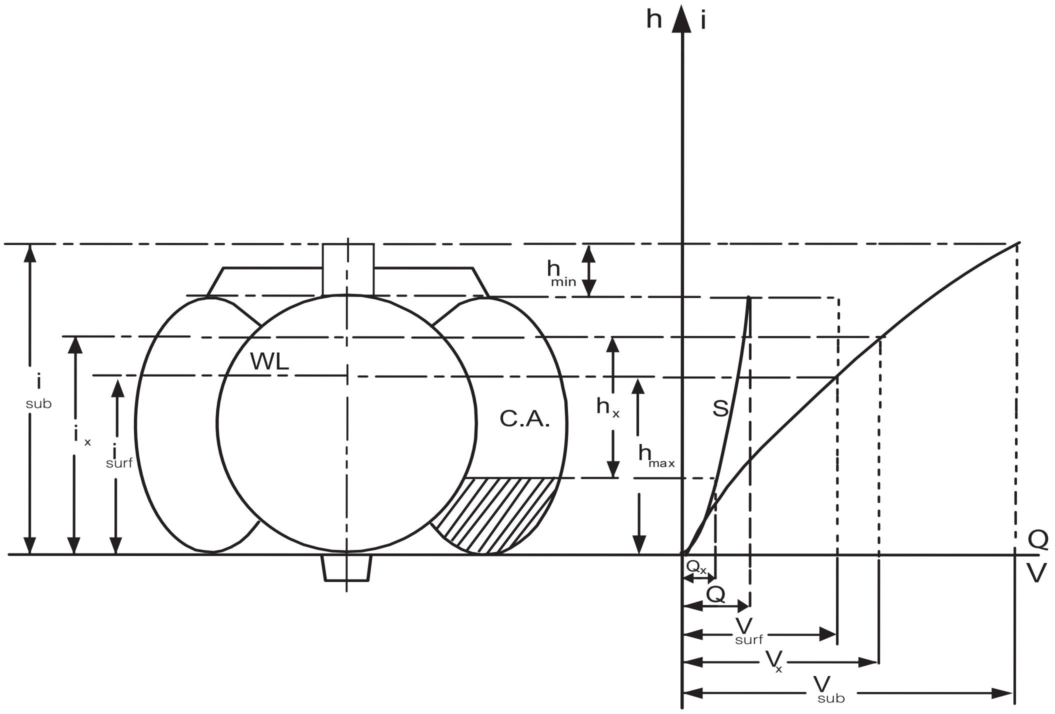
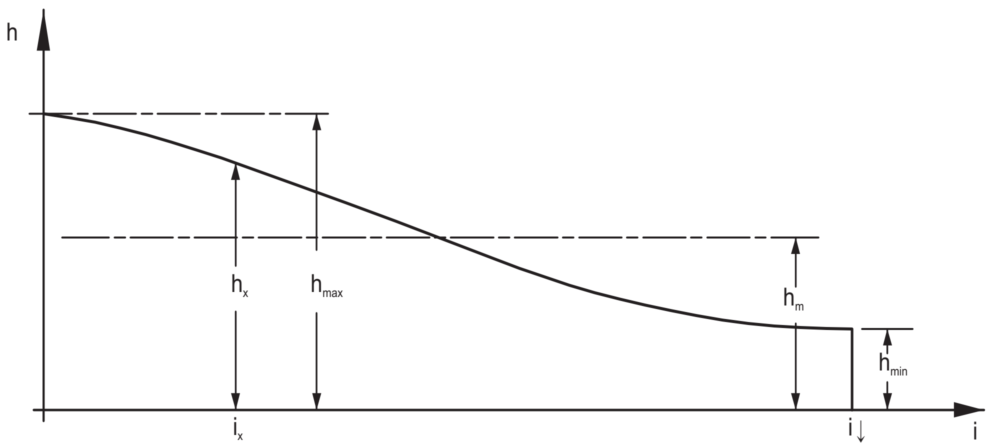


Figure 2



Part C
Machinery, Systems and Fire Protection

Chapter 2
ELECTRICAL INSTALLATIONS

SECTION 1 GENERAL

1 General

1.1

1.1.1 Electrical installations and equipment are to be in accordance with Part C, Ch 2 of the Rules, except as modified in this Section.

2 Documents to be submitted

2.1

2.1.1 The documents listed in Tab 1 are to be submitted in addition to those (where relevant) listed in Pt C, Ch 2, Sec 1, Tab 1 of the Rules.

3 Definitions

3.1 Essential services

3.1.1 Essential services are those services that need to be in continuous operation for:

a) maintaining the unit functionality

b) assuring the safety and health in a hyperbaric environment

c) monitoring of the divers by the crew.

All services supporting divers in the water, in a bell, in a decompression chamber are essential.

3.2 Emergency services

3.2.1 Emergency services are those services that are essential for safety in an emergency condition.

Examples of these services include:

a) condition monitoring of emergency batteries

b) emergency lighting

c) communication systems

d) life support systems

e) heating systems

f) alarm systems for the above services.

4 Environmental conditions

4.1

4.1.1 All electrical equipment is to be designed and constructed for the environment in which it will operate.

4.1.2 Electrical equipment installed in hyperbaric environments is not to be damaged by pressurisation and depressurisation of the environment.

4.1.3 *(1/7/2023)*

Electrical equipment installed inside a compression chamber is to be designed for hyperbaric use, oxygen-enriched atmospheres (when applicable), high humidity levels and marine application.

5 Materials and components

5.1 Insulating materials

5.1.1 Insulating material used in the construction of panels and switchboards is to be of a type that does not give off toxic gases in the event of fire.

5.2 Batteries

5.2.1 Specifications and sufficient test data or details of operating experience are to be provided to ascertain that the batteries can reliably perform for their estimated life under their service conditions.

5.2.2 Gas emission data, as applicable, are also to be considered.

5.3 Plug and Sockets

5.3.1 Electric plugs, sockets and receptacles are to be of types which prevent improper interconnections of the various systems and are to be provided with a means of securing after connection is made.

Table 1 : Documents to be submitted

No	I/A	Document
1	I	Plans showing electrical equipment arrangement
2	A	Single line diagrams of communication systems
3	I	Complete list of components and documentation on any tests carried out on all electrical equipment to be permanently installed within chambers and bells

5.4 Instrumentation

5.4.1 In general, a voltmeter, an ammeter and a device to monitor the insulation level for each conductor of each different voltage system are suitable minimum instrumentation.

5.5 Cables

5.5.1 Cables and wiring are to be in accordance with Part C, Ch 2 of the Rules and, in addition, are to be halogen free and are not to give off toxic, noxious or flammable gases even when overheated.

5.5.2 Standard ship cables with insulation of a halogenated material (e.g. P.V.C.) are not to be used.

5.5.3 All cables are to be provided with an earthed metallic braiding or screen around the conductors and with an insulating outer sheet.

5.6 Flexible Cables

5.6.1 Flexible cords for transmission of electrical power and signals are to be of watertight construction.

5.6.2 For gland type penetrators, the cables are to be of water-block construction.

5.7 Penetrators

5.7.1 Penetrators in pressure vessels are to be gas and watertight even in the event of damage to the connecting cables.

SECTION 2 SYSTEM DESIGN

1 Distribution systems

1.1

1.1.1 Only insulated electrical distribution systems are permitted.

2 Voltages

2.1

2.1.1 The maximum voltages of both alternating current and direct current low voltage systems for installations within a pressure boundary of a space intended for personnel and chambers are:

- for power and heating equipment: max. 250 V a.c. (protection against accidental touching or insulation failures and a trip device as indicated in [4.1.2] are to be provided);
- for lighting, socket outlets, portable appliances and other consumers supplied by flexible cables and for communication and instrumentation equipment: max. 30 V d.c. (these systems are to be supplied by isolating transformers).

The maximum voltages for installations within bells:

- for all electrical equipment: max. 30 V d.c. (these systems are to be supplied by isolating transformers).

Higher voltages than specified above may be accepted upon special consideration, provided additional precautions are taken in order to obtain an equivalent safety standard.

Electrical circuits and equipment used in water will be considered on a case-by-case basis.

3 Main and Emergency Power systems

3.1 Power Source Separation

3.1.1 The emergency source of power is to be separated from the main source as much as possible in order that its operations remain unaffected in the event of fire or other hazard causing failure to the main electrical installation.

3.2 Main source

3.2.1 A main source of electrical power is to be provided to supply essential services as defined in Sec 1, [3.1.1], complying with Pt C, Ch 2, Sec 3 of the Rules or consisting of at least two accumulator batteries.

3.2.2 Essential services are to be maintained for the period required to safely terminate the diving operation, including time for decompression of the divers.

3.2.3 The electrical installations essential to the safe completion of the mission are to be supplied from both main and emergency sources of electrical power.

3.2.4 The main source of electrical power, for all units, is to have sufficient capacity for the design mission.

3.2.5 In addition, for untethered units, prior to commencing any dive, the main power source is to have a reserve capacity sufficient to operate the following systems:

- Emergency internal lighting
- Communication equipment
- Environmental monitoring equipment
- Essential control systems
- Other equipment necessary to sustain life for the duration required by the emergency rescue plan, but in any event not less than 72 hours.

3.3 Emergency source

3.3.1 The emergency source of electrical power is to be a self-contained, independent source of power.

3.3.2 It may be either:

- a generator, driven by a suitable prime mover, or
- an accumulator battery.

3.3.3 Where this source of power is a generator, it is to be started automatically upon failure of the electrical supply from the main source and is to be automatically connected to the emergency distribution system within 45 sec.

3.3.4 Where this source of power is an accumulator battery, it is to be automatically or manually connected to the emergency distribution system in the event of failure of the main source of electrical power.

3.3.5 Where some of the emergency consumers are to be available during the switchover period from main to emergency source, a transitional source of emergency electrical power is to be provided.

The capacity of this transitional source is to be of at least 30 minutes.

3.3.6 The emergency source of electrical power is to be capable of supplying all connected loads and in particular the following users, for the duration specified in [3.3.7]:

- emergency internal lighting
- communication system
- emergency life support system (if electrically powered)
- launch and recovery system
- environmental monitoring equipment
- controls for emergency systems
- any electrical equipment deemed essential for therapeutic procedures or hyperbaric chambers and decompression chambers.

3.3.7 For untethered submersible units the duration of supply to the users indicated in [3.3.6] is to be at least 150% of the time normally required to reach the surface from rated depth, but not less than two hours.

For diving systems, see Sec 5.

4 Distribution

4.1 Distribution systems

4.1.1 The distribution system is to be so arranged that the failure of any single circuit does not cause other services to be put out of operation.

4.1.2 All distribution systems, being insulated, are to be provided with a device capable of automatic insulation monitoring and, in case of insulation failure, actuating switch-off and giving an alarm. Alarm only may be used if a sudden switch-off of the equipment may cause danger for the divers. Systems using double insulated apparatus or earth fault circuit-breakers will be considered on a case-by-case basis.

4.1.3 It is to be possible to disconnect power to each chamber separately.

4.1.4 Each unit is to be provided with normal and emergency lighting to allow safe operations.

4.1.5 The following users are to be supplied from separate feeders:

- handling systems for submersible units
- normal lighting for each unit (or chamber or bell)
- emergency lighting
- normal life support
- emergency life support
- communication systems
- essential instrumentation and equipment
- controls for emergency systems.

5 Protection

5.1 Batteries

5.1.1 All batteries are to be provided with overload and short-circuit protections on each pole.

5.1.2 The protective devices are to be designed for the maximum charge or discharge voltage and current.

5.1.3 Thermal elements of overload protective devices are to be tested for operation at the maximum design pressure of the protective device.

5.1.4 Overload and short-circuit protections are to be located in a separate space from the battery compartment, but the length of cables between the battery and the protection is to be kept as short as feasible.

5.2 Circuits

5.2.1 Circuits are to be protected from overloads and short-circuits by protective devices that open all conductors.

5.2.2 These protective devices are to be circuit-breakers; the use of fuses will be considered on a case-by-case basis.

5.2.3 Fuses and thermal breakers are not permitted in a helium-oxygen environment.

5.3 Motors

5.3.1 All electric motors for propulsion and other essential services are to be equipped with overload alarms in addition to motor overload protection.

5.3.2 However, when the motor is proved to be inherently safe, the requirement for the overload alarms may be waived.

SECTION 3 INSTALLATION

1 Batteries

1.1

1.1.1 Battery housings are to be provided with adequate protection, so that an accumulation of generated flammable gases is avoided.

1.1.2 Battery compartments are to be adequately protected against corrosion.

1.1.3 All electrical equipment in battery compartments is to be explosion proof or intrinsically safe.

1.1.4 When lead acid batteries are located within pressure boundaries, particular attention is to be given to segregation chambers, ventilation, hydrogen monitoring devices and alarms, and use of catalytic burners for gas emissions.

1.1.5 Electrical cables entering the battery compartment are to be provided with water- and gas-tight penetrations of the bulkheads of the compartment.

2 Motors

2.1

2.1.1 All electric motors are to be provided with nameplates showing the information required for their safe use in the electrical installation of which they are part.

2.1.2 Labels are to be affixed to each motor and are to clearly show to which electrical system the motor belongs.

3 Penetrations

3.1

3.1.1 *(1/7/2019)*

Conductors from main and emergency power sources are not to pass through the same penetrator or connection in a pressure boundary.

3.1.2 *(1/7/2019)*

Positive and negative conductors are not to pass through the same penetrator or connection in a pressure boundary, with the exception described in [3.1.3].

3.1.3 *(1/7/2019)*

For voltage which does not exceed 24 Vd.c. and which is isolated from higher voltage circuits, positive and negative conductors may be accepted passing through the same penetrator or connection, provided that:

a) there is low risk of short circuiting or tracking between conductors; and gastight and watertight integrity of the penetrating device is maintained even in the event of loss of the insulation of the connecting cables, or

b) the penetrator is type tested at the presence of the Society in order to demonstrate that the gastight and watertight integrity is maintained after a short circuit at the higher system fault current.

3.1.4 All electrical penetrators in the pressure boundary are to be arranged with couplings that are distinct from penetrators for fluid services. They are to be gas- and watertight even in the event of damage to the connecting cable.

4 Distribution Panels

4.1

4.1.1 All distribution panels are to be accessible during operation.

5 Cables and Wiring

5.1

5.1.1 Cables are to be protected from mechanical damage. Unless installed in pipes, electrical cables are to be readily accessible for visual inspection.

5.1.2 Tensile loads are not to be applied to electrical cables or wiring.

5.1.3 Cables and wiring of circuits supplied at different voltages and by the main and emergency source are to be effectively separated from each other.

5.1.4 Intrinsically safe wiring is to be separated from non-intrinsically safe wiring by at least 50 mm and in accordance with the Manufacturer's recommendations. Other suitable standards may be acceptable.

