RULES FOR BUILDING AND CLASSING

UNDERWATER VEHICLES, SYSTEMS AND HYPERBARIC FACILITIES
2014

American Bureau of Shipping
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the State of New York 1862

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Foreword

The 2014 edition of the *Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities* incorporates all Rule Changes and Corrigenda items since 2012. Requirements for atmospheric diving suits and autonomous underwater vehicles are added. The requirements for remotely operated vehicles have been updated Also, some requirements have been revised for clarity and others to more accurately reflect actual practice.

- Sections 1 through 10 provide the general requirements that are applicable to all categories of underwater vehicles, systems and hyperbaric facilities.
- Section 11 provides the specific requirements that are applicable to manned submersibles.
- Section 12 provides the specific requirements that are applicable to lock-out submersibles.
- Section 13 provides the specific requirements that are applicable to diving systems.
- Section 14 provides the specific requirements that are applicable to atmospheric diving suits.
- Section 15 provides the specific requirements that are applicable to remotely operated vehicles.
- Section 16 provides the specific requirements that are applicable to autonomous underwater vehicles.
- Section 17 provides the specific requirements that are applicable to handling systems.
- Section 18 provides the specific requirements that are applicable to dive control stations.
- Section 19 provides the requirements for surveys after construction.
- Appendix 1 provides relevant excerpts from IMO Res. A.831 (19) Code of Safety for Diving Systems regarding diving bell emergency locating devices

The effective date of each technical change is shown in parentheses at the end of the subsection/paragraph titles within the text of each Section. Unless a particular date and month are shown, the effective date is 1 January of the year shown.

Note Regarding the Changes to Section 1 *(1 January 2008)*

In 2008, Section 1, "Conditions of Classification" was consolidated into a generic booklet, entitled *Rules for Conditions of Classification (Part 1)* for all vessels other than those in offshore service. The purpose of this consolidation was to emphasize the common applicability of the classification requirements in "Section 1" to ABS-classed vessels, other marine structures and their associated machinery, and thereby make "Conditions of Classification" more readily a common Rule of the various ABS Rules and Guides, as appropriate.

Thus, Section 1 of these Rules specifies only the unique requirements applicable to underwater vehicles, systems and hyperbaric facilities. These supplemental requirements are always to be used with the aforementioned *Rules for Conditions of Classification (Part 1)*.

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SECTION 1 Scope and Conditions of Classification

1 Classification *(1 January 2008)*

The requirements for conditions of classification are contained in the separate, generic ABS *Rules for Conditions of Classification (Part 1)*.

Additional requirements specific to underwater vehicles, systems, and hyperbaric facilities are contained in the following portions of this Section.

3 Classification Symbols and Notations *(1 January 2008)*

A listing of Classification Symbols and Notations available to the Owners of vessels, offshore drilling and production units and other marine structures and systems, "List of ABS Notations and Symbols" is available from the ABS website "http://www.eagle.org".

The following notations are specific to underwater vehicles, systems and hyperbaric facilities.

3.1 Classed Units *(2012)*

Manned or occasionally manned underwater vehicles, underwater facilities, hyperbaric facilities, and diving simulators which have been built to the satisfaction of the ABS Surveyors to the full requirements of these Rules, or their equivalent, where approved by the Committee for the service will be classed and distinguished in the *Record* by the symbols ✠ **A1** followed by the appropriate notation, such as **Submersible**, **Passenger Submersible**, **Lock-Out Submersible**, **Remotely Operated Vehicle**, **Habitat**, etc.

3.3 Classed Systems *(2012)*

In addition to the Classification of the individual underwater vehicles, underwater facilities, and hyperbaric facilities mentioned in 1/3.1, a system may be classed and distinguished in the *Record* by the symbols ✠ **A1** followed by the appropriate notation, such as **Air Diving System (P) or (F), Mixed Gas Diving System (P) or (F)**, **Saturation Diving System (P) or (F)** (See Subsection 13/3), **Underwater Complex**, etc., provided the system has been built to the satisfaction of the ABS Surveyors to the full requirements of these Rules, or their equivalent.

3.4 Support Components for Classed Systems *(2012)*

Support components for classed systems include pressure vessels for human occupancy (surface compression chambers, diving bells, hyperbaric evacuation units, etc.), handling systems and dive control stations.

Support components that have been built under the supervision of the ABS Surveyors to the full requirements of these Rules, or their equivalent, may be certified by ABS and issued Underwater System Support Component Certificates (ABS-USC-1) with the symbol ✠ followed by the appropriate notation, such as **Diving Bell**, **Handling System**, **Dive Control Station**, etc.

Support components certified under the provisions of these Rules, whose surveys are maintained current, are eligible for use in a classed system.

3.5 New and Existing Underwater Units, Systems or Support Components Not Built Under Survey *(2012)*

Units, systems or support components not built under ABS survey but for which classification or certification (as applicable) is requested at a later date, will require submittal of available drawings and/or documentation as listed in Subsections 1/7 and 1/9 in conjunction with the following:

i) Welding procedures (WPS) and performance qualifications records (PQR)

ii) NDT records

iii) Material mill test reports

iv) All other certificates of past surveys and tests results conducted by the original certifying agency, insofar as such documentation is available and valid

v) Written test procedures for the tests and trials required to be performed for classification or certification

New and existing pressure hulls and pressure vessels for human occupancy and acrylic windows will only be accepted if proof of fabrication under survey by an IACS member Classification Society or recognized Flag Administration is provided.

Additionally, the units, systems or support components will be subject to special periodical surveys, hydrostatic and functional tests.

Where found satisfactory and thereafter approved by the Committee, the underwater unit or system will be classed and distinguished in the *Record* by the appropriate symbols and notations as described in 1/3.1 and 1/3.3, but the mark ✠ signifying the survey during construction will be omitted.

Where found satisfactory, the support component will be issued an Underwater System Support Component Certificate (ABS-USC-1) with the appropriate notations, but the symbol ✠ as described in 1/3.4 signifying survey during construction will be omitted.

3.7 Other Conditions

The Committee reserves the right to refuse classification of any unit or system in which the machinery, life support, piping, electrical systems, etc., are not in accordance with the requirements of these Rules.

5 Rules for Classification *(1 January 2008)*

5.1 Application of Rules *(2012)*

These Rules in association with the latest edition of the ABS *Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*, present the requirements for the classification of underwater vehicles, systems and hyperbaric facilities intended for use in manned underwater operations as defined in Section 2.

7 Submissions of Plans, Calculations, Data and Test Results

7.1 Submission Schedule and Number of Copies *(2011)*

Before commencement of fabrication, plans and other documents indicating the required particulars are to be submitted. Plans should generally be submitted electronically to ABS. However, hard copies will also be accepted.

7.3 Documentation to be Submitted *(2010)*

The plans and details required for review and approval are as follows and are to be submitted as applicable to the particular design features and/or systems.

7.3.1 Design and Operational Parameters *(2007)*

Design pressures and depths

Design temperatures

Hydrostatic test pressures

Design sea state conditions

Maximum operating depth

Maximum mission time

Maximum number of occupants (passengers and crew) in each unit and/or system

Maximum weight of units including occupants, contents, entrapped water, etc.

Maximum towing speed/towing line tension

Maximum speed while surfaced and submerged

7.3.2 General

General arrangement

Cross-section assembly

Outboard profile

Dimensional details of pressure hull, pressure vessel(s) and scantlings

Material specifications and grades, including tensile and impact values, for all pressure retaining or load bearing items

Weld details of pressure hull, pressure vessel(s) and scantlings

Welding procedures to include base and filler materials, pre and post weld heat treatment, tensile and impact values, extent of nondestructive testing.

Out-of-roundness tolerances

Fabrication tolerances

Dimensional details of penetrators, hatch rings, hatch details, lugs and any other internal or external connection to the hull

Penetrator sealing arrangements

Hatch sealing arrangements

Nameplate, including nameplate material and method of attachment

Plan showing all hull valves, fittings and penetrations

Exostructure details

Dimensional details of viewport components

Hard ballast tanks design details

Soft ballast tanks design details

Piping systems including pump capacities and pressure relief devices

Ballast piping systems

Layout of control stands

Equipment foundation and support arrangements with details where such foundations and supports increase stresses in the pressure hull or experience significant stress due to the operating loads encountered

Release devices and arrangement for jettisonable weights and equipment

Propeller details including shafting, bearings and seals

Propulsion motors, thrusters and wiring diagram

Steering control system

Electrical distribution system

Battery capacity, arrangement and main feeder scheme

Lifting and handling system

Depth indicating systems

Emergency systems

Fire fighting system

Details for permanently installed pressure vessels

Documentation for portable pressure vessels including standards of construction and design calculations for external pressure if units may at any time be subject to this condition.

List and location of implodable volumes

Materials and dimensions of umbilicals including cross sectional details

Any additional system deemed necessary to the intended operations

7.3.3 Life Support Systems and Equipment

Life support system details, both normal and emergency

Life support system capacities, fluids contained and supply arrangement

Specifications for environmental control systems and equipment including heating, gas analysis (CO_2, CO, CH_4, O_2, etc.), absorption, circulation, temperature control, humidity control, equipment for tracing contaminants

Component list including manufacturer, model, design specifications and test documentation for all equipment used in the life support system

For gas analyzers: specifications of type of gas to be detected, principle of detection, range of pressures under which the instrument may be used

Lodging facilities and drainage systems in hyperbaric chambers

7.3.4 Procedures

Procedures for out-of-roundness and sphericity measurements

Cleaning procedures for breathing gas systems

Inclining experiment procedures

Functional test procedures

Sea trial procedures for normal and emergency conditions

7.5 Calculations *(2002)*

The following calculations and analyses are to be submitted for review:

- Pressure vessel stress analysis in compliance with Section 6
- Foundation stress analysis
- Pressure hull support reaction analysis
- Analysis of lifting load and stresses induced in the hull
- Window calculations in compliance with Section 7
- Life support system analysis
- Heat/cooling consumption for the hyperbaric chamber or underwater vehicle under the design conditions and the expected environmental temperatures
- Electrical load analysis and loss of power, power sources; power demands
- Short circuit current calculations
- Coordination of short circuit protection devices (coordination study)
- Calculation for the center of gravity and center of buoyancy

- Intact stability analysis
- Damage stability analysis
- Hydrodynamic ascent calculations under normal and emergency conditions

7.7 Operational Data

The following operational data are to be submitted:

- Description of operations
- Description of units and intended service

7.9 Test Results

Data for the following tests, which are to be performed to the satisfaction of Surveyor, are to be submitted:

- Material tests
- Procedure and welder qualification test results
- Out-of-roundness measurements before and after hydrostatic test
- Hydrostatic tests
- Strain gauge tests, as applicable
- Electrical system insulation tests
- Life support tests
- Functional test of completed unit or chamber
- Test dive of completed underwater unit at rated depth (to include deadweight survey and inclining experiment)

9 Manuals

9.1 Operating Manual *(2007)*

An operating manual describing normal and emergency operational procedures is to be provided and is to be submitted for review. The manual is to include the following as applicable.

- System description
- Operation check-off lists (list to include equipment requiring operational status verification or inspection prior to each dive/operation and verification of the existence of appropriately updated maintenance schedule – see 1/9.3)
- Operational mission time and depth capabilities
- Sea state capabilities (see Section 17, Table 1)
- Geographical dive site limitations (such as maximum current, night/limited visibility operation and list of operational and environmental hazards, if any, to be avoided.) as related to the design parameters addressed in Subsection 1/7 and 11/49.3
- Special restrictions based on uniqueness of design and operating conditions
- Life support system description including capacities
- Electrical system description
- Launch and recovery operation procedures
- Liaison with support vessel

- Emergency procedures, developed from systems analysis, for situations such as power failure, break in lifting cable, break in umbilical cord, deballasting/jettisoning, loss of communications, life support system malfunction, fire, entanglement, high hydrogen level, high oxygen level, internal and external oxygen leaks, stranded on bottom, minor flooding, and specific emergency conditions characteristic of special types of systems.
- Emergency rescue plan (see 11/35.3.1 and 11/35.5)
- Color coding adopted

9.3 Maintenance Manual *(2002)*

A maintenance manual containing procedures for periodic inspection and preventive maintenance techniques is to be submitted for review. The manual is to include the expected service life of the pressure hull and of other vital components/equipment (e.g., viewports, batteries, etc.), methods for recharging life support, electrical, propulsion ballast and control systems and specific instructions for the maintenance of items requiring special attention.

9.5 Availability *(2007)*

The operating and maintenance manuals together with operational and maintenance records are to be readily available at the operation site and copies are to be made available to the Surveyor upon request. Summarized procedures for normal and emergency operations are to be carried onboard the unit.

11 Personnel *(2002)*

Underwater and related operations are a complex undertaking. In addition to the fitness represented by Classification as described in 1-1-1/5 of the ABS *Rules for Conditions of Classification (Part 1)*, appropriate personnel are of utmost importance to the successful and safe completion of a mission. Such issues fall under the purview of local jurisdictions, as noted in Section 1-1-5 of the above referenced Part 1, and so are specifically not addressed by ABS.

Owners and Operators of commercial and non-commercial underwater units are ultimately responsible for, and are to assure themselves of, the competence of those performing activities related to the unit. Guidance may be obtained from the unit manufacturer, persons or entities believed by the Owner/Operator to be competent in the field and with the subject equipment, organizations such as the Association of Diving Contractors (ADC), from publications such as the *Guidelines for Design, Construction and Operation of Passenger Submersible Craft* published by the International Maritime Organization (IMO) or from other sources as may be deemed appropriate by the Owner/Operator.

SECTION 2 Definitions

The following definitions and terms are to be understood in absence of other specifications.

1 Chamber Gas Reclaim System *(2013)*

A gas reclaim system used for reclaiming and reusing the gases exhausted from pressure vessels for human occupancy, transfer trunks/tunnels and medical/service locks.

3 Clinical Hyperbaric Treatment Chamber

A rigid-walled hyperbaric chamber that is used, in general, to treat patients. These treatment chambers are primarily hospital-based.

5 Command Compartment *(2012)*

A compartment located within a lock-out submersible from where the submersible is controlled and operated.

7 Deck Decompression Chamber

A unit consisting, in general, of two chambers (entry lock and main lock) installed on a support ship. This chamber allows for gas saturation, lodging, recovery and desaturation periods for divers performing a mission in a diving bell.

9 Design Depth

The depth in meters (feet) of water (seawater or fresh water) equivalent to the maximum pressure for which the underwater unit is designed and approved to operate, measured to the lowest part of the unit.

11 Design Pressure *(2013)*

The maximum pressure (internal or external) for which the unit is designed and approved to operate.

13 Design Mission Time

The maximum effective recharging interval for life support, compressed air and electrical systems for which the underwater vehicle or hyperbaric chamber is designed and approved to perform the intended function under normal operating conditions.

15 Dive Control Station *(2013)*

A centralized surface based control station from where the diving operations or operations of a tethered underwater unit are controlled and coordinated.

17 Diver Gas Reclaim System *(2013)*

A gas reclaim system used for reclaiming and reusing the gases exhaled by divers.

19 Diver Lock-out Compartment

A compartment within an underwater system or vehicle provided with internally pressurizing capability to transfer a diver to the work site from the submersible and vice versa.

21 Diver Training Hyperbaric Center

A complex intended for training gas saturation divers and simulation of working dives.

23 Diving Bell

A manned non-self-propelled submersible tethered unit consisting of at least one chamber internally pressurized in order to allow a diver to be transported to and from an underwater site.

25 Diving System

Compressed air or gas mixture saturation system for divers. It is composed of a diving bell, a bell launch and recovery system, a deck decompression chamber and other components deemed necessary to the mission.

27 Fire-restricting Materials *(2002)*

Fire-restricting materials are those materials having properties complying with IMO Resolution MSC.40(64); this resolution provides standards for qualifying marine materials as fire-restricting materials. Fire-restricting materials should: have low flame spread characteristics; limit heat flux, due regard being paid to the risk of ignition of furnishings in the compartment; limit rate of heat release, due regard being paid to the risk of spread of fire to any adjacent compartment(s); and limit the emission of gas and smoke to quantities not dangerous to the occupants.

29 Fixed Diving System (F) *(2012)*

A diving system that is installed permanently on a ship or offshore facility.

31 Gas Reclaim System *(2013)*

A closed circuit system used for reclaiming and reusing the gases exhaled by divers or exhausted from pressure vessels for human occupancy, transfer trunks/tunnels and medical/service locks.

33 Habitat

An underwater structure installed on the ocean floor, which is permanently or periodically manned. It is in general maintained at ambient pressure or at a pressure of one atmosphere.

35 Handling System

See Subsection 2/43, "Launch and Recovery System".

37 Hyperbaric Evacuation System *(2010)*

A hyperbaric evacuation system includes the hyperbaric evacuation unit and supporting systems and equipment based on the dive support vessel/offshore facility (such as the launch system) necessary for the evacuation of divers in saturation from a Diving System to another location where decompression can be safely carried out.

39 Hyperbaric Evacuation Unit *(2010)*

A hyperbaric evacuation unit consists of a pressure vessel for human occupancy and associated onboard supporting systems and equipment (such as the life support system) and is used for the evacuation of divers in saturation from a Diving System to another location where decompression can be safely carried out. Hyperbaric evacuation units may include self-propelled hyperbaric lifeboats, towable hyperbaric rescue chambers and hyperbaric rescue chambers that are suitable for offloading to or recovery by an attendant vessel/offshore facility.

41 Hyperbaric Facility

A chamber or combination of chambers intended for operation with human occupancy at internal pressure above atmospheric.

43 Launch and Recovery System *(2011)*

A system supporting launch, recovery and other handling operations of underwater units, hyperbaric facilities and their ancillary equipment. This may include but is not limited to cranes, booms, masts, frames, davits, foundations, winches and associated mechanical, piping and electrical systems as necessary for the intended operations.

45 Light Ship *(2002)*

The condition in which a vessel is complete in all respects but without consumables, stores, cargo, crew and effects and without any liquids on board except that machinery fluids, such as lubricants and hydraulics, are at operating levels.

47 Lock-Out Submersible *(2012)*

A self-propelled submersible fitted with one or more diver lock-out compartments from where diving operations may be carried out and a separate command compartment from where the submersible is controlled and operated.

49 Manipulator

A remotely operated work arm.

51 No-Decompression Limit *(2011)*

The maximum time a diver can spend at a given depth without the need for decompression during the subsequent ascent to the surface.

53 Open Bell

A non-pressurized compartment at ambient pressure that allows the diver to be transported to and from the work site, allows the diver access to the surrounding environment, and is capable of being used as a refuge during diving operations.

55 Passenger Submersible *(2013)*

A submersible carrying passengers in addition to the pilot, crew members and other persons employed or engaged in any capacity on board the submersible on the business of that submersible. (See Subsection 11/49).

57 Personnel Capsule

A manned, non-self-propelled submersible tethered unit consisting of one or more chambers, all of which are maintained at an internal pressure near one atmosphere.

59 Portable Decompression Chamber

A unit intended for human occupancy under greater than atmospheric pressure conditions, that is installed on a vehicle such as a helicopter or truck. This chamber may be utilized for therapeutic purposes.

61 Portable Diving System (P) *(2012)*

A diving system that is installed on a ship or offshore facility on a temporary basis and is capable of being demobilized and installed on another ship or offshore facility.

63 Pressure Boundary *(2013)*

The enclosure (including shells, heads, covers, plugs, fittings, etc.) that forms the pressure resistant structure of a pressure vessel.

65 Pressure Hull *(2011)*

The pressure boundary of a submersible that provides the human occupants with a pressure resistant habitat. (See Section 11.)

67 Pressure Resistant *(2013)*

A structure or component that withstands pressure.

69 Pressure Vessel for Human Occupancy (PVHO) *(2013)*

A vessel or chamber that encloses one or more human beings within its pressure boundary while under internal or external pressure exceeding a differential pressure of 2 psi. (See Section 13.)

71 Rated Depth

The depth in meters or feet of water (seawater or fresh water) equivalent to the pressure for which the underwater unit has been operationally tested in the presence of the Surveyor, measured to the lowest part of the unit. The rated depth may not exceed the design depth.

73 Rated Internal Pressure

The pressure for which the hyperbaric chamber has been operationally tested in the presence of the Surveyor. The rated internal pressure may not exceed the design internal pressure.

75 Remotely Operated Vehicle

Unmanned, remotely actuated underwater vehicle used for a variety of functions. These functions include inspection of underwater structures, photography, cleaning, trenching, etc.

77 ROV

See Subsection 2/75, "Remotely Operated Vehicle".

79 Submersible

A self-propelled craft capable of carrying personnel and/or passengers while operating underwater, submerging, surfacing and remaining afloat. Internal pressure is normally maintained at or near one atmosphere.

81 Submersible Decompression Chamber

See Subsection 2/23, "Diving Bell".

83 Tethered Submersible

A tethered self-propelled unit capable of carrying personnel and/or passengers underwater. Internal pressure is normally maintained at or near one atmosphere.

85 Umbilical

The connecting hose to a tethered submersible unit and from this unit to the divers. It may contain life support, surveillance, communication, remote control and power supply cables.

87 Underwater Complex

A complex comprising of any combination of habitats with transfer chambers, and may include a tethered or untethered submersible unit and its launch and recovery system.

89 Underwater Container

A permanently unmanned submersible vessel containing equipment that is to be protected from water. It may be anchored to the ocean floor.

91 Underwater System

A system comprised of one or more units with all their support components necessary to conduct a specified manned underwater operation such as a diving system and an underwater complex.

93 Underwater Vehicle

A self-propelled craft intended for underwater operations that may or may not be independent of surface support. This would include submersibles and ROVs.

95 Unit *(2007)*

For the purpose of these Rules, a "unit" is an underwater vehicle, system or hyperbaric facility.

97 Wet Submersible

A non-pressurized, open-hulled submersible at ambient pressure which is self-propelled and capable of ascent and descent, and which allows the divers access to the surrounding environment.

99 Working Chamber

An underwater structure permanently installed on the ocean floor, intended for periodically manned operations. It is maintained at ambient pressure or at the pressure of one atmosphere and may be flooded when not in use.

SECTION 3 General Requirements and Safeguards *(2010)*

1 Nonmetallic Materials

1.1 General

Materials and equipment inside manned compartments are to be such that they will not give off noxious or toxic fumes within the limits of anticipated environments or under fire conditions. Where compliance with this requirement has not been demonstrated through satisfactory service experience, a suitable analysis or testing program is to be performed and submitted. Systems are to be designed and equipped to minimize sources of ignition and combustible materials. See also Subsection 8/27.

1.3 Paints, Varnishes and Coatings *(2007)*

Excessive paint and coating thicknesses on exposed interior surfaces are to be avoided unless noncombustible materials are used. Nitrocellulose or other highly flammable or noxious fume-producing paints are not to be used.

1.5 Internal Materials *(2007)*

Linings, deck coverings, ceilings, insulation, partial bulkheads and seating are to be constructed of materials that are fire-restricting under the anticipated environmental conditions. Consideration will be given to materials having properties complying with recognized standards acceptable to ABS. See Subsection 2/27 for the definition of fire-restricting materials.

1.7 External Materials *(2002)*

Decks, deck coverings, skins and fairings are to be of materials that will not readily ignite or give rise to toxic or explosive hazards at elevated temperatures.

3 Proof Testing *(2002)*

3.1 Hydrostatic Test

After out-of-roundness measurements have been taken, all externally-pressurized pressure hulls are to be externally hydrostatically proof tested in the presence of the Surveyor to a pressure equivalent to a depth of 1.25 times the design depth for two cycles. Pressure hulls designed for both internal and external pressure are also to be subjected to an internal hydrostatic pressure test in accordance with Part 4, Chapter 4 of the *Steel Vessel Rules*. Acrylic components are to be tested in accordance with Section 7 of these Rules.

3.3 Strain Gauging

During the external proof testing in 3/3.1, triaxial strain gauges are to be fitted in way of hard spots and discontinuities. The location of strain gauges and the maximum values of stress permitted by the design at each location are to be submitted for approval prior to testing.

3.5 Waiver of Strain Gauging

Hydrostatic testing without strain gauges will be acceptable for units that are duplicates of a previously tested unit and have a design depth not greater than the tested unit. Units designed and built in accordance with the requirements of Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code or other recognized code having an equal or higher design margin (factor of safety) may be accepted without strain gauging. (This does not preclude the use of design standards having a lower factor of safety. See also 3/3.9 and 6/1 of these Rules.)

3.7 Post Test Examination

Following testing, all pressure boundary welds are to be examined in accordance with the requirements for magnetic particle, liquid penetrant or eddy current testing in accordance with Section 5, and out-of-roundness and sphericity measurements are to be taken. Acceptance criteria are to be in accordance with Section 5.

3.9 Alternate Test Procedures

When the pressure boundary is designed in accordance with an acceptable standard other than Section 6 of these Rules, hydrostatic testing may be conducted in accordance with the requirements of that standard. Such units are to be tested for two cycles in the presence of the Surveyor. Strain gauging is to be in accordance with 3/3.3 and 3/3.5. Post-test examination is to be in accordance with 3/3.7, except that the acceptance criteria are to be in accordance with the standard used.

5 Test Dive *(2007)*

A test dive to the design depth is to be conducted in the presence of the Surveyor. All penetrations and all joints accessible from within are to be inspected visually at a depth of approximately 30.5 m (100 ft) before proceeding to greater depths. All components, such as hull valves, whose operation is subjected to submergence pressure and which are required for safe operation, are to be operationally tested at this depth, if practicable. A log of the inspection of all hatches, viewports, mechanical and electrical penetrators, and valves is to be maintained. The submergence is then to be increased in increments of approximately 20 percent of the design depth until design depth is reached. At each 20 percent increment constant depth is to be maintained and accessible welds and other closures are to be inspected, and valves checked. Unsatisfactory operations of a valve or unsatisfactory leak rate may be cause to abort the test. The test dive may be a single dive, as described, or a series of dives to accomplish the same purpose. The test dive is also to demonstrate satisfactory performance of life support systems, air conditioning systems (if installed), propulsion systems, electrical systems, and items required for safe operations. Where the depth of water available is less than the design depth, both the rated depth (depth reached during test dive) and the design depth will be indicated in the *Record*. The rated depth may subsequently be increased by performing a test dive to a greater depth, not exceeding the design depth, in the presence of the Surveyor.

7 Protection

External piping, wiring, and equipment are to be located to minimize the likelihood of damage during handling operations, or they are to be suitably protected.

9 Corrosion Protection *(2007)*

All units, their external metallic structures and accessories are to be effectively protected against marine corrosion, marine growth and galvanic action.

Parts of these structures that are rendered inaccessible by fairings, skins or other external protections or obstructions are to be provided with a permanent corrosion protection system.

The interior of the unit is to be provided with a suitable anti-corrosion coating. See also 3/1.3 for additional coating requirements.

11 Thermal Protection *(2007)*

Based on the operational parameters of the unit, sufficient emergency thermal protection for all occupants is to be carried on board. The emergency thermal protection is to be capable of providing sufficient protection for the maximum dive time, as well as the reserve life support duration in accordance with 11/35.3 or 11/35.5, and the emergency life support duration as per 11/35.7 or 11/35.9.

SECTION 4 Materials

1 General

Materials are to comply with this Section and Chapters 1 and 3 of the ABS *Rules for Materials and Welding (Part 2)*, as applicable.

3 Pressure Boundary Material Specifications

3.1 Plates *(2010)*

Plate materials of pressure boundaries, including attachments, are to comply with one of the following.

i) *Steel (2008):* ABS Hull Grades E, EH32, EH36; U.S. Navy Grades HY-80 and HY-100 per MIL-S-16216; ASTM A516 Grades 55, 60, 65, 70; ASTM A537 Class 1 and 2; ASTM A517 Grades, A, B, E, F, J

ii) *Aluminum:* ASTM B 209 alloy 6061-T6; ASTM B 928 alloys 5083, 5086, 5383, 5456 (see Section 5 of these Rules)

iii) *Titanium Alloys:* ASTM B265 Grade 5

iv) *Stainless Steel:* ASTM A240 Type 304 or 316

v) *Acrylic Plastics* (cast polymethyl methacrylate): ASME PVHO-1 and Section 7 of these Rules

3.3 Bolts, Extrusions, Forgings, and Shapes

Materials of bolts, extrusions, forgings, and shapes are to comply with a recognized standard at least of similar quality to the plate materials specified in 4/3.1 (e.g. MIL-S-23009 for HY-80 forgings, ASTM A350 LF2 or LF3 for forgings comparable to ASTM A516).

3.5 Materials Complying with Other Standards

Consideration will be given to the use of material complying with other recognized standards suitable for the service intended. Approval of the use of other materials will depend on satisfactory evaluation and approval of the specifications prior to construction.

5 Testing

For steel intended for pressure boundaries and pressure retaining welded attachments, the tests, examinations, and inspections required by the material specifications and those indicated below are to be performed in the presence of and to the satisfaction of the Surveyor. Materials other than steel are to be examined, tested, and evaluated for soundness in accordance with recognized standards.

5.1 Inspection

All plates over 12.7 mm (0.5 in.) are to be ultrasonically examined. Steel plates with any discontinuity causing a total loss of back reflection which cannot be contained within a circle, the diameter of which is 75 mm (3.0 in.) or one half the plate thickness, whichever is greater, are unacceptable. Steel plates are to be examined in accordance with the procedures of ASTM A435 and the following:

i) Scanning is to be continuous along perpendicular grid lines on nominal 230 mm (9.0 in.) centers, using a suitable coupling medium such as water, soluble oil, or glycerin.

ii) Grid lines are to be measured from the center or one corner of the plate, with an additional path within 50 mm (2.0 in.) of all edges of the plate on the searching surface.

iii) Where complete loss of back reflection is detected along a given grid line, the entire surface area of the squares adjacent to this indication is to be continuously scanned. The boundaries of areas where complete loss of back reflection is detected are to be established.

5.3 Toughness Testing

Steel plates, shapes, and forgings are to be tested in accordance with 4/5.3.1 or 4/5.3.2, except this testing is not required for material 16 mm (0.625 in.) or less, that is normalized, fully killed, and made in accordance with fine grain practice or for Type 304 and 316 stainless steel.

5.3.1 Charpy Tests

Charpy V-notch tests are to be conducted on three specimens from each steel plate, shape, and forging, as heat treated. The tests are to be conducted in accordance with ASTM A370 and ASTM E23 using Charpy V-notch specimens. The test temperature and the energy absorption for the materials indicated in Subsection 4/3 are to be in accordance with the values given in the material specification or ASTM A20 Table A1.15 "Generally Available Grade-Thickness-Minimum Test Temperature Combinations Meeting Charpy V-Notch Requirements Indicated (Normalized or Quenched and Tempered Condition)", as applicable but in no case less conservative than the values given in Section 4, Table 1. For other materials, the test temperature and energy absorption are to be in accordance with the material specification, but in no case less conservative than the values given in Section 4, Table 1.

5.3.2 Drop Weight Tests

Two specimens from each plate, shape, and forging, as heat treated, are to be drop weight tested in accordance with ASTM E208. Both specimens are to exhibit no break performance when tested at the following applicable temperature:

As-welded fabrication	–28°C (–18°F)
Post-weld heat treated fabrication	–17°C (+2°F)
Seamless fabrication	–17°C (+2°F)

7 Corrosion and Galvanic Action

Protection against corrosion is to be provided as follows.

7.1 Ferritic Materials

Ferritic materials of pressure boundaries exposed to seawater or a seawater atmosphere are to have an increase in thickness over design requirements, protective coatings, or sacrificial anodes to insure that no reduction below design thickness will occur.

7.3 Galvanic Action

Precautions are to be taken to insure that dissimilar metals in combination will not cause metallic deterioration.

TABLE 1
Charpy Impact Testing Requirements

Min. Specified Yield Strength *kg/mm² (psi)*	*Min. Avg.*[1] *kg-m (ft-lb)*	*Test Temp.* *°C (°F)*
Up to 31 (44,000)	2.8 (20) [2]	-30 (-22)
31 (44,000) to 42 (60,000)	3.5 (25) [2]	-30 (-22)
42 (60,000) to 70 (100,000)	3.5 (25) [2]	-40 (-40)

Notes

1 *Longitudinal direction:* Transverse values may be two-thirds of the indicated longitudinal values.

2 Not more than one specimen is to exhibit a value below the specified minimum average and in no case is an individual value to be below 70 percent of the specified minimum average. The use of subsize specimens and retesting are to comply with 2-1-2/11.5 and 2-1-2/11.7 of the ABS *Rules for Materials and Welding (Part 2)*.

SECTION 5 Fabrication

1 Material Identification

Materials of pressure parts are to carry identification markings which will remain distinguishable until completion of fabrication. The marks are to be accurately transferred prior to cutting, or a coded marking is to be used to identify each piece of material during subsequent fabrication if the original identification markings are cut out or the material divided into two or more parts. Materials of pressure boundaries of underwater systems may be marked by stamping, using low stress stamps. An as-built sketch or a tabulation of materials identifying each piece of material with the mill test report and its markings is to be maintained. See Section 7 for marking of acrylic material.

3 Alignment Tolerance

3.1 Butt Weld Alignment

Alignment of sections at edges to be butt welded is to be such that the maximum offset is not greater than the applicable amount as listed in the following table, where *t* is the nominal thickness of the thinner section at the joint.