6 Earthing

6.1

6.1.1 Reference is to be made to Pt C, Ch 2, Sec 12 of the Rules.

6.1.2 All metal parts of switchboards, other than current carrying parts, are to be earthed.

6.1.3 All chambers are to be provided with grounding connection devices for plugs.

SECTION 4 TESTS

1 Tests of cables

1.1

1.1.1 Materials for cable and wiring insulation subjected to external pressure are to be able to withstand a hydrostatic pressure of 1,5 times the unit's design pressure.

1.1.2 A visual inspection is to be carried out on each submerged cable assembly to verify that no cuts, cracks or other physical damage to the cable jackets or over-moulding/potting used in the manufacture of the cable assembly are present.

2 Tests of penetrator cable assemblies

2.1

2.1.1 All electrical penetrator cable assemblies that penetrate a pressure boundary (excluding external light housings, small electrical equipment canisters, thruster housings etc.) and are subjected to external pressure are to be tested as follows.

2.1.2 The penetrator insert assembly, prior to any over-moulding and cable assembly, is to be pneumatically or hydrostatically pressure tested to 1,25 times the unit's design pressure. The pressure is to be held for 5 minutes with no signs of leaks, cracking or other signs of failure.

2.1.3 Penetrator cable assemblies are to be pressure cycled in sea water, or equivalent salt water solution, a total of 6 times in a hydrostatic test chamber. The penetrator cable is to be installed in the test chamber in a manner so as to simulate its intended use. The minimum test chamber pressure is to be 1,25 times the unit's design pressure and the electrical measurements as per 2.4 and 2.5 are to be taken during the final (6^{th}) pressure cycle.

2.1.4 Penetrator cable assemblies are to be tested at an alternating current voltage of at least 500 volts for one minute.

The quality of the assembly is to be such that that the leakage current will not prevent proper operation or expose personnel to unsafe voltages.

2.1.5 Insulation resistance measurements are to be taken and recorded during the last pressure hold cycle as follows:

- between each conductor and all other conductors in the cable assembly;
- between each shield in the cable assembly and all other conductors in the cable assembly (including other shields);
- between each shield and the cable assembly's metal shell (or chamber lid);
- between each conductor and the cable assembly's metal shell (or chamber).

2.1.6 Non-penetrator cable assemblies subject to external pressures for essential and emergency services are to be tested by the continuous application of an alternating current voltage of at least 500 volts for one minute.

2.1.7 The quality of the assembly is to be such that the leakage current will not prevent proper operation or expose personnel to unsafe voltages.

2.1.8 Insulation resistance measurements are to be taken and recorded as follows:

- between each conductor and all other conductors in the cable assembly
- between each shield in the cable assembly and all other conductors in the cable assembly (including other shields)
- between each shield and the cable assembly's metal shell (or chamber lid)
- between each conductor and the cable assembly's metal shell (or chamber lid).

3 Prototype tests of penetrators

3.1

3.1.1 Penetrators used for electrical service are to be type tested by the Manufacturer according to a previously agreed procedure.

SECTION 5 ADDITIONAL REQUIREMENTS FOR DIVING SYSTEMS

1 Materials and components

1.1

1.1.1 Materials for cables to be installed inside the chambers and bell are to be designed for installation in a hyperbaric atmosphere.

1.1.2 Dismantled ends of insulated conductors are be protected with sleeves of a non-combustible material (e.g. glass fibre weave).

2 Main electrical supply

2.1

2.1.1 When the power to the diving system is supplied via a distribution board, this board is to be supplied by two separate feeders from different sections of the main switchboard.

3 Emergency source and circuit

3.1

3.1.1 Diving systems are to be provided with an emergency source of electrical power and an emergency distribution system independent of the main source of power and the main distribution system.

3.1.2 The emergency source may be one of those indicated in Sec 2, [3.3.2] or

- the ship's emergency switchboard, or
- a combination of the above.

3.1.3 The emergency source of power and the emergency power distribution are to be capable of handling peak loads and of immediately supplying at least those services specified as emergency services in Sec 2.

3.1.4 The emergency source is to be capable of supplying

a) all services supporting divers in the water, for at least 20 minutes (minimum time required to ensure that the divers are safely recovered in the bell or to the surface).

b) all services supporting divers in a bell, for at least 24 hours (minimum time required to ensure that the divers are safely recovered in the decompression chambers or to the surface).

3.1.5 The emergency source is to be capable of supplying, at least for the life support time, all services supporting divers in the decompression chambers.

3.1.6 Cables and wiring for emergency circuits are to be fire-resisting type and protected by A0 division trays or piping.

4 Installation

4.1

4.1.1 The electrical power supply arrangement and installation are to be designed to minimise the risk of electrical capacity depletion. Electrical equipment is to be so designed and installed to minimise the risk of:

- fire,
- explosion,
- electric shock,
- emission of toxic gases, and
- galvanic action on the surface of the compression chamber or diving bell.

4.1.2 Batteries are not to be installed within the chamber or bell.

4.1.3 No control gear is to be fitted within the chamber or bell. However, special arrangement may be acceptable after consideration in each case, based on special precautions (e.g. equipment pressurised with pure helium (purging) or protected in accordance with other explosion protection concepts).

4.1.4 Fuses or circuit-breakers are not to be installed within the chamber or the bell, except for emergency battery power supply circuits.

Part C

Machinery, Systems and Fire Protection

Chapter 3

AUTOMATION SYSTEMS

SECTION 1 GENERAL PRINCIPLES

1 General

1.1

1.1.1 Automation systems are to be in accordance with Part C, Ch 3 of the Rules, as far as applicable and reasonable, and with the following requirements.

2 Electrical controls

2.1

2.1.1 Manual backup for electrical controls is to be provided for emergency recovery or surfacing.

2.1.2 Instructions for emergency surfacing are to be permanently affixed adjacent to the manual controls.

2.1.3 Duplicate control leads for a single circuit are not to pass through the same penetrator and are to be spaced as widely apart as is feasible.

3 Communication Systems

3.1

3.1.1 The communication system is to be arranged for direct two-way communication between the control position and the following as applicable:

- diver in water
- bell
- chamber (each compartment)
- diving system handling position and emergency control station
- dynamic positioning room, navigation bridge, ship's command centre, drilling floor, drilling control room.

3.1.2 An emergency means of communication is to be available between the control position and divers in the deck decompression chamber and in the diving bell.

For diving bells, this may be the self-contained through-water communication system required in Sec 2, [1.1.3].

3.1.3 Communication systems are to be installed to minimise disturbances or interference generated by any source of energy.

4 Alarms

4.1

4.1.1 For units intended for transportation of passengers, a bilge alarm is to be provided at the pilot position for early detection of water accumulation.

SECTION 2 ADDITIONAL REQUIREMENTS FOR DIVING SYSTEMS

1 Communication

1.1

1.1.1 Visual observation of divers in each compartment is to be possible. Suitable means (e.g. TV) are to be arranged for visual observation of the divers in the bells and in the chamber compartments from the relevant control positions.

1.1.2 The control position for the bell is to be provided with equipment for audio recording of all communications.

1.1.3 The bell is to be fitted with a self-contained emergency through-water communication system.

1.1.4 A diving bell is to be provided with an emergency locating device.

2 Instrumentation

2.1

2.1.1 Indication and operation of all essential life support conditions to and from the chamber(s) and the bell(s) are to be arranged at the appropriate control position.

Part C

Machinery, Systems and Fire Protection

Chapter 4

FIRE PROTECTION, DETECTION AND EXTINCTION

SECTION 1 REQUIREMENTS FOR FIRE PROTECTION, DETECTION AND EXTINCTION

1 Premise

1.1

1.1.1 As far as applicable, the requirements relevant to fire detection, protection and extinction set out in the Rules for the Classification of Ships may be referred to, in addition to those contained in these Rules.

1.1.2 The requirements of this Chapter 4 are not applicable for the purpose of classification, except where Tasneef carries out plan approval and surveys relevant to fire protec-tion statutory requirements on behalf of the flag Administra-tion. In such cases, fire protection statutory requirements are considered a matter of class and therefore compliance with these requirements is also verified by Tasneef for classifi-cation purposes.

2 Documentation to be submitted

2.1

2.1.1 The following documentation is to be submitted for approval, in triplicate:

a) general arrangement plan, with the indication of the means of escape;

b) passive fire protection plans, with the indication of the adopted materials and the fire tests carried out, if any (specifying the standards taken as reference);

c) active fire protection plans, including the functional plan relevant to the fixed fire-extinguishing system adopted on board, specifying the type of extinguishing media;

d) technical manual as per [3.1.1] b).

3 Active fire protection

3.1 General

3.1.1

a) If specific rules issued by the flag Administration concerning fire protection are available, for the purpose of classification Tasneef may apply such requirements instead of those contained in these Rules.

In such case, a specific annotation is to be reported on the Certificate of Classification.

b) An updated technical manual, containing instructions in case of fire, is to be kept on board.

c) As a general rule, electrical equipment is not to be placed in spaces contaminated or likely to be contaminated by gases and toxic or flammable vapours; however, apparatuses providing measurement, information, alarm, control and telecommunication are allowed in such spaces, provided that that they are certified of a safe type, acceptable to Tasneef on a case-by-case basis, taking into account the nature of the gases and vapors and the type of electrical materials constituting the apparatuses, where their installation is necessary for operational reasons.

To eliminate the danger of explosion due to oxygen leakages, a device is to be installed which prevents the gas supply when the hazard limit is exceeded.

d) Units assigned to purposes having low fire risk may be exempted from the requirements of item [2], when such requirements are deemed unreasonable or unnecessary in the opinion of Tasneef.

e) In enclosed spaces of supply vessels containing underwater units, a fixed water spray system is to be installed. The system is to have manual control and is to have a capacity of at least 10 l/(m^2 · min), to cool the external surface of the units in case of fire in such spaces. If the units are located in open spaces, fire hoses are deemed sufficient.

Fire detection systems fitted in areas located in proximity to decompression chambers are to include:

- automatic alarm devices (siren);
- visual remote signals;
- signals to the "main fire station";
- automatic stopping devices for the DP (Diving Package) ventilation system;
- manual activation of the acoustic alarm.

The detection system may consist of optical smoke detectors; the control panel is to be powered by the emergency source of power. Batteries connected to the control panel are to ensure operation of the system for at least 30 min even in the case of loss of both the on-board main and emergency power supplies.

f) Pressure vessels having a working pressure of at least 0,1 MPa are to be protected by a fixed water spray system provided with manual control and having a capacity of at least 10 l/(m^2 · min) referred to the horizontal projected areas of the vessels.

3.2 Water-based extinguishing system

3.2.1 The system is adopted to cool the external surface of the decompression chambers in case of fire; the system can be considered as a fire-extinguishing system provided that it has a capacity of at least 10 l/(m^2 · min). Activation of the system need only be manual.

3.3 Fixed gas fire-extinguishing system

3.3.1 The system is to protect the Saturation Control Room, the H.P.S. area, the Decompression Chamber Area, the Fire Control Room and the Workshop Area.

Activation of the system is only to be manual.

The system is to be capable of being activated globally or in a dedicated area only.

3.4 Fire detection and fire-extinguishing systems

3.4.1 All fire risk spaces are to be provided with a system capable of detecting the fire and communicating its location.

Such spaces are to be protected by a fixed fire-extinguishing system suitable for the fire risk of the space, having manual and/or automatic activation and deemed acceptable by Tasneef. Foam systems are recommended; CO_2 systems are to be limited to the extinction of fire involving electrical appa-ratus.

Fire growth potential of spaces other than those of fire risk is to be evaluated and safety measures are to be taken as appropriate.

For this purpose, where passing through fire risk spaces (e.g. battery rooms, which may contain H_2 vapours), piping of fixed fire-extinguishing systems is to be provided with bursting disks.

The remote release control of the fixed fire-extinguishing system protecting the engine room is to be located in the manoeuvring control room.

In units provided with only one space, or more than one space but not separated by means of watertight bulkheads, only portable fire extinguishers can be used. Their number and location are to be deemed satisfactory by Tasneef. The release of the fire-extinguishing medium is to be operated manually.

4 Passive fire protection

4.1 General

4.1.1 Hull and structure are to be made of non-combustible materials; internal surfaces are to be faced with paints and varnishes which do not constitute a fire hazard and do not produce smoke or toxic products.

Where combustible materials are used in connection with internal partitions, their combustion potential is to be low, taking into account the areas in which they are used; materials having self-extinguishing capability in an atmosphere containing 18÷28% oxygen are preferable.

Internal partitions made of non-combustible materials may be faced with veneers not exceeding 1,5 mm thickness and having low flame spread characteristics.

A sample of any combustible material used on board is to be subjected to a combustibility test during which it is not to emit smoke or toxic gases.

Fire hazard sources, including related causes and consequences, are to be examined within each compartment.

Spaces like engine rooms, where special measures are likely to be taken due to the proximity to sources of ignition and flammable liquids, are considered by Tasneef as fire risk spaces.

The above areas are to be separated from those adjacent by means of fire-resistant bulkheads capable of preventing the spread of smoke and flames and insulated in such a way as to keep the temperature increase within values deemed suitable by Tasneef.

Escape corridors, control stations and other strategic spaces are to be protected in an equivalent way from the structural fire protection point of view.

Following the standard fire test, the integrity of the main structural members located in or forming the boundaries of fire risk spaces is not to change in such a way as to cause a further fire hazard.

It is to be ascertained that components necessary for fire extinguishing or to steer the unit are not impaired by a fire spreading from a space constituting a fire hazard. Otherwise, they are to be separated from such spaces by means of divisions capable of passing the standard fire test for a time deemed suitable by Tasneef.

Pipes, ducts and cables penetrating fire-resistant divisions are not to impair the fire integrity of the pierced division.

In areas where oil penetration is possible, the insulation surface is to be impervious to oil or oil vapours.

Within hyperbaric chambers, in order to contain the fire hazard, the following equipment is to be installed, as far as practicable:

a) external lights (internal lighting provided, for example, by means of optical fibres);
b) electric motors not fitted with brushgear in order to avoid spark generation.

4.2 Machinery installation

4.2.1 Potential ignition sources, including electrical apparatus, are to be separated, as far as possible, from arrangements containing flammable liquids.

Where adequate separation is not possible, suitable provisions are to be made.

4.3 Arrangements for fuel oil and other flammable oils

4.3.1 Tanks containing fuel oil, lube oil or other flammable oils are to be separated from crew accommodation by means of gas-tight cofferdams. Suitable provisions are to be arranged for ventilation and drying of such cofferdams.

The tanks are to be made of steel or other material deemed suitable by Tasneef and, as far as practicable, they are not to be placed in areas having a fire hazard or in spaces adja-cent to such areas.

Means are to be provided to close the flow of flammable liquids to areas having a fire hazard; such means and their controls are to be placed outside the hazardous areas.