Section Thickness in mm (in.)	*Offset in mm (in.)*	
	Direction of Joints in Cylindrical Shells	
	Longitudinal	*Circumferential*
Up to 12.5 (0.5), incl.	$^1/_4t$	$^1/_4t$
Over 12.5 (0.5) to 19 (0.75), incl.	3.2 ($^1/_8$)	$^1/_4t$
Over 19 (0.75) to 38 (1.5), incl.	3.2 ($^1/_8$)	4.8 ($^3/_{16}$)
Over 38 (1.5) to 51 (2.0), incl.	3.2 ($^1/_8$)	$^1/_8t$
Over 51 (2.0)	$^1/_{16}t$ (9.5 ($^3/_8$) max.)	$^1/_8t$ (19 ($^3/_4$) max.)

Note: Any offset within the allowable tolerance above should be faired at a 3 to 1 taper over the width of the finished weld or, if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld.

3.3 Heads and Spherical Vessels

Joints in spherical vessels, in heads, and between cylindrical shells and hemispherical heads are to meet the above requirements for longitudinal joints.

5 Joints

Joints are categorized in accordance with Section 5, Figure 1.

5.1 Category A and B

All joints of Category A and B are to be full penetration welds. Joints of Category A and B made with consumable inserts or with metal backing strips which are later removed are acceptable as full penetration welds, provided the back faces of such joints are free or made free from weld surface irregularities and are in agreement with 5/5.5.

5.3 Category C and D

All joints of Category C and D are to be full penetration welds.

5.5 Joint Properties

Joints are to have complete penetration and fusion for the full length of the weld. They are to be free from injurious undercuts, overlaps, or abrupt ridges or valleys to eliminate sources of stress concentration. To assure that weld grooves are completely filled so that the surface of the weld metal at any point does not fall below the surface of the adjoining plate, weld metal may be built up as reinforcement on each side of the plate. Reinforcement is not to exceed that permissible for radiographic examination procedures and the following:

Plate Thickness in mm (in.)	*Maximum Thickness of Reinforcement in mm (in.)*
Up to 12.7 (0.5)	1.6 ($^{1}/_{16}$)
Over 12.7 (0.5) to 25.4 (1.0)	2.4 ($^{3}/_{32}$)
Over 25.4 (1.0) to 50.8 (2.0)	3.2 ($^{1}/_{8}$)
Over 50.8 (2.0)	4.0 ($^{5}/_{32}$)

7 Welding of Ferrous Materials

Welding is to comply with this Section and Section 2-4-2 of the ABS *Rules for Materials and Welding (Part 2)*, as applicable.

7.1 General

i) Precautions are to be taken to minimize absorption of moisture by low-hydrogen electrodes and fluxes.

ii) All surfaces to be welded are to be free from moisture, grease, loose mill scale, excessive rust or other oxidation, and paint.

iii) The areas from which temporary attachments have been removed are to be dressed smooth and examined by a magnetic particle, liquid penetrant or eddy current method. If weld repairs are necessary, they are to comply with 5/7.17.

7.3 Qualifications and Procedures

All weld procedures and welder qualifications are to be submitted and approved in accordance with Section 2-4-3 of the ABS *Rules for Materials and Welding (Part 2)*. The Surveyor may, at his discretion, accept electrodes, welding procedures and previous welder's qualification tests in a shipyard or fabricator's plant where it can be established that the particular electrodes, welding procedures, and welders have been qualified satisfactorily for similar work under similar conditions and will employ weld procedures previously approved.

7.5 Special Tests

The applicable special tests of 2-4-3/5.9 of the ABS *Rules for Materials and Welding (Part 2)* apply to new materials, high strength steels, new or unusual welding methods, and use of electrodes other than those listed in "Approved Welding Electrodes, Wire-Flux and Wire-Gas Combinations". For material with a specified minimum yield strength above 42 kg/mm^2 (60,000 psi), except for HY80 and HY100, Charpy V-notch impact tests of the midpoint of the heat affected zone are to be conducted, and the test results are to comply with the requirements for transverse specimens indicated in 4/5.3.1. For high heat input processes, such as electroslag and electrogas welding, Charpy V-notch impact tests of the weld metal, fusion line and 1 mm, 3 mm, 5 mm from the fusion line are to be conducted, and the test results are to comply with the requirements for transverse specimens indicated in 4/5.3.1 or 5/7.7 for the applicable weld metal material.

7.7 Weld Metal Impact Properties

7.7.1 Yield Strength ≤ 27 kg/mm^2 (38,000 psi)

For steel material with a minimum specified yield strength equal to or less than 27 kg/mm^2 (38,000 psi) a minimum average value of 4.8 kg-m (35 ft-lb) at –20°C (–4°F) is to be attained. Filler metals listed in "Approved Welding Electrodes, Wire-Flux and Wire-Gas Combination" as ABS Grade 3 filler metal or as an equivalent American Welding Society (AWS) Classification are considered to meet the impact requirement.

7.7.2 27 kg/mm^2 (38,000 psi) <Yield Strength ≤ 42 kg/mm^2 (60,000 psi)

For steel material with a minimum specified yield strength greater than 27 kg/mm^2 (38,000 psi) and equal to or less than 42 kg/mm^2 (60,000 psi), a minimum average value of 2.8 kg-m (20 ft-lb) at –40°C (–40°F) is to be attained. Filler metals listed in "Approved Welding Electrodes, Wire-Flux and Wire-Gas Combinations" as ABS Grade 3Y filler metal or as an equivalent AWS Classification are considered to meet the impact requirement.

7.7.3 Yield Strength Greater than 42 kg/mm^2 (60,000 psi)

For steel material with a minimum specified yield strength greater than 42 kg/mm^2 (60,000 psi), a minimum average value of 2.8 kg-m, (20 ft-lb) at –51°C (–60°F) is to be attained.

7.9 Weld Metal Tensile Strength

The weld metal utilized is to have a tensile strength comparable to the base material.

7.11 Postweld Heat Treatment *(2014)*

Postweld heat treatment is to be conducted for steel in accordance with 2-4-2/17 of the ABS *Rules for Materials and Welding (Part 2)* or in accordance with a recognized pressure vessels code or standard, except no postweld heat treatment is required for U.S. Navy Grades HY-80 and HY-l00 and ASTM A517 Grades.

For tempered steel, the postweld heat treatment temperature is not to exceed the tempering temperature. Heat treatment temperature and time is to comply with the following:

Minimum Holding Temperature degrees C (degrees F)	*Minimum Holding Time hr/25 mm (hr/in.)*
594 (1100)	1
566 (1050)	2
538 (1000)	3
510 (950)	5
482 (900)	10

Postweld heat treatment procedures are to be detailed in the weld procedure and submitted for review.

7.13 Production Testing

For Category A and B joints production impact testing of weld metal at the midpoint of the heat affected zones is to be performed for materials with a specified minimum yield strength above 42 kg/mm^2 (60,000 psi), except such testing need not be performed for HY-80 and HY-100 fabrication. The extent of testing is to be to the Surveyor's satisfaction and comply with the following:

7.13.1 Temperature

Charpy V-notch tests are to be conducted in accordance with ASTM A370 and ASTM E23 at the temperature used for base material testing. The specimens are to have their longitudinal axis transverse to the weld.

7.13.2 Tests Required

Production tests are to be conducted for the following:

i) Each welding procedure used

ii) Each position employed in automatic or semi-automatic welding

iii) For manual welding, on specimens from vertical test plates. If all welding is to be in flat position only, flat position test plates may be used.

7.13.3 Impact Values

Impact values obtained from production testing are to be at least as high as those required for the base material.

7.15 Nondestructive Examinations

One hundred percent volumetric examination is to be conducted on all Category A, B, C, and D full penetration groove welds, (i.e., 100 percent radiographic examination is to be conducted on all butt joints, 100 percent ultrasonic examination is to be performed on all joints other than butt joints). For butt welds, consideration will be given to the acceptance of ultrasonic examination in lieu of radiographic examination. Methods of surface examination, such as liquid penetrant, magnetic particle, or eddy current may additionally be required by the Surveyor prior to the hydrostatic testing.

7.15.1 Inspection for Delayed (Hydrogen Induced) Cracking

Nondestructive testing of weldments in steels of 42 kg/mm^2 (60,000 psi) yield strength or greater is to be conducted at a suitable interval after the welds have been completed and cooled to ambient temperature. The interval is to be at least 72 hours unless specially approved otherwise. At the discretion of the Surveyor, a longer interval and/or additional random inspection at a later date may be required. Further, at the discretion of the Surveyor, the 72 hour interval may be reduced to 24 hours for radiographic or ultrasonic inspections, provided a complete visual and random magnetic particle, liquid penetrant or eddy current inspection are conducted 72 hours after the welds have been completed and cooled to ambient temperature.

7.15.2 Post Hydrostatic Test Examination

Following hydrostatic testing, all pressure boundary welds are to be examined by magnetic particle or liquid penetrant or eddy current method. See also Subsection 3/3.

7.15.3 Radiographic and Ultrasonic Examinations

Procedures and acceptance standards for radiographic and ultrasonic examinations are to be in accordance with the following:

7.15.3(a) Radiographic Examination. Radiographic examinations of butt joints are to be in accordance with the ABS *Guide for Nondestructive Inspection of Hull Welds (NDI Guide)*. Procedures for radiographic examinations of joints other than butt joints are to be in accordance with a recognized standard such as Section V Article 2 of the ASME Boiler and Pressure Vessel Code or equivalent. Butt joints are to meet the class A acceptance standards of the *NDI Guide* for porosity and slag inclusion only. Cracks, lack of fusion, and incomplete penetration are unacceptable, regardless of length.

7.15.3(b) Ultrasonic Examination. Ultrasonic examinations of butt joints are to be in accordance with the *NDI Guide*. Procedures for ultrasonic examinations of joints other than butt joints are to be in accordance with a recognized standard such as Section V, Article 5 of the ASME Boiler and Pressure Vessel Code, or equivalent. Signals that are interpreted to be cracks, lack of fusion, and incomplete penetration are unacceptable regardless of length. All other signals that are interpreted to be linear discontinuities are unacceptable if the amplitude of the signal exceeds the reference level and discontinuities have lengths exceeding the following:

6 mm ($^1/_4$ in.)	for t up to 19 mm ($^3/_4$ in.)
$^1/_3t$	for t from 19 mm ($^3/_4$ in.) to 57 mm ($2^1/_4$ in.)
19 mm ($^3/_4$ in.)	for t over 57 mm ($2^1/_4$ in.)

where t is the thickness of the weld being examined.

7.15.4 Magnetic Particle, Liquid Penetrant and Eddy Current Examinations

Procedures and acceptance standards for magnetic particle, liquid penetrant and eddy current examinations are to be in accordance with the following:

7.15.4(a) Magnetic Particle and Liquid Penetrant Examinations. The examination procedures are to be in accordance with Section V Articles 6 and 7 of the ASME Boiler and Pressure Vessel Code, or equivalent.

The following relevant indications are unacceptable:

i) Any cracks and linear indications

ii) Rounded indications with dimensions greater than 5 mm ($^3/_{16}$ in.)

iii) Four or more rounded indications in a line separated by 1.6 mm ($^1/_{16}$ in.) or less edge to edge

iv) Ten or more rounded indications in any 3870 mm^2 (6 in^2) of surface with the major dimension of this area not to exceed 152.4 mm (6 in.) with the area taken in the most unfavorable location relative to the indications being evaluated.

7.15.4(b) Eddy Current Examination. Special consideration will be given to the acceptance of eddy current technique in lieu of other surface flaw detecting methods (magnetic particle or liquid penetrant). Procedures and equipment used for eddy current examinations of welds are to be specially approved. The equipment is to be operated by qualified and skilled technicians who are experienced in performing eddy current examinations. Technician qualification and results of eddy current examinations are to be to the satisfaction of the attending Surveyor. Any signals that are interpreted to be relevant discontinuities are to be further investigated by magnetic particle testing and any indication found is to be evaluated as per 5/7.15.4(a). In addition, when eddy current is used as method of surface flaw detection, it is to be supplemented with a sufficient amount of magnetic particle examination to verify that the accuracy of the eddy current method is maintained.

7.17 Weld Repairs

Welds which exhibit discontinuities that are considered unacceptable are to be excavated in way of the defect to sound metal. The excavated area is to be checked by an appropriate NDE method to determine that the discontinuity has been completely removed prior to repair by welding. The areas to be repaired are to be rewelded using qualified welding procedures, approved electrodes and qualified welders. The rewelded area is to be reexamined by the methods specified for the examination of the original weld to show that it has been satisfactorily repaired. See also 5/7.11 for post weld heat treatment requirements. If the depth of the deposit removed does not exceed the lesser of 9.5 mm ($^3/_8$ in.) or 10 percent of the weld thickness, the examination may be made by magnetic particle, liquid penetrant method, or eddy current technique.

9 Welding of Non-Ferrous Materials *(2002)*

9.1 General

Welding of non-ferrous material will be subject to special consideration.

9.3 Welded Joints in Aluminum

9.3.1 Alloys Listed in 4/3.1ii)

The ultimate and yield strengths for welded aluminum alloys listed in 4/3.1ii) are to be taken from 2-5-A1/Table 2 of the ABS *Rules for Materials and Welding (Part 2) – Aluminum and Fiber Reinforced Plastics (FRP)*.

9.3.2 Other Alloys and Tempers

Tensile and yield strengths for welded aluminum alloys and/or tempers not listed in 4/3.1ii), where such use is permitted, are to be obtained from recognized references or approved test results.

11 Out-of-Roundness, Sphericity, and Local Departure from Circularity

11.1 Measurements

Upon completion of fabrication and heat treatment, deviations from true circular form are to be measured before and after hydrostatic testing. The measurements are to be conducted to the Surveyor's satisfaction, and the results submitted for review.

11.3 Permitted Deviations of Cylinders and Conical Sections

The deviations from true circular form are not to exceed one (1) percent of the nominal diameter at the cross section. Where the cross section passes through an opening or within one inside diameter of the opening measured from the center of the opening, the permissible-out-of-roundness may be increased by two (2) percent of the inside diameter of the opening. When the cross section passes through any other location normal to the axis of the vessel, including head-to-shell junctions, the difference in diameters shall not exceed one (1) percent. Additionally, for vessels subject to external pressure, the deviation measured with a template complying with 5/11.3.3 is not to exceed the value of e from Section 5, Figure 2. The lengths, diameters and thicknesses are to be taken in constant units.

11.3.1 Length for Cylinders

Length, L for cylinders is measured parallel to the axis.

11.3.1(a) No Stiffening Rings. The distance between head-bend lines plus one-third the depth of each head.

11.3.1(b) With Stiffening Rings. The greatest center-to-center distance between two adjacent stiffening rings.

11.3.1(c) Stiffening Ring to Head. The distance from the center of the first stiffening ring to the head tangent line plus one-third of the depth of the head, all measured parallel to the axis of the vessel.

11.3.2 Length of Cones and Conical Sections

Length of cones and conical sections, L and D_o values to be used in the figures are given below where:

L_e = equivalent length of conical section = $(L_o/2)(1 + D_s/D_L)$ where

L_o = overall length of conical section under consideration.

D_s = outside diameter at small end of conical section under consideration.

D_L = outside diameter at large end of conical section under consideration.

i) *At large diameter end*

$L = L_e$

$D_o = D_L$

ii) *At the small diameter end*

$L = L_e(D_L/D_s)$

$D_o = D_s$

iii) *At the midlength diameter*

$L = L_e[2D_L/(D_L + D_s)]$

$D_o = 0.5(D_L + D_s)$

iv) *At any cross section having an outside diameter D_x*

$L = L_e(D_L/D_x)$

$D_o = D_x$

11.3.3 Template

Deviation measurements are to be made from a segmental circular template having the design inside or outside radius (depending upon where the measurements are taken) and a chord length equal to twice the arc length obtained from Section 5, Figure 3.

11.5 Permitted Deviations of Spheres and Hemispheres

11.5.1 General

The difference between the maximum and minimum inside diameters at any cross section is not to exceed one (1) percent of the nominal inside diameter at the cross section under consideration. The diameters may be measured on the inside or outside. If measured on the outside, the diameters are to be corrected for plate thickness at the cross section under consideration. When the cross section passes through an opening the permissible difference in inside diameters given above may be increased by two (2) percent of the inside diameter of the opening.

11.5.2 External Pressure

In addition to the requirements of 5/11.5.1, spheres, hemispheres, spherical portions of torispherical and ellipsoidal heads subject to external pressure are to comply with the following. The maximum plus or minus deviation from true circular form measured radially on the outside or inside of the vessel, is not to exceed 0.5 percent of the nominal inside radius of the spherical segment. Measurements are to be made from a segmental template having the design inside or outside radius (depending where measurements are taken) and a chord length, L_c, obtained from Section 5, Figure 4.

11.7 Thickness

11.7.1

For cylinders and spheres, the value of t is to be determined as follows:

i) For vessels with butt joints, t is the nominal plate thickness less corrosion allowance.

ii) Where the shell at any cross section is made of plates having different thicknesses, t is the nominal thickness of the thinnest plate less corrosion allowance.

11.7.2

For cones and conical sections, the value of t is to be determined as in 5/11.7.1, except the thickness in *i)* and *ii)* is to be replaced by t_e, where:

t_e = effective thickness of conical section

= $t \cos \alpha$

α = one-half the apex angle, deg.

11.9 Location of Measurements

11.9.1

The above requirements are to be met in any plane normal to the axis of revolution for cylinders and cones and in the plane of any great circle for spheres.

For conical sections and cones a check shall be made at locations in 5/11.3.2i), ii), iii) and such other locations as may be necessary to satisfy the Surveyor that above requirements are met.

11.9.2

Measurements are to be taken on the surface of the base metal and not on welds or other raised parts of the material.

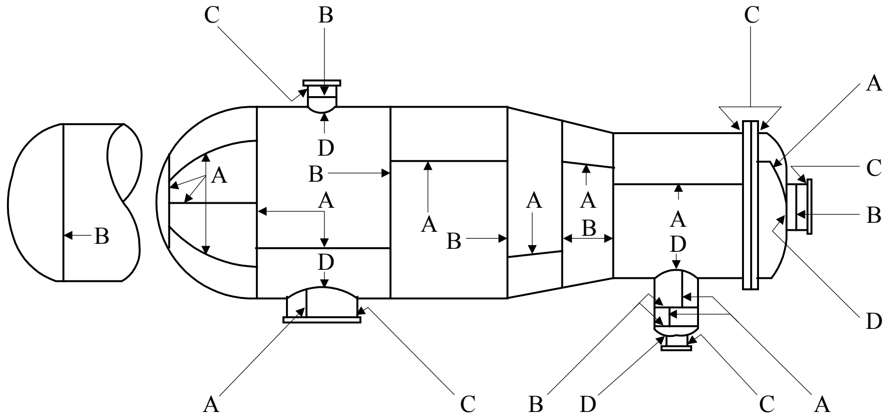
11.9.3

If repairs are needed to bring the completed vessel within above requirements, they are to be carried out with any approved process which will not impair the strength of the pressure hull. Sharp bends and flat spots are not permitted unless they were provided and approved for the original design.

13 Surface Finish

The surface finish of machined parts of pressure boundaries is generally not to exceed 6.35 μm (250 μin) rms. A surface finish of 0.8 μm (32 μin) is required for O-ring sealing surfaces unless otherwise specified by the manufacturer. Surface finish for viewport flanges is to comply with Section 7.

FIGURE 1
Illustration of Welded Joint Locations Typical of Categories A, B, C and D



Category A locations are longitudinal welded joints within the main shell, communicating chambers, transitions in diameter or nozzles; any welded joint within a sphere, within a formed or flat head or within the side plates of a flat-sided vessel; circumferential welded joints connecting hemispherical heads to main shells, to transitions in diameter, to nozzles or to communicating chambers.

Category B locations are circumferential welded joints within the main shell, communicating chambers, nozzles or transitions in diameter, including joints between the transition and a cylinder at either the large or small end; circumferential welded joints connecting formed heads other than hemispherical to main shells, to transitions in diameter, to nozzles or to communicating chambers.

Category C locations are welded joints connecting flanges, Van Stone laps, tube sheets or flat heads to main shell, to formed heads, to transitions in diameter, to nozzles or to communicating chambers; any welded joint connecting on side plate to another side plate of a flat-sided vessel.

Category D locations are welded joints connecting communicating chambers or nozzles to main shells, to spheres, to transitions in diameter, to heads or to flat-sided vessels, and those joints connecting nozzles to communicating chambers.

FIGURE 2
Maximum Permissible Deviation from Circular Form "e" for Vessels Under External Pressure

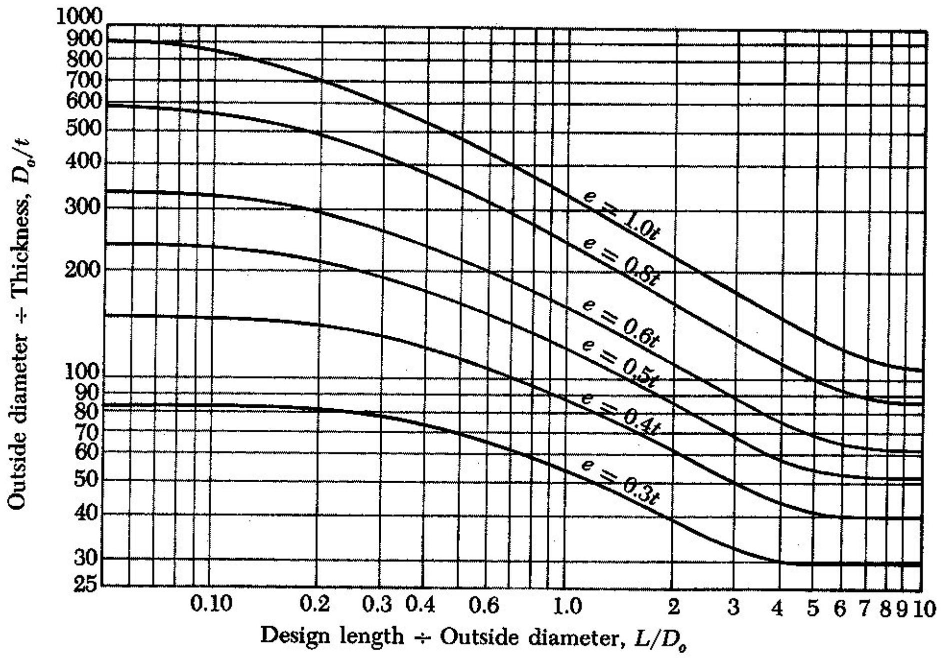


FIGURE 3
Arc Length

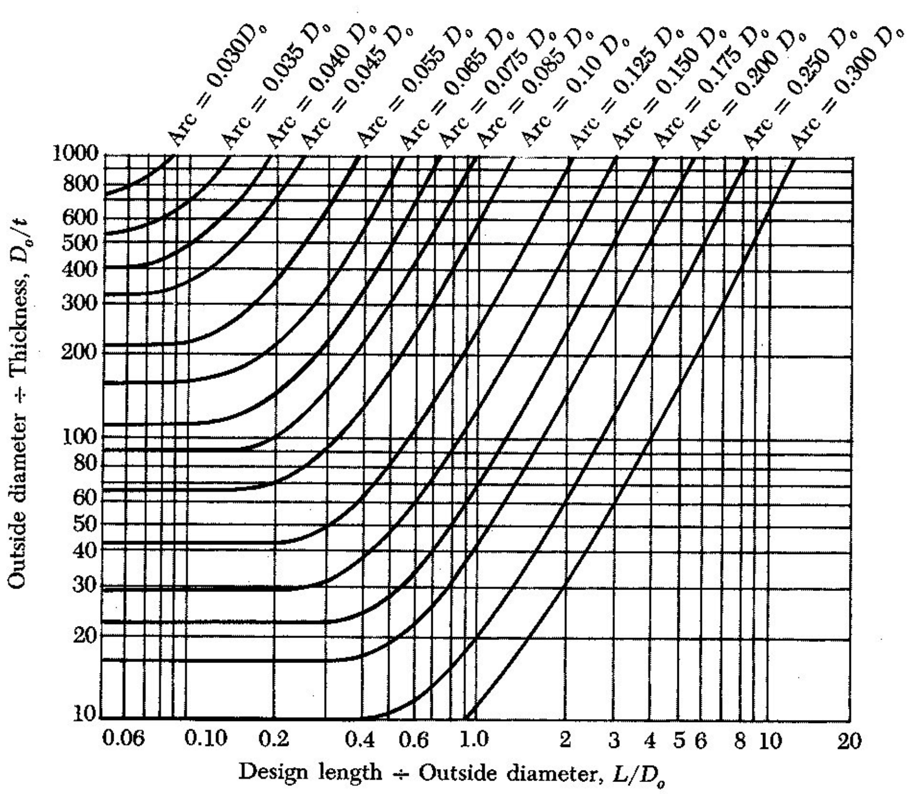
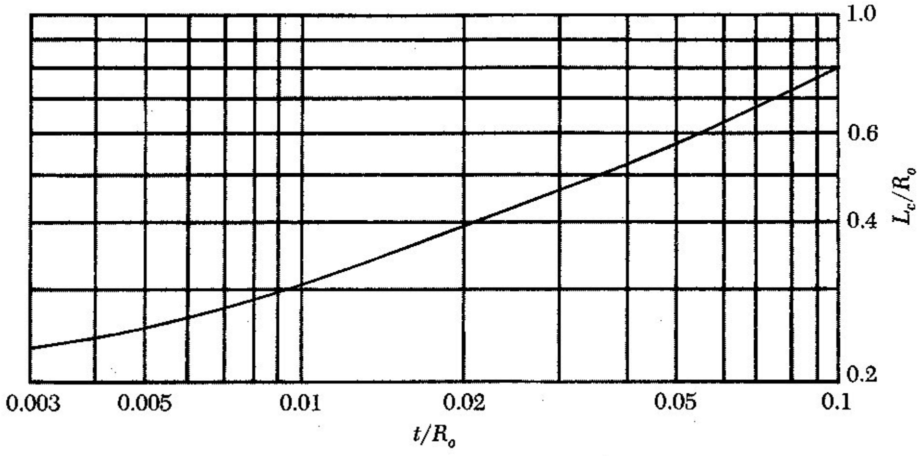


FIGURE 4
Values of Chord Length (L_c) for Out-of-roundness of Spheres



SECTION 6 Metallic Pressure Boundary Components

1 General

Metallic components of pressure boundaries are to comply with this Section. Designs based on other recognized standards will be given special consideration. The pressure vessel design rules in this Section are predicated on the fabrication tolerances as given in Section 5. Any consistent set of units may be used for the calculations required by this Section.

3 Design for Internal Pressure *(2010)*

Pressure hulls and pressure vessels for human occupancy subject to internal pressure are to comply with the requirements applicable to Group I pressure vessels in Part 4, Chapter 4 of the *Steel Vessel Rules*.

5 Design Pressures and Loads *(2010)*

5.1 General

Metallic pressure boundaries of pressure hulls and pressure vessels for human occupancy are to be designed for all anticipated pressures and loads that may act on the pressure boundary under normal and emergency operating conditions. These may include but are not limited to:

i) Internal and/or external pressures

ii) Localized loads due to external forces, impact loads, lifting forces, localized reactions and discontinuities

iii) Nozzle loads due to external manway/piping connections

iv) Loads due to expansion/contraction of the pressure boundaries

v) Deadweight of the installed equipment

vi) Weight of entrapped water/mud

vii) Loads due to the environmental conditions including wind loads, wave loads and current forces

5.3 Localized Loads

External forces, impact loads, support reactions and localized loads are to be analyzed as described below. Under these conditions, stresses are not to exceed the following limits:

Stress	*% of Minimum Specified Yield Strength*	*% of Minimum Specified Tensile Strength*
General membrane	80	—
Local membrane plus bending	120	75
Local membrane plus bending plus secondary membrane	200	100

5.3.1 External Forces

The design is to consider all applicable external forces that may act on the pressure boundary.

For pressure hulls and pressure vessels for human occupancy that are launched and recovered at sea, these forces are to be at least 2 g vertical, 1 g transverse and 1 g longitudinal, unless otherwise determined, all acting simultaneously while the pressure boundary is internally pressurized.

Pressure hulls and pressure vessels for human occupancy used for mating operations are to be designed for hatch/manway impact loads due to mating (on the surface or underwater) under normal conditions and when misaligned 6.35 mm (0.25 in.). A force of not less than twice the weight of the mating vessel, including entrapped water and its contents, is to be used.

5.3.2 Lifting Force

The primary lifting lugs and lifting attachments for pressure hulls and pressure vessels for human occupancy that are launched and recovered at sea are to be analyzed for forces of at least 2 g vertical (1 g static plus 1 g dynamic), 1 g transverse and 1 g longitudinal, unless otherwise determined, acting simultaneously under the most severe loading condition.

5.3.3 Localized Reactions

Bending and radial loads are to be analyzed based on forces and moments anticipated during operation.

5.3.4 Discontinuities

Localized stresses resulting from geometric discontinuities are to be analyzed.

7 Reinforcement

Penetrations are to be reinforced in accordance with Part 4, Chapter 4 of the *Steel Vessel Rules*. For external pressure the reinforcement need only be 50 percent of that required by the Rules and reinforcement pads are not to be used; all reinforcement is to be integral with shell and nozzle walls.

9 Fatigue *(2002)*

A fatigue analysis is to be submitted when it is anticipated that the life time full range pressure cycles N will exceed that obtained from the following equation:

$$N = [1160(3000 - T)/(Kf_\tau - 14500)]^2$$

where

T	=	temperature in degrees C (degrees F) corresponding to application of the cyclic or repeated stress
K	=	5688 SI/MKS units (4 U.S. units)
f_τ	=	range of cyclic stress kg/mm^2 (lb/in^2)

Pressure cycles of less than full pressure are to be included in N in the ratio p/P where p is the actual pressure of the cycle under consideration and P is the design pressure.

11 Drainage *(2002)*

Drainage openings are to be provided at points where liquid may accumulate.

Alternatively, fillers may be used in such locations provided they remain flexible, are adhered to the substrate per the manufacturer's instructions and field inspection procedures are included in the maintenance manual. Inspection procedures must permit detection of corrosion under the filler without removal of the filler or must require that the filler be removed and replaced, per the manufacturer's instructions, at each inspection.

13 Corrosion Allowance

A corrosion allowance in excess of the thickness required by the various formulations in this Section is to be specified by the designer. All strength calculations are to be conducted with the corrosion allowance removed.

15 Definition and Determination of Yield Point and Yield Strength

15.1 Yield Point

The yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point may be determined by the halt of the pointer, or from an autographic diagram. The 0.5 percent total extension under load method will also be considered acceptable.

15.3 Yield Strength

The yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. Yield strength is to be determined by the 0.2 percent offset method. Alternatively, for material whose stress-strain characteristics are well known from previous tests in which stress-strain diagrams were plotted, the 0.5 percent extension under load method may be used.

17 Nomenclature

17.1 General

P Applied External Pressure

η Usage Factor

17.3 Material Properties

E Modulus of Elasticity

ν Poisson's ratio

σ_y specified minimum yield point or yield strength

17.5 Calculated External Pressures

P_a maximum allowable pressure for any failure mode

P_{all} allowable working pressure of the unit (to be taken as the lowest calculated P_a)

P_c cylinder inter-stiffener limit pressure

P_{co} cone inter-stiffener limit pressure

P_{cs} sphere limit pressure

P_{es} sphere linear classical buckling pressure

P_ℓ cylinder stiffener longitudinal yield stress pressure

$P_{\ell o}$ cone stiffener longitudinal yield stress pressure

P_m von Mises buckling pressure for a cylinder

P_{mo} von Mises buckling pressure for a cone

P_n cylinder overall instability pressure

P_{no} cone overall instability pressure

P_t cylinder stiffener circumferential and bending yield stress pressure

P_{to} cone stiffener circumferential and bending yield stress pressure

P_y yield pressure at midbay and midplane of a cylinder

P_{yo} yield pressure at midbay and midplane of a cone

P_{ys} sphere yield pressure

17.7 Shell Parameters

$\theta = [3(1 - \nu^2)]^{1/4}M$

$Q = \theta/2$

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

$$G = \frac{2(\sinh Q \cos Q + \cosh Q \sin Q)}{\sinh(2Q) + \sin(2Q)}$$

$$H = \frac{\sinh(2Q) - \sin(2Q)}{\sinh(2Q) + \sin(2Q)}$$

Note: Other symbols are defined where used.

19 Cylindrical Shells Under External Pressure

19.1 Shell Geometry

D_o outer diameter

L greater of L_b or L_s

L_b unsupported spacing between stiffeners

L_c compartment length for overall instability considerations

L_s center to center spacing of stiffeners

R mean radius

R_f radius to tip of the stiffener outstand away from the shell

R_o outer radius

R_s radius to centroid of stiffener cross section alone

t shell thickness

19.3 Stiffener Properties

A_s area of stiffener cross section alone

I moment of inertia of combined section consisting of stiffener together with an effective length of shell L_e about the centroidal axis of the combined section parallel to the axis of the cylinder

I_z moment of inertia of stiffener alone about the radial axis through the web

L_e effective length of cylindrical shell acting with the stiffener equal to the smaller of $1.5\sqrt{Rt}$ or $0.75L_s$.

t_w thickness of stiffener web

$\bar{z}$ distance of centroid of stiffener cross section alone to the closer shell surface

19.5 Inter-Stiffener Strength

19.5.1

Inter-stiffener strength is to be obtained from the following equation:

$P_c = P_m/2$ if $P_m/P_y \le 1$

$P_c = P_y[1 - P_y/(2P_m)]$ if $1 < P_m/P_y \le 3$

$P_c = \frac{5}{6} P_y$ if $P_m/P_y > 3$

where

$$P_m = \frac{2.42E[t/(2R)]^{5/2}}{(1-\nu^2)^{3/4}[L/(2R) - 0.45(t/(2R))^{1/2}]}$$

$$P_y = \frac{\sigma_y t/R}{1-F}$$

$$F = \frac{A[1-(\nu/2)]G}{A + t_w t + (2NtL/\theta)}$$

$$M = L/\sqrt{Rt}$$

$A = A_s(R/R_s)^2$ for external framing

$= A_s(R/R_s)$ for internal framing

The maximum allowable working pressure based on inter-stiffener strength is given by:

$P_a = P_c\eta$ where $\eta = 0.80$

19.5.2

The limit pressure corresponding to the longitudinal stress at stiffeners reaching yield, is given by the following:

$$P_\ell = \frac{2\sigma_y t}{R}\left[1 + \left(\frac{12}{1-\nu^2}\right)^{1/2} \gamma H\right]^{-1}$$

$$\gamma = \frac{A[1-(\nu/2)]}{A + t_w t + (2NtL/\theta)}$$

The maximum allowable working pressure based on longitudinal stress at the frame is given by:

$P_a = P_\ell\eta$ where $\eta = 0.67$

19.7 Unstiffened Cylinders

Unstiffened cylinders are to be assessed using the inter-stiffener strength expressions given in 6/19.5.1 considering $F = 0$. L is to be taken as L_c (See 6/19.9). The axial length of a conical section adjacent to the cylinder(s) is to be included in the value of L_c (See Section 6, Figure 2) for all unstiffened cylinder-to-cone transitions without heavy members at their junctures. The t/R ratio is to be taken as that of any cylindrical or conical section within L_c which will give the lowest inter-stiffener limit pressure, P_c.

19.9 Length Between Support Members

L_c is the largest spacing between two heavy stiffeners, or the heavy stiffener and the dome end, or the entire (compartment) length between ends of the vessel. In the case of dome ends, the length L_c is to include 40 percent of the height of the head. See Section 6, Figure 2.

19.11 Heavy Stiffeners

Stiffeners used for purposes of reducing the compartment length L_c within which overall buckling performance is checked are termed heavy stiffeners and are to be designed to meet the requirements for heavy stiffeners in 6/19.15.2.

19.13 Overall Buckling Strength

The limit pressure corresponding to the overall buckling mode between heavy support members is obtained from the following equation:

$$P_n = \left(\frac{Et}{R}\right)A_1 + \frac{EIA_2}{LR^3}$$

where

$$A_1 = \frac{\lambda^4}{[A_2 + (\lambda^2/2)][n^2 + \lambda^2]^2}$$

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

$$A_2 = n^2 - 1$$

The number of lobes, n, expected at failure is a positive integer, 2 or higher (see Section 6, Figure 4), that results in the lowest P_n.

The maximum allowable working pressure based on overall buckling strength is given by:

$$P_a = P_n\eta \qquad \text{where } \eta = 0.50$$

19.15 Stiffeners

All stiffeners are to be attached to the shell by continuous welding. Any ring stiffener welded to a cylindrical shell is to comply with the following strength formulations relating to the maximum stress in the stiffener, stiffener tripping, local buckling of webs and flanges, and stiffener flexural inertia. These formulations apply to stiffeners whose outer flanges (where fitted) are symmetric about the web. Other geometries will be subject to special consideration.

19.15.1 Non-Heavy Stiffeners

19.15.1(a) Stress Limits. The yield pressure P_t, including the circumferential (hoop) stress and the bending stress arising from possible out-of-roundness, is calculated by satisfying the following equation:

$$\sigma_y = \frac{P_t\sigma_y}{p_{yf}} + \frac{Ec\delta(n^2-1)P_t}{(P_n - P_t)R^2}$$

where

n = number of overall instability lobes

P_n = corresponding buckling pressure as given in 6/19.13

δ = allowable out-of-roundness, $^1/_2$ percent of R or $0.005R$.

The distance of the stiffener flange from the neutral axis of the combined stiffener and effective shell section L_e is denoted "c".

P_{yf} is calculated as follows:

$$P_{yf} = \frac{\sigma_y t R_f}{R^2[1-(\nu/2)-\gamma]}$$

The maximum allowable working pressure based on stiffener stresses is given by

$P_a = P_t \eta$ where $\eta = 0.50$

19.15.1(b) Stiffener Tripping. The circumferential tripping stress for flanged stiffeners attached to the shell is to be obtained as follows:

$$\sigma_T = \frac{EI_z}{A_s R\bar{z}}$$

The tripping stress as obtained from the above equation is to be greater than the applicable yield stress σ_y.

19.15.1(c) Local Buckling. To address the possibility of local buckling of the flanges and webs of a stiffener cross section welded to the shell, the following slenderness limits are to be met:

Item	
Flat bars, other outstands	Width/Thickness $\leq 0.3\sqrt{E/\sigma_y}$
Web of flanged stiffener	Depth/Thickness $\leq 0.9\sqrt{E/\sigma_y}$

19.15.1(d) Inertia Requirements. The moment of inertia for the combined section consisting of a stiffener welded to the shell and the effective shell length L_e is to be not less than I obtained from the following:

$I = PD_oL_sR_s^2/(6E\eta)$ where $\eta = 0.50$

19.15.2 Heavy Stiffeners

19.15.2(a) Stress Limits. The yield pressure P_t including the circumferential (hoop) stress and the bending stress arising from possible out-of-roundness is calculated by satisfying the following equation:

$$\sigma_y = \frac{P_t\sigma_y}{p_{yf}} + \frac{3Ec\delta P_t}{(P_n - P_t)R^2}$$

where

$$P_{yf} = \frac{\sigma_y t R_f}{R^2[1-(\nu/2)-\gamma]}$$

$$P_n = \frac{3EI}{L_c R^3}$$

$$\gamma = \frac{A[1-(\nu/2)]}{A + t_w t + (2NtL_c/\theta)}$$

$$M = L_c/\sqrt{Rt}$$

I, δ, c, θ, N, R_f, R_s, A, etc. are the corresponding values (as defined previously) for the heavy stiffener being under consideration. The maximum allowable working pressure based on stiffener stresses is given by:

$P_a = P_t \eta$ where $\eta = 0.50$

19.15.2(b) Stiffener Tripping. Item 6/19.15.1(b) is likewise applicable to heavy stiffeners.

19.15.2(c) Local Buckling. Item 6/19.15.1(c) is likewise applicable to heavy stiffeners.

19.15.2(d) Inertia Requirements. The moment of inertia I for the combined section consisting of the stiffener attached to the shell and the effective shell length L_e acting with it, is not to be less than that obtained from the following:

$$I = PD_oL_cR_s^2/(6E\eta) \qquad \text{where } \eta = 0.50$$

The applicable usage factor η is 0.5.

19.15.3 Remaining Stiffeners

The same assessment as above is to be followed for the remaining heavy stiffeners bounding a compartment length and non-heavy stiffeners within that compartment length.

21 Conical Shells Under External Pressure

21.1 Shell Geometry

R_1 mean radius of shell at small end of conical bay

R_2 mean radius of shell at large end of conical bay

R_b $(R_1 + R_2)/2$ or $(R_2 + R_3)/2$, etc.

R_c $(R_{H1} + R_{H2})/2$

R_{H1} mean radius of shell at heavy member of the smaller end of the conical section

R_{H2} mean radius of shell at heavy member of the larger end of the conical section

L greater of L_b or L_s

L_b unsupported spacing between stiffeners

L_c compartment length for overall instability considerations

L_s center to center spacing of stiffeners

t shell thickness

α half-apex angle of a cone

21.3 Stiffener Properties (See Notes in 6/21.7 and 6/21.15)

A_s area of stiffener cross section alone

d distance of centroid of stiffener cross section alone to the tip of stiffener outstand (away from the shell)

I moment of inertia of combined section consisting of stiffener together with an effective length of shell L_e about the centroidal axis of the combined section parallel to the axis of the cone

I_z moment of inertia of stiffener alone about the radial axis through the web

L_e effective length of conical shell acting with the stiffener

t_w thickness of stiffener web

$\bar{z}$ distance of centroid of stiffener cross section alone to the closer shell surface

21.5 General

Conical shells are to have a half-apex angle, α (see Section 6, Figure 5) not greater than 60°. Special consideration will be given to cones with a half-apex angle, α, greater than 60° when their design is not in compliance with the requirements for unstayed flat heads of Part 4, Chapter 4 of the *Steel Vessel Rules*.

The radial axis of all stiffeners is to be normal to the cone axis. Stiffened cones are to have their ends bounded by two heavy stiffeners each located as close as possible to the point of cone-to-cylinder transition (see Section 6, Figure 2).

Local stresses and stress concentrations are to be considered for cone-to-cylinder transition regions.

21.7 Inter-Stiffener Strength

21.7.1

The inter-stiffener strength of the conical shell is to be calculated for each bay using the following equation:

$P_{co} = P_{mo}/2$ if $P_{mo}/P_{yo} \le 1$

$P_{co} = P_{yo}[1 - (P_{yo}/2P_{mo})]$ if $1 < P_{mo}/P_{yo} \le 3$

$P_{co} = \frac{5}{6} P_{yo}$ if $P_{mo}/P_{yo} > 3$

where

$$P_{mo} = \frac{2.42E[t\cos\alpha/(R_1+R_2)]^{5/2}}{(1-\nu^2)^{3/4}\left[\left(\frac{L}{R_1+R_2}\right) - 0.45\left(\frac{t\cos\alpha}{R_1+R_2}\right)^{1/2}\right]}$$

$$P_{yo} = \frac{\sigma_y t\cos\alpha}{R_2(1-F)}$$

$$F = \frac{A[1-(\nu/2)]G}{A + t_w t\cos\alpha + (2Nt(\cos\alpha)L/\theta)}$$

$$M = \frac{L}{\sqrt{R_b t\cos\alpha}}$$

$A = A_s(R_b/R_{se})^2$ for external framing, where $R_{se} = R_b + (t/2) + \bar{z}$

$ = A_s(R_b/R_{si})$ for internal framing, where $R_{si} = R_b - (t/2) - \bar{z}$

The maximum allowable working pressure based on inter-stiffener strength is given by:

$P_a = P_{co}\eta$ where $\eta = 0.72$

Note: For the purpose of calculating stiffener properties (I, A, etc.) for each bay, the following are to be considered in conjunction with the nomenclature already given in Subsections 6/17 and 6/21:

i) The stiffener (bounding the conical bay) with the smallest moment of inertia about its own neutral axis, taken parallel to the cone axis.

ii) The effective length of the conical shell, L_e, being parallel to the cone axis and perpendicular to the stiffener web with a magnitude equal to the smaller of $1.5\sqrt{R_b t\cos\alpha}$ or $0.75L_s$.

iii) The centroid of the effective shell [see *ii)* above] of the combined stiffener located at a radius (from the cone axis) not less than R_b of the bay under consideration. See detail in Section 6, Figure 5.

21.7.2

The limit pressure corresponding to the longitudinal stress at stiffeners reaching yield, is given by the following:

$$P_{\ell o} = \frac{2\sigma_y t\cos\alpha}{R_b}\left[1 + \left(\frac{12}{1-\nu^2}\right)^{1/2}\gamma H\right]^{-1}$$

where

$$\gamma = \frac{A[1-(\nu/2)]}{A + t_w t\cos\alpha + (2Nt(\cos\alpha)L/\theta)}$$

The maximum allowable working pressure based on longitudinal stress and the frame is given by:

$P_a = P_{\ell o}\eta$ where $\eta = 0.67$

21.7.3

The same assessment as in 6/21.7.1 and 6/21.7.2 is to be followed for each of the remaining bays of the cone.

21.9 Unstiffened Cones

Unstiffened cones (including unstiffened cones whose ends are bounded by heavy members, see 6/21.13) are to be assessed using the inter-stiffener strength expressions given in 6/21.7.1 considering $F = 0$. L is to be taken as the axial length of the cone (see Section 6, Figure 5). In addition, all "unstiffened-cylinder-adjacent-to-unstiffened-cone" designs without heavy members at their transitions, are to comply with the requirements of 6/19.7.

21.11 Length between Support Members

L_c is the largest spacing between two heavy stiffeners, or the heavy stiffener and the dome end, or the entire (compartment) length between ends of the vessel. In the case of dome ends, the length L_c is to include 40 percent of the height of the head. See Section 6, Figure 2.

21.13 Heavy Stiffeners

Stiffeners used for purposes of reducing the compartment length L_c within which overall buckling performance is checked are termed heavy stiffeners and are to be designed to meet the requirements for heavy stiffeners in 6/21.17.2.

21.15 Overall Buckling Strength

The limit pressure corresponding to the overall buckling mode between heavy support members is obtained from the following equation:

$$P_{no} = \left[\frac{Et\cos\alpha}{R_c}\right]A_1 + \frac{EIA_2}{LR_{H2}^3}$$

where

$$A_1 = \frac{\lambda^4}{[A_2 + (\lambda^2/2)][n^2 + \lambda^2]^2}$$

$$\lambda = \frac{\pi R_c \cos\alpha}{L_c}$$

$$A_2 = n^2 - 1$$

The number of lobes, n, expected at failure is a positive integer, 2 or higher (see Section 6, Figure 4), that results in the lowest P_{no}.

The maximum allowable working pressure based on overall buckling strength is given by:

$$P_a = P_{no}\eta \qquad \text{where } \eta = 0.50$$

Note: For the purpose of calculating stiffener properties for each conical section bounded by heavy members, the following are to be considered in conjunction with the nomenclature already given.

i) The stiffener (within the heavy members) with the smallest moment of inertia about its own neutral axis, taken parallel to the cone axis.

ii) The effective length of the conical shell, L_e, being parallel to the cone axis and perpendicular to the stiffener web with a magnitude equal to the smaller of $1.5\sqrt{R_c t\cos\alpha}$ or $0.75L_s$.

iii) The centroid of the effective shell [see *ii)* above] of the combined stiffener located at a radius (from the cone axis) not less than R_c. See detail in Section 6, Figure 5.

21.17 Stiffeners

All stiffeners are to be attached to the shell by continuous welding. Any ring stiffener welded to a conical shell is to comply with the following strength formulations relating to the maximum stress in the stiffener, stiffener tripping, local buckling of webs and flanges, and stiffener flexural inertia. These formulations apply to stiffeners whose outer flanges (where fitted) are symmetric about the web. Other geometries will be subject to special consideration.

21.17.1 Non-heavy Stiffeners

21.17.1(a) Stress Limits The yield pressure P_{to}, including the circumferential (hoop) stress and the bending stress arising from possible out-of-roundness, is calculated by satisfying the following equation for the stiffener considered in 6/21.7 for each bay.

$$\sigma_y = \frac{p_{to}\sigma_y}{p_{yfo}} + \frac{Ec\delta(n^2-1)P_{to}}{(P_{no}-P_{to})R_b^2}$$

where

n	=	number of overall instability lobes
P_{no}	=	corresponding buckling pressure as given in 6/21.15
δ	=	allowable out-of-roundness, 1/2 percent of R_b or $0.005R_b$

The distance of the stiffener flange from the neutral axis of the combined stiffener and effective shell section L_e, is denoted "c".

P_{yfo} is calculated as follows:

$$P_{yfo} = \frac{\sigma_y t(\cos\alpha)R_{fo}}{R_b^2[1-(\nu/2)-\gamma]}$$

where

R_{fo}	=	$R_b + (t/2) + \bar{z} + d$	for external framing
R_{fo}	=	$R_b - (t/2) - \bar{z} - d$	for internal framing

The maximum allowable working pressure based on stiffener stresses is given by:

$P_a = P_{to}\eta$ where $\eta = 0.50$

21.17.1(b) Stiffener Tripping. The circumferential tripping stress for flanged stiffeners attached to the shell is to be obtained as follows:

$$\sigma_T = \frac{EI_z}{A_s R_b \bar{z}}$$

The tripping stress as obtained from the above equation is to be greater than the applicable yield stress σ_y.

21.17.1(c) Local Buckling. To address the possibility of local buckling of the flanges and webs of a stiffener cross section welded to the shell, the following slenderness limits are to be met:

Item	
Flat bars, other outstands	Width/Thickness $\leq 0.3\sqrt{E/\sigma_y}$
Web of flanged stiffener	Depth/Thickness $\leq 0.9\sqrt{E/\sigma_y}$

21.17.1(d) Inertia Requirements. The moment of inertia for the combined section, consisting of a stiffener welded to the shell and the effective shell length L_e (see Note in 6/21.7) acting with it, is to be not less than I obtained from the following:

$$I = P(2R_b + t)L\,R_{so}^2/(6E\eta\cos\alpha)$$

where

R_{so}	=	R_{se}	for external framing
R_{so}	=	R_{si}	for internal framing

The applicable usage factor η is 0.50

21.17.1(e) Remaining Non-Heavy Stiffeners. The same assessment as 6/21.17.1(a) through 6/21.17.1(d) is to be followed for each stiffener considered in 6/21.7 for the remaining conical bays.

21.17.2 Heavy Stiffeners

21.17.2(a) Stress Limits The yield pressure P_{to}, including the circumferential (hoop) stress and the bending stress arising from possible out-of-roundness, is calculated by satisfying the following equation for the heavy stiffener under consideration.

$$\sigma_y = \frac{P_{to}\sigma_y}{P_{yfo}} + \frac{3Ec\delta P_{to}}{(P_{no} - P_{to})R_c^2}$$

where

$$P_{yfo} = \frac{\sigma_y t(\cos\alpha)R_{fc}}{R_c^2[1-(\nu/2)-\gamma]}$$

$$P_{no} = \frac{3EI}{L_c R_{H2}^3}$$

R_{fc}	=	$R_c + (t/2) + \bar{z} + d$	for external framing
	=	$R_c - (t/2) - \bar{z} - d$	for internal framing

$$\gamma = \frac{A[1-(\nu/2)]}{A + t_w t\cos\alpha + (2Nt(\cos\alpha)L_c/\theta)}$$

$$M = \frac{L_c}{\sqrt{R_c t\cos\alpha}}$$

A	=	$A_s(R_c/R_{sx})^2$	for external framing, where $R_{sx} = R_c + (t/2) + \bar{z}$
	=	$A_s(R_c/R_{sn})$	for internal framing, where $R_{sn} = R_c - (t/2) - \bar{z}$

I, δ, c, z, d, θ, N, etc. are the corresponding values (as defined previously) for the heavy stiffener in the conical section under consideration.

The maximum allowable working pressure based on stiffener stresses is given by:

$P_a = P_{to}\eta$ where $\eta = 0.50$

21.17.2(b) Stiffener Tripping. Item 6/21.17.1(b) is likewise applicable to heavy stiffeners when R_b is replaced by R_c.

21.17.2(c) Local Buckling. Item 6/21.17.1(c) is likewise applicable to heavy stiffeners.

21.17.2(d) Inertia Requirements. The moment of inertia I for the combined section, consisting of the stiffener attached to the shell and the effective shell length L_e (see Note in 6/21.15) acting with it, is not to be less than that obtained from the following:

$$I = P(2R_c + t)L_c R_{sc}^2/(6E\eta \cos\alpha)$$

where

R_{sc}	=	R_{sx}	for external framing
R_{sc}	=	R_{sn}	for internal framing

The applicable usage factor η is 0.50

21.17.2(e) Transitions. Heavy stiffeners located at cylinder-to-cone transitions are to be in compliance with both 6/19.15.2 and 6/21.17.2.

21.17.3 Remaining Stiffeners

The same assessment as above is to be followed for the remaining heavy stiffeners bounding a compartment length and non-heavy stiffeners within that compartment length.

23 Spherical Shells Under External Pressure

23.1 Shell Geometry

D	mean diameter
D_i	inner diameter
D_o	outer diameter
R_o	outer radius
t	shell thickness

23.3 General

The limit pressure for spherical shells is to be obtained from the following equation:

$$\frac{P_{cs}}{P_{ys}} = 0.7391[1 + (P_{ys}/(0.3P_{es}))^2]^{-1/2} \qquad \text{for } P_{es}/P_{ys} > 1$$

$$\frac{P_{cs}}{P_{ys}} = 0.2124P_{es}/P_{ys} \qquad \text{for } P_{es}/P_{ys} \le 1$$

where

P_{ys}	=	$2\sigma_y t/R_o$
R_o	=	nominal outside radius of the spherical shell
P_{es}	=	$(2/\sqrt{3(1-\nu^2)})E(t/R_o)^2$

The maximum allowable working pressure is given by:

$P_a = P_{cs}\eta$ where $\eta = 0.67$

23.5 Hemispherical Dished Heads

For hemispherical dished heads, the maximum allowable working pressure is to be determined as for spherical shells, using the hemisphere external radius R_o. The applicable usage factor, η is to be taken as 0.67.

23.7 Ellipsoidal Heads

For ellipsoidal heads, the maximum allowable working pressure is to be obtained as for spherical shells, using an equivalent spherical radius R_e substituted for R_o, related to the maximum radius of the crown, and given by the following:

$$R_e = D_o D_i / 4h$$

where

D_i	=	inner diameter
h	=	head inside depth, measured along the tangent line (i.e., head bend line)
D_o	=	shell outer diameter (see Section 6, Figure 6)

The applicable usage factor, η is to be taken as 0.67.

23.9 Torispherical Heads

The maximum allowable working pressure for torispherical heads is to be obtained as for spherical shells, using a spherical radius R_o equal to the dished crown radius of the head, measured to shell outer surface. (See Section 6, Figure 6.) The applicable usage factor η is to be taken as 0.67.

23.11 Shape Limitations

The thickness of hemispherical heads is to be such that 0.0002 $D \le t \le 0.16D$, where D is the mean diameter. Shape limits for ellipsoidal and torispherical heads are shown below. (See Section 6, Figure 6.)

Ellipsoidal:	$0.0002D \le t$	$\le 0.80D$
	h	$\ge 0.18D$
	ℓ_h	$\ge 2t$
Torispherical:	$0.0002D \le t$	$\le 0.80D$
	h	$\ge 0.18D$
	ℓ_h	$\ge 2t$
	r	$\ge 0.06D$
	r	$\ge 2t$
	R	$\le D$

25 Fasteners *(2013)*

Fasteners (including bolts, studs and nuts) employed in joining of metallic pressure boundary components are to meet a recognized national or international standard for fasteners. They are to have adequate strength and corrosion resistance suitable for the intended service. Round bottom or rolled thread profiles are to be used.

High-Strength Steel Fasteners: Zinc or Aluminum coated fasteners or Cadmium plated fasteners of tensile strength greater than 150 ksi are not be used in applications subject to submergence in-water, exposure to the weather, or where they may be subjected to periodic wetting or heavy condensation. (Under wet conditions, these coatings/platings increase the susceptibility of the fasteners to hydrogen embrittlement).

FIGURE 1
Illustrative Hull Components

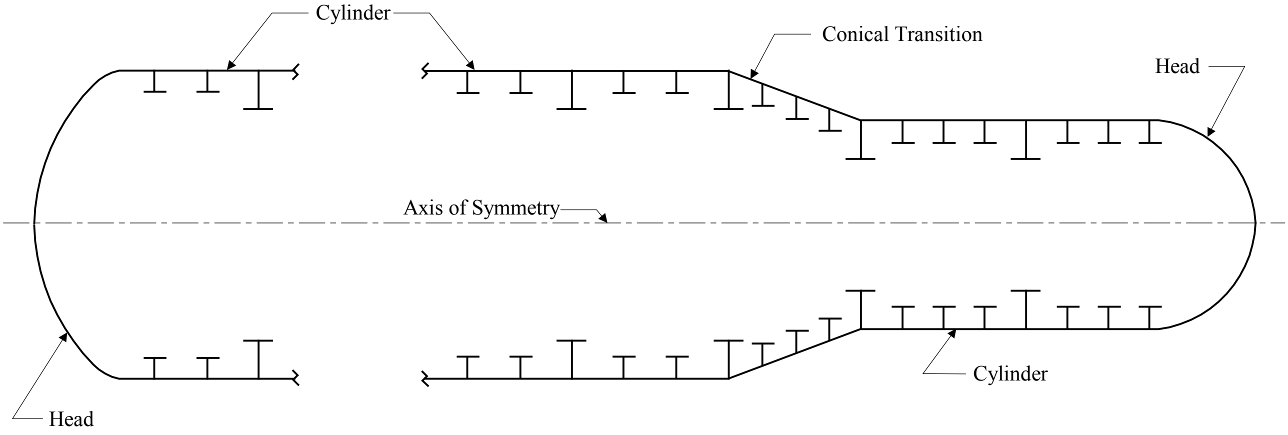


FIGURE 2
Definitions – Compartment Length

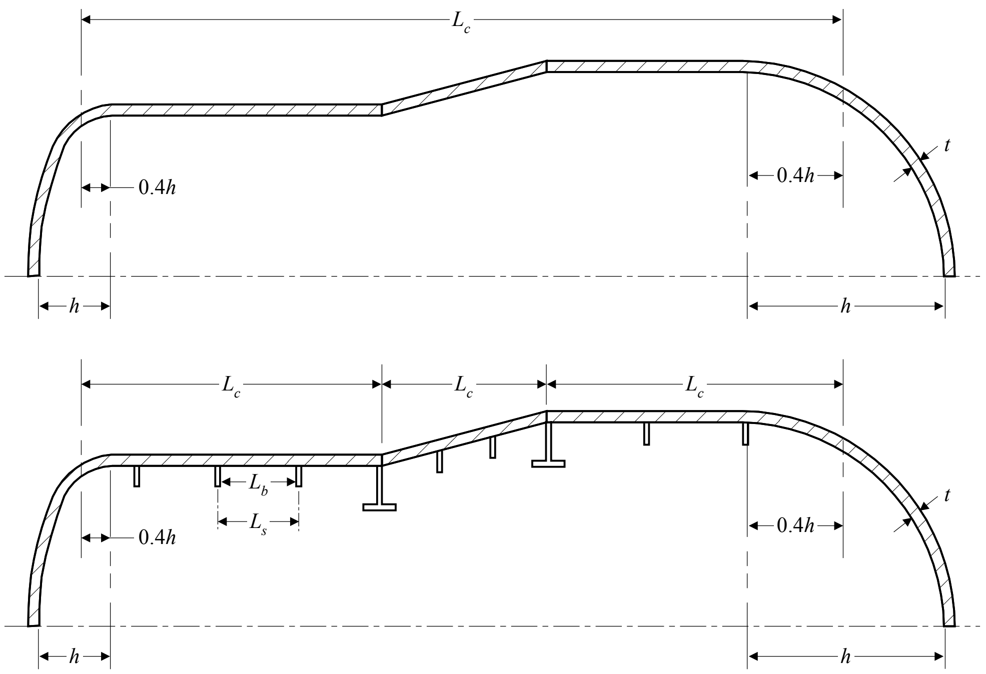


FIGURE 3
Definitions

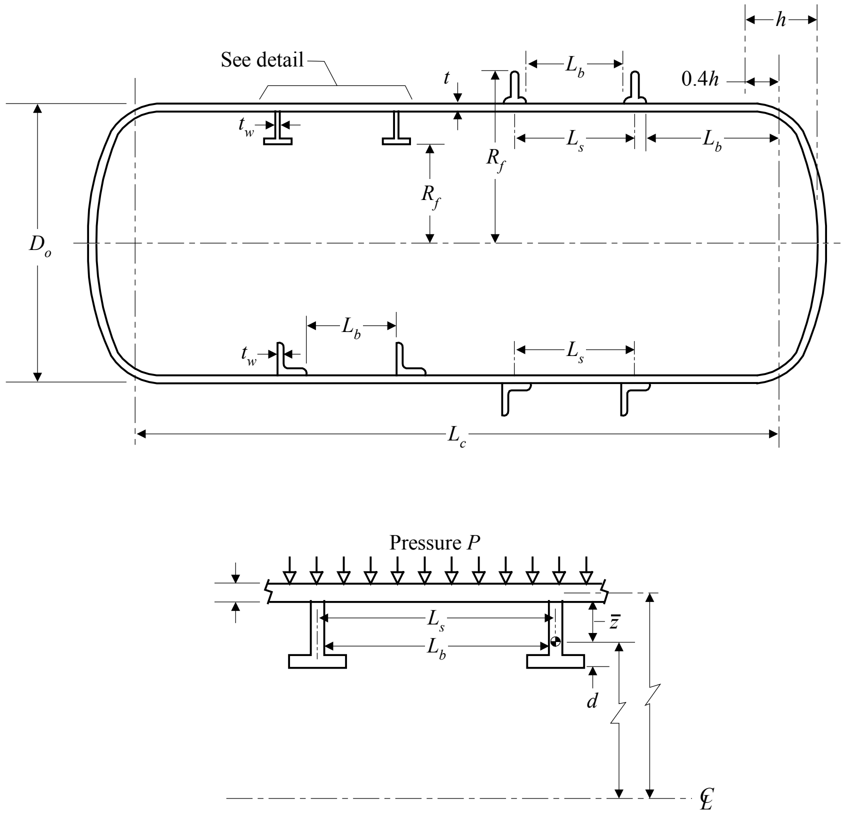


FIGURE 4
Overall Buckling Strength – Lobes Expected at Failure

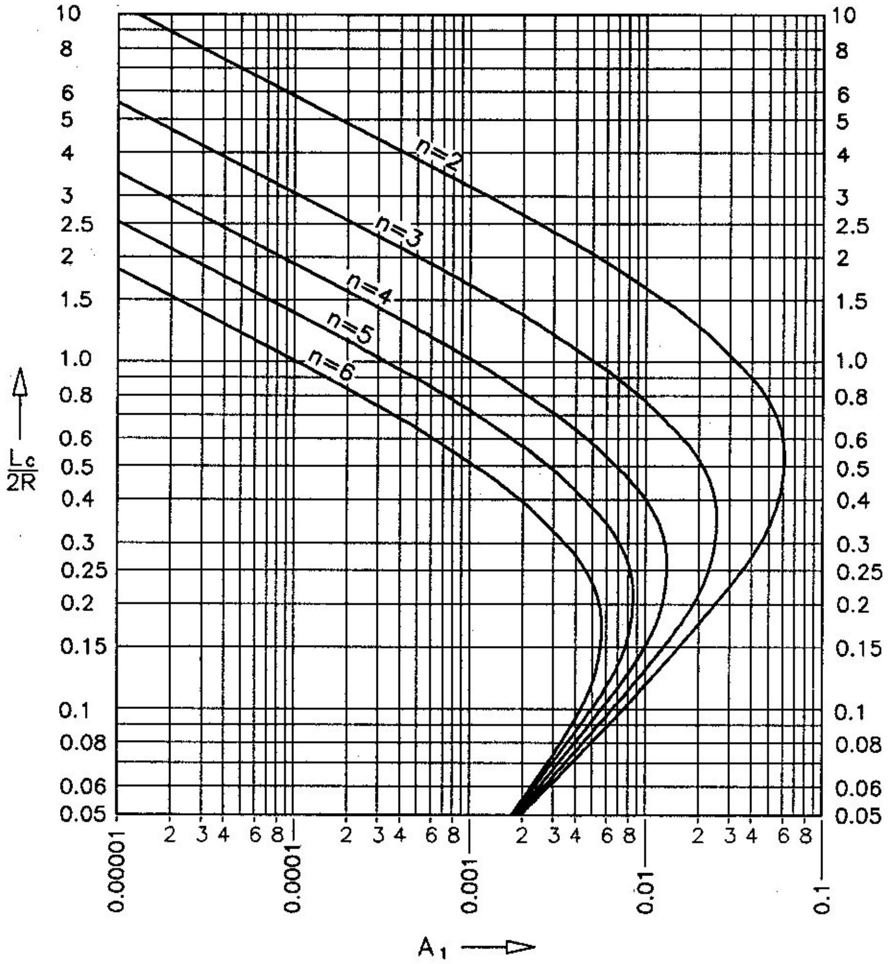


FIGURE 5
Definitions – Cones

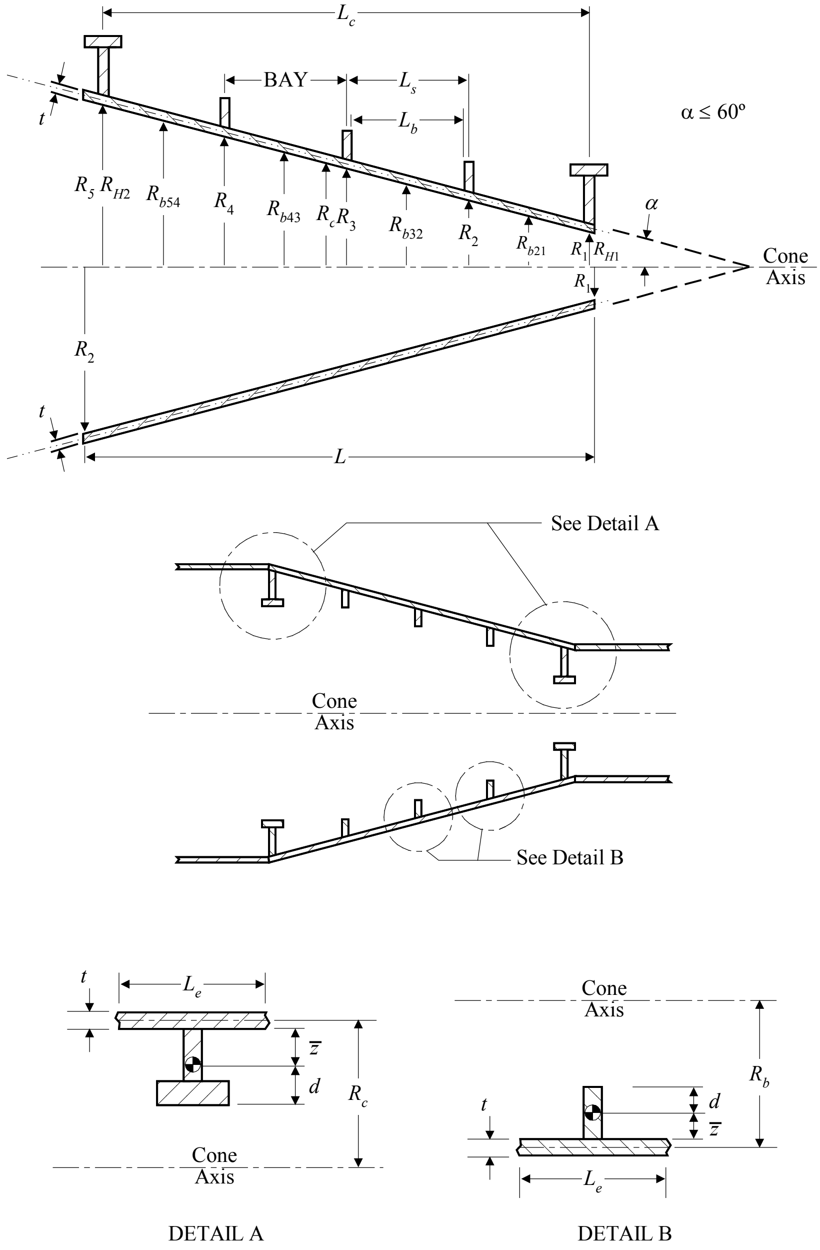
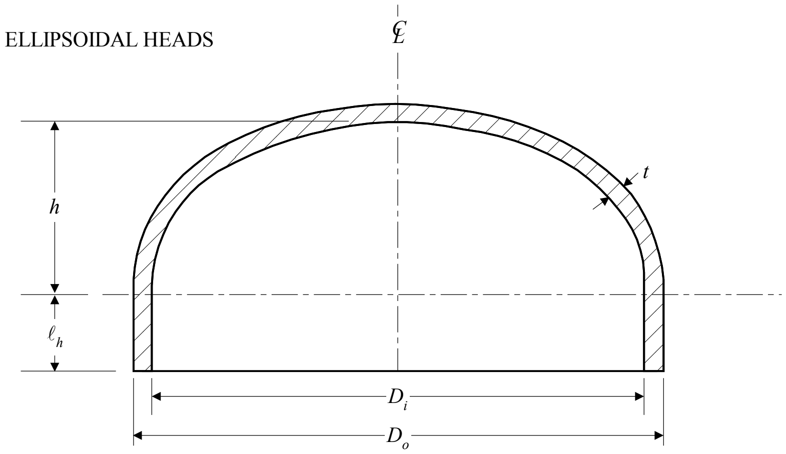
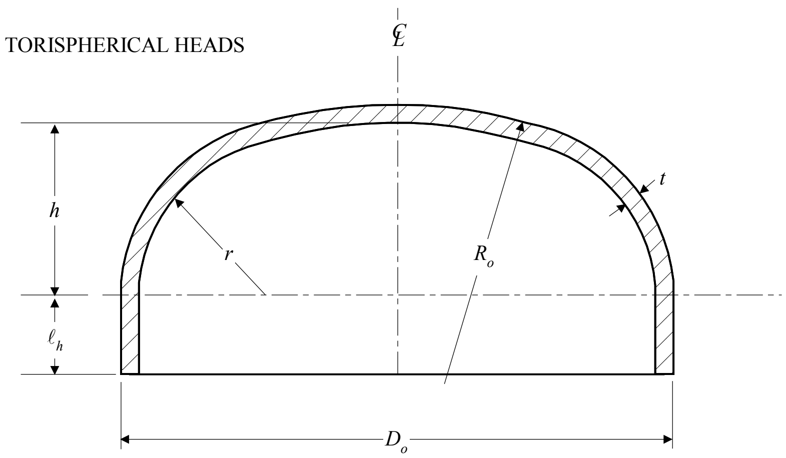


FIGURE 6
Definitions – Heads





SECTION 7 Windows and Viewports

1 General

1.1

Windows and window installation are to comply with the latest edition, including addenda, of the ASME PVHO-1 Safety Standard for Pressure Vessels for Human Occupancy (ASME PVHO-1).