Piping conveying flammable liquids is to be made of steel or other material deemed suitable by Tasneef taking into account its strength and resistance to fire, and considering the fire hazard of the areas where pipes pass through.

Pipe connections are to be deemed satisfactory by Tasneef. Flexible pipes can be used only where strictly necessary and are to be of a type approved by Tasneef.

Sections of fuel piping penetrating watertight bulkheads are to be made of steel. The connection between such piping and the fuel tanks is to be made by means of flanges.

4.4 Ventilation

4.4.1 All fans are to be capable of being stopped from a position located outside the spaces served.

Ventilation ducts are to be capable of being closed from outside the compartments having a fire hazard.

Duct penetrations through watertight compartments are to be made in such a way as not to impair their fire resistance.

4.5 Fire hazard

4.5.1 The fire hazard is considered significant when oxygen concentration in the atmosphere exceeds 21%.

Products such as paints, lubricants, adhesives, furniture and furnishings, etc. are to be certified by the Manufacturer as non-combustible even in such conditions.

Crew members operating within and having access to decompression chambers (irrespective of whether they are pressurised) cannot take lighters or matches inside the chambers.

Fluorocarbon or silicon grease is to be used for the lubrication of parts located within decompression chambers and bells and within their proximity.

5 Portable fire-fighting appliances for units having L > 20 m

5.1

5.1.1 The following portable fire-fighting appliances are to be carried on board, as a minimum:

- two safety lamps;
- two fire fighter's axes;
- one crowbar;
- four buckets with lines (the line is to be long enough to reach the sea surface standing on the main deck and considering the unit in the lightest seagoing conditions);
- one fire-resistant blanket;
- spare bulbs and batteries;
- two CO_2 or foam portable fire extinguishers for each space where crew/personnel are foreseen (CO_2 is preferable)
- portable fire extinguishers of an approved type as requested by the Rules for the Classification of Ships for machinery spaces containing internal combustion engines, spaces where fuel-related equipment is located, settling tanks, service spaces, galleys containing cooking equipment using gaseous fuel, paint stores and stores containing flammable liquids, manoeuvring control room, radio station (if located in a dedicated space);
- one CO_2 portable fire extinguisher of an approved type in proximity to any electric switchboard having a power of at least 20 kW;
- five spare charges for foam extinguishers;
- one spare CO_2 extinguisher.

6 Portable fire-fighting appliances for units having L ≤ 20 m

6.1

6.1.1 The following portable fire-fighting appliances are to be carried on board, as a minimum:

- two safety lamps;
- spare bulbs and batteries;
- one CO_2 portable fire extinguisher of an approved type, for each space.

7 Breathing system

7.1

7.1.1 In the case of smoke on board, the crew are to be capable of breathing by means of one of the following systems:

a) a system which is made up of a mask connected by means of a flexible hose to the pipeline of the (main and emergency) breathing system;

b) a self-contained system which is made up of a gas-tight PBS (packaged breathing system) set, connected to an air bottle and provided with valves for CO_2 discharge; this device is to allow breathing for a time equal to twice that necessary to emerge or 1 hour, whichever is the greater.

Masks or PBS sets are to be available for all crew members on board. Two additional masks or PBS sets are to be provided. At least two crew members are to be provided with breathing apparatus connected with air bottles.

RULES FOR THE CLASSIFICATION OF UNDERWATER UNITS

Part D
Materials, Welding and Testing

Chapters **1 2 3**

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MATERIALS

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CHAPTER 2
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Section 1 Testing Procedures

Part D

Materials, Welding and Testing

Chapter 1

MATERIALS

SECTION 1 MATERIALS USED FOR HULL CONSTRUCTION

1 General

1.1

1.1.1 The characteristics of the materials to be used in hull construction are to comply with the applicable requirements of Part D of the Rules and with any addition or modification contained in this Section.

1.2

1.2.1 Materials not dealt with in Part D of the Rules are to comply with the reference specifications used for their acceptance for classification purposes and shown on the approved drawings and/or in the testing application documentation.

For acceptance of the said materials, generally, detailed information about their characteristics and fabrication procedures are to be submitted for review and preliminary tests may be requested.

1.3

1.3.1 As far as material soundness, relevant examination and acceptance criteria are concerned, the requirements of Part D of the Rules are applicable except when more stringent requirements exist.

1.4

1.4.1 Fabrication procedures are to be suitable in order not to damage the materials' characteristics.

1.4.2 In particular, materials to be welded are to have proper weldability properties with reference to the applicable processes and procedures in order to guarantee the required soundness and mechanical characteristics in the as-welded condition or after thermal stress relieving, if any.

1.5

1.5.1 Quality and testing requirements are contained in the following [3] and in Pt D, Ch 1, Sec 2, [1] of the Rules.

Special precautions are to be taken in order to avoid galvanic corrosion should dissimilar materials come into contact.

2 Materials intended for hull or other elements under external hydrostatic pressure

2.1

2.1.1 Such parts are, generally, to be made of steel of the 5000 series, aluminium alloy (Al-Mg), non-metallic materials such as fibre reinforced plastic (FRP) and acrylic polymers.

Different materials from the above may be considered on a case-by-case basis.

2.1.2 The materials to be used are to be evaluated as globally suitable for the design load and environment having considered all possible risks of failure during the whole operating period.

Therefore, in addition to the characteristics essential to the structural stability and weldability, the properties of the materials relevant to brittle fracture, fatigue, corrosion, stress corrosion, flammability and compatibility with other materials are to be evaluated when applicable.

Resistance to the external hydrostatic pressure throughout the life of the component is to be considered in particular for FRP.

2.2

2.2.1 The materials exposed to the atmosphere, including the welding joints, if any, are to be suitable for the minimum design temperature of the classified unit.

2.3

2.3.1 Special precautions (i.e. insulation) are to be taken in order to limit thermal flux through the hull structure, which may otherwise damage the unit's internal equipment.

2.4

2.4.1 Detailed specifications of the material properties and of the fabrication process are to be submitted for approval.

2.5

2.5.1 Approval of the fabrication process may be required. Such approval is generally required if FRP is used.

2.6

2.6.1 In the case of request for acceptance of materials or applications that have not been properly tested, specific tests may be required.

3 Steel products

3.1 General

3.1.1 Normal and higher strength hull plates and profiles are to comply with Pt D, Ch 2 of the Rules.

3.1.2 Forgings and castings are to comply with:

- Pt D, Ch 3 and Ch 4 of the Rules
- recognised standards

Their characteristics are to be suitable for the parts they are joined with and, when applicable, to meet the requirements stated in [3.4].

3.1.3 The weldability of products different from those specified in [3.1.1] is to be evaluated by Tasneef if intended for welded structures. Information and tests may be required for this purpose.

3.2 Structure subdivision

3.2.1 Unit structures are divided into three categories: special, primary and secondary, in decreasing order of importance, as defined in [3.2.2], [3.2.3] and [3.2.4]. This subdivision is to be considered in selecting the relevant steel grades.

3.2.2 The following structures are included in the special category:

- inhabited hulls subjected to hydrostatic pressure,
- parts directly connected to the above hulls,
- considered as such on the approved drawings.

3.2.3 The following structures are included in the primary category:

- non-pressure bearing parts, used to contain or support equipment in inhabited hulls,
- non-inhabited hulls subjected to hydrostatic pressure,
- parts directly connected to the above parts and hulls,
- considered as such on the approved drawings.

3.2.4 Structures not included in the special or primary categories are to be considered in the secondary category.

3.3 Hull steels - Selection based on structure category

3.3.1 Thickness limits of wrought steels intended for hull structures operating at ambient temperature not lower than -10°C, for thicknesses up to 100 mm, are to be in compliance with Pt B, Ch 4, Sec 1 of the Rules.

Thickness limits are considered for products with tested impact properties.

3.3.2 For the three categories listed in [3.2], 100 mm maximum plate thickness may be used. Based on the plate thickness, a suitable post-weld heat treatment is required.

3.3.3 In the case of plate thickness > 100 mm, steel properties will be established by Tasneef on a case-by-case basis.

3.4 Steel grades other than hull wrought grades. Charpy V-notch impact test.

3.4.1 Weldable C-Mn and micro-alloyed steel grades, other than Tasneef hull grades, considered acceptable are to meet the requirements stated in [3.4.2], [3.4.3] and [3.4.4] for Charpy V-notch impact tests with longitudinal speci-mens.

These requirements are to be verified during testing activities according to the procedures stated in Part D of the Rules. The values stated below are considered as the average value on three test specimens with only a single value below the average value, but not below 70% of it.

The requirements on transverse specimens are 2/3 of the longitudinal specimen values.

3.4.2 For products intended for special structures to be operated in the as-welded condition, the Charpy V-notch impact test requirements are listed below, tp being the test temperature, td the minimum design temperature and s the product thickness (mm).

a) Steels having minimum specified yield strength ≤ 270 N/mm²:

$s \leq 25$ $KV \geq 27$ J at $t_p \leq t_d - 10°C$

$25 < s \leq 40$ $KV \geq 27$ J at $t_p \leq t_d - 20°C$

$40 < s \leq 50$ $KV \geq 27$ J at $t_p \leq t_d - 30°C$

$50 < s \leq 60$ $KV \geq 27$ J at $t_p \leq t_d - 40°C$

$60 < s \leq 70$ $KV \geq 27$ J at $t_p \leq t_d - 50°C$

When the test temperature, as required above, is below -60°C, it may be limited to -60°C.

b) Steels having minimum specified yield strength $> 270 \div 360$ N/mm²:

required $KV \geq 40$ J

Test temperature depending on product thickness, according to item a) above.

c) For steels having minimum specified yield strength or thickness above the values specified in a) and b) above, the requirements will be established by Tasneef on a case-by-case basis.

3.4.3 For products intended for special structures to be operated in post-weld heat treatment condition and for permanently submerged parts, the test temperature may be 20°C above the value prescribed in [3.4.2], the other conditions remaining unchanged; in any event, the test temperature is not to be above 0°C.

3.4.4 For products intended for structures other than special structures, made with steel grades with minimum specified yield strength ≤ 360 N/mm², the impact requirements are in accordance with the provisions in [3.3].

3.4.5 Requirements for products made with steel grades with minimum specified yield strength > 360 N/mm² are considered by Tasneef on a case-by-case basis.

3.4.6 Tasneef may consider alternative test methods to the impact test if the reliability level is considered not lower than that of the impact test.

3.5 Ultrasonic examination of plates

3.5.1 Plates intended for special structures are to be examined by means of ultrasonic test by the Manufacturer using procedures and requirements agreed with Tasneef.

3.5.2 Tasneef Surveyors may witness the examination.

SECTION 2 GENERAL REQUIREMENTS FOR PLASTIC MATERIALS OF WINDOWS

1 Transparent plastic material windows

1.1 General

1.1.1 Transparent polymethyl methacrylate (PMMA) windows are accepted having minimum specified compressive yield strength $\geq$ 105 N/mm^2. The semi-finished products are to be obtained by catalytic polymeralisation cell casting from monomer methacrylate (MMA) with suitable additives.

The semi-finished products are to be free from plasticising substances and inert charges. Wrought products are not allowed.

Weight composition, minimum physical properties, nominal thickness and related tolerances for PMMA are shown in Tab 1, Tab 2 and Tab 3.

The window conical or spherical angle is not to shift from the nominal value by more than 0,25°.

Semi-conical windows supporting the surface conical angle are not to shift from the nominal value by more than 0,25°.

The spherical window bend radius is not to shift from the nominal value by more than 5% of the external bend radius.

Each window is to be annealed after forming and cleaning.

Table 1

PMMA weight composition **(1)**	
Homopolymer MMA	≥ 95 %
Free monomer	≤ 1,5 %
Total water	≤ 1,2 %
Ashes	absent
Additives	balance
(1) according to the Manufacturer's declaration	

Table 2 : Physical PMMA properties

Property	Required value	Test method	Note
Mass, at 20°C	1,18 ± 0,01 g/cm^3	ISO1183 / ASTM D7922	**(1)**
Tensile strength, at 20°C	≥ 65 N/mm^2	ISO527 / ASTM D638	**(2)**
Elongation, at 20°C	≥ 2 %	C.S.	**(2)**
Modulus of elasticity, at 20°C	≥ 3200 N/mm^2	C.S.	**(1)**
Charpy (no notched specimens), at 20°C	/	/	/
average value	≥ 2,5 J/cm^2	ISO 179	**(2)**
minimum value	≥ 2 J/cm^2		
M-Rockwell hardness, at 20°C	≥ 100	ISO2039 / ASTM 785	**(2)**
Light transmittance, "C" factor	≥ 92 %	/	**(1)**
Turbidity	≤ 2%	/	**(1)**
Vicat softening temperature, method A	≥ 120 °C	ISO306 / ASTM D1525	**(1)**
Temperature of deflection under load	≥ 105 °C	ISO75 / ASTM D648	**(1)**
Warm dimensional stability	± 2 %	/	**(1)**

(1) according to the Manufacturer's declaration
(2) to be checked when accepting the material

Table 3 : Nominal thicknesses and admissible tolerances of PMMA sheets

5	± 0,55 mm
6	± 0,60 mm
8	± 0,65 mm
10	± 0,70 mm
12	± 0,72 mm
15	± 0,75 mm
20	± 0,80 mm
25	± 1,00 mm
> 25	± 4 mm

Note 1: PMMA may be used up to 55°C (maximum operating temperature). Burst tests are to be performed at the maximum operating temperature on two samples taken from the same batch. The following conditions are to be satisfied:

- temperature between -10 and +55°C
- material in contact with chemically inert fluids.

SECTION 3 SEA WATER METALLIC PIPING SYSTEM

1 General

1.1

1.1.1 The sea water metallic piping system is to have good corrosion resistance to stagnating and moving sea water, to be workable (i.e. formable at low bend radius) and joinable with other parts by welding or brazing.

2 Copper piping

2.1

2.1.1 Copper alloys have good general and pitting corrosion resistance in stagnating sea water. For Cu-Ni 90/10 alloy, a 0,025 mm/year corrosion rate may be assumed, considering also that such alloy has a low tendency to pitting corrosion.

"Impingement attack" is a relevant failure mode for copper alloys: such localised failure is due to the combined corrosion-erosion effect of a fast flowing fluid on a metal surface. Such phenomena occur when sea water turbulence damages the oxide protective layer. The local unprotected surface acts as the anode, the remaining protected surface being the cathode. The attack takes place when turbulent flow includes air bubbles.

Resistance to the said failure mode increases from copper to admiralty brass, aluminium brass, Cu-Ni 90/10 and Cu-Ni 70/30.

The "impingement attack" resistance increases considerably if some iron is contained in the copper-nickel alloys: 0,7% iron content in Cu-Ni 70/30 and 1,5% iron content in Cu-Ni 90/10 is suitable.