1.3

Window retaining rings, bolts and seat dimensions in viewport flanges, are to comply with the latest edition of ASME PVHO-1.

3 Definitions *(2010)*

3.1 Design Life

The *Design Life* of an acrylic window is the length of time and/or the number of design cycles defined by Sections 2-2.7 and 2-1.2 of ASME PVHO-1 for an acrylic window of a particular geometry and meeting the requirements of the PVHO-1 standard.

3.3 Service Life

The *Service Life* of an acrylic window is the maximum length of time and/or number of service cycles that an acrylic window meeting the requirements of ASME PVHO-2 may be used in a pressure vessel for human occupancy.

3.5 Service Cycle

The pressurization of an acrylic window to a pressure above the ambient pressure (regardless of the pressure) and a subsequent depressurization to ambient pressure constitutes one service cycle. The maximum pressure is not to exceed the design pressure of the window.

3.7 Viewport Assembly

A *Viewport Assembly* is a pressure vessel penetration consisting of a window, flange, retaining rings and seals.

3.9 Window

A *Window* is the transparent, impermeable and pressure resistant insert in a viewport.

5 Submission of Drawings and Data

Detailed dimensional drawings of viewport components, material specifications including materials for flanges, retaining rings, gaskets and bolts, and design calculations demonstrating compliance with these Rules, are to be submitted for review.

7 Design Parameters and Operating Conditions *(2009)*

The windows of underwater vehicles and hyperbaric installations are subject to the design parameters contained in the latest edition of ASME PVHO-1. The design parameters below are based on ASME PVHO-1-2007. It is the responsibility of the designer to determine that these requirements are consistent with the latest edition of the ASME PVHO-1 safety standard.

i) The operating temperature is to be within a –18°C to 66°C (0°F to 150°F) temperature range.

ii) The pressurization or depressurization rate is to be less than 10 bar/s (145 psi/s).

iii) The contained fluid (external or internal) is to be only water, seawater, air, or breathing gases.

iv) The number, or the total duration, of pressure cycles during the operational life of the windows is not to exceed 10,000 cycles or 40,000 hr, respectively.

v) The maximum operational pressure is not to exceed 1380 bar (20,000 psi)

vi) The exposure to nuclear radiation shall not exceed 4 megarads

vii) The design life of the windows is to be in accordance with the following:

- Not to exceed 20 years for windows that are exposed only to compressive stresses
- Not to exceed 10 years for all windows subject to tensile stresses.

The design life of a window is counted from the date of fabrication, regardless of the effective length of time during which the window has been used.

Design parameters different from the above will be subject to special consideration.

9 Certification *(2009)*

Copies of the following certifications are to be submitted for each window:

9.1 Design Certification

A design certification is to be provided for each window and viewport assembly design. This document is to certify that the design complies with ASME PVHO-1. The certificate is to include the information required by Form VP-2 in Section 2 of ASME PVHO-1.

9.3 Material Manufacturer's Certification

The manufacturer of the acrylic material is to provide a document certifying that the material complies with ASME PVHO-1. The Acrylic material is to be marked so as to be traceable to this certificate. The certificate is to include the information required by Form VP-3 in Section 2 of ASME PVHO-1.

9.5 Material Testing Certification

After annealing, material acceptance tests are to be performed by the material manufacturer or by an independent testing laboratory. The material acceptance tests are to be documented by a certificate that includes the information required by Form VP-4 in Section 2 of ASME PVHO-1.

9.7 Pressure Testing Certification

Window pressure testing in accordance with Subsection 7/19 is to be documented by a certificate. The certificate is to include the information required by Form VP-5 in Section 2 of ASME PVHO-1.

9.9 Fabrication Certification

The window fabricator is to provide an overall window certification confirming that the window was fabricated in compliance with these Rules and ASME PVHO-1. The certificate is to provide traceability of the window through all stages of manufacture and fabrication and is to include the information required by Form VP-1 in Section 2 of ASME PVHO-1.

11 Viewport Flanges

Viewport flanges are to be designed to meet the reinforcement and strength requirements in Section 6. Viewport flange materials are to comply with the requirements in Section 4.

Because of the difference between the moduli of elasticity of metals and of polymethyl methacrylate, it is to be assumed in reinforcement calculations for the window opening that the acrylic window does not provide reinforcement of the pressure hull.

13 Dimensional Tolerances

Dimensional tolerances and surface finish are to be submitted for review.

15 Window Fabrication

Fabrication of windows is to be in accordance with ASME PVHO-1 and is to be carried out under an approved quality assurance program.

ABS Surveyor's attendance at the shop of the fabricator is required during fabrication and testing to verify that these processes are conducted in accordance with the approved program.

15.1

Windows are to be fabricated from cast polymethyl methacrylate per ASME PVHO-1.

15.3

Each window is to be annealed after all forming, machining, repairs and polishing processes have been completed. The annealing procedures are to be in accordance with the acrylic manufacturer's recommendations. A copy of the time/temperature chart for the final window anneal is to be attached to the certification required in 7/9.9.

15.5

Windows are to be fabricated from material tested in the presence of the Surveyor to show compliance with ASME PVHO-1. The certificate required in 7/9.5 documents these minimum material properties.

15.7

Dimensional checks of all windows are to be carried out in the presence of the Surveyor after all fabrication processes are completed.

17 Installation of Windows

17.1

Before installation of the window in the seat cavity, the seat cavity must be suitably cleaned with material compatible with the acrylic plastic.

17.3

After installation the window is to be checked in order to determine that the bolts in the retaining ring have been tightened with the same bolt torque.

17.5

Conical window seats are to be coated with silicon grease or other suitable grease prior to installation of the window.

19 Pressure Testing *(2009)*

19.1

Each window is to be pressure tested in the presence of and to the satisfaction of the Surveyor at least once prior to being accepted for service. The pressure test shall take place with the window installed in the viewport (see also Subsection 3/3), or in a test fixture whose window seat dimensions, retaining ring, and seals are identical to those of the chamber. If the window is tested in a test fixture, details of the test fixture are to be submitted.

19.3

The window shall be pressurized with gas or water until design pressure is reached. The design pressure shall be maintained for a minimum of 1, but not more than 4, hours followed by depressurization at a maximum rate not to exceed 4.5 MPa/min (650 psi/min).

19.5

The temperature of the pressurizing medium during the test shall be the design temperature for which the window is rated with a tolerance of +0°/–2.5°C (+0°/–5°F). Brief deviations from above temperature tolerances are allowed, providing that the deviation does not exceed 5.5°C (10°F) and lasts less than 10 min.

19.7

Windows that leak during the pressure tests shall be removed, fitted with new seals, and retested. If, during the retest, the leakage continues, efforts will be made to complete the test by stopping the leak with a temporary seal. The inability of seals to operate properly during the test shall be noted in the test report, which shall be submitted at the conclusion of the pressure test to the chamber manufacturer/user.

19.9

At conclusion of the pressure test, the windows are to be visually inspected for the presence of crazing, cracks or permanent deformation. This examination may be performed without removal of the window from the chamber.

19.11

Presence of crazing, cracks or permanent deformation visible with the unaided eye (except for correction necessary to achieve 20/20 vision) shall be the cause of rejection of the windows and shall be so noted on the test report. Permanent deformation less than $0.001D_i$ in magnitude measured at the center of the window shall not be cause for rejection.

19.13 *(2009)*

A hydrostatic or pneumatic test in excess of design pressure may be substituted for the tests specified in 7/19.3 and 7/19.5 for windows with a design temperature of 52°C (125°F) or less. During the hydrostatic or pneumatic test, the pressure shall be maintained for a minimum of 1, but not more than 4, hours. The test pressure shall not exceed 1.5 times the design pressure or 138 MPa (20,000 psi), whichever is the lesser value. To prevent permanent deformation of windows tested above design pressure, the temperature of the pressurizing medium during the test shall be at least 14°C (25°F) lower than the design temperature. For windows with a 10°C (50°F) design temperature, the temperature of the pressurizing medium during the test shall be 0°C to 4°C (32°F to 40°F). All the other requirements of the mandatory pressure test specified in Paragraphs 7/19.7, 7/19.9, and 7/19.11 remain applicable.

21 Marking

Windows complying with these requirements and those of ASME PVHO-1 and tested in the presence of the Surveyor are to be identified with the markings required by ASME PVHO-1 preceded by the symbols ✠ **AB**. Markings are to be oriented so that they can be read from the high pressure side. Required forms and enclosures are to be issued for each window in accordance with ASME PVHO-1.

Windows fabricated under an ABS approved quality assurance program are to be marked as required by ASME PVHO-1 preceded by the symbols ✠ **AB**, but need not be marked with the letters “PVHO”.

23 Window Repairs

Repairs of new or used windows will be subject to special considerations.

SECTION 8 Life Support and Environmental Control Systems

1 General

Life support systems are to be constructed, installed, and tested to the satisfaction of the Surveyor in accordance with these Rules. In addition to complying with this Section, mechanical, electrical and emergency systems are to comply with Sections 9, 10, 11, 12, and 13, as applicable.

3 Plans and Data to be Submitted

Plans and calculations for the following systems, as applicable, are to be submitted for review and approval. Plans are to include general arrangement and detail drawings; calculations are to address piping systems, gas mixtures, system capacity, etc. (See also Subsection 1/7)

- Breathing gas systems
- Air and gas storage systems
- Carbon dioxide removal systems
- Emergency life support systems
- Life support instrumentation
- Temperature control; heating and cooling
- Other life support features essential for safe operation (such as catalytic burners for carbon monoxide)

5 Design Principles

5.1 Definitions *(2010)*

5.1.1 Normal Life Support System

The life support system(s) used when all operating parameters for a unit are within those specified in the Operations Manual.

5.1.2 Reserve Life Support System

The life support system(s) used when an abnormal operating parameter prevents the submersible unit's return to the surface or when a hyperbaric evacuation unit is launched at sea. This life support system allows time for the unit's rescue by others.

5.1.3 Emergency Life Support System

The life support system(s) that permits the occupants of a pressure vessel for human occupancy to breathe safely in an atmosphere whose quality might have been compromised.

5.3 General *(2012)*

All units are to be provided with equipment to generate, monitor and maintain suitable life support conditions.

5.5 Standard Person *(2013)*

The following table is provided as a reference for performing life support calculations.

Item		*Quantity*	*Units (per person)*
Oxygen (O_2) Consumption		0.038 (0.083)	kg (lbs.) per hour at 1 atm
Drinking Water		2.72 (6)	kg (lbs.) per day
Food, Dry		3350 (804)	kJ (Cal) per day
Carbon Dioxide (CO_2) Produced		0.0523 (0.115)	kg (lbs.) per hour at 1 atm
Water Vapor Produced		1.81 (4)	kg (lbs.) per day
Urine		1.81 (4)	kg (lbs.) per day
Feces		0.18 (0.4)	kg (lbs.) per day
Flatus		0.1	cu. ft. per day
Heat Output	Sensible	250	BTU per hour
	Latent	220	BTU per hour

5.7 Fire Hazard *(2007)*

The design of any system that controls, manually or automatically, the percentage of oxygen in the atmosphere of the personnel compartment, is to consider the increased fire hazard as the volume concentration of oxygen starts exceeding 21 percent by volume. All materials in the personnel compartment (paints, lubricants, adhesives, furniture coverings, etc.) are to be investigated for combustibility. The evaluation is to consider at least the rate of combustion, quantity of material, exposed surface area and proximity to heat sources. See 3/1.5.

7 Breathing Gas

7.1 Oxygen Supply *(2009)*

Oxygen supply systems are to be capable of supplying oxygen at the rate of 0.038 kg (0.083 lbs) per hour per person at 1 atmosphere.

7.3 Closed Breathing Gas Circuits

The use of closed breathing circuits with gas reclaim systems will be subject to special consideration.

7.5 Breathing Gas Storage

7.5.1 Compressed Storage

Gas is to be stored in accordance with CGA Regulations or any other recognized standard.

7.5.2 Container Location

The volume of a single internal source is to be limited such that complete release of its contents will not increase the pressure more than 1 atm nor raise the oxygen level above 23 percent by volume. This can be demonstrated by calculations. If the calculated pressure rise is more than 1 atm or the increase of oxygen concentration is above 23 percent by volume, then the container is to be stored outside the manned compartment.

7.7 Fresh Air *(2010)*

Habitats and working chambers, etc. are to be provided with means to remove, prior to a mission, any potentially explosive or toxic gas mixtures which may develop.

9 Carbon Dioxide (CO_2) Removal Systems

9.1 Capacity *(2013)*

CO_2 removal systems are to be provided and are to be capable of maintaining the CO_2 concentration at or below 0.5 percent by volume referenced to standard temperature and pressure [a CO_2 mass of 0.00989 kg/m^3 at 1 atmosphere and 0°C (0.000572 lbm/ft^3 at 1 atmosphere and 70°F)] or 0.005 ata. Systems are to be designed based upon an assumed CO_2 production rate of 0.0523 kg (0.115 lbs.) per hour per person at 1 atmosphere. Design calculations are to take into account temperature, humidity, CO_2 density at rated depth, absorption efficiency, and flow rate. See also 8/31.3 and Subsection 10/5.

9.3 Expendable Methods

9.3.1 Solid Reagents

Solid absorbents are to be granular and low dusting (particle sizes usually in the 4 to 20 mesh range). Solid reagents are to be stored in containers free of moisture.

9.3.2 Liquid Reagents

LiOH removal systems are to be located to prevent drippings from falling on crew members, the structure, or equipment. LiOH canisters or panels are to be replaceable as complete units. Proper heating is to be provided to maintain the temperature of canisters containing other alkaline hydroxides at or above 15°C (60°F).

9.5 Regenerable Reagents

9.5.1 Solid Reagents

A solid reagent capable of removing carbon dioxide from a gas stream, and which can be regenerated will be considered acceptable, provided the entering gas stream is free of organics and moisture and a suitable means of disposing of the CO_2 is provided. Solid reagents are to be stored in containers free of moisture.

9.5.2 Liquid Reagents

Liquid scrubbing systems using aqueous solution capable of removing carbon dioxide from a gas stream, and which can be regenerated, are to be provided with means to assure that the entering gas stream is free of organics and moisture. Suitable means of disposing of the CO_2 are to be provided.

9.7 Other Means of CO_2 Removal

The use of means other than those in 8/9.3 and 8/9.5 will be subject to review of supporting data demonstrating satisfactory performance under the intended service conditions.

9.9 Materials

Corrosion resistant non-toxic materials are to be used in the construction of CO_2 removal systems. Materials are to be compatible with the CO_2 removal agent.

9.11 Canister Replacement

Canisters are to be designed for ease of replacement by the crew without the need for special tools.

11 Distribution Piping

11.1 Materials

Material specifications and details of piping systems are to be submitted for review. Piping, tubing, and hoses are to have a burst strength of at least four times the maximum allowable working pressure (MAWP).

11.1.1

Systems are to be of nickel-copper alloy (Monel), 304 or 316 stainless steel, copper, aluminum bronze (except those alloys subject to dealuminification), copper nickel, brass (except those alloys subject to dezincification), or C-69100 copper alloy.

11.1.2

SAE 100-R3 may be used.

11.1.3

Fire retardant non-metallic armored hose may be accepted for use up to 350 kg/cm^2 (5000 psi) based on evidence of satisfactory in-service experience and test data in association with the requirements of Section 9.

11.1.4

Other suitable materials will be specially considered.

11.1.5 Soft Goods *(2013)*

The manufacturer's specifications for soft goods (non-metallic materials such as gaskets, O-rings, valve seats, etc.) used in life support piping systems are to be submitted to the ABS Technical Office for review.

11.1.6 Lubricants *(2013)*

The manufacturer's specifications for lubricants used in life support piping systems are to be submitted to the ABS Technical Office for review.

11.1.7 Thread Sealants *(2013)*

The manufacturer's specifications for thread sealants used in life support piping systems are to be submitted to the ABS Technical Office for review.

Teflon (PTFE) tape type thread sealant, when used in threaded joints, is to meet the following additional requirements:

i) The designer/fabricator is to demonstrate that all potential hazards associated with the disintegration/shredding of the tape have been addressed.

ii) The installation procedure is to be submitted to the ABS Technical Office for review.

11.3 Fittings *(2013)*

11.3.1 General Requirements

11.3.1(a) Fittings are to be one of the following:

i) Flared, flareless, and compression fittings of the non-bite type

ii) Threaded fittings

iii) Brazed fittings

iv) Welded fittings

v) Flanged fittings

vi) Other special purpose fittings may be considered on a case-by-case basis.

11.3.1(b) Materials for fittings are to comply with 8/11.1.1.

11.3.1(c) Fittings are to have a pressure rating equal to or greater than the MAWP of the piping system in which they are used.

11.3.1(d) Fittings are to have a burst strength of at least four times the MAWP of the piping system.

11.3.2 Threaded Fittings

11.3.2(a) Straight Thread O-Ring Sealed Fittings. Straight thread fittings with O-ring seals may be used without limitation on size.

11.3.2(b) Taper-Thread Fittings. Size-pressure limits for taper-threaded fittings are to be as follows:

Pipe/Tube Nominal Diameter (d) (in.)	*Pressure (psi)*
$d > 3$	Not permitted
$2 < d \leq 3$	400
$1 < d \leq 2$	600
$0.75 < d \leq 1$	1200
$d \leq 0.75$	MAWP of the fittings or piping/tubing, whichever is less

11.3.2(c) When threaded fittings are used in locations that may subject the fitting to vibration or a torque that would tend to unscrew it, mechanical means are to be provided to prevent inadvertent loosening of the fittings.

11.5 Valves

Valves are to have the manufacturer's guarantee that they are suitable for service with the gas at the system's maximum allowable working pressure (MAWP) and are to have a burst strength of at least four times the MAWP.

11.5.1

Valves are to be of materials specified in 8/11.1.1.

11.5.2 *(2002)*

Control valves used in oxygen systems operating at pressures exceeding 125 psig are to be of the slow-opening type, such as needle valves.

11.5.3

Flow control valves are to provide smooth flow transition from full open to full closed.

11.7 Supply Piping *(2013)*

11.7.1

Each independent gas supply line is to be equipped with a supply pressure gauge and a shut-off valve downstream of the supply pressure gauge connection. A block valve, located such that it is capable of being monitored during operation, is to be installed between the supply line and the supply pressure gauge to permit isolating the pressure gauge.

11.7.2

The shut-off valve on a gas supply line must be accessible and is to be located such that release of the volume contained in the downstream piping will not increase the internal pressure more than 1 atm.

11.7.3

Supply lines are to be secured in place to prevent movement.

11.7.4

See also 9/7.21.

11.9 Pressurized Oxygen Supply Piping *(2002)*

11.9.1

The primary shut-off valve, or the final shut-off valve where accessible, on an oxygen supply line is to be located such that release of the volume contained in the downstream piping does not permit the oxygen concentration to exceed the maximum permitted in 8/17.1. Oxygen supply piping is to meet the requirements of 8/11.7.

11.9.2

Both lubricants and sealants used in potentially pressurized oxygen piping systems are to be compatible with oxygen at the maximum system supply pressure.

11.11 Color Coding

Piping systems are to be clearly color coded in accordance with a recognized national or international color code to indicate the fluid transported (see Section 9).

13 Umbilicals

Umbilical hoses are to have a burst pressure at least 4 times system working pressure and be rated for not less than the system pressure. Additionally, umbilical hoses are to be rated for not less than the pressure equivalent of the design depth of the unit plus 28 kg/cm^2 (400 lb/in^2). Hoses are to be kink-resistant or arranged to resist kinking and have connectors that are corrosion-resistant, resistant to accidental disengagement, and rated at least equal to the rating of the hose. Umbilical hoses are to be arranged so that the weight of the assembly is borne by the strength member where the umbilical is considered to be a secondary means of recovering the bell. Umbilical hoses and fittings are to be tested to 1.5 times the system's pressure in the presence of a Surveyor.

15 Life Support Instrumentation

15.1 Monitored Parameters *(2012)*

The following items are to be monitored.

- Oxygen content of breathing atmospheres
- Carbon dioxide content of breathing atmospheres
- Internal and external pressure
- Compartment temperature in saturation systems
- Relative humidity in saturation systems

15.3 Monitoring Equipment *(2007)*

Life support instrumentation systems, including power supplies, are to be provided in duplicate or an alternative means of measurement is to be provided. Changes in temperature, humidity and total pressure are not to affect the accuracy of measurements. Electronic life support instrumentation is to incorporate provisions for calibration.

Internal pressure is to be monitored using a mechanical type instrument in addition to any other type of pressure indicating instrument

15.5 Display Locations *(2012)*

Under normal operating conditions, the concentrations or partial pressures of breathing gases are to be continuously monitored at the pilot stand and/or at the control station (as applicable).

17 Controls

17.1 General

Means are to be provided for maintaining the oxygen content of the interior atmosphere below 23 percent by volume. Controls may be manual or automatic however; manual back-up is to be provided for automatic controls.

17.3 Manual Controls

As a minimum manual systems are to consist of a cylinder shut-off valve, a manual flow control valve, a means of regulating pressure, and a manual bypass of any installed regulator.

17.5 Automatic Controls

Automatic controls are to maintain the required partial pressures and concentration of breathable gases. Failure of the automatic control is to be indicated by audible alarms at the pilot stand or control station and the manual back-up system is to be available for immediate use.

19 Diving Temperature and Humidity Controls

19.1 Heating and Cooling

Means are to be provided for thermal insulation and temperature control during all stages of a mission. The high thermal conductivity of gases such as helium is to be considered.

19.3 Humidity

Provisions are to be made to permit control of humidity in the cabin during all phases of operation. A control range of 50 percent ± 20 percent relative humidity is recommended.

19.5 Electric Water Heaters

Electric water heaters are to comply with Section 10 and be provided with the following.

19.5.1

A high temperature cut-out in addition to the unit's normal thermostat. The cut-out is to disconnect all ungrounded conductors, is to be installed to sense maximum water temperature, is to operate at or below 99°C (210°F), and is to be either a trip-free, manually reset type or a type having a replacement element. A thermometer is to be provided capable of indicating a temperature up to the steam saturation temperature at design pressure of the heater.

19.5.2

A pressure relief device which will prevent a pressure rise of more than 0.2 kg/cm^2 (3 psi) above the maximum allowable working pressure with the heating elements operating continuously at maximum rating.

19.7 Air Conditioning

When air conditioning systems are installed, detailed plans of piping and components are to be submitted for review showing compliance with Sections 9, 10, 11, 12, and 13, as applicable.

21 Cleaning *(2013)*

Piping systems intended for life support are to be thoroughly cleaned by the use of methods suitable for the gas to be transported in the system.

The cleaning and component/system handling procedures are to be submitted to the ABS Technical Office for review prior to the commencement of the cleaning operations. The cleaning and handling of the components/systems is to be to the satisfaction of the attending Surveyor. A certificate of compliance from the system assembler or system manufacturer for the cleaning and handling of the components/systems is to be provided to the Surveyor.

23 Filtration Systems

Where dust filtration systems are provided, filter materials are to be fire retardant.

25 Air Compressors *(2013)*

Air compressors are to be provided with nameplates indicating manufacturer, model, serial number, maximum rated outlet pressure, rated capacity, and safety valve setting. Compressed air purity for human respiration is to be in accordance with CGA specification G-7.1 Grade D as a minimum requirement.

27 Mercury

Mercury is not to be used in equipment, instruments, etc.

29 Gas Reclaim Systems *(2012)*

29.1 Monitored Parameters

The following parameters are to be monitored for gas reclaim systems:

- Oxygen content of the breathing gases supplied to the chambers/divers
- Carbon dioxide content of the breathing gases supplied to the chambers/divers
- Breathing gas supply pressure
- Breathing gas supply temperature
- Breathing gas relative humidity
- Carbon monoxide when hydrocarbon based oil lubricated cylinder compressors are used

29.3 Diver Gas Reclaim Systems

29.3.1 Parameters

The following parameters are to be used for the design of diver gas reclaim systems:

Range of respiratory minute volumes (RMVs)	15 to 75 liters/minute (BTPS) per diver.
Oxygen consumption	1/24 × RMV liters/minute (SLPM) per diver
Carbon Dioxide production	1/25 × RMV liters/minute (SLPM) per diver

Note:

Respiratory Minute Volume (RMV): Volume of gas moving in and out of the lungs per minute

BTPS: Body temperature (98.6°F), ambient barometric pressure, saturated with water vapor at body temperature.

Standard Liters Per Minute (SLPM): Volume in liters specified at a temperature of 32°F and a pressure of 1 atmosphere.

29.3.2 CO_2 Removal Systems

29.3.2(a) CO_2 Removal Systems are to be capable of maintaining the partial pressure of CO_2 below 0.005 atmosphere absolute (ata).

29.3.2(b) Covers/lids of CO_2 scrubber housings that unseat with pressure are to the provided with locking mechanisms and safety interlocks (positive locking device). The interlocks are to prevent accidental opening of the covers/lids while under pressure and are to prevent pressurization of the CO_2 scrubber housings if the covers/lids are not properly closed and locked.

29.3.3 Water Traps

Water traps, when provided, are to be designed for simplicity of cleaning, disinfecting and drying.

29.3.4 Equipment Failure/Malfunction

In the event of equipment failure/malfunctioning, means are to be provided to ensure that the lung over or under pressure per diver does not to exceed ± 6.0 kPa relative to the lung centroid pressure.

29.3.5 Alternative Means to Supply Breathing Gas

Alternative means are to be provided to supply the divers with breathing gas in case the Diver Gas Reclaim System needs to be taken offline due to equipment failure/malfunctioning.

29.3.6 In-Shop Testing

Diver gas reclaim systems are to undergo in-shop life support testing in the presence of the Surveyor. The tests may be conducted at surface conditions or at shallow depths.

During testing, the oxygen (O_2) and carbon dioxide (CO_2) levels, pressure, relative humidity and temperature are to be monitored and recorded at intervals suitable to verify the reclaim system design but not exceeding 15 minutes. The monitored parameters are to be within acceptable ranges to the satisfaction of the Surveyor.

The testing is to include the following:

29.3.6(a) A manned test with the maximum number of divers is to be conducted until equilibrium is achieved by the CO_2 scrubber, plus an additional one hour. This manned test is to be conducted for a minimum of three hours for all cases. The following is to be demonstrated during the test:

i) CO_2 and O_2 levels, pressure, relative humidity and temperature can be maintained within required parameters.

ii) Changing-out of the CO_2 scrubber canister can be achieved without exceeding a CO_2 concentration of 1.5% by volume referenced to standard temperature and pressure (0.015 ata) and that the concentration of CO_2 can be reestablished and maintained at or below 0.5% (0.005 ata) following the change-out.

29.3.6(b) A manned test with the maximum number of divers or a simulated test (using CO_2 injection) is to be conducted to determine the time to CO_2 scrubber breakthrough, where breakthrough is defined as a CO_2 concentration of 0.5% by volume referenced to standard temperature and pressure (0.005 ata). The test may be continued beyond a CO_2 concentration of 0.5% [up to a maximum of 1% (0.01 ata)] to ensure that breakthrough is reached. The time required to achieve breakthrough is to be used in confirming the quantity of CO_2 absorbent required by the scrubber. For simulated testing, the CO_2 injection rate is to be not less than 1/25 × RMV as defined in 8/29.3.1 above.

29.3.7 Integration Testing

After integration with the diving system, diver gas reclaim systems are to be functionally tested in the presence of the Surveyor. The tests are to demonstrate that the CO_2 and O_2 levels, pressure, relative humidity and temperature can be maintained within required parameters. (The breathing gas supply temperature is not to exceed 37°C for humidified breathing gas or 32°C for dry breathing gas).

31 Testing *(2013)*

(2014) The test procedures for the testing (pressure testing (see 8/31.1.1), leak testing (see 8/31.1.2) and off-gas testing [see 8/31.3.1(a) and (b)] are to be reviewed by the ABS Technical Office prior to the testing. The testing is to be conducted in the presence of the Surveyor. Upon completion of the testing, the test results are to be submitted to the ABS Technical Office for review.

Gas sample analysis for the off-gas testing specified in this Subsection [see 8/31.3.1(a) and (b)] is to be conducted by a laboratory that is accredited by an independent third-party (such as the American Industrial Hygiene Association or equivalent) as being compliant with an applicable quality assurance standard for laboratories (such as ISO/IEC 17025, ANSI/ASQC Q2 or equivalent).

31.1 Breathing Gas Piping Systems

31.1.1 Pressure Test

The breathing gas system, except for pressure sensitive components, is to be tested to 1.5 times maximum allowable working pressure (MAWP) with water, oil free dry air, or dry nitrogen as appropriate. This test may be conducted prior to installation with the system assembled and with the components in their relative positions. Following the completion of the testing, the system is to then be purged and tested to insure that all traces of test gases are removed.

31.1.2 Leak Test

After installation, the system is to be given a leak test at maximum allowable working pressure. This is to be done with the gas normally used in service. Leakage is not to exceed a rate which will cause the pressure to decrease more than 1 percent in 4 hours. No leakage is permitted for oxygen systems.

31.3 Pressure Vessels for Human Occupancy and Pressure Hulls

31.3.1 Off-gas Testing

31.3.1(a) General Requirements. Toxicity off-gas testing is to be carried out on all PVHOs or Pressure Hulls that have internal paint or contain non-metallic materials (other than acrylic windows).

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

The use of higher temperatures (above the maximum operating temperatures) and/or longer durations to “bake out” sources of contaminants prior to the testing is permitted. However, care must be taken not to exceed the design temperature of the components including the acrylic windows.

For internally pressurized PVHOs or pressure hulls, it is recommended that prior to commencement of the off-gas testing, the PVHOs or pressure hulls be pressurized at least once to the MAWP (30 to 60 minutes hold time) followed by thorough ventilation. (This procedure eliminates the majority of off-gas contaminants that are often released from paints, resins and foams during first time exposure to pressure).

The off-gas testing is to be carried out after fabrication and completion of all outfitting, with all openings sealed. The PVHOs or pressure hulls are to be loaded with all applicable non-metallic materials that will be used in actual service (such as mattresses, breathing masks and hoses). Electrical devices (such as displays, environmental control systems and blowers for Carbon Dioxide scrubbers) are to be energized and remain energized throughout the test, as far as practicable.

The list of target compounds for the analysis is to consider the anticipated contaminants in the PVHOs or pressure hulls based on the non-metallic materials used in actual service. When hydroxide based Carbon Dioxide absorbents (e.g., LiOH, Soda Lime) are used within the pressure boundary of PVHOs or pressure hulls, the target compounds are to also include those specified in Section 8, Table 1 below.

The gas samples are to be analyzed using appropriate Gas Chromatography (GC) or Mass Spectrometry (MS) methods. If the total halogen concentration can be shown to be less than 10 ppm, and the total hydrocarbon concentration (expressed as methane) can be shown to be less than 25 ppm, then, GC/MS analysis and evaluation need not be done. However, if either of these limits is exceeded, GC/MS analysis and evaluation is required.

When hydroxide based Carbon Dioxide absorbents (e.g., LiOH, Soda Lime) are used within the pressure boundary of PVHOs or pressure hulls, the concentrations of the following compounds are not to exceed the limits specified in Section 8, Table 1 below, regardless of their ACGIH TLV or duration of occupation. (Section 8, Table 2 below does not apply for these four compounds).

TABLE 1
Monochloro/Dichloroacetylene Precursor Compounds *(2013)*

Compounds	*Max. Exposure Limit*
Trichloroethylene	0.1 ppm
Vinylidene Chloride	0.1 ppm
Methyl Chloroform	0.1 ppm
Acetylene Dichloride	0.1 ppm

When reactive compounds (e.g., Ammonia, Chlorine, Hydrogen Sulfide, Sulfur Dioxide) are anticipated, on-site testing for the presence of these compounds is to be done using appropriate color-change indicator tubes (e.g., Draeger, Gastec). Evaluation of the test results are to be in accordance with 8/31.3.1(b)i), ii) or iii) below, as applicable.

When potential sources of mercury vapor are anticipated, on-site testing for its presence is to be done using either color-change indicator tubes with sufficiently low detection limit or a gold-film type analyzer. Evaluation of test results are to be in accordance with 8/31.3.1(b)i), ii) or iii) below, as applicable.

31.3.1(b) One Atmosphere Off-Gas Testing. One atmosphere off-gas testing is to be conducted with the PVHOs or pressure hulls at one atmosphere internal pressure. (A slight pressurization of the PVHOs or pressure hulls (prior to closing or sealing) may be used to aid in obtaining gas samples).

Based on the normal duration of occupation of the PVHOs or pressure hulls, the testing is to be conducted as per 8/31.3.1(b)i), ii) or iii) below, as applicable:

i) *Normal Duration of Occupation Does Not Exceed 8 hours.* The PVHOs or pressure hulls are to be sealed and maintained at maximum operating temperature for at least 8 hours, after which time atmospheric gas samples are to be obtained from inside the PVHOs or pressure hulls and are to be sent for analysis.

The measured concentration levels of volatile compounds are not to exceed the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) as specified in the latest edition of the publication “Threshold Limit Values for Chemical Substances and Physical Agents: Biological Exposure Indices”. Special consideration may be given to the limits specified in equivalent recognized national or international standards on a case-by-case basis.

If any of these limits are exceeded, the PVHO or pressure hull is to be thoroughly ventilated with clean air and the off-gas testing is to be repeated until satisfactory results are obtained.

ii) *Normal Duration of Occupation Exceeds 8 hours But Does Not Exceed 24 Hours.* When the normal duration of PVHO or pressure hull occupation exceeds 8 hours, the requirements of 8/31.3.1(b)i) above apply with the exception that the PVHO or pressure hull is to be sealed and maintained at maximum operating temperature for at least the maximum anticipated duration of occupation.

Based on the duration of occupation, the ACGIH TLV values used for the evaluation of the gas samples are to be modified by multiplying them by a value of “*Fp*” as shown in Section 8, Table 2 below. (Linear interpolation for intermediate values is permitted)

TABLE 2
Conversion Factor (*Fp*) *(2013)*

Duration	*Fp*
8 hr (or less)	1.0
12 hr	0.85
16 hr	0.75
24 hr	0.65
36 hr	0.56
48 hr	0.52
72 hr	0.46
7 days	0.37
14 days	0.32
30 days	0.28
60 days	0.26
90 days (or longer)	0.25

iii) *Normal Duration of Occupation Exceeds 24 hours.* When the normal duration of PVHO or pressure hull occupation exceed 24 hours, the requirements of 8/31.3.1(b)i) above apply with the exception that the PVHO or pressure hull may be sealed and maintained at maximum operating temperature for a duration of less than 24 hours (but not less than 8 hours), provided the gas sampling results obtained are extrapolated by multiplying by the ratio of occupation duration to test duration and does not exceed the ACGIH TLV allowable limits divided by the aforementioned ratio.

31.5 Leak Testing

PVHOs or pressure hulls that are designed to be internally pressurized during normal operations are to be leak tested to MAWP with the gas normally used in service. Leakage is not to exceed a rate which will cause the pressure to decrease by more than 1 percent in 4 hours.

The leak testing is to be carried out after fabrication and completion of all outfitting.

31.7 Life Support Testing

Life Support testing is to be carried out as specified in 11/35.11, 12/39.11.9 or 13/3.13.11, as applicable.

SECTION 9 Piping Systems and Mechanical Equipment

1 General

Pressure vessels, piping systems and other mechanical equipment necessary for the operations of the underwater vehicle or the hyperbaric facility are to be designed, constructed, installed, inspected and tested in accordance with the *Steel Vessel Rules*, to the satisfaction of the Surveyor, except as modified herein. Additionally, life support and engineering systems are to comply with Sections 8, 10, 11, 12, and 13 of these Rules.

3 Production Equipment

Equipment for the production of hydrocarbon is to comply with the ABS *Rules for Building and Classing Facilities for Offshore Installations*. As an alternative, this equipment may be accepted based on compliance with a recognized standard.

5 Pressure Vessels, Heat Exchangers and Heaters

5.1 General *(2002)*

5.1.1

Plans, calculations and data for all pressure vessels, heat exchangers and heaters are to be submitted for review and approval in accordance with Subsection 1/7 of these Rules. They are to be constructed, installed, inspected and tested in the presence and to the satisfaction of the Surveyor in accordance with approved plans.

5.1.2

All pressure vessels, heat exchangers and heaters are to comply with the requirements applicable to Group I pressure vessels in Section 4-4-1 of the *Steel Vessel Rules*.

5.1.3

Mass produced pressure vessels may be accepted in accordance with 4-4-1/1.11.2 of the *Steel Vessel Rules*.

5.1.4

Seamless pressure vessels for gasses may be accepted in accordance with 4-4-1/1.11.4 of the *Steel Vessel Rules*, provided their application does not violate any restrictions contained in the standard applied.

5.1.5

Fiber reinforced plastic (FRP) pressure vessels may be accepted on a case-by-case basis.

5.3 Pressure Vessels Subject to External Pressure *(2002)*

5.3.1

Pressure vessels, heat exchangers and heaters subject to external pressure are to comply with Sections 4, 5, and 6 and are to be tested in accordance with Subsection 3/3 in the presence and to the satisfaction of the Surveyor.

5.3.2

As an alternative to the design requirements of 9/5.3.1, pressure vessels, heat exchangers and heaters subject to external pressure are to comply with the appropriate external pressure requirements in the codes or standards acceptable for Group I pressure vessels in Section 4-4-1 of the *Steel Vessel Rules*.

5.3.3

Fiber reinforced plastic (FRP) pressure vessels are to be hydrostatically tested in accordance with Subsection 3/3 in the presence and to the satisfaction of the Surveyor.

5.5 Pressure Vessel Location

Pressure vessels and heat exchangers are not to be located within the pressure boundary of the underwater vehicle or hyperbaric installation unless calculations are submitted showing that the inadvertent release of the contained fluid(s) will not increase the pressure inside the chamber by more than one atmosphere. See 8/7.5.2.

5.7 Safety Relief Devices *(2010)*

5.7.1

Pressure vessels, heat exchangers and heaters are to be protected by suitably-sized safety relief devices set at a pressure not exceeding their maximum allowable working pressure (MAWP) and they are to be installed with no intervening valves between the pressure container and the safety relief device.

5.7.2

The maximum allowable working pressure is the maximum pressure permissible at the top of the pressure vessel, heat exchanger or heater in its normal operating condition and at the designated concurrent temperature specified for that pressure.

5.7.3

If the safety devices are mounted outside the pressure boundary of the pressure hull or pressure vessel for human occupancy, they are to be constructed of suitable non-corrosive materials and are to be inspected on a regular basis in accordance with the procedure outlined in the approved Maintenance Manual (See 1/9.3). Where applicable, the designer is to consider the effect of seawater back-pressure acting on the downstream side of the safety device.

5.7.4

If the safety devices are mounted within the pressure boundary of the pressure hull or pressure vessel for human occupancy, then it is to be demonstrated by calculations that the release of the fluid contained in the pressure vessel will not increase the pressure within the pressure boundary by more than one atmosphere, nor raise the partial pressure of the atmospheric gases above their maximum allowable levels (see 8/7.5.2.). For surface-based systems, the exhaust of safety relief devices may be piped outside the pressure boundary or to an enclosed tank connected to the outside. This tank is to be provided with a pressure gauge and a check valve. Special consideration will be given to the equivalent alternative arrangements, such as multiple pressure vessel installations, as determined suitable by ABS.

7 Piping Systems

7.1 General

Piping systems and auxiliaries are to be designed, constructed, installed, inspected, tested and surveyed in accordance with the requirements for Class I piping systems in Chapter 3 and Chapter 4 of the ABS *Rules for Materials and Welding (Part 2)*, Part 4, Chapter 6 of the *Steel Vessel Rules* and the ABS *Rules for Survey After Construction (Part 7)*, except as modified below.

7.3 Wall Thickness of Pipes and Tubes

The minimum thickness of pipes and tubes is to comply with Part 4, Chapter 6 of the *Steel Vessel Rules*.

7.5 Wall Thickness of Pipes and Tubes Subject to External Pressure

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

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

$$t = 3WR_o/Q_y$$

where

W	=	external pressure
T	=	thickness
E	=	modulus of elasticity
R	=	mean radius
R_o	=	outside radius
ν	=	Poisson's ratio
Q_y	=	yield strength
c	=	0.00 for plain-end pipe or tubing
	=	1.27 mm (0.05 in.) for all threaded pipe 17 mm ($^3/_8$ in.) O.D. and smaller
	=	depth of thread h for all threaded pipe over 17 mm ($^3/_8$ in.) O.D.
	=	depth of groove for grooved pipe

7.7 Piping Systems Penetrating the Pressure Boundary

Piping systems penetrating pressure boundaries are to have valves as required below, and pipes and fittings connecting shell penetrations to those valves are to be as short as possible. Pipes connecting the stop valves to the penetrations on the pressure boundary are to be adequate for the design pressure and temperature, but are not to be less than the equivalent of ANSI Schedule 160 construction. As an alternative, special consideration will be given to pressure boundary penetrations provided with internal and external mechanical protection and protection against corrosion. These valves and the fittings connecting the valves to shell penetrations, are to have pressure ratings corresponding to the pressure and temperature of the fluid contained.

7.7.1 Submersibles, Personnel Capsules, and Habitat

A manually operated stop valve is to be provided. An additional stop valve or a check valve is to be provided for systems connected to sea suctions or discharges.

7.7.2 Hyperbaric Chambers and Diving Bells

A manually operated stop valve is to be provided at each pressure boundary piping penetration. All interior breathing and pressure supply controls are to be provided with means of overriding and controlling them from the exterior. Additionally, piping exclusively carrying fluids into the diving bell is to have a check valve close to and downstream of the stop valve.

7.7.3 All Units

7.7.3(a) Oxygen piping in all underwater systems and hyperbaric installations is to run, as far as practicable, apart from other systems.

7.7.3(b) Breathing gas pipes are to run, as far as practicable, apart from electrical cable conduits.

7.7.3(c) Valves are to be constructed so that the stem is positively restrained from being screwed out of the body.

7.7.3(d) The open and close position of each valve and its turning direction are to be clearly indicated as far as practical.

7.9

Expansion in piping systems is to be compensated by pipe bends or other means. Piping supports and support arrangements are to be provided.

7.11

Means are to be provided for complete draining and venting of all piping systems.

7.13 *(2010)*

7.13.1

Piping systems that may be exposed to a pressure higher than that for which they are designed are to be provided with suitably-sized safety relief devices.

7.13.2

If the safety devices are mounted outside the pressure boundary of the pressure hull or pressure vessel for human occupancy, they are to be constructed of suitable non-corrosive materials and are to be inspected on a regular basis in accordance with the procedure outlined in the approved Maintenance Manual (See 1/9.3). Where applicable, the designer is to consider the effect of seawater back-pressure acting on the downstream side of the safety device.

7.13.3

If the safety devices are mounted within the pressure boundary of the pressure hull or pressure vessel for human occupancy, then it is to be demonstrated by calculations that the release of the fluid contained in the pressure vessel will not increase the pressure within the pressure boundary by more than one atmosphere, nor raise the partial pressure of the atmospheric gases above their maximum allowable levels. For surface-based systems, the exhaust of safety relief devices of gas piping systems may be piped outside the pressure boundary or to an enclosed tank connected to the outside. This tank is to be provided with a pressure gauge and a check valve. See 8/7.5.2.

7.15 *(2002)*

Pipe sections are to be joined by full penetration welds. Flange connections may be accepted provided they comply with a recognized standard. Butt weld flanges are to be used except that socket weld flanges may be used up to the equivalent of 3-inch NPS and for non-essential service. Special considerations will be given to other pipe connections.

7.17

Piping, fittings, and penetrations exposed to sea water or to a sea water atmosphere are to be corrosion resistant and have demonstrated satisfactory performance for the intended service.

7.19

Flexible, non-metallic hose and tubing may be used provided particular attention is paid to the hose (or tubing) material, pressure, temperature of the fluid carried, and environment toxicity, combustibility, etc. See 8/11.1.3.

All hoses and tubing are to be of approved design, fabrication and testing to the satisfaction of the Surveyor. Tubing and hoses are to be rated for not less than the MAWP of the system and are to have a minimum burst strength of 4 times the MAWP of the system.

Flexible non-metallic hoses are to be complete with factory assembled end fittings or factory supplied end fittings installed in accordance with manufacturer's procedures. Hose clamps and similar types of attachments are not permitted in pressurized or vital systems.

7.21

When internal pressure-reducing valves are fitted, provision is to be made for overriding them in the event of failure. All piping downstream and upstream of reducing valves are to be adequate for the maximum supply pressure. A check valve is to be provided downstream of the reducing valve to protect against back pressure during override.

7.23 *(2007)*

Power driven pumps of hydraulic systems used for emergency services are to be backed up with at least one manually operated pump.

Filters are to be installed in all hydraulic piping systems, and they are to be replaceable without impairing the system's integrity.

9 Color-coding and Labeling

9.1

All underwater systems and hyperbaric facilities are to use consistent color-coding and labeling for piping, pressure vessels and other mechanical equipment. See also 8/11.11.

Piping and gas storage bottles are to be colored and labeled to indicate content and maximum working pressure. For labeling, a color that contrasts with that of the pipe is to be used. Section 9, Table 1 gives the color codes required by the US Navy however, other color codes, such as that provided in IMO "Code of Safety for Diving Systems" Resolution A.536(13), may be used.

TABLE 1
Color Codes for Piping and Gas Storage Bottles

Name	*Designation*	*Color*
Oxygen	O_2	Dark Green
Nitrogen	N	Light Gray
Air (Low Pressure)	ALP	Black
Air (High Pressure)	AHP	Black
Helium	He	Buff
Helium-Oxygen Mix	He-O_2	Buff and Dark Green
Exhaust	E	Silver

9.3

Color code and labeling requirements vary substantially between the various jurisdictions under which the underwater system or hyperbaric facility will be used. It is therefore the responsibility of the owner/user of the units to specify the appropriate color coding and labeling system.

11 Radiographic Examination of Welded Piping Connections

All Group I welded pipe connections are to be subjected to 100 percent radiographic examination without any limitations of wall thickness or diameter. Socket pipe welds or any other combination welded and mechanical joints, where permitted and where radiographic examination is impracticable, are to be inspected by other approved methods.

13 Pumps and Compressors

Tests demonstrating the adequacy of pumps, compressors and their arrangements used in underwater systems and hyperbaric facilities may be required in the presence of the Surveyor.

Capacities of all pumps, compressors, and associated pressure relief devices are to be included in piping systems plan submittals. Pressure relief devices are to relieve and discharge in a manner that will not affect the chamber's internal pressure nor the operational integrity of the piping system.

15 Air Conditioning System *(2007)*

When an air conditioning system is provided, documentation is to be submitted for review and approval in accordance with Sections 8, 9, 10 11, 12, and 13. The air conditioning system is to be functionally tested during the life support system tests as per Subsections 3/5 and 11/35.11.

17 Equipment

Underwater vehicles and systems are to be equipped with the following as applicable:

i) Valves, gauges and such other equipment as is necessary to control all vital systems, including any fuel supply and exhaust systems.

ii) Valves, gauges and other equipment as are necessary to control the depth, attitude, and rate of descent and ascent.

iii) Valves or other fittings to enable manipulators, grasping or anchoring devices and jettisonable equipment to be released in an emergency situation.

iv) An internal release device, suitably protected against inadvertent operation, for severing or releasing the umbilical cable.

v) *(2007)* For underwater towing applications, an internal release device, suitably protected against inadvertent operation, for releasing the towing cable of a towed submersible.

vi) Anchors and cables of sufficient number weight and strength, if necessary.

SECTION 10 Electrical Systems

1 General

Electrical installations and equipment for the systems covered by these Rules are to be designed, fabricated, installed, inspected, and tested to the satisfaction of the Surveyor in accordance with Part 4, Chapter 8 of the *Steel Vessel Rules* except as modified hereinafter.

3 Application

3.1 Environment

All electrical equipment is to be designed for the environment in which it will operate in order to minimize the risk of fire, explosion, electric shock and emission of toxic gases to personnel, and galvanic action on the pressure boundary.

3.3 Pressurization

Electrical equipment installed in hyperbaric environments is not to be damaged by pressurization and depressurization of the environment.

3.5 Hazardous Areas

Electrical equipment installed in hazardous areas, electrical equipment in underwater units which contain installations for the production of hydrocarbons, and electrical equipment in compartments which are intended to be used to transfer personnel to such units or areas are to be certified by a competent independent testing laboratory as explosion proof or intrinsically safe.

3.7 Underwater Electrical Equipment

Underwater electrical equipment is to be rated for an ambient temperature of 30°C (86°F). Electrical installations exposed to the open atmosphere are to be rated for an ambient temperature of 40°C (104°F).

3.9 Humidity *(2007)*

All electrical equipment necessary to the safe completion of the mission, including equipment that may be needed during an emergency, is to be suitable for 100 percent relative humidity or the conditions anticipated onboard the unit.

5 Power

5.1 Main and Emergency Power *(2002)*

The electrical installations essential to the safe completion of the mission are to be supplied from independent main and emergency sources of electrical power. The emergency source of electrical power is to be available in not more than 45 seconds after interruption of the main power source. The main power source for all units is to have sufficient capacity for the design mission. 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 for the duration required in 11/35.3 or 11/35.5, as applicable to the subject unit.

i) Emergency internal lighting

ii) Communication equipment

iii) Life support systems

iv) Environmental monitoring equipment

v) Essential control systems

vi) Other equipment necessary to sustain life

5.3 Power Source

The main and the emergency power sources may be either a generator driven by a prime mover or batteries.

5.5 Power Source Separation

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.

5.7 Automatic Emergency Power Changeover

If the changeover to emergency power is automatic it is to activate an alarm at the control station or pilot stand and means are to be provided to manually switch back to main power.

5.9 Equipment on Emergency Power

The independent emergency source of power is to be capable of feeding the following users for the duration specified in 11/35.7.3:

i) Emergency internal lighting

ii) Communication system

iii) Emergency life support system (if electrically powered)

iv) Launch and Recovery System

v) Environmental monitoring equipment

vi) Controls for emergency systems

vii) Any electrical equipment deemed essential for therapeutic procedures or hyperbaric chambers of hospital facilities and helicopter (or truck) decompression chambers

5.11 Sizing of Emergency Source

The emergency source of power is to be sized to supply all connected loads.

7 Voltage

7.1 Maximum Voltage

In general, installations for the mission within a personnel pressure boundary are to have the following maximum voltages:

i) For power and heating equipment permanently installed, 250 volts AC or DC.

ii) For lighting, socket outlets, portable appliances and other users supplied by flexible cables, and for communication and instrumentation equipment, 48 volts.

iii) Voltages for temporary connections to ship's or shore power will be specially considered.

7.3 Protection from Higher Voltages

Higher voltages than those specified above may be fitted, provided additional precautions are taken in order to obtain an equivalent level of safety, e.g.:

i) By providing a higher degree of enclosure

ii) By reducing the possible earth fault currents

iii) By providing a fixed barrier which keeps divers at safe distance from the equipment

iv) By providing double insulation, comprising two layers of insulation with a conducting screen in between

v) By providing protective diver suits

9 Underwater Safeguards

9.1 Electrical Equipment

Electrical equipment used in water will be subject of special design consideration in each separate case. However, provisions are to be taken to reduce to harmless levels the possible fault currents to which the divers can be exposed.

9.3 Habitats and Working Chambers

For habitats and working chambers see 8/7.7.

11 Batteries *(2012)*

11.1 General Requirements

11.1.1 Reliability

Battery specifications and sufficient test data or operating experience are to be provided to ascertain that the batteries can reliably perform for their estimated life under their service conditions.

11.1.2 Batteries Within Pressure Boundaries of PVHOs or Pressure Hulls *(2013)*

When batteries capable of generating explosive gases are located within the pressure boundary of PVHOs or Pressure Hulls, they are to be installed in segregated (gas tight) chambers that can be ventilated during recharging.

Means with sufficient capacity are also to be provided to mitigate or remove explosive gases generated during discharge of the batteries. (These means may include monitoring devices and alarms for explosive gases, catalytic burners for gas emissions, etc.). Also see 11/37.3.

11.3 Battery Compartments

11.3.1 Corrosion

Battery compartments are to be adequately protected against corrosion.

11.3.2 Battery Compartment Penetrations

Electrical cables entering the battery compartment are to be routed through water- and gas-tight electrical penetrators.

11.3.3 Hazardous Areas

All electrical equipment in battery compartments is to be explosion proof or intrinsically safe. See 10/3.5.

11.3.4 Battery Chargers

Charging equipment for batteries is to be provided with reverse current protection.

11.3.5 Overload and Short Circuit Protection *(2013)*

11.3.5(a) All batteries are to be provided with circuit protection devices (overload and short circuit protection) on each ungrounded conductor (see 10/15.1).

11.3.5(b) The circuit protection devices are to be designed for the maximum charge or discharge voltage and current.

11.3.5(c) Circuit protection devices with thermal elements are to be tested for operation at maximum anticipated pressure at the location of installation of the protective device.

11.3.5(d) Except as permitted in 10/11.3.5(e) below and 10/15.5, circuit protection devices are to be located in a separate space from battery compartments containing batteries capable of generating explosive gases (such as Hydrogen gas), but length of cables between battery and the protection device is to be kept as short as feasible.

11.3.5(e) Circuit protection devices may be installed within battery compartments containing Hydrogen producing batteries, provided the following additional requirements are met:

i) The battery compartment is provided with at least one Hydrogen monitoring device that is to be located in close proximity and preferably above the circuit protection device. Hydrogen monitoring devices are to comply with 10/3.5.

ii) The Hydrogen concentration within the battery compartment is verified (by the operational personnel) to be no more than 40% of the Lower Explosive Limit (LEL) of Hydrogen prior to energizing any circuit(s) deriving power from the batteries within the subject battery compartment.

iii) During the pre-startup check of the battery compartment's Hydrogen concentration, Hydrogen monitoring devices normally receiving power from batteries within the compartment (they are monitoring), are to receive power from an alternate power source located outside the monitored battery compartment.

iv) The procedure for determining the Hydrogen concentration (including the maximum Hydrogen concentration below which the circuits may be energized) is to be documented in the underwater unit's Operations Manual and is to be submitted to the Technical Office for review.

11.3.6 Terminal Potting

Cell top terminal potting, if used, is to possess good dielectric properties and is not to absorb electrolyte, oil or water at design operating pressures. Potting is not to block cell/battery vents. A dry insulation resistance measurement is to be made by means of a 500 volt DC insulation resistance test instrument (megger) between the leads and the insulated casing and is to show a reading of at least 50 megohms.

11.3.7 Pressure Compensation

When pressure compensated systems are used, they are to contain a sufficient volume of compensating fluid to supply the batteries throughout the extremes of pressure, temperature and entrained gas volumes for the design depth. Consideration is to be given to the bulk modulus and expansion characteristics of the compensating fluid to ensure sufficient quantity.

The pressure compensated system is to contain pressure relief provisions, so that generated gases from cell gas traps may be vented overboard. Relief devices are to be jam free to prevent cell or system damage due to gas generated internal pressure. Relief devices are to be sized for release of expanding gas at a rate corresponding to the emergency rate of ascent of the unit. Manufacturer's capacity data and capacity calculations for the relief devices are to be submitted for review before installation.

11.5 Lithium Batteries

11.5.1 General Requirements

11.5.1(a) Lithium batteries (include lithium-ion, lithium-alloy, lithium metal and lithium polymer batteries) will be considered on a case-by-case basis for specialized applications. These batteries are not permitted on passenger submersibles or other applications involving passengers. (See Subsection 11/49).

11.5.1(b) Lithium batteries are to be certified by a third-party independent agency (such as Underwriters Laboratories (UL), Canadian Standards Association (CSA), etc.) in accordance with the requirements of one of the following standards:

i) NAVSEA S9310-AQ-SAF-010, US Navy Technical Manual for Batteries

ii) UL 1642, UL Standard for Safety of Lithium Batteries

iii) Section 38.3, UN Manual of Tests and Criteria

iv) Other recognized national or international standards for lithium batteries

Testing of the batteries is to be conducted at a competent battery testing facility.

11.5.1(c) Lithium batteries are to be fabricated under an approved quality assurance program. (See 1-1-A3/5.3 of the ABS *Rules for Conditions of Classification (Part 1)*).

11.5.1(d) Lithium batteries are to be suitable for marine applications and are to have appropriate service experience or test data for underwater applications.

11.5.1(e) A detailed risk analysis is to be carried out for evaluating and mitigating potential risks associated with lithium battery installations. The risk analysis is to be conducted as per the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries* or equivalent recognized national or international standards.

11.5.2 Installation

For manned applications, lithium batteries are to be located outside the pressure hull in pressure resistant or pressure compensated battery pods.

Battery pods are to be mechanically protected from direct impact loads and are to be installed in locations that are as far away as practicable from compressed gas cylinders and acrylic windows on the pressure hull and sources of heat.

Consideration is to be given to installing battery pods at a suitable distance from the pressure hull in order to prevent damage in the event of a fire.

For manned applications, means are to be provided for jettisoning the battery pods in the event of an internal fire. An alternative or emergency source of power is to be available in the event of loss of power due to a jettisoned battery pod. Jettisoning mechanisms, if electrically actuated, are to be supplied with electrical power from a source other than the battery pod being jettisoned. Stability of the unit with jettisoned battery pod(s) is to meet the appropriate damage stability criteria of these Rules. Alternative arrangements that provide an equivalent level of safety will be considered on a case-by-case basis

For manned applications, pressure resistant battery pods are to be provided with appropriate fire detectors and temperature sensors with audio-visual alarms at the pilot stand and/or the control station.

The pressure boundary of pressure resistant battery pods is to meet the A-60 class fire resistance rating.

Battery pods containing lithium batteries are to be labeled appropriately and are to be provided with appropriate signs warning personnel against inadvertent abuse of the pods.

11.5.3 Battery Management System (BMS)

11.5.3(a) Lithium battery installations are to be provided with an electronic battery management system (BMS). The BMS is to provide means for:

i) Battery monitoring

ii) Charge control to prevent cell overcharging/undercharging.

iii) Discharge control to prevent cell over-discharging

iv) Inter-module and intra-module balancing of the cells

11.5.3(b) For manned applications, the BMS is to provide real-time data at the pilot stand and/or the control station for the following parameters:

- Voltages (cell level and module level)
- Currents (cell level and module level)
- State-of-Charge (cell level and module level)
- Temperature (module level)

An audio-visual alarm is to activate at the pilot stand and/or the control station in the event that any of the parameters are outside their allowable limits.

11.5.3(c) The BMS is to be certified by the manufacturer as being suitable for the intended application.

11.5.3(d) The BMS is to be functionally tested to the satisfaction of the attending Surveyor.

11.5.4 Operating and Maintenance Procedures

The normal and emergency operating procedures and maintenance procedures for the use of lithium batteries is to be documented in the Operations and Maintenance Manuals of the unit.

The emergency procedures are to include those for events such as fires, leaking batteries, overheated batteries, etc.

11.5.5 Charging

For manned applications, charging is not to be carried out while the unit is operating at sea with personnel on-board the unit.

Charging of lithium batteries is to be carried out using the chargers specified by the battery manufacturer.

The operator is to take appropriate precautions when charging lithium batteries. Appropriate means of fire fighting are to be provided in the vicinity of the charging site.

11.5.6 Replacement

Lithium batteries (including individual cells) are to be replaced at or before the interval recommended by the battery manufacturer.

The replacement batteries are to be from the same manufacturer and are to be of the same type/model as the original batteries.

11.7 Other Battery Types

Batteries other than the lead-acid type will be considered on a case-by-case basis for specialized applications.

Batteries of other types are to be suitable for marine applications and are to have appropriate service experience or test data for underwater applications. Data demonstrating that the batteries are capable of providing the required output and being recharged to required power levels over a specified period of time is to be submitted for review.

Details of explosive or toxic off-gassing from the batteries (if any) are to be submitted for review. Gas emission data, as applicable, are also to be considered in connection with 10/11.3.7 and 10/11.1.2.

When applicable, fire protection, detection and fire fighting details are to be submitted for review.

A detailed risk analysis is to be carried out for evaluating and mitigating potential risks associated with the battery installation. The risk analysis is to be conducted as per the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries* or equivalent recognized national or international standards.

13 Motors

13.1 Propulsion Motors Not Subject to Pressure *(2002)*

Propulsion motors inside a pressure boundary of submersible units are to be suitable for marine atmosphere, anticipated operating temperatures and shock loading.

13.3 Propulsion Motors Subject to Pressure *(2002)*

Propulsion motors subject to operational pressure are to be designed with due considerations to the consequences of environmental corrosion and pressure temperature and shock loading.

Test data or satisfactory service experience demonstrating adequacy for intended service are to be used to substantiate the design. When pressure compensators are used, they are to be supported by complete design and detail plans and calculations. When the adequacy of pressure compensators is predicated on the complete removal of air inside the housing, the contemplated air purging procedure is to be included in the operations manual.

13.5 Other Electric Motors

Other electric motors are to be certified by the manufacturer as suitable for the intended location and service conditions.

13.7 Overload Alarms

All electric motors for propulsion and other vital services are to be equipped with overload alarms in addition to motor overload protection.

13.9 Nameplates

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. Labels are to be affixed to each motor and are to clearly show to which electrical system the motor belongs.

15 Distribution and Circuit Protection

15.1 General

The pressure boundary is not to be used as a current carrying conductor for power, heating, lighting, control and instrumentation. All electrical power distribution systems are to be ungrounded and insulated to minimize the occurrence of faults and stray currents that may create galvanic corrosion.

15.3 Ground Detectors

Ground detectors or interrupters are to be provided for all systems.

15.5 Circuit Breakers and Fuses *(2007)*

Circuits are to be protected from overloads and short circuits by protective devices that open all conductors. These protective devices are to be circuit breakers, except fuses may be used for immersion heaters and where overcurrent devices are inaccessible during normal operations. Essential and emergency circuits are to be provided with short circuit relays that can be reset. In general, fuses are not to be used in oil compensated compartments. Special consideration will be given to the use of fuses in oil compensated compartments, provided it can be demonstrated that the fuses are designed to operate in ambient pressure. Fuses and thermal breakers are not permitted in a Helium-Oxygen environment. See also 10/3.7.

15.7 Pressure Boundary Power Penetrations *(2010)*

Both positive and negative conductors from the main and emergency power sources are not to pass through the same penetrator or connection in the pressure boundary (of a pressure hull or pressure vessel for human occupancy) and are to be sufficiently spaced to prevent damaging currents. All power leads passing through the pressure boundary are to be adequately protected by circuit breakers or fuses against overload and short circuit. The circuit breakers or fuses are to be located on the power source side of the pressure boundary and are to have the ability to open the circuit quickly to prevent damage to the watertight integrity of the electrical penetration. Tests may be required to demonstrate the ability of the device to perform as mentioned above.