0,0125 mm/year corrosion rates for Cu-Ni 90/10 (1,5% iron content) and Cu-Ni 70/30 (0,7% iron content) may be assumed. 0,015 mm/year corrosion rates for Cu-Ni 90/10 (0,8% iron content) may be assumed.

MONEL 400 alloy has low applicability because of pitting susceptibility.

Port sea water, polluted by urban and industrial wastes, and sometimes containing hydrogen sulphide, may have a low oxygen content. When the copper alloy surface is in contact with such water, the oxide protective layer cannot form on the alloy surface and, in the event of the unit operating for a long time in such water, intergranular corrosion may occur in Cu-Ni alloys.

The optimum and maximum allowable design velocities of sea water in a copper alloy piping system are shown in Tab 1.

At higher velocity values, the failure probability increases (it is to be considered that higher values may be admitted in higher diameter pipes). Cu-Ni alloys, having higher design velocity, allow smaller diameter pipes giving weight reduction.

Pitting and intergranular corrosion in Nickel and MONEL 400 alloy may be eliminated by applying cathodic protection having a polarising voltage from 600 to 800 V with respect to the reference calomel electrode.

Table 1

Material	Optimum design velocity (m/s)	Maximum allowable design velocity (m/s)
Copper (phosphorus deoxidised)	0,75	1
Aluminium brass	2,5	2,6
Cu-Ni 90/10	3	4
Cu-Ni 70/30	3,5	4

3 Zinc coated steel piping

3.1

3.1.1 The corrosion rate in steel pipes increases with water velocity, from 0,1 mm/year in still water to 0,75 mm/year in 3 m/s flowing water. Zinc coating increases piping life. In Fig 1 the zinc corrosion rate in sea water is shown with reference to the sea water flow velocity (Tc is the corrosion rate in μm/year and V is the water flow velocity in m/s). Zinc coated piping requires more frequent maintenance compared to Cu-Ni piping.

4 Stainless steel piping

4.1

4.1.1 Stainless steel is subject to pitting corrosion in sea water: its use is not recommended.

5 Fabrication practice

5.1

5.1.1 Copper alloy pipes may be cold formed. In order to obtain a smooth surface after forming, pipes are preferably to be filled with Sodium Thiosulphate, which is highly water soluble. If coal is used as a filling medium, any residual coal film trace is to be removed from the pipe surface since the material may corrode where such film is damaged. If pitch or resin is used, their residues may be burned by heating the pipe at 600-650°C with internal air or oxidising flow.

To facilitate the filling operation, the pipe ends may be closed with lead caps.

A smooth curve surface is preferred to a wrinkled one because wrinkle bending may cause turbulence and pipe failure. The bending procedure is to be such that the outer surface of the curve is strained rather than the inner surface being compressed.

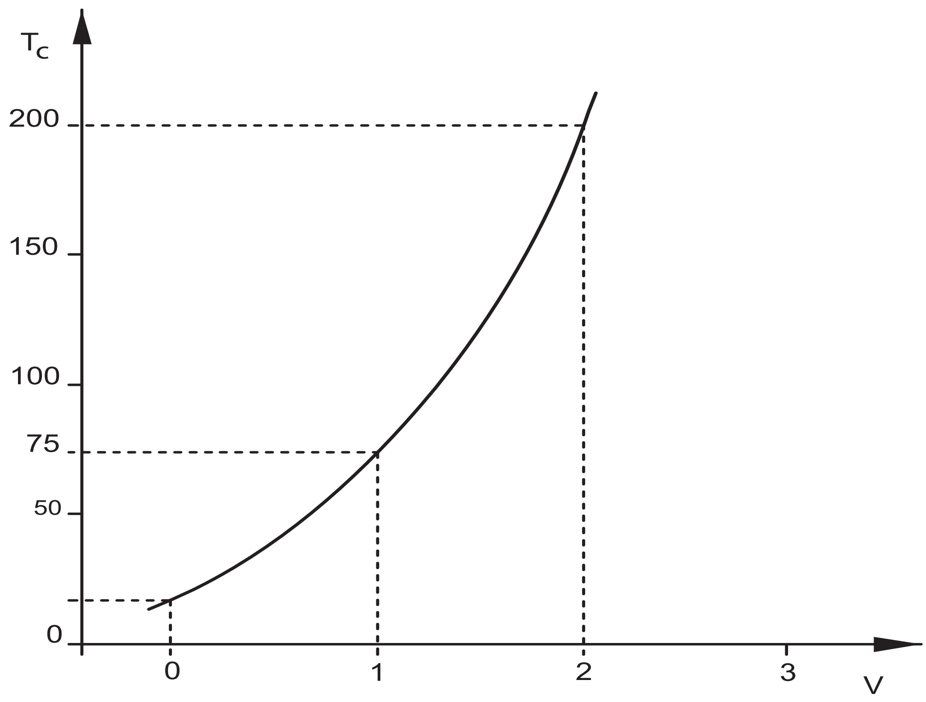
Deposits in way of the wrinkles may cause crevice corrosion.

Forming procedure to obtain a medium bending radius less than 3,5 times the pipe diameter is to be agreed with Tasneef.

When required, hot forming of Cu-Ni 90/10 pipes is to be carried out in a 650-800°C temperature range.

In the case of hot forming, sand free from organic material, traces of oil and dirt is the preferred filling medium. It is preferable to concentrate the heat flow on the outer curve surface so that it is strained during forming rather than the inner surface being compressed.

Figure 1



SECTION 4 HIGH STRENGTH NUTS AND BOLTS

1 General

1.1

1.1.1 Bolts for dismountable hatches may be admitted in units suitable for the exit of underwater operators. Bolts are made with head and screwed stem, screwed nut and, possibly, a washer.

Two high strength steel nuts and bolts are usually applied:

a) Quality 1:
- steel bolt with $R_m = 1000 \div 1200$ N/mm²
- steel nuts with $R_m = 800 \div 1000$ N/mm²

b) Quality 2:
- steel bolt with $R_m = 800 \div 1000$ N/mm²
- steel bolt with $R_m = 600 \div 800$ N/mm²

where R_m is the minimum tensile strength.

The steelmaking process for steel nuts and bolts is to be: Martin-Siemens type, electric arc furnace, pure oxygen ignition or any other process approved by Tasneef.

The chemical composition of steel used for nuts and bolts is shown in Tab 1. Different compositions may be accepted by Tasneef provided that the mechanical properties listed below are verified on the finished products.

1.2 Heat treatments

1.2.1 Nuts and bolts are to be quenched in oil or water and then tempered at a temperature not below 500°C.

Washers may be quenched and tempered or, preferably, carburised and subsequently quenched and tempered.

Table 1

Component %	Steel with R_m = 1000 N/mm²	Steel with R_m = 800 N/mm²	Steel for washers
C	0,35 ÷ 0,45	0,35 ÷ 0,45	≤ 0,25 if not carburised
Mn	≥ 0,5	≥ 0,5	≤ 1,00
P	≤ 0,035	≤ 0,035	≤ 0,04
S	≤ 0,035	≤ 0,035	≤ 0,05
Cr	0,85 ÷ 1,15	≥ 0,3 (Ø > 16 mm)	-
Mo	0,15 ÷ 0,3 (Ø > 16 mm)	-	-

Part D
Materials, Welding and Testing

Chapter 2
WELDING

SECTION 1 CONSUMABLES AND WELDING PROCEDURES

SECTION 1 CONSUMABLES AND WELDING PROCEDURES

1 Consumables, welding processes and procedures

1.1 General

1.1.1 Consumables, welding processes and procedures are to be approved in accordance with Pt D, Ch 5 of the Rules. The consumable grade selection is to be in compliance with Pt B, Ch 12, Sec 1, [1.3.2] of the Rules.

1.1.2 Except when otherwise allowed, test samples for the approval of welding procedures are to be taken from plates of the same steel type and grade and having thickness not lower than that used for the relevant structures.

1.1.3 Independently of the base and filler materials, processes and welding procedures, the impact V-notch requirement in the fusion and heat-affected zones is 27 J at a test temperature not higher than that prescribed for the base material.

2 Welded structures

2.1

2.1.1 Welding execution is to be in compliance with the requirements of Pt B, Ch 12 of the Rules.

2.1.2 For special category structures, tests on production welded samples are to be carried out as required for class 1 pressure vessels. In particular, impact tests are to be conducted in the fusion and heat-affected zones as required in [1.1.3].

2.1.3 Weld joints of special category structures are to be subjected to visual and non-destructive examination as required for class 1 pressure vessels. For all other structures, the requirements relevant to hull structures in Pt B, Ch 12 of the Rules apply.

3 Brazing and welding of the copper alloy piping system for sea water

3.1 Brazing and welding

3.1.1 Brazing

To obtain good sea water corrosion resistance, the use of silver alloy filler materials with minimum 50% silver content is recommended. Alloy with lower silver content may be subject to selective corrosion, similar to zinc depletion phenomena, and this may lead to failure in sea water.

The brazing process is to be performed by skilled operators and maximum attention is to be given to all process phases. Defective brazed joints are to be rejected.

The use of Cu-Zn alloys may lead to corrosion and, when using Cu-Ni alloys, the use of Cu-P filler materials may result in brittle joints.

Joint clearance between the pipe, flange and other accessories to be brazed is to be at least 0,08 mm and accordingly, the difference between the external pipe diameter and internal flange/accessory diameter is to be between 0,1 and 0,2 mm.

Joint surfaces are to be cleaned, either chemically or mechanically, before brazing.

If Cu-Ni pipes have been cold worked, they are to be heated to 600-650°C (cherry red) for 3 minutes before brazing. During this operation, de-oxidant flux may be applied on joint surfaces but not the filler metal, since there is a risk of cracking due to intergranular penetration of the liquid filler material.

Neutral flame is recommended and the joint surfaces are to be heated uniformly.

The filler metal is to be applied by making it melt on the pipe surface and not in the flame.

The joint is to be obtained thanks to the capillarity property of the fused filler material. It is not required to create a large filler layer.

When brazing, the joint is not to be moved or forced. When the clearance is filled, the joint is to cool down without being touched until it becomes black. At this stage, oxides and flux residues may be removed. Flux residues are normally soluble in water but, if the joint has been heated for a long time, they are difficult to remove so it may be necessary to do this by means of mechanical tools such as metal brushes and chisels.

3.1.2 Welding

Cu/Ni alloy is welded by the TIG process (for butt weld thickness below 5 mm) and the MIG process (in other cases, with V-groove) and, if the joint comes into contact with sea water, a Cu-Ni 70/30 filler metal is to be used, trying to avoid excess filler metal in order to limit turbulent flow inside the pipe, which could lead to erosion-corrosion phenomena.

Argon backing gas is to be used. Nitrogen is not allowed since it reacts with fused metal, forming a porous brittle layer on the back of the weld joint.

If the piping is made of Cu-Ni 90/10 alloy, steel flanges may be used in lieu of brass flanges. Steel flanges, obtained from plate, may be welded to Cu-Ni 90/10 alloy, while brass is to be brazed to Cu-Ni 90/10 alloy.

Welding is to be performed in a flat position, as far as possible.

A composite flange (fig 1) is more complicated but is advantageous since the external flange may be rotated to match the bolt holes during assembly.

Pipes are usually welded to flanges by the TIG process with Cu-Ni 90/10 filler metal. When bronze or brass cast flanges are used, preheating the flange with a wide gas flame until the surface reaches 650°C is recommended. In this way, the risk of cracking due to differential thermal gradient after welding is reduced.

Preheating is not required when using steel or Cu-Ni flanges.

3.2 Thermal stress relieving

3.2.1 Cu-Ni 90/10 has a high stress corrosion resistance in sea water. Thermal stress relieving after cold forming is recommended but not essential.

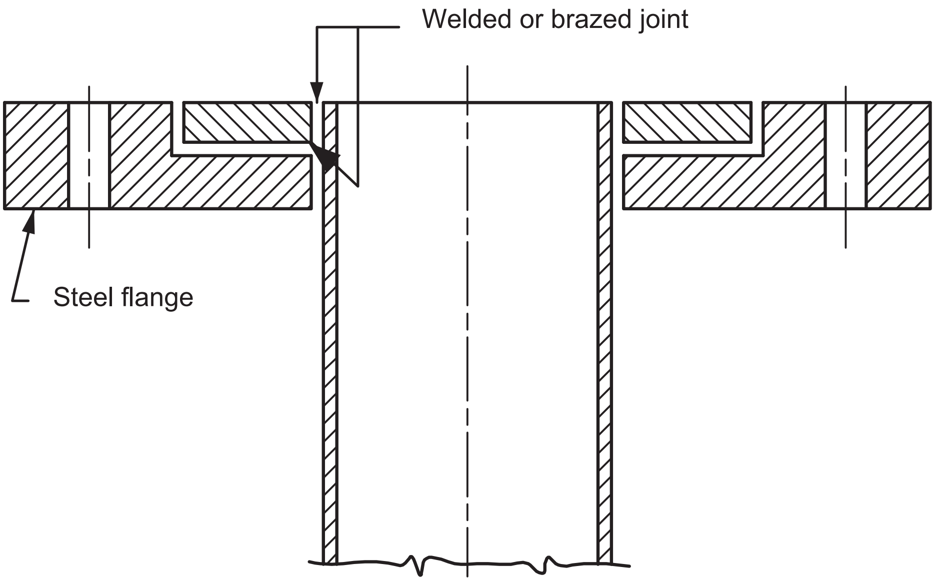
The brazing filler metal may cause cracks when wetting the restrained pipe surface. In order to avoid thermal stress relieving, precautions are to be agreed with Tasneef so as to prevent contact between the restrained pipe surface and the fused brazing filler material.

Thermal stress relieving is required on aluminum brass piping since such alloy may undergo stress corrosion cracking. After thermal stress relieving, piping is to be pickled with 5-10% sulphuric acid solution and 25-50 g of sodium bichromate per litre. After pickling, piping is to be rinsed with warm water.

Pickling is not mandatory if pipes are not heated after cold forming; however, it is also recommended in such case.

Soft annealing on Cu-Ni 90/10 at 750-800°C is performed if pipes are to be further cold formed. Stress relieving is to be carried out at 350-450°C.

Figure 1



Part D
Materials, Welding and Testing

Chapter 3
TESTING

SECTION 1 TESTING PROCEDURES

SECTION 1 TESTING PROCEDURES

1 General

1.1

1.1.1 Testing of materials is to comply, as far as possible, with the requirements of Part D of the Rules, with any modifications stated hereafter. Different procedures may be accepted to Tasneef's satisfaction.

2 Testing of plastic transparent materials for windows

2.1 Tests required in the presence of the Surveyors

2.1.1

a) Each sheet is to be subjected to tensile, impact and hardness tests.

b) The test samples are to be obtained from a strip taken from the whole side of the sheet at a distance of at least 50 mm from the original sheet edge. By means of mechanical working, 5 specimens for tensile tests and 5 samples for impact tests are to be prepared. On the same strip, 5 Rockwell hardness imprints are to be measured. The strip is to be wide enough so that test and re-test samples may be taken.

c) Samples are to be worked by the milling machine, so that the sample edges are clean and free from cuts and irregularities which may impair the test results. The milling machine is to be water- or air-cooled.

d) Before test execution, samples are to be thermally treated in a recirculation air oven at 50 ± 2°C for 48 hours, then kept in a standard laboratory atmosphere (23°C, 50% relative humidity) for 40 hours for sheet thickness up to 7 mm and for 60 hours for sheet thickness above 7 mm.

e) Tensile, impact and hardness tests are to be carried out according to the following procedures:
   - Tensile test to be in compliance with Pt D, Ch 1, Sec 2, Tab 2.

     The average value from 5 specimens is to be at least 65 N/mm^2 and no single value is to be below 80% of 65 N/mm^2 (52 N/mm^2).
   - Impact test to be in compliance with Pt D, Ch 1, Sec 2, Tab 2. The average value from 5 specimens is to be at least 2,5 J/cm^2 and no single value is to be below 2 J/cm^2.
   - Rockwell M hardness test to be in compliance with Pt D, Ch 2, Sec 1, Tab 2. Tests are to be carried out on a sheet having the same thickness as that under examination. The average Rockwell hardness, measured on 6 imprints, 3 on each sheet face, is to be not lower than 100.

2.2 Re-test

2.2.1 If any one of the tensile, impact or hardness tests does not meet the requirements stated in [2.1.1] it is possible to repeat the failed test on double the number of samples, i.e. 10 samples for tensile and impact tests, 12 imprints for hardness test. If more than one of the tensile, impact and hardness tests fails, it is not permissible to repeat the tests.

All the results of the re-test are to meet the requirements stated in [2.1.1]. Re-testing is allowed only once.

2.3 Certificates and marking

2.3.1

a) Each sheet is to have the relevant Manufacturer's certificate on which the following data are recorded: material specification, fabrication procedure, resin composition as per Pt D, Ch 1, Sec 2, Tab 1, dimensions, Manufacturer's name, sheet identification number, material properties as per Pt D, Ch 1, Sec 2, Tab 2.

b) The Manufacturer's name and sheet identification number are to be marked by means of indelible ink or hot punching with depth not exceeding 0,1 mm.

2.4 Forming and fabrication

2.4.1

a) The Manufacturer is to verify that the forming procedure does not modify the original chemical and mechanical properties and that the fabrication procedures do not induce residual strains which may modify the stability conditions of the component.

b) All joints are to be butt type with polymerising adhesives and without butt straps.

2.5 Final inspection

2.5.1

a) After fabrication, the frame is to be visually examined. Abrasion marks, cuts, scratches, inhomogeneity or anomalous colouration are not allowed.

b) All joints are to be checked by means of:
   - visual examination to detect absence of gas inclusions, discontinuities or discolouring.
   - tensile test transverse to the joint: three specimens for each joint are to be taken from a production sample. The joint is to be localised in the middle of the specimen. The measured minimum tensile

strength is to be not below 60% of the relevant value of the sheet as per Pt D, Ch 1, Sec 2, Tab 2.

c) A hydrostatic test at 2,5 times the operating pressure is required.

2.6 Testing of acrylic resin windows

2.6.1 Flat windows are preferable to conical windows, since the latter require accurate fabrication procedure and high dimensional precision also in the flange fit-up.

Design pressure may be ¼ of the critical breaking pressure p_c. Critical pressure pc for conical windows (Fig 1) with $\alpha \geq 90°$ and diameter $\phi = D_o - 2\varepsilon$ is nearly the same as for flat windows with the same thickness t.

The test is to be carried out by placing the window on a particular flange as shown in Fig 2.

Windows are to be subjected to pneumatic or hydrostatic pressure. The pressurising fluid temperature is to be equal to the design window temperature with 0°C / - 2,5°C tolerance. Deviation from this value may be admitted, but not higher than 5,5°C for not more than 10 minutes.

Pressure is to be increased, on the side to be tested, until failure of the window at a velocity of 4,2 ÷ 4,9 N/mm^2 per minute (MPa/min) and keeping the gas or water temperature between 18 and 24°C; during depressurization, the pressure gradient is not to be higher than 4,5 MPa/min.

The following symbols are used:

D_i : net internal diameter at the opening on the support flange "F" on the atmospheric pressure side.

D_o : internal diameter at the opening on the support flange "F" on the test pressure side.

D_p : tested window diameter

$$\varepsilon = \frac{D_o - D_p}{2}$$

p_c : pressure at which the tested window breaks

t : nominal thickness of the tested window.

Tolerance on the nominal thickness t ± 0,05.

During the test, the test pressure, once reached, is to be maintained for at least 1 hour but for no more than 4 hours. If even a small leakage from the support flange is found, the flange is to be changed and a new test performed.

After the test, the window is to be visually examined to check for any defects, cracks or permanent deformation. If there are any, the window is to be rejected.

Figure 1

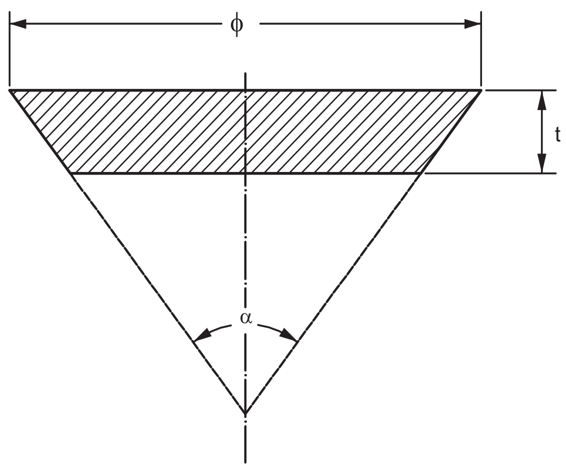
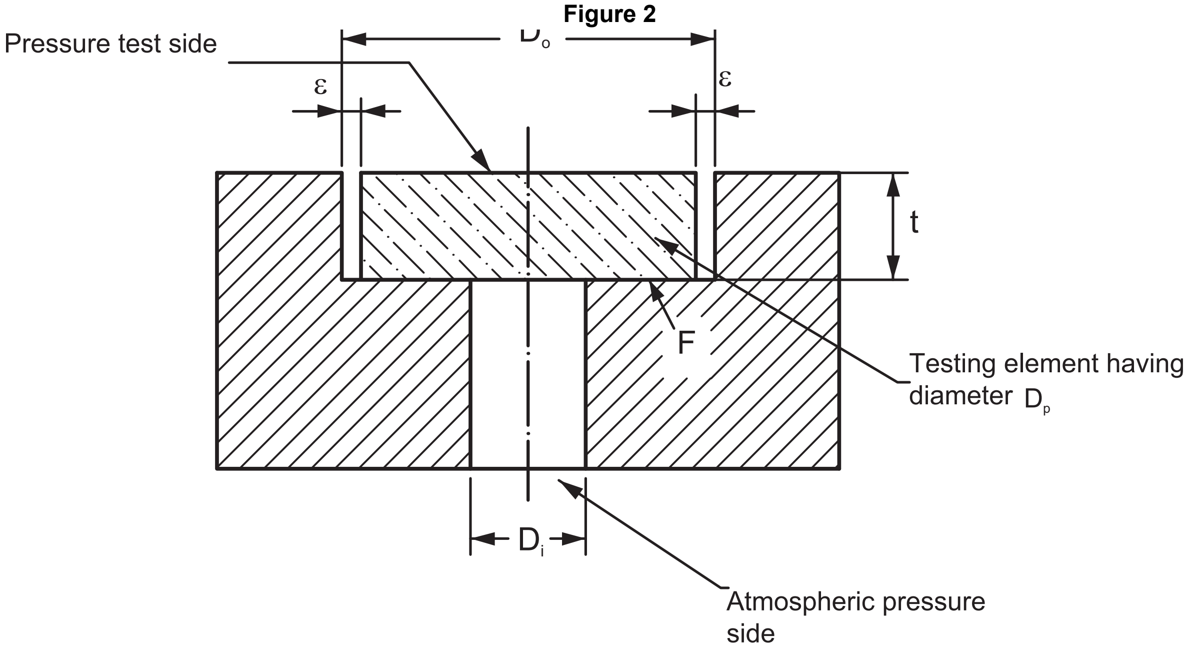


Figure 2



3 Testing of components of underwater vehicles operating without on-board personnel

3.1 General

3.1.1

a) Pipes for auxiliary systems (nitrogen, water, air, oil), valves and flexible hoses: the Manufacturer's test certificate may be accepted provided that a hydrostatic test at 1,5 times the maximum working pressure is performed in the Surveyor's presence.

b) Hydraulic motors (i.e. for track drive): the Manufacturer's test certificate may be accepted provided that a hydrostatic test at 1,5 times the maximum working pressure of the pressurised parts is performed in the Surveyor's presence.

c) Oil filters: the Manufacturer's test certificate may be accepted.

d) Track or other equipment: the Manufacturer's test certificate may be accepted.

4 Testing of bottles for breathing apparatus

4.1 General

4.1.1 Bottles are to be manufactured so that they can guarantee:

- external and internal pressure resistance
- corrosion resistance
- lightness
- aerodynamic and compact shape for optimum functionality.

Bottle thickness s is to be, in general, as shown in Fig 3, where:

a :is the phosphatised zone (made with Mn and Zn phosphates) or equivalently treated. Phosphatisation, to be applied after blasting, is to be homogeneous to avoid internal oxidation. Transparent non-toxic resin coating is not acceptable since it flakes the distributor sintered filter and interrupts the mixture supply

b : is the bottle base material (i.e. high strength steel, aluminum alloys)

c : is the galvanic zinc coating having 40 μm minimum thickness (after blasting)

d : is the epoxy coating having high corrosion resistance

e : is the high strength enamel paint.

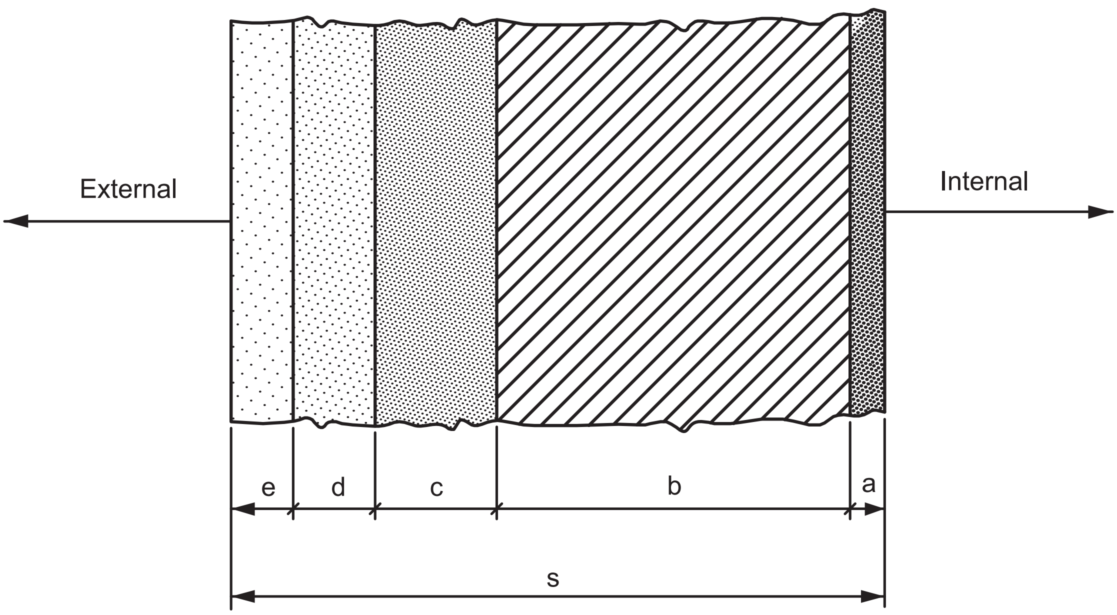
Solutions other than the one shown in Fig 3 will be evaluated by Tasneef for equivalency.

Plastic bottoms are to protect the bottle when they are standing. In addition to non-destructive tests on 100% of the bottles (hydraulic test at 1,5 times the normal operating pressure), destructive tests are required on 2 bottles for every 200 unit batch, with tensile, bend and burst tests. The burst test is carried out by increasing the water pressure gradually until the bottle bursts. 45 N/mm^2 is considered as the threshold value to accept 20 N/mm^2 working pressure bottles.

Testing is to be performed according to the standards applicable to pressure vessels.

Testing carried out by the Navy or another recognized organisation may be accepted provided that it has been carried out according to procedures deemed equivalent.

Figure 3



5 Testing of pressure vessels

5.1 General

5.1.1 All pressure vessels are to be tested and relevant certificates issued.

6 Testing of electrical cables located outside the pressure bearing shell

6.1

6.1.1 Electrical cables and relevant connectors, if any, are to be tested. A cable sample, at least 40 cm long, with hermetic connectors from both ends and curved on a mandrel having a diameter equal to 8 times the cable external diameter, is to be kept in a salt water container for 100 hours at a pressure corresponding to 1,5 times the pressure measured at the maximum working depth and at the minimum operating temperature. A cyclic pressure is recommended.

After the test, the external surface is to be checked to detect any defect or crack. In addition, the sample is to be tested under tension at twice the nominal working voltage plus 1000 V. This test is to be performed with the cable in sea water.

The insulation is to be such that there is no risk of any damage to control equipment or any danger to operators.

7 Testing of navel strings

7.1

7.1.1 Flexible hose constituting the external envelope of the navel string is to be hydrostatically tested at 1,5 times the design pressure.

RULES FOR THE CLASSIFICATION OF UNDERWATER UNITS

Part E
Additional Requirements for Specific Types of Vehicles, Systems, Devices and Services

Chapters **1 2 3 4**

Chapter 1
Specific types of underwater vehicles

Section 1 Bell

CHAPTER 2
SPECIFIC SYSTEMS FOR UNDERWATER ACTIVITIES

CHAPTER 3
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Section 4 Devices On Board the Support Ship to Handle the Underwater Units

CHAPTER 4
SPECIFIC SERVICES OF UNDERWATER UNITS

Part E

Additional Requirements for Specific Types of Vehicles, Systems, Devices and Services

Chapter 1

SPECIFIC TYPES OF UNDERWATER VEHICLES

SECTION 1 BELL

SECTION 1 BELL

1 Isobaric diving bells

1.1 General

1.1.1

a) Diver exit from these units is not foreseen during the work phase.

b) Each diving bell is to be equipped with at least one scuttle in order to allow a view from outside to inside and vice versa.