For low voltage (24 volts or lower) DC applications, special consideration will be given to both the positive and negative conductors from the main and emergency power sources passing through the same penetrator or connection in a pressure boundary, provided it can be demonstrated that:

i) There is little risk of short circuiting or tracking between conductors.

ii) The voltages and currents are of such an order that in the event of failure in any way of the conductor insulation, the integrity of the penetrating device's gas/water block is maintained.

15.9 Distribution Panels *(2002)*

All distribution panels are to be accessible during operation. It is to be possible to disconnect power to each chamber separately.

15.11 Electromagnetic and Radio Frequency Interference

The effect of electromagnetic and radio-frequency interference from adjacent circuits on controls and instruments is to be considered. Circuits are to be shielded if necessary.

15.13 Separation of Cables and Wiring

15.13.1

Cables and wiring of circuits supplied by different voltages and by the main and emergency circuits are to be effectively separated from each other. Electric plugs, sockets and receptacles are to be of a type which prevent improper inter-connections of the various systems and are to be provided with a means of securing after connection is made. The use of a color coding for the various systems is recommended.

15.13.2 *(2002)*

Intrinsically safe wiring is to be separated from non-intrinsically safe wiring by at least 50 mm (2 in.) and in accordance with the manufacturer's recommendations. Other suitable standards may be acceptable.

15.15 Feeds

The following users are to be supplied from separate feeders:

i) Handling systems for submersible units

ii) Normal lighting for each unit (or chamber)

iii) Emergency lighting

iv) Normal life support

v) Emergency life support

vi) Communication system

vii) Vital instrumentation and equipment

viii) Controls for emergency systems

15.17 Insulation

Insulating material used in the construction of panels and switchboards is to be of a type that does not give off toxic gases in case of fire.

15.19 Electrical Instrumentation

Sufficient drawings, specifications and test data or operating experience are to demonstrate that the reliability of the measuring devices is consistent with control requirements in the intended environment. Vital measuring devices used to control may have a backup or alternative means for providing measurements. In general, a voltmeter, an ammeter, and a ground detector (or interrupter) for each conductor of each different voltage system are suitable minimum instrumentation. This instrumentation may be located in a centralized panel or station.

15.21 Grounding

All metal parts of the switchboards, other than current carrying parts, are to be grounded. All chambers are to be provided with grounding connection devices for plugs.

17 Distribution Cables, Wiring and Penetrators

17.1 General *(2010)*

Cables and wiring are to be in accordance with Part 4, Chapter 8 of the *Steel Vessel Rules*. Cables and wiring used for power and lighting applications within the pressure boundary of pressure hulls and pressure vessels for human occupancy are to be low smoke, low/zero halogen cables.

17.3 Testing of Cable Assemblies *(2010)*

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. Each submerged cable assembly is to be tested as indicated below. Test procedures for the testing of the cable assemblies are to be reviewed by the Technical Office prior to testing. Testing is to be conducted in the presence of the Surveyor.

17.3.1 Visual Examination

A visual inspection of the cable assembly shall be made to verify there are no cuts, cracks, or other physical damage to the cable jackets or over molding/potting used in the manufacture of the cable assembly. In addition, a visual inspection of sealing grooves, sealing faces and threads shall be made to verify there are no defects that may cause a failure of the seals or that there are any defects or inclusions, including the presence of residual epoxy or urethane materials from the manufacturing process.

17.3.2 Penetrator Cable Assemblies

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, shall be tested as follows in a manner that simulates the intended use of the cable. This applies to compensated and uncompensated cables.

17.3.2(a) Pressure Testing of the Penetrator. The penetrator insert assembly, prior to any overmolding and cable assembly, shall be pneumatically or hydrostatically pressure tested to 1.25 times unit's design pressure. The pressure is to be held for 5 minutes with no signs of leaks, cracking, extrusion or other signs of failure.

17.3.2(b) Hydrostatic Tests. Penetrator cable assemblies shall be pressure cycled in seawater, or equivalent salt water solution, a total of 6 times in a hydrostatic test chamber. The penetrator cable shall be installed in the test chamber in a manner so as to simulate its intended use. The minimum test chamber pressure shall be 1.25 times the unit's design pressure and the electrical measurements as per 10/17.3.2(c) shall be taken during the final (6^{th}) pressure cycle.

17.3.2(c) Electrical Tests. Penetrator cable assemblies are to be tested by the continuous application of 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 nor expose personnel to unsafe voltages. Special consideration will be given to voltage sensitive cables.

Insulation resistance measurements are to be taken and recorded during the last pressure hold cycle as follows:

i) Between each conductor and all other conductors in the cable assembly.

ii) Between each shield in the cable assembly and all other conductors in the cable assembly (including other shields if applicable).

iii) Between each shield and the cable assembly's metal shell (or chamber lid).

iv) Between each conductor and the cable assembly's metal shell (or chamber lid).

17.3.3 Non Penetrator Cable Assemblies Subject to External Pressures

This requirement is only applicable to cable assemblies used for essential and emergency services.

17.3.3(a) Electrical Tests. Non penetrator cable assemblies are to be tested by the continuous application of 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 nor expose personnel to unsafe voltages. These tests are to be performed with the jacket exposed to seawater (Jackets of compensated cables do not have to be exposed to sea water). Special consideration will be given to voltage sensitive cables.

Insulation resistance measurements are to be taken and recorded as follows:

i) Between each conductor and all other conductors in the cable assembly.

ii) Between each shield in the cable assembly and all other conductors in the cable assembly (including other shields if applicable).

iii) Between each shield and the cable assembly's metal shell (or chamber lid).

iv) Between each conductor and the cable assembly's metal shell (or chamber lid).

17.5 Flexible Cables *(2007)*

Flexible cords for transmission of electric power and signals are to be of the watertight construction. For gland type penetrators, the cables must be of waterblock construction.

17.7 Mechanical Protection

Cables are to be protected from mechanical damage. Tensile loads are not to be applied to electrical cables or wiring.

17.9 Umbilical Cable Connectors

Umbilical cables are to have connectors that are corrosion resistant and resistant to accidental disengagement. They are to be arranged so that the weight of the bell (or capsule) is borne by the strength member where the umbilical is considered to be a secondary means of recovery. See also Subsection 8/13.

17.11 Electrical Penetrators *(2010)*

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. Manufacturer's specifications and pressure ratings of all electrical penetrators are to be submitted to the Technical Office for review.

17.13 Testing of Penetrators *(2010)*

Fabrication of the penetrators is to be carried out under an approved quality assurance program. Alternatively, each individual penetrator is to be tested to the prototype testing requirements specified below. Test procedures for the testing of the penetrators are to be reviewed by the Technical Office prior to testing. Testing is to be conducted in the presence of the Surveyor.

17.15 Prototype Testing of Gland Type Penetrators *(2007)*

Gland type penetrators (those for which the electrical cable forms part of the pressure boundary) used for electrical service are to be tested by the manufacturer as indicated below, in the listed sequence of tests. These penetrators are to be tested assembled with a short length of cable of the type that will be used in the final installation. The cable and penetrator assemblies are to show no sign of deficiency during and after the testing.

17.15.1

Voltage test by applying 1 kV plus twice the design voltage for 1 minute to each conductor and armor separately.

17.15.2

Hydrostatic test to a pressure of 1.5 times the unit's design pressure repeated six times. The pressure is to be applied to the side that will be under pressure in the actual application and is to be maintained for 20 minutes after the last cycle.

17.15.3

For applications where the actual pressurizing medium is gas, a gas leakage test with cable cut open using air to twice the design pressure or helium to 1.5 times the unit's design pressure.

17.15.4

Insulation test to 5 megohm at the unit's design pressure applying salt water. Tests are to be made between each conductor and armor.

Novel designs that have not be substantiated by service experience or acceptable test data for the operating depth will require full scale strength and cycling testing to at least 2.5 times the operating depth.

17.17 Prototype Testing of Pin Type Penetrators *(2007)*

Pin type penetrators (those for which the electrical cable does not form part of the pressure boundary) used for electrical service are to be tested by the manufacturer as indicated below, in the listed sequence of tests. The penetrator assemblies are to show no sign of deficiency during and after the testing.

In cases where it is not clear that the method of attachment of the conductors will not compromise the penetrator pin sealing arrangement, the ABS Technical Office or Surveyor may require the attachment of a short piece of conductor to each pin, prior to testing.

17.17.1

Voltage test by separately applying 1 kV plus twice the design voltage for 1 minute across each conductor pin and the penetrator body.

17.17.2

Hydrostatic test to a pressure of 1.5 times the unit's design pressure repeated six times. The pressure is to be applied to the side that will be under pressure in the actual application and is to be maintained for 20 minutes after the last cycle.

17.17.3

For applications where the actual pressurizing medium is gas, a gas leakage test using air to twice the unit's design pressure or helium to 1.5 times the unit's design pressure.

17.17.4

Insulation test to 5 megohm at the unit's design pressure. Tests are to be made between each conductor pin and the penetrator body.

Novel designs that have not been substantiated by service experience or acceptable test data for the operating depth will require full scale strength and cycling testing to at least 2.5 times the operating depth.

19 Lighting

Each unit is to be provided with adequate normal and emergency lighting to allow for safe operations by the occupants.

21 Electrical Controls

21.1 Back Up *(2007)*

Manual back up for electrical controls is to be provided for emergency recovery or surfacing. Printed instructions for emergency surfacing are to be permanently affixed adjacent to the manual controls in underwater vehicles. For deep-diving units, special consideration will be given to the equivalent alternative arrangements as determined suitable by ABS based on submission of a risk assessment study.

21.3 Separation of Control Leads

Duplicate control leads for a single circuit are not to pass through the same penetrator and should be spaced as widely apart as is feasible.

23 Communication Systems

23.1 Locations

The communication system is to be arranged for direct two-way communication between the control stand and the following as applicable:

i) Diver in water, except scuba divers

ii) Diving bell

iii) Each compartment of the chamber

iv) Diving system handling position and emergency control station

v) Dynamic positioning room (on drilling platforms)

vi) Navigation bridge, ship's command center, drilling floor, drilling control room. See also Section 3.

23.3 Emergency Communication

An emergency means of communication between control stand and divers in the deck decompression chamber and in the diving bell is to be available. For diving bells, this may be a self-contained, through water communication system.

23.5 Interference

Communication systems are to be installed to minimize disturbances or interference generated by foreign sources of energy.

SECTION 11 Submersibles *(2010)*

1 Scope

This Section, along with Sections 1 through 10, provides the requirements for the design, fabrication and testing of manned submersibles, including passenger submersibles.

2 Class Notations *(2012)*

New construction submersibles and passenger submersibles built under ABS survey are to be assigned the class notations ✠ **A1 Submersible** and ✠ **A1 Passenger Submersible** respectively, subject to the conditions of classification referenced in Section 1 of these Rules. New and existing submersibles and passenger submersibles not built under ABS survey are to be assigned the class notations **A1 Submersible** and **A1 Passenger Submersible**, respectively, subject to the conditions of classification referenced in Section 1 of these Rules.

3 Pressure Hulls

Metallic pressure boundaries of pressure hulls for human occupancy are to meet the applicable requirements of Sections 4, 5, and 6.

5 Access Hatches

5.1 Number and Location

Submersibles carrying more than six persons are to be fitted with at least two access hatches. Special consideration will be given to an alternative number and arrangements of hatches, based on the design, safety evaluations and risk analysis demonstrating an equivalent level of safety.

The number and location of the access hatches are to consider the length/diameter of the submersible, the length/diameter of the pressure hull, the number of persons, the conditions of operation, the rescue facilities, the relevant risks such as fire and smoke, safe evacuation under all operational and emergency conditions on the surface, etc.

5.3 Operation

All hatches are to be operable from both internal and external sides. Hatches should be designed to seat with pressure. Hatches that unseat with pressure will be considered based on the application of the unit. The means for opening and closing of hatches should permit operation by a single person under all anticipated operating and emergency conditions. Hatches are to have means for securing in the open and closed positions. Means are to be available to ensure that hatches are clear of water before opening. All hatches are to be considered when evaluating the surface stability of the submersible. See Subsection 11/31.

5.5 Pressure Equalization

Means are to be provided for equalizing pressure on each side of a hatch prior to hatch opening. As an alternative, an absolute pressure indicator with means of adjusting the internal pressure on either side may be provided.

5.7 Access

Hatch coaming ways are to be free from obstacles.

5.9 Display, Alarm and Interlock for Hatch Open Position

In order to prevent the pilot from initiating descent with the hatches in the open position, the following are to be provided in addition to the normal check procedures among pilot, submersible-crew and support-vessel-diving-supervisor, unless operational procedures state that at least two people verify hatch position prior to initiating descent.

5.9.1 Display

A failsafe display is to be provided at the pilot stand and is to clearly show the position of the hatch covers.

5.9.2 Alarm

A visual and audible alarm is to be provided at the pilot stand and is to be activated at any attempt of the pilot to initiate descent with the hatch covers in the open position.

7 Windows and Viewports

Windows and viewports are to meet the applicable requirements of Section 7.

9 Exostructures

Exostructures are to be of adequate construction, consideration being given to their size and the loads which may be imposed upon them.

Loads to be considered include those which result from bottoming, striking objects, wave slap, bumping alongside the tender, and other loads resulting from being recovered in sea state 6 (see Section 17, Table 1). A lesser sea state may be considered when it is intended that the unit be operated with a launch and recovery system whose design parameters are less than sea state 6. Stress is not to exceed the allowable stress f_a as obtained from the following equation:

$$f_a = f\eta_e$$

where

f = critical or shear stress for buckling considerations, or

= minimum specified material yield stress

η_e = usage factor as follows:

Type of Stress	η_e
Compressive or shear buckling	0.8
Axial and/or bending stresses	0.8
Shear stresses	0.53

11 External Structures

External structures include all non-pressure retaining structures outside the pressure hull (e.g., floodable structures, supporting equipment and hydrodynamic fairings, submersible towers, wave splash plating, etc.).

External structures are to be of construction adequate to the function performed, consideration being given to their size and the anticipated loads which may be imposed on them, and they are to be constructed following sound engineering practice in accordance with approved plans.

Loads to be considered include those which result from bottoming, wave action, bumping alongside the tender, striking objects, and other loading resulting from the unit being operated, launched and recovered in sea state 6. A lesser sea state may be considered when it is intended that the unit be operated with a launch and recovery system whose design parameters are based on a lesser sea state. Stress is not to exceed the allowable limits as defined in Subsection 11/9.

In order to avoid detrimental buoyancy effects on the unit, all free flooding parts of submersibles are to be designed so that all their inner spaces are fully flooded and vented. Suitable openings in the uppermost and bottom parts of the structure are to be provided.

Flood and vent openings are to be properly dimensioned and care is to be exercised to eliminate electrolytic action when dissimilar metals are used while exposed to sea water. Consideration is to be given to material deterioration in service.

Means of securing the closing appliances are to be permanently attached to the structure or to the appliances, and the arrangements are to be such that the closing appliances in way of personnel access hatches can be closed and secured from both sides. Consideration is to be given to the height of sills so that a minimum freeboard can be maintained. See Subsection 11/31.

Ballast tanks, piping systems, ballast lead rails and other equipment essential for the safe operation of the underwater vehicles, located outside the pressure hull, are to be as independent of the exostructure as possible.

All welded connections of the external structures to the exterior of the pressure hull are to be welded such as to minimize local stresses induced in the pressure hull. Inspection of such connections is to be feasible.

13 Nameplates

Submersibles are to be fitted with permanent nameplates indicating the design depth, maximum allowable working pressures/temperatures, hydrostatic test pressure, pressure hull manufacturer's name, serial number, and year built. The nameplates are to be stainless steel or other suitable material and are to be permanently attached. This information is also to be stamped on a rim of a flange of the unit.

15 Surface Anchoring, Mooring and Towing Equipment

An accessible towing point, appropriately sized for the anticipated conditions, is to be provided. When anchoring and mooring equipment is carried on the submersible, the number, weight, strength and size of anchors, chains and cables are to be appropriate for the anticipated conditions.

17 Emergency Recovery Features

Permanent features for the attachment of recovery equipment are to be provided. It is to be demonstrated by appropriate analysis that recovery feature attachments are adequate for lifting under the heaviest emergency condition following a casualty. The analysis is to include consideration of entrained water, mud and sand. Recovery features need not be provided for habitats or other permanently or semi-permanently attached underwater structures.

19 Entanglement

External appendages susceptible to entanglement are to be provided with means of disconnecting them from the main hull of a submersible. Alternatively, considerations may be given to availability of rescue divers in conjunction with remotely operated vehicles having equivalent capability.

21 Ballast Tanks

21.1 Hard Ballast Tanks

Hard ballast tanks subject to internal and/or external pressure are to comply with the requirements applicable to Group I pressure vessels in Section 4-4-1 of the *Steel Vessel Rules* and in accordance with the applicable requirements of Sections 4, 5, and 6 of these Rules.

Their capacity must be sufficient to compensate for all loading conditions. The quantity of water in the ballast tanks, along with their internal pressure, must be indicated at all times at the vehicle pilot stand.

21.3 Soft Ballast Tanks

Soft ballast tanks are compartments not subject to differential pressures. They are considered to be gravity tanks and are to be designed accordingly, together with their supports, fittings and openings. Control of the vents on the tanks is to be arranged so that failure of one valve or control line will not affect the integrity of the rest of the system.

23 Propulsion Systems, Steering Equipment, and Their Control

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

These Rules apply to all propulsion systems, steering equipment, thrusters for dynamic positioning and depth control of submersibles.

23.1 General *(2012)*

23.1.1

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

23.1.2

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

23.1.3

Detailed plans of foundations or attachments for propulsion systems, thrusters, and steering equipment are to be submitted for review. Welded connections are to comply with Subsection 11/11.

23.2 Internal Combustion Engines *(2012)*

Use of internal combustion engines on submersibles will be considered on a case-by-case basis.

23.3 Shaft Design

Design basis and stress calculations may be required to substantiate the suitability and strength of the shaft for the intended service. The stress calculations are to cover the worst expected load conditions.

The factor of safety is not to be less than 2.0 as determined by the following equation:

$$1/FS = (S_s/Y) + (S_a/E)$$

where

FS = factor of safety

S_s = steady stress

S_a = cyclic stress

Y = yield strength of the material

E = corrected corrosion fatigue strength of the material

Consideration will be given to other not less effective recognized methods and standards for shaft designs.

23.5 Protection of Shafting

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

23.7 Shaft Seals

Detailed plans of shaft seals penetrating the hull are to be submitted. Tests demonstrating the adequacy of the shaft seals and shafting fabrication arrangements may be required.

23.9 Propeller Design

Calculations substantiating the design of the propellers in accordance with a recognized method may be required.

23.11 Steering Control System Arrangement

Detailed plans of the control systems for steering are to be submitted for review. Control systems are to be satisfactorily operated during trials to the Surveyor's satisfaction.

23.13 Externally Mounted Thrusters of 20 kW (25 hp) or Less

Where thrusters having an output of 20 kW (25 hp) or less are proposed with shafts not penetrating the pressure boundary of the submersible, manufacturer's data indicating suitability of the thruster for service at the intended water depth and evidence of satisfactory testing or service experience of the thruster under design service conditions may be considered in lieu of plans and data required to determine compliance with 11/23.3, 11/23.5, and 11/23.9. Submitted manufacturer's data is to include electrical rating, temperature rise and class of insulation.

25 Navigational Equipment

Submersibles are to be provided with the following equipment:

i) At least one compass or gyro

ii) An obstacle avoidance system such as sonar

iii) Where low-light operations are expected, appropriate lighting is to be provided

iv) Means for determining distance from the seabed

v) Two independent means of measuring the depth of the unit. If both means are electrical, then at least one must be operable upon loss of the main source of power

vi) Means to indicate heel and trim, as applicable

vii) Locating devices as per Subsection 11/29

27 Communication Systems

All submersibles are to have voice communication systems providing the capability to communicate with the surface control station. The systems are to include communication among pilot, lock-out compartments and other manned compartments. Speech unscramblers are to be provided when mixed gas is used. The communication systems are to be supplied by two independent sources of power, one of which is to be the emergency source of power. Surface radios are to be included and have the capability of transmitting on the Safety Channel 16-VHF. Underwater communication systems for passenger submersibles are to maintain contact with the support facility when it is at a distance equivalent to twice the design depth of the unit. For other submersibles, the design range is to be suitable to meet the operational requirements of the specific application.

29 Emergency Locating Devices

A surface locating device such as a strobe light or VHF radio and a subsurface locating device such as an acoustic pinger, sonar reflector or buoy are to be provided. Surface detectors or other equipment as required for the detection of subsurface locating devices is to be available.

Electric locating devices not designed and equipped to operate using a self-contained power source are to be arranged to be powered by both the normal and the emergency power supplies. Non-electric locating devices are to be deployable without electric power.

31 Buoyancy, Emergency Ascent, and Stability

31.1 Normal Ballast System

Each submersible is to be fitted with a ballast system capable of providing normal ascent and descent and necessary trim adjustments. Ballast tanks that are subjected to internal or external pressure are to comply with the requirements of Section 6. Two independent means of deballasting are to be provided; one is to be operable with no electric power available. Consideration will be given on a case-by-case basis for both means of deballasting to be operated electrically, provided both means are completely independent (i.e., they have two independent power sources, separate wiring, separate actuators or motors, etc.).

31.3 Depth Keeping Capability

Submersibles are to be capable of remaining at a fixed depth within any operational depth and within all normal operating conditions.

31.5 Emergency Surfacing System

In addition to the normal ballast system, an emergency surfacing system is to be provided. This system is to provide positive buoyancy sufficient to ascend to the surface from any operational depth and safely evacuate all occupants. The system is to have at least two positive manual actions for operation and is to be independent of electric power. For deep-diving submersibles, special consideration will be given to the equivalent alternative arrangements of the emergency surfacing systems as determined suitable by ABS based on submission of a risk assessment study. The emergency surfacing system is to operate properly under all anticipated conditions of heel and trim and is to comply with one of the following:

i) The system is to jettison sufficient mass so that if the largest single floodable volume, other than the personnel compartment, is flooded, the ascent rate will be equal to the normal ascent rate. The released mass may consist of a drop weight, appendages subject to entanglement, or a combination of both.

ii) The personnel compartment may be provided with a means of separating it from all other parts of the system, including appendages, provided the personnel compartment is positively buoyant and meets the stability criteria of 11/31.11 when released.

31.7 Intact Surface Stability

Each submersible is to have sufficient intact stability on the surface so that in the worst loading condition, when subjected to a roll expected under the worst conditions listed in Section 17, Table 1 for the design sea state, the submersible will not take on water through any hatch that may be opened when surfaced. In addition, the distance from the waterline to the top of coamings around hatches that may be opened with the submersible afloat is not to be less than 2.5 feet with the submersible upright.

31.9 Underwater Operation

Adequate static and dynamic stability in submerged conditions is to be demonstrated by the tests and calculations required in Subsection 3/5 and 11/31.13.

For all normal operational conditions of loading and ballast, the center of buoyancy is to be above the center of gravity by a distance GB which is the greater of either 51 mm (2 in.) or the height as determined below:

$$GB_{min} = nwNd/W \tan \alpha$$

where

n = 0.1 (This represents 10 percent of the people aboard moving simultaneously)

w = 79.5 kg (175 pounds) per person (for passenger submersibles, w may be taken as 72.5 kg (160 lbs) per person)

d = interior length of the main cabin accessible to personnel, in mm (in.). This should not include machinery compartments if they are separated from the main cabin with a bulkhead.

N = total number of people onboard the submersible.

W = total weight (in units consistent with w) of the fully loaded submersible, not including soft ballast.

α = 25 degrees (representing the maximum safe trim angle. A smaller angle may be required if battery spillage or malfunction of essential equipment would occur at 25 degrees. This assumes that each person has an individual seat that is contoured or upholstered so that a person can remain in it at this angle).

31.11 Emergency and Damaged Condition

Submersibles are to have adequate stability under any possible combination of dropped jettisoned masses. Under some emergency conditions, the distance between the center of buoyancy and center of gravity may be reduced, but in no case is it to be less than one-half of that required in 11/31.9. Inverted surfacing is not permitted.

31.13 Calculations and Experiments

The following calculations are to be submitted and tests are to be witnessed by the Surveyor:

31.13.1 Detailed Weight Calculations

Calculations are to be provided and are to include calculated positions of center of buoyancy (*CB*), center of gravity (*CG*), total weight of the submersible (W) and displacement (Δ). This can be achieved by maintaining a detailed spreadsheet during design and construction.

31.13.2 Hydrostatic Model

A mathematical model is to be used to calculate Δ, the positions of the center of buoyancy (*CB*) and the metacenter (*CM*), by computing the hydrostatic properties during design.

31.13.3 Deadweight Survey and Lightship Measurement

The location, number and size of all items listed on the spreadsheet are to be physically checked after construction and outfitting. The completed submersible is weighed with a scale and the measured weight is then compared to the total spreadsheet weight, compensating for any extraneous weights that were onboard the submersible at the time of testing.

31.13.4 Inclining Experiments

The completed submersible is inclined on the surface and submerged in order to fix *GB* (the distance between *CG* and *CB*) and *GM* (the distance between *CG* and the metacenter *CM*). Guidance for design and performance of inclining experiments may be obtained from ASTM F 1321 and Enclosure (2) to Navigation and Vessel Inspection Circular No. 5-93 (NVIC 5-93). Such testing is not required for submersibles that are duplicates of a previously tested submersible.

31.13.5 Scenario Curves

CB, *CG*, W, *CM*, and Δ are to be assembled in graphic form for interpretation and comparison with criteria.

33 Fire Fighting

33.1 General

All submersibles are to be provided with fire detection, alarm and extinguishing systems. Automatic fire detection and fire alarm systems are to be provided in normally closed, unmanned spaces within the main pressure hull containing electrical or mechanical equipment. For compartments always occupied by alert persons during operation, the occupants may comprise the fire detection and alarm system provided such occupants possess normal ability to smell.

Saltwater is not to be used as an extinguishing agent. Propellants of extinguishing mediums are to be nontoxic. Consideration is to be given to the increase in compartment pressure resulting from use of extinguishers. See also 8/7.5.2.

33.3 Extinguishing Systems

Each compartment within the main pressure hull is to be provided with a suitable fire extinguishing system. This may include portable extinguishers. Capacity calculations for all systems are to be submitted for review.

Chemical extinguishing agents or propellants with toxic or narcotic effects for any operating conditions are not permitted. Choking hazards of extinguishing agents should be taken into consideration.

33.3.1 Fixed Systems

When submersibles are provided with a fixed fire extinguishing system using a gaseous medium suitable for manned spaces, the system is to be designed to evenly distribute the extinguishing medium throughout each compartment of the pressure boundary. Capacity of the system is to be such that a complete discharge of the extinguishing medium will not result in a toxic concentration. Suitable means are to be provided to prevent inadvertent operation of fixed fire extinguishing systems.

33.3.2 Portable Systems *(2012)*

When submersibles are not provided with a fire extinguishing system per 11/33.3.1, the fire extinguishing means is to consist of portable extinguishers using distilled water or other non-conductive liquid agent, dry chemical or a gaseous medium suitable for use in manned spaces.

Portable extinguishers are to be of an approved type. The extinguishers are to be provided with documentation confirming their approval by an appropriate third-party independent agency or laboratory for marine services.

The capacity of a portable extinguishing system using a gaseous medium is to be such that complete discharge of the extinguishers will not result in a toxic concentration.

35 Life Support and Environmental Control Systems

35.1 General

Life support systems are to meet the applicable requirements of this Section and Section 8.

Submersibles are to be provided with equipment to generate, monitor and maintain suitable life support conditions inside the manned compartment. One atmosphere chambers/systems are to be designed so that the concentration of O_2 (oxygen) will be kept within the limits of 18.0 to 23.0 percent by volume and the concentration of CO_2 (carbon dioxide) will never exceed 0.5 percent by volume.

35.3 Reserve Life Support Capacity

At the commencement of a dive, the breathing gas supply and CO_2 removal systems are to have sufficient capacity for the anticipated mission time plus a reserve capacity as required below.

The breathing gas supply system reserve time is to be based on the requirements in Subsection 8/7; the CO_2 removal system reserve time is to be based on the requirements in Subsection 8/9.

35.3.1 Untethered Submersibles

Untethered submersibles are to have a minimum reserve capacity consistent with the emergency rescue plan but not less than 72 hours.

35.3.2 Tethered Submersibles *(2012)*

The duration is to be consistent with the emergency rescue plan but is not to be less than 72 hours.

For surface supplied tethered submersibles, as an alternative to the requirements above, the duration is to be consistent with the emergency rescue plan but is not to be lesser than the greater of 10% of the design mission duration or 8 hours, provided the submersible is part of an underwater complex (See Subsection 2/87) having two independent means of recovery to the surface.

35.5 Reduced Reserve Life Support

Reserve life support is to be in accordance with 11/35.3, except that the minimum reserve in 11/35.3.1 may be reduced to a minimum reserve of 24 hours for submersibles complying with this Section and meeting the following requirements.

35.5.1

The submersible is used at one of a finite number of sites, each of which is described in the approved Operations Manual, and the site selected for each dive is recorded in a shore-based log prior to the dive. The maximum bottom depth at the site must not exceed the depth that can be safely reached by SCUBA divers. In addition, maximum depth may be limited per 11/35.5.8 or by emergency procedures in the Operations Manual (see 1/9.1).

35.5.2

The subsurface locating device required as per Subsection 11/29 is to be a device that will enable divers to quickly locate the position of the submersible in emergencies.

35.5.3

The submersible's surface support vessel can be reached by shore-based divers within one hour. At the end of the one hour period, the divers should have reached the submersible's surface support vessel and be ready to make a dive with their diving gear.

35.5.4

The unit is equipped with *two* separate ballast systems and a jettisonable weight.

35.5.5

At least one of the ballast systems in 11/35.5.4 is designed such that divers may manually blow a sufficient number of tanks to achieve positive buoyancy sufficient to safely evacuate passengers and crew as specified in the dive plan.

35.5.6

Design features and/or procedures intended to implement 11/35.5.1 through 11/35.5.5 are to be submitted to the technical office for approval prior to implementation of a minimum reserve capacity less than that specified in 11/35.3.1.

35.5.7

Prior to approval of the design features and/or procedures referenced in 11/35.5.6, performance of a simulated rescue may be required at the discretion of the technical office or the attending Surveyor. This test may be conducted at a depth less than the design depth.

35.5.8

This provision requires preparation and maintenance of a dive plan, including a decompression schedule, for use in the event of an emergency. The dive plan is to consider the emergency procedures included in the Operations Manual (see 11/35.5.1) and be appropriate for the worst-case conditions at the dive site in which the submersible will be operated. The plan is to include the number of divers required, their qualifications and certifications and the required equipment. The dive plan is to clearly address the method by which the divers will be able to quickly locate the unit in emergencies. Rescue drills are to be performed on a suitable schedule to insure that a realistic estimate of bottom time is used in the plan.

35.5.9

A life support duration less than that required in 11/35.3.1 is to be documented in the *Record*.

35.7 Emergency Life Support System

In addition to the normal breathing gas and CO_2 removal systems, an emergency life support system is to be provided. The emergency life support system is to be independent of any surface support systems and independent of the normal life support systems. Where open circuit systems are used, the effects of increased compartment pressure are to be considered.

35.7.1 Masks

Emergency breathing gas is to be supplied to either full-face masks, oral-nasal masks or self-contained rebreathers suitable for the intended service. One mask per person is to be provided.

35.7.2 CO_2

The system is to be designed such that CO_2 levels in the gas being breathed do not exceed 1.5 percent by volume referenced to standard temperature and pressure [a CO_2 mass of 0.0297 kg/m^3 at 1 atmosphere and 0°C (0.00185 lbm/ft^3 at 1 atmosphere and 70°F)].

35.7.3 Duration – Tethered and Untethered Submersibles *(2012)*

150 percent of the time normally required to reach the surface from rated depth, but not less than two hours.

35.9 Personnel Protection

For submersibles demonstrating compliance with the requirements below, the emergency life support system required in 11/35.7 may be replaced by individual devices, one per person, that provides protection from inhalation of hazardous products of combustion including carbon monoxide (CO).

Protective devices intended for such use are to be submitted for review; device approval is on a case-by-case basis. Crewmembers' emergency life support is to meet the requirements of 11/35.7.

35.9.1

The submersible must be able to surface from rated depth and open the hatch(es) within a time period such that the oxygen level within the personnel compartment does not fall below 18 percent by volume referenced to standard temperature and pressure, with the oxygen supply turned off and with full occupancy. Additionally, the carbon dioxide concentration is not to exceed 1 percent by volume with the scrubber turned off.

35.9.2

The time period described in 11/35.9.1 is not to exceed the lesser of 15 minutes or 80 percent of the manufacturer's rating for the individual breathing device.

35.11 Life Support Testing *(2013)*

After the submersible is completely outfitted and before conducting the test dive (see Subsection 11/47 below), the life support system is to be tested in the presence of the Surveyor with all the hatches closed. (Also see Subsection 9/15). During testing, the oxygen and carbon dioxide levels, the atmospheric pressure, relative humidity and temperature are to be monitored and recorded at intervals suitable to verify the system design but not exceeding 15 minutes. The monitored parameters are to be within acceptable ranges to the satisfaction of the Surveyor.

35.11.1

The test is to be conducted for 150 percent of the maximum normal dive time with the maximum number of occupants onboard.

35.11.2

The following must be demonstrated during the test:

i) CO_2 and O_2 levels and barometric pressure, relative humidity and temperature can be maintained within required parameters.

ii) Changing-out of the CO_2 absorbent can be achieved without exceeding a CO_2 concentration of 1% by volume referenced to standard temperature and pressure and that the concentration of CO_2 can be reestablished and maintained at or below 0.5% following the change-out.

35.11.3

A manned test with the maximum number of occupants, or a simulated occupancy test is to be conducted to determine time to breakthrough, where breakthrough is defined as a CO_2 concentration of 0.5% by volume referenced to standard temperature and pressure. The test may be continued beyond a CO_2 concentration of 0.5% (up to a maximum of 1%) to ensure that breakthrough is reached. The time required to achieve breakthrough is to be used in confirming the quantity of CO_2 absorbent required to be carried onboard for the reserve life support requirements.

35.11.4

As an alternative to 11/35.11.1, a manned test with the maximum number of occupants onboard is to be conducted until equilibrium is achieved by the CO_2 scrubber, plus an additional one hour. This manned test should be conducted for a minimum of three hours for all cases. This does not preclude the requirements of 11/35.11.2 and 11/35.11.3.

37 Ventilation

37.1

Ventilation of submersibles on surface may be achieved via an air duct arranged to prevent admission of spray water.

37.3

When the battery compartment is located inside the submersible, a fan or similar device is to be provided for positive ventilation of the compartment during charging and for a suitable time before and after charging. Fans are to be of non-sparking construction and the ventilation system is to provide thirty (30) air changes per hour. The venting of the battery compartment is to be separate from any other ventilation system. If the fan becomes inoperable, then charging of the batteries is to be automatically discontinued.

37.5

Battery compartments located inside the submersible and containing batteries charged by a device having an output of 200 watts or less, arranged so as to prevent driving the batteries to their gassing potential, may be provided with natural ventilation provided the ventilation opening(s) are located at the highest point(s) in the compartment and have an aggregate area equal to the volume of the compartment divided by 30 inches.

39 Piping Systems

39.1 General

Piping systems are to meet the applicable requirements of this Section and Sections 8 and 9.

39.3 Pressure Hull Valves

A manually operated stop valve is to be provided. An additional stop valve or a check valve is to be provided for systems connected to sea suctions or discharges.

39.5 Oxygen Supply External to the Pressure Hull

When pressure containers for oxygen supply are stored outside the pressure boundary, there are to be at least two banks with separate penetrations entering the craft. These penetrations should be positioned such as to minimize the possibility that a single incident would cause failure of both penetrators.

39.7 Pressure Relief Device

Each internally pressurized compartment of the pressure hull is to be provided with a pressure relieving device to prevent the pressure from rising more than 10 percent above the maximum allowable working pressure. A quick-operating, manual shut-off valve is to be installed between the compartment and the pressure relief device and is to be wired open with frangible wire. Rupture discs are not to be used, except in series with pressure relief valves.

41 Equipment

Submersibles are to be equipped with the following as applicable:

i) Valves, gauges and such other equipment as is necessary to control all vital systems, including any fuel supply and exhaust systems.

ii) Valves, gauges and other equipment as are necessary to control the depth, attitude, and rate of descent and ascent.

iii) Valves or other fittings to enable manipulators, grasping or anchoring devices and jettisonable equipment to be released in an emergency situation.

iv) An internal release device, suitably protected against inadvertent operation, for severing or releasing the umbilical cable for tethered submersibles.

v) For underwater towing applications, an internal release device, suitably protected against inadvertent operation, for releasing the towing cable of a towed submersible.

vi) Anchors and cables of sufficient number weight and strength, if necessary.

43 Electrical Systems

Electrical systems are to meet the applicable requirements of Section 10.

45 Access to Vital Equipment *(2013)*

Vital equipment (such as hull shut-off valves, circuit breakers, fire-fighting equipment, etc.) required for safety of the occupants under emergency conditions, as determined by the builder or operator, is to be readily accessible to the pilot and/or members of the crew.

The list and location of vital equipment is to be submitted to the Technical Office for review. A survey is to be conducted to verify that the vital equipment is readily accessible.

47 Test Dive *(2012)*

A manned test dive to the design depth is to be conducted in the presence of the Surveyor. The test dive may be conducted with a suitable number of occupants onboard the submersible (full occupancy is not required).

All penetrations and all joints accessible from within are to be inspected visually at a depth of approximately 30.5 m (100 ft) before proceeding to greater depths. All components, such as hull valves, whose operation is subjected to submergence pressure and which are required for safe operation, are to be operationally tested at this depth, if practicable. A log of the inspection of all hatches, viewports, mechanical and electrical penetrators, and valves is to be maintained.

The submergence is then to be increased in increments of approximately 20 percent of the design depth until design depth is reached. At each 20 percent increment constant depth is to be maintained and accessible welds and other closures are to be inspected, and valves checked. Unsatisfactory operations of a valve or unsatisfactory leak rate may be cause to abort the test.

The test dive may be a single dive, as described, or a series of dives to accomplish the same purpose. The test dive is also to demonstrate satisfactory performance of life support systems, air conditioning systems (if installed), propulsion systems, electrical systems, and items required for safe operations.

Where the depth of water available is less than the design depth, both the rated depth (depth reached during test dive) and the design depth will be indicated in the *Record*. The rated depth may subsequently be increased by performing a test dive to a greater depth, not exceeding the design depth, in the presence of the Surveyor.

49 Additional Requirements for Passenger* Submersibles

* *Note:* A passenger is every person other than the pilot and the members of the crew or other persons employed or engaged in any capacity on board a submersible on the business of that submersible.

49.1 General

Submersibles intended for transportation of passengers are to comply with the following additional requirements.

49.3 Operational Restrictions and Safeguards

49.3.1

Classification of passenger submersibles is issued for operation in waters with a sea-bed depth not greater than 105 percent of the rated depth of the submersible, within the design parameters in Subsection 1/7 and 11/49.3.2 and under the supervision of dedicated surface support during missions. Special consideration will be given for operation in waters with a sea-bed depth greater than 105 percent of the rated depth of the submersible, on the basis of safety evaluations and risk analysis demonstrating the additional safety characteristics of the design and/or operational procedures.

Passenger submersibles are to be operated only in areas surveyed in accordance with 11/49.5.

49.3.2

In addition to the required plans, calculations and data in Subsection 1/7, the designer of the submersible is to submit the following operational parameters as a basis for design review and classification:

i) Maximum current

ii) Night/limited visibility operation

iii) Number of passengers/crew

iv) Maximum towing speed/towing line tension

v) Maximum speed while surfaced and submerged

vi) List of hazards to be avoided.

49.5 Dive Sites

Dive sites for passenger submersibles are to be investigated by the operator for operational hazards prior to diving. Results of this investigation are to be documented as a dive site report. This dive site report is to be provided to the pilot prior to the first dive at each new dive site. Updates to the dive site report for the same site may be necessary if conditions affecting the safe operation of the submersible are known to have changed significantly.

49.7 Segregation of Spaces

Requirements for segregation chambers for machinery other than batteries will be subject to special consideration.

Pilot control stations or critical controls for the safe operation of submersibles are to be protected from accidental activation by passengers. When this is not practicable, special consideration will be given to alternative arrangements including operational procedures providing an equivalent level of safety.

49.9 Bilge System

49.9.1

Passenger submersibles are to be provided with a fixed bilge system capable of draining all spaces inside the submersible. When overboard discharges penetrating the pressure boundary are fitted they are to have an internal stop-check valve as close as possible to the hull and a check valve in the discharge side of the pump. Special consideration may be given to alternative bilge pumping arrangements based on a risk assessment and the submersible's design.

49.9.2

A bilge alarm is to be provided at the pilot stand for early detection of water accumulation.

49.11 Emergency Lifting

Submersibles are to be equipped with an appropriate number of lifting points. Each of these points is to be capable of independently raising the submersible to the surface in an emergency. At least one of these points is to be accessible under the most severe damaged conditions. Each lifting point is to be designed as per the loads specified in Subsection 11/17.

49.13 Acrylic Window Protection

A transparent, shatterproof protective screen is to be provided on the interior of all windows normally accessible to passengers. Where this is not practical or feasible, precautions are to be taken to prevent passengers from causing physical damage to the windows.

SECTION 12 Lock-Out Submersibles *(2012)*

1 Scope

This Section along with Sections 1 through 11 provide the requirements for the design, fabrication and testing of lock-out submersibles.

3 Class Notations

New construction lock-out submersibles built under ABS survey are to be assigned the class notation ✠ **A1 Lock-Out Submersible** subject to the conditions of classification referenced in Section 1 of these Rules. New and existing lock-out submersibles not built under ABS survey are to be assigned the class notation **A1 Lock-Out Submersible** subject to the conditions of classification referenced in Section 1 of these Rules.

For lock-out submersibles, in addition to the design depth, the maximum lock-out depth is to be also indicated in the *Record*.

5 Pressure Hulls

Pressure hulls are to meet the applicable requirements of this Section and Sections 3, 4, 5, and 6.

Lock-out submersibles are to be provided with at least one pressure hull with two separate compartments or two separate pressure hulls so designed as to permit ingress or egress of personnel while the diver lock-out compartment remains pressurized.

In general, the internal pressure within command compartments is to be maintained at or near one atmosphere (See 12/37.11 below).

Internal pressure within diver lock-out compartments may be maintained at atmospheric pressure or a pressure not exceeding the pressure corresponding to the maximum lock-out depth.

7 Navigation and Observation

Command compartments are to be provided with suitable means (such as viewports or sonars) to assist the pilot(s) in navigating the lock-out submersible.

Navigational equipment is to meet the applicable requirements of Subsection 11/25.

Command compartments are to be provided with suitable means (such as viewports or cameras) to enable the command compartment personnel to visually observe all occupants within lock-out compartments. Suitable lighting is to be provided in the lock-out compartments to permit observation.

Command compartments are to be provided with suitable means (such as viewports or cameras) that as far as practicable allow the divers entering or exiting the submersible to be observed by the command compartment personnel.

Windows and viewports, when installed, are to meet the applicable requirements of Section 7.

9 Exostructures

Exostructures are to meet the applicable requirements of this Section and Subsection 11/9.

Lock-out submersibles are to be provided with suitable means that permit the divers to exit and re-enter the lock-out compartments safely under normal operating conditions.

11 External Structures

External structures are to meet the applicable requirements of this Section and Subsection 11/11.

Lock-out submersibles that are designed to be transported are to be provided with suitable attachment points to enable the submersible to be secured to the means of transportation.

13 Nameplates

Nameplates are to meet the applicable requirements of this Section and Subsection 11/13.

In addition to the design depth, the maximum lock-out depth is to be also indicated on the nameplate.

15 Surface Anchoring, Mooring and Towing Equipment

Surface anchoring, mooring and towing equipment, when provided, is to meet the applicable requirements of Subsection 11/15.

17 Emergency Recovery Features

Emergency recovery features are to meet the applicable requirements of Subsection 11/17.

19 Entanglement

External appendages susceptible to entanglement are to meet the applicable requirements of Subsection 11/19.

21 Ballast Tanks

Ballast tanks are to meet the applicable requirements of Subsection 11/21.

23 Propulsion Systems, Steering Equipment and their Control Systems

Propulsion systems, steering equipment and their control systems are to meet the applicable requirements of Subsection 11/23.

25 Emergency Locating Devices

Emergency locating devices are to meet the applicable requirements of Subsection 11/29.

27 Buoyancy, Emergency Ascent and Stability

Buoyancy, emergency ascent and stability of lock-out submersibles are to meet the applicable requirements of this Section and Subsection 11/31.

Lock-out submersibles are to be provided with suitable means to compensate for changes in buoyancy, list and trim that may occur while conducting lock-in/lock-out operations. The means are to have sufficient control to counteract the effect of divers exiting or entering lock-out compartments in quick succession.

The stability analysis for underwater operations (See 11/31.9) is to also consider partial flooding of lock-out compartments.

Partial flooding of upright lock-out compartments during diver lock-in/lock-out operations (See 12/39.11.8 below) is to be limited to a level that is below the location of the electrical and life support equipment (such as CO_2 scrubbers) within the lock-out compartments. The flooded volume is not to exceed 40% of the internal volume of the lock-out compartment. Special consideration will be given on a case-by-case basis for lock-out compartments that are flooded to a level or volume exceeding those specified above.

Means are to be provided for de-watering partially flooded lock-out compartments under normal, reserve and emergency conditions.

Lock-out submersibles are to be designed to prevent internal flooding of the lock-out compartments in the event of uncontrolled descent from the surface or an intermediate depth to the design depth.

The design of emergency surfacing systems that jettison masses is to consider the largest single floodable volume other than the command / lock-out compartment [see 11/31.5i)] or a partially flooded lock-out compartment, whichever is greater.

Emergency surfacing systems that are designed to release the personnel compartment [see 11/31.5ii)] are to release the command compartment as well as the lock-out compartments along with their associated emergency life support systems.

For submersibles complying with the additional requirements of 12/37.11, special consideration will be given on a case-by-case basis for the command compartment personnel locking-out of the lock-out compartment in lieu of release of the command compartment.

For submersibles operating in areas with shallow sea-bed depths (not exceeding 165 FSW (50.3 MSW)), special consideration will be given on a case-by-case basis for the divers locking-out of the lock-out compartments in lieu of release of the lock-out compartments. For such cases, means are to be provided to permit the divers to exit the lock-out compartments safely when the submersible is resting on the sea-bed under emergency operating conditions.

29 Ventilation

Ventilation is to meet the applicable requirements of Subsection 11/37.

31 Piping Systems

Piping systems are to meet the applicable requirements of this Section and Subsection 11/39.

Umbilicals, when provided, are to be securely attached to the submersible by means of a strength member or strain relief fitting so that the individual connections are not subjected to tensile loads.

33 Equipment

Lock-out submersible equipment is to meet the applicable requirements of Subsection 11/41.

35 Electrical Systems

Electrical systems are to meet the applicable requirements of this Section and Section 10.

Lock-out submersibles are to be provided with external lights that illuminate the area around the lock-out hatches over 360 degrees under normal operating conditions. These lights are to be wired in such a way that failure of one light does not cause the other lights to stop functioning. The lights are to be positioned at suitable distances from the acrylic windows in order to prevent inadvertent heating of the windows. Alternatively, divers may carry sufficient lighting to illuminate the area around the lock-out hatches while they enter or exit the submersible.

37 Command Compartments

37.1 General

Command compartments are to be provided with adequate internal space for the maximum number of occupants envisaged. A minimum of two occupants are to be considered for all designs.

Seating is to be provided for the maximum number of occupants.

The required controls and instrumentation for lock-out compartments are to be provided in the command compartment. Additional controls and instrumentation may be provided in the lock-out compartments.

Controls and instrumentation for command compartments and lock-out compartments are to be placed on separate control panels.

Suitable means are to be provided in the command compartment for overriding and controlling the breathing, pressure supply and exhaust controls for lock-out compartments.

37.3 Access Hatches

Access hatches for command compartments are to meet the applicable requirements of Subsection 11/5.

37.5 Communication Systems

Communication systems for command compartments are to meet the applicable requirements of this Section and Subsection 11/27.

Command compartments are to be provided with voice communication systems arranged for direct two-way communication with the lock-out compartments, the in-water divers (where appropriate) and the support vessel.

37.7 Fire Fighting

37.7.1 General

i) Command compartments are to be provided with suitable fire extinguishing systems. This may include portable fire extinguishers.

ii) Chemical extinguishing agents/propellants with toxic or narcotic effects for any operating conditions are not permitted. Salt water is not to be used as an extinguishing agent/propellant. Choking hazards of extinguishing agents/propellants are to be taken into consideration. Extinguishing agents/propellants that are carcinogenic, mutagenic, or teratogenic at the expected concentrations during use are not permitted.

iii) The capacity of extinguishing systems using gaseous agents/propellants is to be such that complete discharge of the extinguishing system will not result in a toxic concentration.

iv) Consideration is to be given to the increase in compartment pressure resulting from the discharge of the extinguishing agents/propellants.

37.7.2 Fixed Fire Extinguishing Systems

i) Fixed fire extinguishing systems are to be capable of providing rapid and efficient distribution of the extinguishing agent to any part of the command compartment under all foreseeable conditions.

ii) The systems are to be manually actuated. Means are to be provided to actuate the systems from within the command compartment. Suitable safeguards are to be provided to prevent inadvertent actuation.

iii) The extinguishing agent is to be fresh water or other liquid agents suitable for use in manned compartments.

iv) The systems are to have the capability to discharge less than the total supply of the extinguishing agent.

v) Fixed extinguishing systems are to be functionally tested in the presence of the Surveyor.

37.7.3 Portable Fire Extinguishers

i) When command compartments are not provided with a fixed fire extinguishing system, the fire extinguishing means is to consist of portable fire extinguishers.

ii) Fire extinguishers are to be of an approved type. The extinguishers are to be provided with documentation confirming their approval by an appropriate third-party independent agency or laboratory for marine services.

iii) The extinguishing agent is to be distilled water or other non-conductive liquid agents suitable for use in manned compartments.

37.7.4 Fire Detection and Alarm Systems

Command compartments are to be provided with automatic fire detection and alarm systems. For command compartments always occupied by alert persons during operation, the occupants may comprise the fire detection and alarm system provided such occupants possess normal ability to smell.

Faults (voltage failure, breakage in the detection loops, earth faults, etc.) in the fire detection and alarm systems are to be indicated at the command compartment by means of visual and audible signals.

37.9 Life Support and Environmental Control Systems

Life support and environmental control systems for command compartments are to meet the applicable requirements of Subsection 11/35.

37.11 Emergency Evacuation

Where it is intended that emergency evacuation of the command compartment personnel be carried out through the lock-out compartment, the following additional requirements are to be met:

i) The lock-out submersible is to operate in areas with shallow sea-bed depths [not exceeding 165 FSW (50.3 MSW)].

ii) Means of egress (such as hatches, transfer trunks, etc.) are to be provided between the command compartment and lock-out compartment.

iii) Means of equalizing the pressure between the command compartment, transfer trunk and lock-out compartment (as applicable) are to be provided.

iv) Implodable volumes within the command compartment are to be designed for a pressure corresponding to the maximum lock-out depth.

v) The evacuation is to be carried out without subjecting the pressure hull of the command compartment to a net internal pressure. Alternatively, the pressure hull of the command compartment is to be also designed for internal pressure corresponding to the maximum lock-out depth.

vi) The command compartment personnel are to be provided with self-contained breathing systems suitable for the emergency evacuation.

vii) Means are to be provided that permit the command compartment personnel and divers to exit the lock-out compartments safely when the submersible is resting on the sea-bed under emergency operating conditions.

39 Diver Lock-Out Compartments

39.1 General

Diver lock-out compartments are to be provided with adequate internal space for the maximum number of occupants (divers) envisaged, together with their equipment. A minimum of two divers are to be considered for all designs.

When it is intended that diver decompression be carried out within the lock-out compartments, the dimensions of lock-out compartments are to be sufficient to permit decompression to be carried out in an uncramped position.

Seating is to be provided for the maximum number of occupants.

Suitable means are to be provided for taking unconscious divers into lock-out compartments.

Hand and/or footholds are to be provided in the vicinity of lock-out hatches to assist divers in entering / exiting the lock-out compartments.

39.3 Access Hatches

Metallic hatches for lock-out compartments are to meet the applicable requirements of this Section and Sections 3, 4, 5, and 6.

The design of hatches (including the doors, hatch operating and hinge mechanisms) are to take into account all applicable loads including pressures loads and dynamic loads (due to submersible motion in the design sea state, mating operations, etc.).

Hatches that are used as a normal means of personnel ingress or egress are to have an opening diameter of not less than 610 mm (24 in.).

Hatches that are used for lock-in/lock-out operations are to be sized to facilitate the recovery of an unconscious diver wearing full diving gear and are to have an opening diameter of not less than 711 mm (28 in.). Larger opening diameters may be necessary to accommodate divers with emergency life support systems activated.

Locking mechanisms, when provided, are to be operable from both sides of a closed hatch.

Hatches that unseat with pressure are to be provided with locking mechanisms and safety interlocks. The interlocks are to prevent accidental opening of the hatch covers/doors while under pressure. Locking mechanisms are to be designed such that the fully closed position of the mechanisms are clearly verifiable before application of pressure.

Means are to be provided to prevent inadvertent operation of hatches that use springs or similar assist mechanisms to open the hatch covers/doors. Fluids used in hatch assist mechanisms are to be compatible with the internal environment of the compartment.

39.5 Communication Systems

Lock-out compartments are to be provided with voice communication systems arranged for direct two-way communication with the command compartment.

Communication Systems are to consist of a primary and secondary system. The primary system is to be supplied by two independent sources of power, one of which is to be the emergency source of power. Speech unscramblers are to be provided when mixed gas is used. The secondary system is to consist of a sound-powered telephone or other means that is capable of operating in the event of loss of main and emergency power.

In case the command compartment personnel and the lock-out compartment occupants do not have direct visual contact, the secondary system is to be equipped with a signaling device such as an audible annunciator that is capable of alerting the command compartment personnel or the lock-out compartment occupants.

39.7 Fire Fighting

39.7.1 General

i) Lock-out compartments are to be provided with suitable fire extinguishing systems. This may include portable hyperbaric fire extinguishers. The extinguishing systems are to be suitable for operation for all depths till the maximum lock-out depth of the submersible.

ii) Chemical extinguishing agents/propellants with toxic or narcotic effects for any operating conditions are not permitted. Salt water is not to be used as an extinguishing agent/propellant. Choking hazards of extinguishing agents/propellants are to be taken into consideration. Extinguishing agents/propellants that are carcinogenic, mutagenic, or teratogenic at the expected concentrations during use are not permitted.

iii) The capacity of extinguishing systems using gaseous agents/propellants is to be such that complete discharge of the extinguishing system will not result in a toxic concentration.

iv) Consideration is to be given to the increase in compartment pressure resulting from the discharge of the extinguishing agents/propellants.

39.7.2 Fixed Fire Extinguishing Systems

i) Fixed fire extinguishing systems are to be capable of providing rapid and efficient distribution of the extinguishing agent to any part of the lock-out compartment under all foreseeable conditions.

ii) The systems are to be manually actuated. Means are to be provided to actuate the systems from within the lock-out compartments. Consideration is to be given for providing means of remote actuation from outside the lock-out compartments. Suitable safeguards are to be provided to prevent inadvertent actuation.

iii) The extinguishing agent is to be fresh water or other liquid agents suitable for use in manned compartments under hyperbaric conditions.

iv) The systems are to be capable of recharging without the need for depressurizing the lock-out compartments.

v) The systems are to have the capability to discharge less than the total supply of the extinguishing agent.

vi) Fixed extinguishing systems are to be functionally tested in the presence of the Surveyor over the full range of depths till the maximum lock-out depth of the submersible.

39.7.3 Portable Fire Extinguishers

i) When lock-out compartments are not provided with a fixed fire extinguishing system, the fire extinguishing means is to consist of portable hyperbaric fire extinguishers.

ii) Hyperbaric fire extinguishers are to be of an approved type. The extinguishers are to be provided with documentation confirming their approval by an appropriate third-party independent agency or laboratory for marine services.

iii) The extinguishing agent is to be distilled water or other non-conductive liquid agents suitable for use in manned compartments under hyperbaric conditions.

39.7.4 Fire Detection and Alarm Systems

Lock-out compartments are to be provided with automatic fire detection and alarm systems suitable for hyperbaric applications. For lock-out compartments always occupied by alert persons during operation, the occupants may comprise the fire detection and alarm system provided such occupants possess normal ability to smell. Consideration will be given to continuous visual monitoring of compartments by the command compartment personnel in lieu of fire detection and alarm systems.

Faults (voltage failure, breakage in the detection loops, earth faults, etc.) in the fire detection and alarm systems are to be indicated at the command compartment by means of visual and audible signals.

39.9 Piping Systems

Piping systems for lock-out compartments are to meet the applicable requirements of this Section and Sections 8, 9 and 11.

A manually operated stop valve is to be provided at each pressure boundary piping penetration. Additionally, piping exclusively carrying fluids into the lock-out compartments are to have a check valve close to and downstream of the stop valve.

Piping systems are to be designed so as to minimize the noise inside the lock-out compartments during normal operations. Mufflers/silencers are to be provided on blowdown and exhaust outlets.

Anti-suction protective devices are to be provided inside lock-out compartments on the openings of exhaust outlet lines.

Where the design of lock-out compartments is such that a vacuum could be inadvertently drawn while draining/exhausting the compartments, suitable means of under-pressure protection (such as vacuum breakers) are to be provided.

39.11 Life Support and Environmental Control Systems

39.11.1 General

Life support and environmental control systems for lock-out compartments are to meet the applicable requirements of this Section and Sections 8 and 9.

Lock-out submersibles are to be provided with the necessary equipment to generate, monitor and maintain suitable life support conditions inside the lock-out compartments.

Adequate quantities of life support gases and carbon dioxide (CO_2) absorbent for operation at the maximum pressure under normal, reserve and emergency conditions are to be provided. In determining the duration and amount of life support necessary, consideration is to be given to the environmental conditions, the O_2 and mixed gas consumption and CO_2 generation under different working conditions, the effect of temperature, humidity, flow rate and CO_2 density on the CO_2 absorption efficiency, the heat input or removal and the emergency services that may be available for the decompression of the divers.

Breathing gases are to be provided in sufficient quantities to permit repeated pressurization, flushing and de-watering of the diver lock-out compartments as defined by the mission requirements. Gas losses as a result of lock-in/lock-out operations, medical/service lock operations and minor leakages are to be taken into consideration in determining the life support capacity.

Life support systems for lock-out compartments are to be designed so that the partial pressure of oxygen (O_2) is kept within the appropriate limits for the particular application (air diving, mixed gas diving, etc.) as specified in the US Navy Diving Manual or an equivalent recognized national or international standard.

Oxygen supply systems for lock-out compartments are to be provided with dosage systems to enable the oxygen within the lock-out compartments to be maintained at the proper partial pressure.

Each lock-out compartment is to be provided with at least the following breathing gas systems:

i) Two (2) independent gas supply systems for compression/breathing gas supply

ii) Two (2) independent gas exhaust systems

iii) One (1) Built-in Breathing System (BIBS) with breathing masks

iv) Where pure oxygen (O_2) or gases containing more than 25% O_2 by volume is being supplied, a separate piping system is to be provided for this purpose.

The gas supply system to the lock-out compartments is to be designed for a minimum pressurization rate of 60 FSW/minute up to 60 FSW, followed by a rate of 30 FSW/minute thereafter. The gas exhaust system for the lock-out compartments is to be designed for a decompression rate of at least 30 FSW/minute down to 33 FSW.

The actual pressurization/exhaust rates during diving operations are to be determined by the operator and are to be consistent with the rates specified in the US Navy Diving Manual or equivalent recognized national or international standards.

The gas supply and exhaust systems are to be arranged to ensure even mixing of the gases within the lock-out compartments.

Gas system valves are to be arranged so that valve leakage does not lead to inadvertent mixing of pure oxygen (O_2) or gases containing more than 25% O_2 by volume with other breathing gases. Intersections between oxygen and non-oxygen systems are to be isolated by two shut-off valves with a vent valve in between.

Filters and automatic pressure regulators are to be arranged so that they can be isolated without interrupting vital gas supplies.

39.11.2 Diver Decompression

When it is intended that diver decompression be carried out within the lock-out compartments, a sufficient supply of life support gases required for the decompression period (in accordance with the applicable decompression table) is to be available for the expected maximum number of divers plus one.

If divers are to be decompressed while the submersible is at depth, means for overboard dumping or storage of the lock-out compartment gases are to be provided.

Under normal operating conditions, diver decompression is to be controlled from the command compartment. Additional decompression controls may be provided in the lock-out compartments for use during an emergency.

An appropriate supply of treatment gases (in accordance with the applicable treatment table) is to be available for the treatment of divers.

When diver decompression/treatment is not carried out within the lock-out compartments, it is the responsibility of the submersible operator to ensure that appropriate decompression/recompression and/or treatment facilities are available in the vicinity of the submersible's operating site and suitable means are available for transporting and transferring the divers to the facility.

39.11.3 Normal Life Support System

Lock-out compartments are to be provided with a normal life support system.

For tethered submersibles, the breathing gases may be surface supplied or carried on the submersible. For untethered submersibles, the breathing gases are to be carried on the submersible.

The capacity of the normal life support system is to be sufficient to supply the maximum number of occupants (divers) plus one with the appropriate breathing gases and provide CO_2 removal for the complete duration of the mission.

The carbon dioxide (CO_2) removal system is to be capable of maintaining the partial pressure of CO_2 below 0.005 atmosphere absolute (ata).

39.11.4 Reserve Life Support System

Lock-out compartments are to be provided with a reserve life support system. The reserve life support system may be an independent system or may be a part of the normal life support system.

For tethered submersibles, the breathing gases may be surface supplied or carried on the submersible. For untethered submersibles, the breathing gases are to be carried on the submersible.

The carbon dioxide (CO_2) removal system is to be capable of maintaining the partial pressure of CO_2 below 0.005 atmosphere absolute (ata).

The capacity of the reserve life support system is to be sufficient to supply the maximum number of occupants (divers) plus one with the appropriate breathing gases and provide CO_2 removal for the durations specified below:

39.11.4(a) Untethered Submersibles. The duration is to be consistent with the emergency rescue plan but is not to be less than 72 hours. For submersibles complying with the requirements of 11/35.5, the above duration may be reduced to 24 hours.

39.11.4(b) Tethered Submersibles. The duration is to be consistent with the emergency rescue plan but is not to be less than 72 hours. For submersibles complying with the requirements of 11/35.5, the above duration may be reduced to 24 hours.

For surface supplied tethered submersibles, as an alternative to the requirements above, the duration is to be consistent with the emergency rescue plan but is not to be lesser than the greater of 10% of the design mission duration or 8 hours, provided:

i) The submersible is part of an underwater complex (See Subsection 2/87) having two independent lifting means.

ii) Each lifting means complies with the requirements of Section 17 and is capable of independently raising the submersible to the surface.

39.11.5 Emergency Life Support System – Tethered and Untethered Submersibles

Lock-out compartments are to be provided with an emergency life support system. The emergency life support system is to be independent of the normal and reserve life support system and is to be carried on the submersible.

For submersibles operating in areas with shallow sea-bed depths (not exceeding 165 FSW [50.3 MSW)], special consideration will be given on a case-by-case basis for self-contained breathing systems being provided for the divers in-lieu of the submersible's emergency life support system. The self-contained breathing systems are to be suitable to enable emergency evacuation of the divers.

Emergency/treatment gas is to be supplied through a dedicated piping system (BIBS) to breathing masks (either full-face masks or oral-nasal masks) or diver's masks/helmets. Suitable masks or helmets are to be provided for the maximum number of occupants plus one (see 12/39.11.6 below).

The carbon dioxide (CO_2) removal system is to be capable of maintaining the partial pressure of CO_2 below 0.015 atmosphere absolute (ata).

The capacity of the emergency life support system is to be sufficient to supply the maximum number of occupants (divers) plus one with the appropriate breathing gases and provide CO_2 removal for the durations specified below:

39.11.5(a) In-Water Divers with Self-Contained Breathing Systems. When the in-water divers carry their own normal breathing gases, the capacity of the emergency life support system on the submersible is to be the greater of the following two items:

i) Capacity that is sufficient to supply the maximum number of occupants (divers) plus one on BIBS supply for 150 percent of the time normally required to reach the surface from rated depth, but not less than 2 hours. A respiratory minute volume of not less than 12 liters/minute or 0.42 actual cubic feet/minute (acfm) per diver for average rest conditions and/or 22.5 liters/minute or 0.8 acfm per diver for light work conditions at ambient pressure is to be used for determining the capacity.

ii) Capacity that is sufficient to de-water a lock-out compartment filled with 40% water while at the maximum operating depth.

39.11.5(b) In-Water Divers Supplied from Umbilicals. When the in-water divers are supplied with their normal breathing gases from the submersible or the surface, the capacity of the emergency life support system on the submersible is to be the greatest of the following three items:

i) Capacity that is sufficient to supply the maximum number of occupants (divers) plus one on BIBS supply for 150 percent of the time normally required to reach the surface from rated depth, but not less than 2 hours. A respiratory minute volume of not less than 12 liters/minute or 0.42 actual cubic feet/minute (acfm) per diver for average rest conditions and/or 22.5 liters/minute or 0.8 acfm per diver for light work conditions at ambient pressure is to be used for determining the capacity.

ii) Capacity that is sufficient to supply each of the divers with breathing gas for at least 15 minutes when they are outside the lock-out compartment. A respiratory minute volume of not less than 45 liters/minute or 1.5 actual cubic feet/minute (acfm) per diver for the lock-out divers under heavy work conditions and 62.5 liters/minute or 2.2 acfm per diver for the stand-by diver under severe work conditions at ambient pressure is to be used for determining the capacity.

iii) Capacity that is sufficient to de-water a lock-out compartment filled with 40% water while at the maximum operating depth.

39.11.6 Built-in Breathing System (BIBS)

The BIBS gas supply piping is to be independent of the lock-out compartment normal and reserve gas supply piping. The emergency and treatment gas cylinders are not to be used for supplying the lock-out compartment normal and reserve gas supply system.

The BIBS is to be capable of supplying emergency gas at the maximum operating depth and treatment gas at the appropriate partial pressure as per the appropriate treatment table.

Breathing masks are to be permanently connected or easily connectable to the BIBS supply piping.