1.2 Safety systems for diving bell

1.2.1 All diving bells are to have at least the safety systems in Fig 1, where:

A : Shock absorber for lifting point movements

S : Lifting cable

U : Umbilical

P : Pulley

C : Guide and rescue cables in case of emergency

B : Lower base

The bell may emerge:

a) due to positive thrust, releasing ballast, or

b) by cable S, or

c) by cable U, or

d) by cables C.

The moon-pool is to be equipped with vertical guide rails (in general, there are four), fitted at the corners. The bell protection cursor runs along the rails during its transit through the support ship hull and during the critical phase of transit from air to water and vice versa.

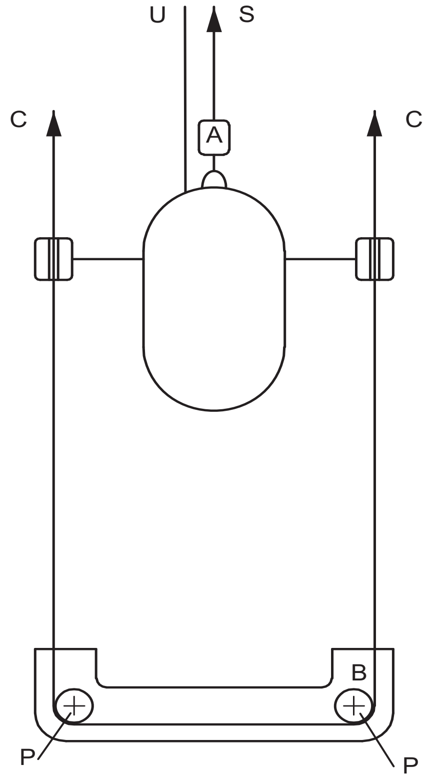
In addition, the diving bell runs along the steering cables, which are kept in tension by ballast laid on the base and by the compensation system of ship movement due to the sea state.

Cable guide systems for the ballast are to be lubricated only with silicone grease.

Bells are to be equipped with an emergency emersion device; if releasable ballast is provided, the bell is to be equipped with an unhook system which needs at least two manoeuvres in order to unhook it.

Each bell is to be equipped with an additional lifting point suitable for holding the whole weight of the bell in the air, completely equipped and containing inside the expected maximum number of completely equipped operators.

Figure 1



1.3 Internal arrangements

1.3.1

a) Seats equipped with safety belts are to be arranged for each person on board.

b) Safety equipment for the head is to be provided for each person on board.

2 Hyperbaric diving bells

2.1 General

2.1.1

a) Diver exit from these units is foreseen during the work phase.

The diameter of the opening on the lower part of the bell for the transit of divers is to be at least 700 mm.

The relevant cover is to be manoeuvrable from inside.

b) Buoys with line graduated by unmovable indicators are to be provided to facilitate possible ascension to the surface of individual operators from the bell. The indicators allow stopping for decompression at certain depths.

These buoys may be replaced by conveniently graduated cables.

c) A hyperbaric diving bell is not to be equipped with a galley: pre-packaged provisions are to be supplied from outside.

d) Inside the hyperbaric diving bell, a quick control is to be fitted to open the safety valves if the inside pressure exceeds the expected values. It is to be operated if the safety valves do not automatically open at the set pressure.

2.2 Safety systems for hyperbaric diving bells

2.2.1 The provisions of [1.2] of this Section apply, with the following additions:

a) During the operational stage, an operator (bellman) is to remain next to the bell, outside, and is to stay there unless an emergency occurs.

b) During underwater operations, a fully equipped operator is to be kept ready for immediate intervention from the surface (surface standby diver).

   He is to be an expert in underwater operator rescue procedures in the case of an emergency.

Part E

Additional Requirements for Specific Types of Vehicles, Systems, Devices and Services

Chapter 2

SPECIFIC SYSTEMS FOR UNDERWATER ACTIVITIES

SECTION 1 HYPERBARIC SYSTEMS

1 General Notes

1.1

1.1.1 A hyperbaric system, is generally to consist of at least the following parts (essential components are to be redundant):

a) oxygen supply system O_2;

b) CO_2 removal system;

c) device to maintain temperature and humidity within certain limits;

d) system for purification of breathing mixture from odours and from man-made fermentative substances, with control of hygienic environmental conditions.

Around this basic life support system, all necessary systems to make it operational are to be provided, namely:

- sources of energy;
- laboratory for gas analysis;
- sanitary control;
- working tools;
- safety equipment;
- any other services related to habitability (laundry, etc.).

SECTION 2 DECOMPRESSION CHAMBERS

1 General

1.1

1.1.1

a) A galley is not to be fitted in a decompression chamber: pre-packaged provisions are to be supplied from outside.

b) Inside the decompression chamber, a quick control is to be fitted to open the safety valves if the inside pressure exceeds the expected values. It is to be operated if the safety valves do not automatically open at the set pressure.

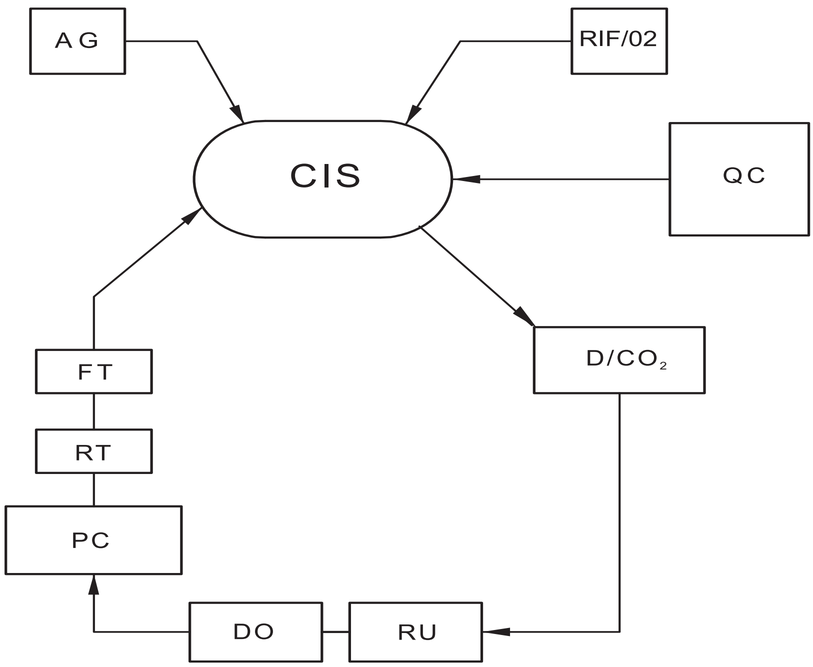
c) The general scheme of a hyperbaric system related to a decompression chamber is shown in Fig 1, where the symbols mean:

AG : sampling system for gas analysis
CIS : hyperbaric chamber for the stay
RIF/O_2 : O_2 supply
QC : pressure monitoring and control consoles
D/CO_2 : O_2 purification
RU : humidity control
DO : odour purification
PC : circulating pump
RT : temperature control
FT : filter of aluminium-potassium permanganate

d) At the end of the decompression cycle, or after therapeutic treatment, the diver is to remain near a decompression chamber for 12 hours and he is not to undertake a new cycle of underwater work for 24 hours.

Decompression chambers are to be soundproof and thermally insulated and they are to be equipped with a redundant heating plant, in order to guarantee divers a comfortable environment.

Figure 1



2 Details/features of decompression chambers

2.1 General requirements

2.1.1 *(1/7/2023)*

a) The decompression chamber is to be operated by a pressure manual control. In addition, an automatic control system is to be fitted, which can be overridden at any time.

A valve which permits a maximum depressurisation equivalent to 10 m/min emersion speed is to be provided; compartments that may be used for transfer of food and materials may be provided with an additional valve allowing the fast depressurization/pressurization at a maximum rate of 2 bar/min when the internal pressure exceeds 2 bar.

Depressurisation is to be controlled from outside the chamber.

In the chamber, partial O_2 pressure is not to be more than 0,1MPa and, for O_2 therapy treatment, O_2 release or adequate ventilation is to be provided in order to maintain the O_2 concentration below 30%, to reduce the fire hazard.

These chambers are not to be so small that the operator cannot stay in a fully upright position; openings are to let a fully equipped diver enter and exit without difficulty (even if carried on an hyperbaric stretcher).

The inner space is to permit at least one other person to enter.

If the decompression period is at least 24 hours, the inner space is to be such that two persons are able to stand up inside comfortably.

The minimum value of the inner height is to be:

- 1,50 m, for chambers where it is anticipated that divers will stay for no longer than 12 hours;
- 2 m, for chambers where it is anticipated that divers will stay for more than 12 hours, but not longer than 2 weeks;
- 2,10 m, for chambers where it is anticipated that divers will stay for more than 2 weeks.

The minimum diameter of the opening for transit from one chamber to another, under inner pressurisation condition, is to be 600 mm.

The length of the chamber is to be such that it allows divers to lie on the floor.

It is recommended that at least two decompression chambers should be available on the support ship; if only one chamber is fitted, it is to have two compartments, each with a separate door which can be opened from both sides.

The O_2 quantity is to be such that it permits four persons to simultaneously undergo the longest O_2 therapy in accordance with the treatment tables.

Decompression chambers are to be equipped with a breathing mixture purification system which is always able to maintain the CO_2 level below 5hPa.

Viewports are to be located on the chamber itself, in accordance with the requirements of Pt B, Ch 1, Sec 5, [2] and Pt D, Ch 1, Sec 2, [1].

Openings are to be provided, through which food or anything else can be introduced, leaving the operator inside under pressure.

Decompression chambers are to be built so that the installed equipment does not produce annoying noise when in operation.

If decompression chambers are connected together, they are to be well aligned, if necessary, with chocks: the maximum allowable gap between flanges of the connecting assembly is not to be more than that stipulated by the Manufacturer.

A safety valve is to be fitted suitable for discharging excess gas so that inside the pressure does not exceed 10% of the expected value.

This valve is to be suitably protected from impacts and it is to be set at a pressure value not greater than 3% of the maximum working pressure. A high pressure audible alarm is to be fitted; the alarm is to be given before the safety valve opens. The use of rupture discs is not allowed, even if they are associated with safety valves.

The discharge of safety valves is to be led to the open air, in a "safe" position.

In addition, a manual device is to be fitted to permit the quick closure of the safety valve. It is to be protected by a fragile screen, which can be broken easily if necessary. It is recommended that this screen should not be made of glass.

b) Decompression chambers can have smaller dimensions than those indicated in a), if they are not specifically designed to be permanently located on board the support ship, and they are exclusively used for emergency therapeutic recompression of an injured diver. Their inner volume is to be such that it does not create CO_2 build-up.

In addition, they are to be equipped with at least:

- a food lock,
- an equilibrium chamber,
- a direct entrance to the main chamber (without passing through the equilibrium chamber),
- a bed,
- a chair for a possible assistant.

c) An essential component of the hyperbaric system of the decompression chambers is the ECU (Environmental Control Unit), which is the automatic control system of the inner atmosphere.

This automatic system has to be designed to assure the maintenance of the stated temperature with ±1% °C of accuracy and the relative humidity with ±3% of accuracy. In addition, it has to remove the CO_2 produced by persons who are inside the chambers.

In general, it is external to the chamber, i.e. it supplies circulation, heating or cooling and dehumidification of the breathing mixture from outside the chamber: during decompression, divers do not have to carry out any manoeuvres inside the chamber.

The changing of the baskets of soda lime and the various control operations are also done by external operators.

Only the following fittings may be installed inside the chamber:

- temperature and humidity sensors
- valves on the inlet and outlet of the supply lines and of the return lines of the gas mixture
- diffusers.

The ECU system is to consist of:

- an external control unit
- supply and return lines (piping in general of stainless steel, suitable to withstand the design pressure)
- temperature and humidity sensors located inside the chamber
- a remote control panel for humidity and temperature inside the chamber
- two CO_2 and odour absorbing filters (in general, two baskets containing soda lime and active carbon)
- a gas circulating pump
- a cooler
- a heat exchanger (in order to heat the gas before it enters the chamber)
- valves, piping and associated connections installed inside the chamber
- a water heater and associated circulating pumps with control valves;
- a water cooler and associated circulating pumps with control valves;
- a control panel for supply with local temperature control.

The gas flow of the chamber is generally assumed to be 0,1 m^3/min for each person who can fit inside.

The supply line from the ECU to the chamber is to be thermally isolated in order to minimise heat loss.

The cooling water may be fresh water (supplied from the plant of the support ship) or salt water. In the first case, the heat exchanger outlet is connected to the above-mentioned plant of the ship; in the second case, it is connected to the discharge overboard.

The cooling circuit is always to be filled up with an anti-freeze solution (50% of ethylene/alcohol and 50% of fresh water or equivalent).

The heating circuit is to be filled up with clean fresh water.

The (compressed) gas circulating pump is to be lubricated with vaseline oil.

2.1.2 The fresh water and fire-fighting system (PWFS: potable water-fire suppression unit) is another essential component of the hyperbaric system of the decompression chambers.

It supplies water to the decompression chambers for the following services:

- WC,
- hot/cold water for showers and sink,
- fire fighting (see [4] and Pt A, Ch 1, Sec 1, [7.1.2]).

Water is to be supplied to the chamber by a pump at a higher pressure than the chamber working pressure.

The line between the pump and the chamber is to be constantly kept (in rest condition) at a fixed pressure which depends on the supply pressure of the air pump.

This plant is to have the following features:

- capacity:
  - hot water: 10 l/min,
  - cold water: 10 l/min,
  - fire-fighting water: 20 l/min (see [4] and Pt A, Ch 1, Sec 1, [7.1.2]),
- volume:
  - hot water tank: 50 l,
  - cold water tank: 105 l.

2.2 Penetrations through the resistant shell of the decompression chamber

2.2.1

a) Pipes which penetrate the chamber are to be equipped with external shut-off valves, located on the resistant shell or next to it, provided that the part between the chamber and the valve is well protected against damage due to impacts and the pipe thickness is deemed suitable.

b) In addition to a), inner control or shut-off valves are to be provided.

   The inner shut-off valves are to be locked in "open" position, by a system sealed with lead, and they are to be used only in case of emergency.

3 Pressure chamber

3.1

3.1.1 A "pressure chamber" is a particular type of decompression chamber.

It is an underwater unit used for transporting divers to the surface or between operating zones, generally in pressurised conditions.

4 Fire-fighting system

4.1 Applicability

4.1.1 For the applicability of this item [4], see also Pt A, Ch 1, Sec 1, [7.1.2].

4.2 Requirements

4.2.1 The extinguishing system inside the decompression chambers is to be of the water spray type; it is to be activated from outside the chambers or from inside (by manual devices).

Arrangements are to be provided within the "life-compartment" of the chamber, so that the system can be rapidly activated by the operators from any internal point of the chamber

The fire-fighting system installed in each compartment is to include:

externally:

- a supply water line, connected to the chamber main: two inlets are to be provided for each compartment,
- one pneumatically operated shut-off valve on each inlet; the remote control is to be located on the control panel of the chamber,
- one hand-operated shut-off valve on each inlet.

internally:

- shut-off valves,
- spray nozzles.

SECTION 3 DIVING SYSTEM

1 General

1.1

1.1.1

a) A diving system or "deep diving system" consists of at least:
   - a device for the transfer of persons under pressure (clamping),
   - a diving bell (whether or not hyperbaric),
   - a decompression chamber,
   - a control station for the bell(s) during working phases,
   - a control station for the decompression chamber,
   - systems (on board the support ship) to launch and recover bell(s) and associated umbilical,
   - equipment and systems relative to the underwater activity, such as:
     - reserve of gas for breathing,
     - equipment for mixing breathing gases and for transferring them to the equipment for underwater work,
     - equipment for hot water production,
     - systems for handling the umbilical,
     - interface with the support systems (energy, communication, fire protection, etc.),
     - devices for evacuation and transfer of persons under hyperbaric conditions,
     - devices for the treatment and regeneration of the breathing mixtures,
     - tools for underwater activities and devices for their use.

b) A diving system is to include at least one decompression chamber equipped with two separate compartments or with two interconnected chambers in order to allow the entrance or the exit of operators to/from a compartment or one of the chambers, while the other compartment or chamber remains pressurised.

c) The diving system (which includes the system for the stowage and distribution of the breathing mixture) is not to be located in spaces containing other machinery or in spaces where explosive air-gas mixtures may be present.

   The diving system and associated auxiliaries are to be located in spaces whose boundaries are insulated to the standard of structural fire protection equivalent to that required for control stations.

2 Fire-fighting systems

2.1 Applicability

2.1.1 For the applicability of this item [2], see also Pt A, Ch 1, Sec 1, [7.1.2].

2.2 Requirements

2.2.1 Enclosed spaces containing the diving system (including the decompression chamber and/or bell) and used for storage of gas bottles, compressors and control units are to be provided with an automatic fire detection and alarm system and with a suitable fixed fire-extinguishing system.

An automatic fire detection and alarm system need not be provided in continuously manned spaces.

Part E

Additional Requirements for Specific Types of Vehicles, Systems, Devices and Services

Chapter 3

DEVICE AND SPECIFIC ARRANGEMENTS FOR UNDEWATER ACTIVITY

SECTION 1 UNIT FOR GEOCHEMICAL INSPECTIONS

1 General

1.1

1.1.1 The unit for geochemical inspections (sniffer/hound dog) is an underwater unit (generally suitable for operating unmanned up to 500 m depth), controlled from an underwater unit but in general from the support ship. It is linked to an umbilical through which salt water is pumped to a very accurate gas chromatograph, located on the mother unit. The gas chromatograph is capable of identifying and analysing hydrocarbons in volumentric concentrations of less than 0,5 ppm of gas per water volume.

The total content of hydrocarbons is continuously analysed and recorded by a digital computer together with other environmental parameters such as temperature, conductivity, salinity and depth.

The purposes of the possible prospecting may be the following:

a) survey campaigns of large areas where there is the necessity to identify zones where the presence of hydrocarbons exceeds the normal parameters, with consequent exclusion of the remaining areas during the planning of the geo-seismic and geotechnical prospecting campaign

b) survey campaigns in areas which are already defined in geo-seismic prospecting, to permit planning priorities during exploration (drilling)

c) local geotechnical inspections, generally as support for geo-seismic prospecting, to identify gas baskets of biogenic origin

d) inspection of the pollution level of the underwater environment due to hydrocarbons near the coast, normally produced by biogenic degradation of waste material

e) inspection "on stream" of underwater piping for the localisation of any leakages.

Together with environmental parameters, the following gas concentrations are measured and recorded in real time: methane, ethylene, ethane, propane, isobutane, normal butane. They are measured and recorded for further data processing by computer and for the production of maps representing the iso-concentrations at a suitable scale.

1.2 Scantling

1.2.1 For the scantling, the relevant parts of the Rules are valid as far as applicable.

SECTION 2 DEVICE FOR ASSISTANCE OF FAILED UNDERWATER UNITS

1 Lifting eye bolt

1.1

1.1.1 Lifting eye bolts are generally to be fitted on units whose length is 20m or less. They are provided in order to allow the underwater unit to be slung with the help of divers, as deep as they can go, and brought to the surface by the available lifting means on the support ship and/or on a floating unit equipped with suitable lifting means.

Eye bolts are to be of forged steel and arranged in two or more couples, firmly connected to the pressure hull.

2 Localisation of the failed underwater unit

2.1

2.1.1 For this purpose, a telephone buoy is to be provided on the underwater unit. The buoy is also to allow rescue boats and the crew inside the vehicle to communicate. On bigger units, two of these buoys are to be provided: one at the stern and the other at the bow. They are to consist of two steel shells, resistant at the maximum operating depth of the unit (with a safety coefficient equal to 2 in respect of the yield point), and they are to be connected to the pressure hull by a screwed bar which is releasable from inside or by another equivalent system. These buoys are to be placed in suitable recesses of the hull in order to be protected against potential impacts.

A telephone cable, whose length is 50% more than the maximum operating depth of the unit, is to connect a telephone placed inside the buoy with another telephone placed inside the unit.

In the upper part of the buoy, an electric lamp is to be provided and inserted in a resistant, transparent, watertight globe. It is to be switched on from inside the unit, in order to facilitate the location of the buoy and is to give Morse code or equivalent signals. Once it has been released, this buoy is to be able to emit an alarm message every 10 minutes for at least 30 hours. The emission is to have a range of at least 35 miles in the worst atmospheric conditions.

3 Air supply from outside in the failed underwater unit

3.1

3.1.1 In order to supply air for breathing from outside to the failed underwater unit, air intakes are to be provided. The intakes are to be equipped with suitable valves (manoeuvrable also from inside) where divers or frogmen can connect hoses from the support ship. However, this arrangement depends on the depth which the divers can reach. Two of these connections are to be installed in each space, in order to connect two hoses and be able to change the air inside.

3.1.2 Similar connections to supply air, without valves manoeuvrable from inside, are to be provided for ballast compartments.

A flow control valve and a pressure reducing valve are to be fitted on the inner side of the air intakes.

4 Unmanned units failed on the seabed

4.1

4.1.1 For unmanned underwater units (e.g. digging units for underground laying of cables or underwater piping) which are fed by electrical cable from the support ship, the drawing of the support system of the cable is to be submitted to Tasneef for approval. This also applies to the device which disconnects the electrical supply cable in case of emergency, in order to abandon the unit on the seabed without any damage to the cable or problems for its recon-nection. A disconnecting system for any protrusions (e.g. manipulating arm, etc.) and for the ejection of some parts (battery-pod, drop weight, etc.) is to be provided.

5 Dumping of parts of the unit on the seabed

5.1

5.1.1

a) The dumping of some parts of the unit (in particular small parts) on the seabed may be carried out by unhooking them by manual control from the manned space or by using explosion or hydraulic systems.

   Localisation and rescue means are to be arranged on board the support ship.

b) All hull appendages, such as manipulators, anchoring systems, racks and other prominent structures, which can constitute a hazard insofar as they can get caught in underwater obstacles, are to be fitted with devices suitable to disconnect them from the hull in case of emergency. If necessary, the watertightness of the hull is to be restored.

The manoeuvres as per a) and b) are also to be possible with a list and trim 20° greater than those anticipated in operational conditions.

6 Emergency ascent

6.1

6.1.1 At least one of the following methods is to be used for emergency emersion:

a) expelling the water from the ballast tanks (see [3.1.2]);

b) putting the ballast pump into operation, at the proper time, with an automatic device (see Ch 2, Sec 3, [1.7.1] e));

c) releasing ballast (drop weight) on the seabed;

d) detaching appendages.

In any case, if a unit is not provided with means (e.g. vertical propellers) for emersion in case of emergency, the unit being fully ballasted, it is also to have a positive thrust which is not less than 7% of the total displacement, the unit being at the maximum operational depth.

7 Additional systems and devices of the support ship for underwater units having length L $\leq$ 20 m, self-propelled and manned

7.1

7.1.1 The support ship is to be equipped with:

a) means, in general cranes, for the launch and recovery on board of the underwater unit, operated from a position where it is possible to control the manoeuvre visually;

b) a rescue boat (e.g. pneumatic) for immediate use, of the launchable type, with capacity for twice the number of persons on board the submersible unit. It is to be used for the rescue and transfer of the persons to the support ship. This rescue boat may also be used to assist underwater operations: lowering and recovery of the umbilical, lowering and recovery of underwater units, washing of the different equipment during recovery, etc.;

c) two lifebuoys with ropes and self-activating lights;

d) means to suitably light the deck zone used for the above-mentioned operations and the launching sea water area (e.g. searchlight);

e) two devices to localise the unit on the sea surface, such as radar and a (directional) radio station able to receive signals from the transmitter installed on board the unit;

f) an electro-acoustic device to localise the underwater vehicle;

g) instrumentation to measure the temperature, salinity, turbidity and salt water density at different depths;

h) echo sounder;

i) a decompression chamber; this is recommended in general, but mandatory when the unit operates in hyperbaric conditions;

j) emergency breathing apparatuses for divers;

k) a dynamic positioning system complying with the requirements for the additional class notation DYNAPOS AM/AT R or other equivalent arrangements to maintain the ship's position during diving operations.

8 Signalling means

8.1

8.1.1 At least one signalling device is to be provided for night visual localisation of the unit when it is on the surface.

This device may be an intermittent orange light which automatically switches off when the vehicle exceeds 10 m in depth.

SECTION 3 UMBILICAL

1 General

1.1 Arrangement and characteristics

1.1.1 The flexible hoses constituting the umbilical are to contain a steel strength rope which, in normal conditions, can support the weight.

In rest conditions, on board the support ship, umbilicals are to be reeled in on a drum of suitable diameter, or laid in overlapped coils, within an appropriate housing. Suitable holes are to be made on the bottom of the housing to avoid water stagnation.

1.1.2 The umbilical may contain:

- gas supply hoses (compressed air, N_2-O_2 mixture, O_2, He, He-O_2 mixture) or pipes to pressurise the inner part of the bell;
- a hose to convey the no longer suitable breathing mixtures and CO_2 to the surface;
- a cable for audio communications;
- a cable for video communications;
- a cable for the supply of electrical users, if any
- a hot water supply hose for the heating coils of the bell and for the umbilical connected to the wetsuits of divers (hookah, as described in point i) below).

The following requirements apply:

a) flexible hoses for breathing mixture are to be manufactured without joints and made of materials which are hydrocarbon and salt water resistant (synthetic rubber or similar materials suitably reinforced). The materials are also to be resistant to the conveyed gases at temperatures ranging from -40°C to 60°C. In addition, they are not to generate toxic vapours when heated at 60°C;

b) flexible hoses for hot water are to be manufactured without joints and made of synthetic rubber or similar materials which are chemically resistant to water up to 99°C;

c) in the event of failure or breakage of the pressurisation hose, automatic non-return valves are to isolate the hoses and the independent gas circuit is to be brought into operation from inside. The gas circuit is supplied by bottles fitted outside the bell;

d) the umbilical is to be manually coupled to the strength rope, on the surface, during the immersion phase, by suitable chains (a connection approximately every 30 m). The purpose of this is to reduce their separation due to currents;

e) all cables are to be certified by the Manufacturer as suitable to be used with external temperatures ranging from -40°C to 60°C;

f) the umbilical is not to be subject to bending stress in way of its connection to the pressure hull and penetrator;

g) an emergency release device for the umbilical is to be provided in the bells;

h) two groups of bottles are to be installed on the bell frame, mounted so that they can operate independently of each other. An O_2 bottle is also to be installed to supplement the consumed oxygen;

i) during their stay on the seabed, divers operating outside are to be connected to the bell by the umbilical called "hookah". It consists of:

   1) a flexible hose for breathing mixture supply (working pressure: 1MPa plus the value in MPa of hydrostatic pressure the diver is subjected to)
   2) a flexible hose for wetsuit heating and
   3) a cable for communication with the bell;

j) the mechanical characteristics of the strength ropes are to be specified by the Manufacturer and subjected to the approval of Tasneef (see Sec 4, [1]);

k) the umbilical is to be well protected from impacts or any other mechanical damage;

l) the length of the umbilical and lifting ropes is to be such as to permit an excursion of the bell 5% longer than the local depth of the sea;

m) the electrical cables inside the umbilical are not to have joints.

2 Constructional details

2.1

2.1.1 *(1/7/2023)*

The umbilical is to include a steel core whose ultimate tensile strength can withstand a load which is at least twice the weight in air of the bell itself, in the case of strength rope failure.

Umbilicals are to be designed, tested and certified in accordance with a recognised standard such as ISO 13628-5, or equivalent.

2.1.2 The bursting pressure of the flexible pipe constituting the external casing of the umbilical is to be at least four times greater than its working pressure. It is to be designed for an external pressure equal to the bell pressure increased by 300 m.

It is to be able to withstand accidental bending.

Its metallic joints are to be corrosion-resistant and protected against accidental unhooking and are to have the same strength characteristics as the flexible hose.

SECTION 4 DEVICES ON BOARD THE SUPPORT SHIP TO HANDLE THE UNDERWATER UNITS

1 General

1.1

1.1.1 All systems for handling the underwater units installed on board the support ship, as well as the systems for lowering or recovery of the underwater unit outboard (jib crane, bridge cranes, fixed portals, etc., with associated manoeuvring systems, such as winches, actuators, junction boxes, hydraulic circuits, etc.) or through moon-pools, are subject to the Rules for loading and unloading arrangements and for other lifting appliances on board ships (see also Pt A, Ch 1, Sec 2, [4]).

1.1.2 Documentation to be sent for approval

In order to verify the movement and lifting arrangements, the documentation requested in [1.1.1] above is to be submitted for approval taking into account that the systems concerned also operate in open sea conditions.

The following is to be considered:

a) weight in air of the underwater unit (if completely floating);

b) water friction during its recovery (if still immersed);

c) load due to vertical accelerations of the underwater unit caused by the sea waves (when the unit is held by lifting ropes);

d) loads due to the movement of the support ship (pitching, rolling, yawing), in relation to the maximum wave height in which the underwater vehicle is allowed to operate.

1.2 Tests for some components of lifting systems

1.2.1 Any hooks applied to the ropes for lifting or lowering the units are to be subjected to tensile testing with a load equal to twice the working load.

Lifting devices used for lowering and recovery of the underwater units on board and outboard of the support ship are to be designed for a load equal to twice the maximum weight of the units in air.

1.2.2 A static test of the bell handling system is carried out. The static load is to be not less than three times the maximum weight in air of the bell when it is ready for operation and has the maximum expected number of divers, completely equipped, on board.

The static load so determined will be kept suspended by the brake of the bell strength winch. The lifting rope used for this test is to be different from the one used for operation but is to be carried by the usual operating pulley.

The static test of the bell handling device is performed to check the efficiency of the braking system of the winch which controls bell movement.

The bell handling system will also be tested with the emergency source of energy.

1.2.3 Drums and driving pulleys of machinery for handling systems where metallic ropes are reeled in, are to have a diameter equal to or greater than 25 times the external diameter of the ropes and not less than 300 times the external diameter of the wires of the ropes, unless otherwise provided by special requirements.

The diameter of the lead pulley is to be not less than 20 times that of the rope diameter and not less than 250 times the diameter of the wires of the ropes.

Ropes and chains are to have a safety coefficient at least equal to:

- 8, for metallic ropes;
- 10, for fibre ropes;
- 5, for chains.

Ropes and chains are to be subjected to the periodical surveys foreseen for all lifting systems.

Winches are to be permanently marked with the following characteristic data:

- name of the Manufacturer;
- serial number;
- safe working load;
- test load;
- design load (which is to be at least twice the working load).

The brake is to be suitable to keep a load suspended which is twice the working load.

Part E

Additional Requirements for Specific Types of Vehicles, Systems, Devices and Services

Chapter 4

SPECIFIC SERVICES OF UNDERWATER UNITS

SECTION 1 ADDITIONAL REQUIREMENTS FOR UNDERWATER UNITS INTENDED FOR TRANSPORTATION OF PASSENGERS

1 Particular requirements

1.1 Use restrictions

1.1.1 In general, authorisation to transport passengers on underwater units of small dimensions is limited to 50 persons, including crew, for journeys lasting less than 2 hours, at depths not greater than 105% of the maximum design depth, with continuous assistance of units on the surface during immersion.

The immersion zone is to be carefully examined by the person in charge of the operations in order to ascertain the absence of hazards. The relevant results are to be given to the pilot before immersion.

1.2 Access openings

1.2.1 Underwater units with more than 6 persons on board are to be fitted with at least two access openings.

1.3 Separation of inner spaces

1.3.1 The pilot control and manoeuvring position is to be protected from accidental tampering by passengers.

1.4 Bilge pumping system

1.4.1 Underwater units are to be equipped with a fixed bilge pumping system in order to drain all inner spaces.

Overboard outlets crossing the pressure hull are to be fitted with an inner quick-closing valve, located as near as possible to the pressure hull. A shut-off valve is to be fitted on the delivery side of the bilge pumps. In addition, a level alarm is to be fitted to inform the pilot of unexpected water ingress.

1.5 Lifting eye bolt

1.5.1 At least two lifting points are to be provided to connect the systems to ascend to the surface in case of failure.

Both eye bolts and their connections to the hull are to be designed considering the forces created by a vertical acceleration of 2g (1g static + 1g dynamic), by a horizontal (transverse) acceleration of 1g and by a longitudinal acceleration of 1g. All these forces are to be considered acting simultaneously when the unit is at its maximum displacement.

Less severe conditions may be considered on the basis of the results of dynamic analysis resulting in lower loads.

1.6 Viewport protection

1.6.1 A transparent and unbreakable protection shield is to be located on the inner side of each viewport which is accessible to passengers. If this is not possible, adequate precautions are to be taken in order to prevent possible damage to viewports.

1.7 Final test of breathing system

1.7.1 When the underwater unit is fully equipped and before doing the planned immersion tests, final testing of the system is to be carried out with the unit on the surface and openings closed. The test is to last 150% of the normal anticipated time of immersion with the maximum number of persons on board.

The levels of oxygen and carbon dioxide, pressure, relative humidity and inner temperature are to be measured every 15 minutes and the levels are to be to Tasneef's satisfaction.

1.8 Oxygen supply

1.8.1 For units designed to operate at depths greater than 50 m, the available oxygen quantity, including the emergency supply, is to be sufficient for the entire duration of the mission, plus 96 hours, unless Tasneef allows this requirement to be waived totally or partially, considering the type of unit as well as the brevity and low hazard level of the mission.

APPENDIX 1 ALPHABETICAL LIST OF THE MOST FREQUENT ABBREVIATIONS USED IN THE DIVING FIELD

1 Introduction

1.1

1.1.1 The list of the most frequent abbreviations used in the diving field is given below in alphabetical order.

These abbreviations come from Great Britain or the USA and they are commonly used, at national and international level, in technical literature, drawings, commercial documentation and everyday speech about units, equipment and systems used in underwater work.

1.1.2 The meaning which is usually assigned by specialists in the underwater field is given for each acronym.

However, the same abbreviation may have different meanings depending on who uses it, as:

- shipyards;
- people who operate in the diving and offshore fields;
- Navies;
- research institutes (universities, specialised laboratories, oceanographers, meteorologists, underwater medicine centres);
- submersibles;
- firms specialised in microelectronics and underwater acoustics;
- societies which train people intending to carry out underwater activities (people in charge of operations, people on board underwater units, skilled institutes).

2 List of abbreviations

2.1

2.1.1 The English terminology listed below is that used officially.

ABM : appropriate breathing mixture
ABS : automatic blow system
ACD : acoustic control device
ACTS : acoustic control and telemetry system
ACU : atmospheric conditioning unit
ADS : atmospheric diving suit
AMBT : aft main ballast tank
AOB : atmospheric observation bell
AOC : atmospheric observation chamber
AP : ambient pressure
APDB : ambient pressure diving bell
APRS : acoustic position reference system
AS : altitude sonar
ASD : advanced submarine design
ASKS : automatic station keeping system
ASR : auxiliary submarine rescue
AVLD : acoustic valve leak detector
AW : acrylic window
AWOC : atmospheric working observation chamber
BAH : bow access hatch
BAPS : breathing air purification system
BAT : bow access trunk
BBS : built-up breathing system
BHS : bell handling system
BIBS : built-in breathing system
BM : breathing mixture
BP : battery-pod
BS : bathymetric system
BSA : battery section aft
BSF : battery section forward
BT : ballast tank
BTV : buoyancy transport vehicle
CAV : construction assistance vehicle
CB : Citizens' Band
CCTV : closed circuit television (system)
CEL : (Navy's) civil engineering laboratory
CLS : control and living spaces
CNO : Chief of Naval Operations
CP : critical pressure
CR : control room
CS : cruising speed or control system or communication system
CTFM : continuous transmission frequency modulated
CURV : controlled underwater recovery vehicle or controlled underwater research vessel
D : diver
DAVID : diving assistance vehicles in duty
DB : diving bell
DBS : detachable ballast system
DC : depth control or dry chamber
DCC : deck compression chamber
DCP : design collapse pressure
DDC : deck decompression chamber
DDS : deep-diving submersible or deep-diving system
DDU : deep diving unit
DH : directional hydrophone
DLO (W & DS):diver lock-out (wet and dry space)
DLOC : diver lock-out compartment
DLOS : diver lock-out submersible

DM : diving manual
DMS : diverless monitoring system
DO : diving operation
DOD : Department of Defence
DOL : deep ocean laboratory
DOS : deep ocean search
DOT : deep ocean technology or deep ocean transponder
DOWB : deep ocean work boat
DOWV : diver operated work vehicle (or vessel)
DP : diving procedure or diving package
DPSS : dynamically positioned support ship
DPSV : dynamically positioned diving support and survey vessel
DR : design range
DS : diver support or depth sonar or Döppler system or deep submersible or diving system or deepwater search
DSRV : deep submergence rescue vehicle (or vessel) or deep submergence research vessel
DSS : deep sea survey system
DSSV : deep submergence search vehicle
DSV : diving support vessel or deep submergence vehicle
DT : deepwater technology
DTMB : David Taylor Model Basin
DTNSRDC: David Taylor Naval Ship Research & Development Center
DW : drop weight
DWD : deep-water drilling
DWS : diver work system
ECU : environmental control unit
EDTS : emergency diver transfer system
EI : external illumination
EMI : electromagnetic interference
EMP : electromagnetic pulse
EMWCM: electromagnetic water current meter
EN : endurance
EP : electrical power
EPLS : emergency provisions for life support
ES : echo sounder
FCS : fire control system
FLS : forward looking sonar
FMBT : forward main ballast tank
FSW : feet of sea water or feet of salt water
GERS : Group Etudes et Recherches Sousmarines
GFR : gas flow regulator
GRP : glass reinforced plastic
HASINS : high accuracy submersible inertial navigation system
HC : hyperbaric centre
HELIOX : helium - oxygen mixture
HH : hemispherical heads
HM : hull material
HOAS : horizontal obstacle avoidance sonar
HP : hydraulic power
HPC : hydrostatic pressure chamber
HPS : hyperbaric packaged system
HRCS : hyperbaric research centre submersibles
HRL : hyperbaric rescue lifeboat
HrP : horizontal propulsion
HSV : hydrospace service vehicle
HT : hull thickness
HW : hyperbaric welding
HY : high yield
HYDROX: hydrogen - oxygen mixture
IHV : induction head valve
LAUNS : local area underwater navigation system
LBS : lock-out breathing system
LC : living compartment
LD : location display
LF : lifting fixture
LOSS : large object salvage system
LP : launching procedure
LS : life support or launch system
LSS : life support system or life saving system
MA : manipulator arm
Mar Ad : Maritime Administration
MBSA : model-based system analysis
MBT : main ballast tank
MC : microcomputer
MCC : main control console
MD : manipulator device or manned device
MDU : mobile diving unit
MEV : manipulator equipped vehicle
MMBT : midship main ballast tank
Mnp : manipulator
MOB : manipulation & observation bell
MP : main propulsion or moon-pool
MPE : main propulsion engine
MPL : marine physical lab
MS : manned submersible (or submarine)
MWS : manned workboat system
MV : manned vehicle
MWB : mobile work base
NASL : Naval Applied Science Lab
NAVSAT: satellite navigation system
NAVSEC: Naval Ship Engineering Center
NBIV : neutrally buoyant inspection vehicle
NCEL : Naval Civil Engineering Lab
NCSL : Naval Coastal Systems Lab
NDD : normal diving depth
NDT : non-destructive testing
NE : navigation equipment
NEDU : Navy Experimental Diving Unit
NITROX: nitrogen - oxygen mixture
NOD : normal operating depth

NOSC : Naval Ocean Systems Center
NPH : non-pressure hull
NPS : naval propulsion system
NRL : Naval Research Lab
NS : navigation system
O & OS : operating and observation service
OB : observation bell
OBA : oxygen breathing apparatus
OBC : on-board computer
OD : operating depth
OEM : original equipment manufacturer
OFFSH : offshore
OH : outer hull
OI : offshore installation
OMB : observation manipulator bell
OPS : offshore power system
OR : operational requirements
OS : observation system or oceanographic service or operating service
OSF : ocean simulation facility
OV : offshore vessel
PMB : pipe burying machine
PH : pressure hull
PIV : pontoon implacement vehicle
PS : power source or propulsion system or positioning system
PTC : personnel transfer chamber or personnel transfer capsule
PTFE : polytetrafluoroethylene
PVHO : pressure vessels for human occupancy
PVRC : Pressure Vessel Research Committee
PW : panoramic window
PWFS : potable water fire suppression unit
QA : quality analysis
QC : quality control
RCSV : remote controlled subsea vehicle
RCV : remote controlled vehicle
ROV : remote-operated vehicle
RP : recovering procedure
RS : rescue sphere or recovery system
RSP : routine submerged procedure
RSWV : remote subsea work vehicle
RTF in BLU: radiotelephone in single lateral band
RFT in SSB: radiotelephone in single side band (as RTF in BLU)
RUSS : remote underwater survey system
RUWS : remote unmanned work system
RV : research vehicle
SAH : stern access hatch
SAR : search & rescue
SAS : special application system
SAT : stern access trunk
SAWS : submarine acoustic warfare system
SCADA : supervisory control and data
SCC : submersible compression chamber or stress corrosion cracking
SCPT : submarine cable for power transmission
SCR : silicon controlled rectifier
SCUBA : self-contained underwater breathing apparatus
SD_{sub} : submerged displacement
SD_{surf} : surface displacement
SDBA : surface demand breathing apparatus
SDC : submersible decompression chamber or submersible diving chamber
SDHU : submersible diver's heating unit
SDP : safe diving practice
SDS : saturation diving system or salvage diving system
SEIE : submarine escape immersion equipment
SfP : surfacing procedure
SINS : ship inertial navigation system
SL : submersible launch
SLNGV : submarine LNG (liquefied natural gas) (transporting) vessel
SLS : side-looking sonar
SMARTIE: submarine automatic remote television inspection equipment
SMB : submarbell
SMS : supporting mother-ship
SNPAC : compressed air intoxication
SP : submarine pipeline or submerging procedure
SPCC : strength, power and communication cables or Ships Parts Control Center
SPS : submerged production system
SRC : submarine rescue chamber
SRS : short range sonar
SS : survey submersible or subsea station
SSD : surface standby diver
SSMS : submarine safety monitoring system
SSTV : slow scan television
STS : submersible television survey
SURS : submersible underwater repair system
SV : support vehicle or supply vessel or submersible vehicle
SW : salt water
TAP : transparent acrylic plate
T & RC : trim and roll control
TC : temperature controller or tether cable
Tender : assistant and colleague of diver who remains in the bell. He supervises the diver from outside and he is in contact with the surface by telephone
TGBM : tri-gas (He-O_2-N_2) breathing mixture
THR : thruster
TL : transfer lock. It can be dry D TL or wet W TL
TP : thruster propulsor
TPS : thruster propulsion system

TREC : tethered remote camera
TS : towed system
TSS : total saturation system
TUP : transfer-under-pressure (chamber) or transfer-under-pressure (system)
TUSS : tethered underwater survey system
UC : umbilical cable or underwater connector
UCC : underwater colour camera
UCS : underwater communication system
UD : unmanned device
UDATS : underwater damage assessment TV system
UDT : underwater demolition team
UFO : underwater flying observer
UI : underwater inspection
UMB : umbilical
UMS : unmanned submersible
UMV : unmanned vehicle
UN : underwater noise
UNS : underwater navigation system
URV : undersea research vehicle
US : unmanned submarine
USE : underwater survey equipment
USS : unmanned search system
UT : underwater telephone
UTAS : underwater television automatic system
UTV : unmanned tethered vehicle or underwater tethered vehicle
UTVS : underwater television system
UUV : unmanned underwater vehicle
UV : see UMV
UW : underwater or underwater work
UWH : underwater work habitat or underwater welding habitat
UWS : undersea work system
VB : variable buoyancy or variable ballast
VOAS : vertical obstacle avoidance sonar
VP : vertical propulsion
VS : video system
WD : water detector
WS : wet submersible