Breathing masks are to be provided with back-pressure regulators to protect against pressure drops on the exhaust side.

Automatic pressure reducers are to be provided on supply lines. Alternative arrangements that provide an equivalent level of safety will be considered on a case-by-case basis.

Where open circuit systems are used, the effects of increased lock-out compartment pressure are to be considered.

The exhaust sides of masks intended for oxygen service are to be connected to an external dump or storage tank or the masks are to be of the closed-circuit type.

When masks of the closed-circuit type are used, consideration is to be given to the increase in Oxygen concentration resulting from purge procedures during mask start-up.

39.11.7 Diver Umbilicals

Diver umbilicals, when provided, are to be supplied with breathing gases from both the normal life support system as well as the emergency life support system. Each diver's gas supply is to be arranged so that failure of one umbilical does not interfere with another diver's breathing gas supply.

Suitable means are to be provided for stowing the diver umbilicals on the submersible. The means of stowing is to consider the minimum bend radius of the umbilical.

The primary breathing gas supply to the stand-by diver's umbilical is to be independent of the primary breathing gas supply to the lock-out diver's umbilicals. The primary breathing gas to the stand-by diver may be supplied from the normal or the emergency life support system and is to be sufficient to allow the stand-by diver to exit the lock-out compartment and recover an injured diver. The secondary breathing gas supply to the stand-by diver may be common with the lock-out diver's primary breathing gas supply, provided it has the capability to continue supplying breathing gas to the stand-by diver if the working diver's umbilical fails.

Breathing gas supplies are to be arranged so that blowing-down or flushing of the lock-out compartment does not interfere with the breathing gas supplied to any diver outside the lock-out compartment.

39.11.8 Temperature and Humidity Control

A heating system, when provided, is to maintain the temperature of the lock-out compartment internal atmosphere and the umbilical supplied in-water divers at a comfortable level. Suitable safety features are to be provided for preventing overheating. Suitable means are to be provided for isolating the heating arrangement of the lock-out compartment from the heating arrangement for the umbilical supplied in-water divers.

For diving operations exceeding 500 FSW (152 MSW), suitable means are to be provided for heating the inspired gases of umbilical supplied in-water divers. Suitable safety features are to be provided for preventing overheating.

39.11.9 Life Support System Testing *(2013)*

Life support system testing is to meet the applicable requirements of this Section and 11/35.11.

Life support system testing of the command compartment and the lock-out compartments is to be carried out independently.

41 Medical/Service Locks

Medical/Service locks, when provided, are to meet the applicable requirements of this Section and Sections 3, 4, 5, and 6.

Medical/Service locks are to be sized for their intended purpose. The dimensions of these locks are to be adequate for enabling essential supplies such as carbon dioxide (CO_2) scrubber canisters, diving helmets, etc., to be safely transferred into/out of the chambers. As far as practicable, the dimensions are to also minimize the loss of gas when the lock is being used.

Medical/Service lock doors/covers that unseat with pressure are to be provided with locking mechanisms and safety interlocks. The interlocks are to prevent accidental opening of the doors/covers while under pressure and are to prevent pressurization of the locks if the locking mechanisms are not properly closed.

Medical/Service locks are to be provided with an external means for monitoring, venting and equalizing pressure with the compartment being serviced or the atmosphere.

43 Transfer Trunks/Tunnels

Trunks/tunnels, when installed on lock-out submersibles, are to meet the applicable requirements of this Section and Sections 3, 4, 5, and 6.

Trunks/tunnels are to be capable of allowing the safe transfer of divers between compartments and are to have a minimum internal diameter of 610 mm (24 inches).

Trunks/tunnels are to be provided with an external means for monitoring, venting and equalizing internal pressure with the compartment being serviced or the atmosphere.

Trunks/tunnels exceeding 914 mm (36 inches) in length are to be provided with internal hand and/or footholds.

45 Mating Systems

Mating systems, when installed on lock-out submersibles, are to meet the applicable requirements of this Section and Sections 3, 4, 5 and 6.

Mating systems are to enable the connection and disconnection of lock-out compartments and other units (See Subsection 2/89) easily and securely under the worst expected sea state. (See Section 17, Table 1.).

Consideration is to be given to compatibility of mating flanges on the lock-out submersible and the unit with which mating operations are to be carried out.

The mating devices are to be of suitable construction, consideration being given to the anticipated loads that may be imposed on them. Loads to be considered are to include applicable loads such as dynamic loads due to mating operations and submersible motion in the design sea state, internal and/or external pressures and other environmental loads (current loads, wind loads, etc.).

Mating systems are to be provided with safety interlocks in order to prevent inadvertent opening of the mating devices while under pressure and to prevent pressurization of the transfer trunks/tunnels if the mating devices are not properly closed. Mechanical locking mechanisms are required for hydraulically or pneumatically actuated mating devices.

Where a power actuating system is used for the mating operations, a manual or stored mechanical power means is to be provided as a backup to connect or disconnect the two units in the event of failure of the normal power actuating system.

47 Access to Vital Equipment *(2013)*

Access to vital equipment is to meet the applicable requirements of Subsection 11/45.

49 Test Dive

The test dive is to meet the applicable requirements of this Section and Subsection 11/47.

The test dive is to also include functional testing of the lock-out compartments at the maximum lock-out depth. A lock-in/lock-out operation is to be conducted at the maximum lock-out depth in order to verify operation of the ballast systems, lock-out hatches, etc.

SECTION 13 Diving Systems *(2010)*

1 Scope

This Section, along with Sections 1 through 10 and Sections 17 and 18, provides the requirements for the design, fabrication, and testing of diving systems.

2 Class Notations *(2012)*

For the purposes of Classification, diving systems may be categorized as follows:

TABLE 1
Diving System Categorization *(2012)*

Parameter	*Class Notation*		
	Air	**Mixed-Gas**	**Saturation**
Design/Rated Depth	≤ 190 FSW (57.9 MSW)	≤ 300 FSW (91.4 MSW)	≤ 1500 FSW (457.2 MSW)
Diving Duration	≤ 8 hours	≤ 24 hours	No restrictions
Breathing Gases	Compressed Air or Enriched Air (Nitrox)	Heliox, Trimix (Helium Nitrogen Oxygen) or equivalent	Heliox, Trimix (Helium Nitrogen Oxygen, Helium Hydrogen Oxygen) or equivalent

Diving system operators are to examine and identify the type of diving system, depth and duration of the dive and breathing gases that are best suited for the area and type of operation in which they are engaged.

New construction air/mixed gas/saturation diving systems built under ABS survey are to be assigned the class notations ✠ **A1 Air Diving System**, ✠ **A1 Mixed-Gas Diving System**, and ✠ **A1 Saturation Diving System**, respectively, subject to the requirements of Section 13, Table 1 above and the conditions of classification referenced in Section 1 of these Rules.

New and existing air/mixed gas/saturation diving systems not built under ABS survey are to be assigned the class notations **A1 Air Diving System**, **A1 Mixed-Gas Diving System**, and **A1 Saturation Diving System**, respectively, subject to the conditions of classification referenced in Section 1 of these Rules.

For fixed diving systems, the notation **(F)** is to follow the notations specified above. Example: ✠ **A1 Air Diving System (F)**. For portable diving systems, the notation **(P)** is to follow the notations specified above. Example: ✠ **A1 Air Diving System (P)**.

3 General Requirements

3.1 Pressure Vessels for Human Occupancy (PVHOs)

3.1.1 Metallic Pressure Boundaries

Metallic pressure boundaries are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

3.1.2 Windows and Viewports

3.1.2(a) Windows and viewports are to meet the applicable requirements of this Section and Section 7.

3.1.2(b) Windows are to be provided with appropriate means of protection to prevent mechanical damage from the inside or outside.

3.1.3 Personnel Access Hatches/Manways

3.1.3(a) Metallic hatches are to meet the applicable requirements of this Section and Sections 4, 5, and 6. The design of the hatches (including the doors, hatch operating and hinge mechanisms) are to take into account all applicable loads including dynamic loads due to mating operations and PVHO motion in the design sea state.

3.1.3(b) Hatches that are used as a normal means of personnel ingress or egress are to have an opening diameter of not less than 610 mm (24 in.). Diving bell lock-out hatches are to be sized to facilitate the recovery of an unconscious diver wearing full diving gear and are to have an opening diameter of not less than 711 mm (28 in.). Larger opening diameters may be necessary to accommodate divers with emergency life support systems activated.

3.1.3(c) Hatches are to be operable from both internal and external sides. The means for opening and closing of hatches is to permit operation by a single person under all anticipated operating and emergency conditions. Locking mechanisms, when provided, are to be operable from both sides of a closed hatch. Means are to be provided for equalizing the pressure on both sides of hatches prior to opening.

3.1.3(d) In general, hatches are to be designed to seat with pressure. Hatches that unseat with pressure will be given special consideration based on the application of the PVHO. Hatches that unseat with pressure are to be provided with locking mechanisms and safety interlocks. The interlocks are to prevent accidental opening of the doors while under pressure. Locking mechanisms are to be designed such that the fully closed position of the mechanisms are clearly verifiable before application of pressure.

3.1.3(e) Hatch coaming ways are to be free from obstacles.

3.1.3(f) Hatches are to be provided with a mechanical means for securing in the fully open position.

3.1.3(g) Means are to be provided to prevent inadvertent operation of hatches that use springs or similar assist mechanisms to open the doors. Fluids used in hatch assist mechanisms are to be compatible with the internal environment of the PVHO.

3.1.4 Nonmetallic Materials

Paints, coatings, insulation and other internal and external materials are to meet the applicable requirements of Subsection 3/1.

3.1.5 Nameplates

PVHOs are to be fitted with permanent nameplates indicating the maximum allowable internal and/or external working pressures, maximum and minimum rated temperatures, internal and/or external hydrostatic test pressures, manufacturer’s name, serial number and year of fabrication. This information is to be also stamped on a rim of a flange of the PVHO. The nameplates are to be stainless steel or other suitable material and are to be permanently attached.

3.3 External Structures

External structures include all structural members located outside the pressure boundaries of PVHOs. These include members such as crash cages, support frames and lifting lugs.

All welded connections of external structures to the PVHO pressure boundaries are to be welded so as to minimize the local stresses induced in the pressure boundaries. Inspection of such connections is to be feasible.

3.3.1 Crash Cages

3.3.1(a) PVHOs that are launched and recovered at sea are to be provided with crash cages to protect the pressure boundaries and critical components such as the windows and the emergency breathing gas cylinders. Consideration will be given to other means providing an equivalent level of protection such as chambers enclosed within lifeboats. See 13/11.3.20.

3.3.1(b) Crash cages are to be of adequate construction, consideration being given to their size and the loads which may be imposed upon them and they are to be constructed following sound engineering practice in accordance with approved plans. Loads to be considered include those which result from striking objects, wave slap, bumping alongside the tender, bottoming and other loads resulting from being recovered in sea state 6 (see Section 17, Table 1), as applicable. A lesser sea state may be considered when it is intended that the PVHO be operated with a launch and recovery system whose design parameters are less than sea state 6. When it is intended to carry out hydrostatic testing of PVHOs with the crash cages installed, the maximum static load due to the hydrostatic testing is to also be considered in the design. Stresses are not to exceed the allowable stresses f_a as obtained from the following equation:

$$f_a = f\eta_e$$

where

f = critical or shear stress for buckling considerations, or

= minimum specified material yield stress

η_e = usage factor as follows:

Type of Stress	η_e
Compressive or shear buckling	0.8
Axial and/or bending stresses	0.8
Shear stresses	0.53

3.3.2 Support Frames/Skids

3.3.2(a) Support frames/skids of PVHOs mounted on the deck of a dive support vessel/offshore facility are to be of construction adequate to the function performed, consideration being given to their size and the anticipated loads which may be imposed on them, and they are to be constructed following sound engineering practice in accordance with approved plans.

3.3.2(b) Loads to be considered include applicable loads such as dynamic loads due to vessel motion, mating loads, wave slap, wind loads and ice loads. The mating loads are to consider a force of not less than twice the weight of the mating PVHO (diving bell, hyperbaric evacuation unit, etc.) and are to include other applicable loads such as the weight of entrapped mud and water. When it is intended to carry out hydrostatic testing of PVHOs with the support frames/skids installed, the maximum static load due to the hydrostatic testing is to also be considered in the design. Calculated stresses are not to exceed those specified in 13/3.3.1.

3.3.2(c) Support frames/skids of PVHOs that also support handling system elements such as A-frames and winches are to meet the applicable requirements of Section 17.

3.3.3 Lifting Lugs/Attachments

3.3.3(a) The lifting lugs/attachments used for launch and recovery of PVHOs at sea are to be designed for forces of at least 2 g vertical (1 g static plus 1 g dynamic), 1 g transverse and 1 g longitudinal, unless otherwise determined, acting simultaneously under the most severe loading condition. Where appropriate, the increased loading due to other applicable loads such as entrained water and mud, added mass and drag are to be also considered. Calculated stresses are not to exceed those specified in 13/3.3.1.

3.3.3(b) The lifting lugs/attachments of PVHOs other than those in 13/3.3.3(a) are to be suitable for handling the PVHOs during installation/ demobilization on/from dive support vessels/offshore facilities. Calculated stresses are not to exceed $^1/_3$ of the minimum material yield strength or $^1/_5$ of the minimum material tensile strength, whichever is the least.

3.5 Transfer Trunks/Tunnels

3.5.1

Trunks/tunnels incorporated in or created by the coupling of PVHOs are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

3.5.2

Trunks/tunnels are to be capable of allowing the safe transfer of divers between PVHOs and are to have a minimum internal diameter of 610 mm (24 inches).

3.5.3

Trunks/tunnels are to be provided with an external means for monitoring, venting and equalizing internal pressure with the compartment being serviced or the atmosphere.

3.5.4

Trunks/tunnels exceeding 914 mm (36 inches) in length are to be provided with internal hand and/or footholds.

3.7 Medical/Service Locks

3.7.1

Medical/Service locks are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

3.7.2 *(2012)*

Medical/Service locks are to be sized for their intended purpose. The dimensions of these locks are to be adequate for enabling essential supplies such as CO_2 scrubber canisters, diving helmets, etc., to be safely transferred into/out of the PVHOs. As far as practicable, the dimensions are to also minimize the loss of gas when the lock is being used.

3.7.3

Medical/Service lock doors/covers that unseat with pressure are to be provided with locking mechanisms and safety interlocks. The interlocks are to prevent accidental opening of the doors/covers while under pressure and are to prevent pressurization of the locks if the locking mechanisms are not properly closed.

3.7.4

Medical/Service locks are to be provided with an external means for monitoring, venting and equalizing pressure with the compartment being serviced or the atmosphere.

3.9 Mating Systems

3.9.1

Mating systems and clamping arrangements are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

3.9.2

Mating systems between diving bells, hyperbaric evacuation units (HEUs) and surface compression chambers are to enable their connection and disconnection easily and securely under the worst expected sea state. (See Section 17, Table 1.). Mating systems for HEUs are to be designed to ensure easy disconnection when the ship/offshore facility is under unfavorable conditions of up to 20 degrees list and 10 degrees trim either way.

3.9.3

The mating devices are to be of suitable construction, consideration being given to the anticipated loads that may be imposed on them. As a minimum, loads resulting from a sea state 6, in addition to the internal and external pressure, are to be considered. A less severe sea state may be considered when the mating system will be used on a support structure whose design parameters are based on a condition lesser than sea state 6. (See Section 17, Table 1.)

3.9.4

Mating systems are to be provided with safety interlock in order to prevent inadvertent opening of the clamping arrangements while under pressure and to prevent pressurization of the transfer trunks/tunnels if the clamps are not properly closed. Mechanical locking mechanisms are required for hydraulically or pneumatically actuated clamping arrangements.

3.9.5

Units equipped for mating with habitats, working chambers and other underwater structures are subject to special consideration, due importance being given to the expected loads from the mating forces, moments, pressure, currents, etc.

3.9.6 *(2012)*

Where a power actuating system is used for the mating operations, a manual or stored mechanical power means is to be provided as a backup to connect or disconnect the two units in the event of failure of the normal power actuating system.

3.11 Piping Systems

3.11.1

Piping systems are to meet the applicable requirements of this Section and Sections 8 and 9.

3.11.2

PVHOs are to be equipped with valves, gauges and other fittings as necessary to control and monitor the internal environments of compartments/chambers from the dive control station. All interior breathing and pressure supply controls are to be provided with means of overriding and controlling them from the exterior.

3.11.3

The external pressures acting on diving bells and hyperbaric evacuation units (HEUs) designed for underwater operation are to be indicated inside the bells/HEUs.

3.11.4 *(2012)*

A manually operated stop valve is to be provided at each pressure boundary piping penetration. Additionally, piping exclusively carrying fluids into the PVHOs are to have a check valve close to and downstream of the stop valve.

3.11.5

Each compartment of a PVHO which may be pressurized separately is to be fitted with a pressure relief device. Rupture discs are not to be used, except in series with pressure relief valves. A quick-operating manual shut-off valve is to be installed between the PVHO pressure boundary and the pressure relief device and is to be wired opened with a frangible wire. This shut-off valve is to be readily accessible to the personnel monitoring the operation of the diving system. Pressure relief devices are to be capable of preventing the pressure from rising more than 10% above the maximum allowable working pressure of the PVHO.

3.11.6

Piping systems are to be designed so as to minimize the noise inside the PVHOs during normal operations. Mufflers/silencers are to be provided on blowdown and exhaust outlets.

3.11.7

Anti-suction protective devices are to be provided inside PVHOs on the openings of exhaust outlet lines.

3.11.8

All high-pressure piping is to be well-protected against mechanical damage.

3.11.9

Piping systems carrying mixed gas or oxygen under high pressure is not to be arranged inside accommodation spaces, engine rooms or similar compartments.

3.11.10

Flexible hoses, except for umbilicals, are to be reduced to a minimum.

3.13 Life Support and Environmental Control Systems

3.13.1 General

3.13.1(a) Life support systems are to meet the applicable requirements of this Section and Sections 8 and 9.

3.13.1(b) (2012) Diving systems are to be provided with the necessary equipment to generate, monitor and maintain suitable life support conditions inside the various PVHOs and transfer trunks/tunnels. Life support systems are to be such that adequate quantities of gases for operation at the maximum pressure for normal and emergency conditions are provided. A sufficient supply of gases essential for the desaturation (or decompression) period in accordance with the applicable decompression table is to be kept available for the expected maximum number of personnel. In determining the duration and amount of life support necessary, consideration is to be given to the environmental conditions, the O_2 and mixed gas consumption and CO_2 generation under such conditions, the heat input or removal and the emergency services that may be available for the decompression of the divers. Gas losses as a result of using toilet facilities which discharge outside the PVHOs and medical/equipment lock operations are to be taken into consideration in determining the amount of gases and CO_2 absorbent required for the diving operation.

3.13.1(c) Life support systems are to be designed so that the partial pressure of O_2 is kept within the appropriate limits for the particular application (mixed gas diving, saturation diving, etc.) as specified in the US Navy Diving Manual or an equivalent recognized national or international standard.

3.13.2

Each compartment of surface compression chambers, hyperbaric evacuation units and each diving bell is to be provided with at least the following breathing gas systems:

i) Two (2) independent gas supply systems for compression/breathing gas supply

ii) One (1) gas exhaust system

iii) One (1) Built-in Breathing System (BIBS) with breathing masks

iv) Where pure oxygen (O_2) or gases containing more than 25% O_2 by volume is being supplied, a separate piping system is to be provided for this purpose.

3.13.3 *(2014)*

The gas supply system to the chambers is to be designed for a minimum pressurization rate of 60 FSW/minute up to 60 FSW followed by a rate of 30 FSW/minute thereafter. The gas exhaust system is to be designed for a decompression rate of not greater than 30 FSW/minute down to 33 FSW.

The actual pressurization/exhaust rates during diving operations are to be determined by the operator and are to be consistent with the rates specified in the US Navy Diving Manual or equivalent recognized national or international standards.

3.13.4

The gas supply and exhaust systems are to be arranged to ensure even mixing of the gases.

3.13.5

Gas system valves are to be arranged so that valve leakage does not lead to inadvertent mixing of pure oxygen (O_2) or gases containing more than 25% O_2 by volume with other breathing gases. Intersections between oxygen and non-oxygen systems are to be isolated by two shut-off valves with a vent valve in between.

3.13.6

Filters and automatic pressure regulators are to be arranged so that they can be isolated without interrupting vital gas supplies.

3.13.7

The discharge from relief devices, vents and exhausts are to be vented to the open air away from sources of ignition, personnel or any area where the presence of the discharged gases could be hazardous.

3.13.8 Built-in Breathing System (BIBS)

3.13.8(a) Emergency/treatment gas is to be supplied through a dedicated piping system to breathing masks (either full-face masks or oral-nasal masks) suitable for the intended service. The BIBS supply piping is to be independent of the chamber gas supply piping. The emergency and treatment gas cylinders are not to be used for supplying the chamber gas supply system.

3.13.8(b) (2012) The BIBS is to be capable of supplying emergency gas at the maximum operating depth and treatment gas at the appropriate partial pressures as per the appropriate treatment table.

3.13.8(c) Breathing masks are to be permanently connected or easily connectable to the BIBS supply piping.

3.13.8(d) (2012) Breathing masks are to be provided with back-pressure regulators to protect against pressure drops on the exhaust side.

3.13.8(e) (2012) Automatic pressure reducers are to be provided on supply lines. Alternative arrangements that provide an equivalent level of safety will be considered on a case-by-case basis.

3.13.8(f) Where open circuit systems are used, the effects of increased chamber pressure are to be considered.

3.13.8(g) (2012) The exhaust sides of masks intended for oxygen service are to be connected to an external dump or the masks are to be of closed-circuit type. When masks of the closed-circuit type are used, consideration is to be given to the increase in oxygen concentration resulting from purge procedures during mask start-up.

3.13.9

Each compartment of surface compression chambers, hyperbaric evacuation units and each diving bell is to be provided with a carbon dioxide (CO_2) removal system for use under normal operating conditions. The system is to be capable of maintaining the partial pressure of CO_2 below 0.005 atmosphere absolute (ata) under normal operating conditions. CO_2 removal systems are to be provided with full redundancy.

3.13.10 *(2011)*

External Environmental Control Units (ECUs), when fitted, are to be capable of providing heating/cooling, humidity control and CO_2 removal services. The piping between the ECU and the PVHO is to be appropriately sized to ensure adequate circulation of gases between the ECU and the PVHO. The piping at the PVHO pressure boundary penetration is to be provided with a non-return valve on the supply line and a flow-fuse on the exhaust line. These may be fitted either internally or externally.

Sizing calculations for flow-fuses are to be submitted for review. In addition, means are to be considered for resetting flow-fuses.

3.13.11 PVHO Life Support Testing *(2012)*

All PVHOs associated with a diving system are to undergo life support testing in the presence of the Surveyor.

For diving systems incorporating duplicate (100% identical, i.e., same dimensions, same outfitting and same life support systems) PVHOs, such testing is only required for one of the duplicate PVHOs.

Life support testing is to be conducted after the PVHO is completely outfitted and before conducting the test dive. The tests may be conducted at surface conditions or by pressurizing the PVHOs to shallow depths.

When External Environmental Control Units (ECUs) are provided, they are to be tested independent of the scrubbers within the PVHO.

During testing, the oxygen (O_2) and carbon dioxide (CO_2) levels, pressure, relative humidity and temperature are to be monitored and recorded at intervals suitable to verify the life support system design but not exceeding 15 minutes. The monitored parameters are to be within acceptable ranges to the satisfaction of the Surveyor.

The testing is to include the following:

i) A manned test with the maximum number of occupants within the PVHO is to be conducted until equilibrium is achieved by the CO_2 scrubbers, plus an additional one hour. This manned test is to be conducted for a minimum of three hours for all cases. The following is to be demonstrated during the test:

- *a)* CO_2 and O_2 levels, pressure, relative humidity and temperature can be maintained within required parameters.
- *b)* Changing-out of the CO_2 absorbent can be achieved without exceeding a CO_2 concentration of 1.5% by volume referenced to standard temperature and pressure (0.01 ata) and that the concentration of CO_2 can be reestablished and maintained at or below 0.5% (0.005 ata) following the change-out.

ii) A manned test with the maximum number of occupants or a simulated occupancy test is to be conducted to determine the time to CO_2 scrubber breakthrough, where breakthrough is defined as a CO_2 concentration of 0.5% by volume referenced to standard temperature and pressure (0.005 ata). The test may be continued beyond a CO_2 concentration of 0.5% [up to a maximum of 1% (0.01 ata)] to ensure that breakthrough is reached. The time required to achieve breakthrough is to be used in confirming the quantity of CO_2 absorbent required to be carried onboard.

3.13.12

The dive control station and local control stations for handling systems are to be provided with emergency breathing devices with communication equipment to enable the personnel to perform their duties in smoky/polluted environments. The emergency breathing devices are to be capable of functioning for at least 30 minutes. The emergency breathing devices may be self-contained or umbilical supplied. If umbilical supplied, all air intakes for the supplying air compressors are to be located in safe areas and away from exhausts/ventilation outlets from machinery spaces and galleys.

3.15 Electrical Systems

3.15.1

Electrical systems are to meet the applicable requirements of this Section and Section 10.

3.15.2

Electrical systems, including power supply arrangements, are to be designed for the environment in which they will operate to minimize the risk of fires, explosions, electrical shocks, emission of toxic gases and galvanic action on the PVHOs.

3.15.3

Electrical systems installed within PVHOs are to be limited to those necessary for the safe operation of the PVHO and the monitoring of its occupants. All electrical equipment used within PVHOs is to be designed for hyperbaric use, high humidity levels and marine application. The equipment is to be such that pressurization and depressurization of the environment will not cause damage.

3.15.4

PVHOs are to be provided with adequate means of normal and emergency lighting of sufficient luminosity to allow the occupants to read gauges and operate essential systems within each compartment safely.

3.15.5 Power Sources

3.15.5(a) The normal source of electrical power to the diving system may be the main generators of dive support vessel/offshore facility. Alternatively, electrical power may be supplied by dedicated self-contained generators.

3.15.5(b) In the event of failure of the main source of electrical power to the diving system, an independent emergency source of electrical power is to be available for the safe termination of the diving operation. The emergency generator of the dive support vessel/offshore facility may be used as the emergency source of electrical power provided it has sufficient electrical power capacity to supply the diving system and the emergency loads of the dive support vessel/offshore facility at the same time. Alternatively, the emergency source of electrical power may be a dedicated self-contained generator.

3.15.5(c) Generators that are being used as the emergency source of power for the diving system are to be located outside the machinery spaces of the dive support vessel/offshore facility and as far apart as practicable from other generators being used as the normal source of power for the diving system.

3.15.5(d) Generators of 100 kW (135 hp) and over that are part of a classed diving system are to be certified by ABS for compliance with the appropriate provisions of Section 4-8-3 of the *Steel Vessel Rules*.

3.15.5(e) Generators of 100 kW (135 hp) and over that are part of the dive support vessel/offshore facility and are being used to supply power to the diving system are to be certified by the Classification Society or Flag State Administration of the dive support vessel/offshore facility.

3.15.5(f) Generators of less than 100 kW (135 hp) that are part of a classed diving system are to be designed, constructed and tested in accordance with established industrial practices and manufacturer's specifications. Manufacturer's tests for generators less than 100 kW (135 hp) are to include at least the tests described in Sections 4-8-3/3.15.2 through 4-8-3/3.15.11 of the *Steel Vessel Rules*, regardless of the standard of construction. The test certificates are to be made available when requested by the Surveyor. Acceptance of these generators will be based on satisfactory performance tests after installation.

3.15.5(g) Generators of less than 100 kW (135 hp) that are part of the dive support vessel/offshore facility and are being used to supply power to the diving system are to be certified by the Classification Society or Flag State Administration of the dive support vessel/offshore facility. Alternatively, they are to meet the requirements specified in 13/3.15.5(f).

3.17 Communication Systems

3.17.1

All PVHOs are to have voice communication systems providing the capability to communicate with the dive control station.

The communication systems are to be arranged for direct two-way communication between the dive control station and the following as applicable:

i) Divers in water, except scuba divers

ii) Diving bell

iii) Hyperbaric evacuation units

iv) Each compartment of surface compression chambers

v) Local control stations for handling systems

vi) Dynamic positioning room (on dynamically positioned vessels)

vii) Navigation bridge, ship's command center, drilling floor, drilling control room.

3.17.2

Communication Systems are to consist of a primary and secondary system. The primary system is to be supplied by two independent sources of power, one of which is to be the emergency source of power. Speech unscramblers are to be provided when mixed gas is used. The secondary system is to consist of a sound-powered telephone or other means that are capable of operating in the event of loss of main and emergency power. In case the dive control station personnel and the PVHO occupants do not have direct visual contact, the secondary system is to be equipped with a signaling device such as an audible annunciator that is capable of alerting the dive control station personnel or the PVHO occupants.

3.19 Fire Fighting

3.19.1 Internal Fire Extinguishing Systems for PVHOs

3.19.1(a) General

i) Each compartment of PVHOs are to be provided with suitable fire extinguishing systems. This may include portable hyperbaric fire extinguishers. The extinguishing systems are to be suitable for operation for all depths till the maximum operating depth of the diving system.

ii) Chemical extinguishing agents/propellants with toxic or narcotic effects for any operating conditions are not permitted. Salt water is not to be used as an extinguishing agent/propellant. Choking hazards of extinguishing agents/propellants are to be taken into consideration. Extinguishing agents/propellants that are carcinogenic, mutagenic, or teratogenic at the expected concentrations during use are not permitted.

iii) The capacity of extinguishing systems using gaseous agents/propellants is to be such that complete discharge of the extinguishing system will not result in a toxic concentration.

iv) Consideration is to be given to the increase in compartment pressure resulting from the discharge of the extinguishing agents/propellants.

3.19.1(b) Fixed Fire Extinguishing Systems

i) Fixed fire extinguishing systems are to be capable of providing rapid and efficient distribution of the extinguishing agent to any part of the compartment under all foreseeable conditions.

ii) The systems are to be manually actuated. Means are to be provided to actuate the systems from within and outside the PVHOs. Suitable safeguards are to be provided to prevent inadvertent actuation.

iii) The extinguishing agent is to be fresh water or other liquid agents suitable for use in manned compartments under hyperbaric conditions.

iv) The systems are to be capable of recharging without the need for depressurizing the PVHOs.

v) The systems are to have the capability to discharge less than the total supply of the extinguishing agent.

vi) Fixed extinguishing systems are to be functionally tested in the presence of the Surveyor over the full range of depths till the maximum operating depth of the diving system.

3.19.1(c) Portable Fire Extinguishers

i) When PVHOs are not provided with a fixed fire extinguishing system per 13/3.19.1(b), the fire extinguishing means is to consist of portable hyperbaric fire extinguishers.

ii) Hyperbaric fire extinguishers are to be of an approved type. The extinguishers are to be provided with documentation confirming their approval by an appropriate third-party independent agency or laboratory for marine services.

iii) The extinguishing agent is to be distilled water or other non-conductive liquid agents suitable for use in manned compartments under hyperbaric conditions.

3.19.2 Internal Fire Detection and Alarm Systems for PVHOs

3.19.2(a) Each compartment of a PVHO is to be provided with automatic fire detection and alarm systems suitable for hyperbaric applications. For compartments always occupied by alert persons during operation, the occupants may comprise the fire detection and alarm system provided such occupants possess normal ability to smell. Consideration will be given to continuous video camera monitoring of compartments by the dive control station personnel in lieu of fire detection and alarm systems.

3.19.2(b) Faults (voltage failure, breakage in the detection loops, earth faults, etc.) in the fire detection and alarm systems are to be indicated at the dive control station by means of visual and audible signals.

5 Surface Compression Chambers

5.1

Diving systems are to be provided with at least one chamber with two separate compartments or two separate interconnected chambers so designed as to permit ingress or egress of personnel while one compartment or chamber remains pressurized.

5.3

Each compartment or chamber is to be provided with sufficient number and size of viewports/ windows to allow observation of all internal occupants (divers) from the outside.

5.5

Compartments or chambers that serve as living facilities and other compartments that may be used for decompression are to be provided with suitable medical/equipment locks. See 13/3.7.

5.7 Built-in Breathing System (BIBS)

5.7.1

All compartments or chambers are to be provided with emergency/treatment gas using a Built-in Breathing System (BIBS). The system is to be designed such that the partial pressure of CO_2 in the gas being breathed does not to exceed 0.015 atmosphere absolute (ata).

5.7.2

The capacity of the emergency/treatment gas supplies is to be sufficient for the safe conclusion of the diving operation.

5.7.3

Compartments or chambers that serve as living facilities are to be provided with BIBS masks corresponding to the maximum number of divers for which the compartments or chambers are rated plus one.

5.7.4

Compartments or chambers that serve as transfer locks are to be provided with BIBS masks corresponding to the maximum number of divers that may simultaneously transfer through the lock plus one.

5.7.5

All other compartments or chambers are to be provided with at least two BIBS masks.

5.9

Surface compression chambers are to have installed illumination which provides a general interior illumination level of at least 270 lumens/m^2 (25 foot-candles) with 540 lumens/m^2 (50 foot-candles) over bunks and in work areas under normal operating conditions.

5.11

When chambers are to be used for operations exceeding 12 hours, they are to have the following features:

5.11.1

Compartments or chambers that serve as living facilities are to be provided with one bunk for each occupant. The dimensions of the bunks are to be suitable for enabling the occupants to rest comfortably.

5.11.2

Compartments or chambers that serve as living facilities are to have internal dimensions sufficient to allow most occupants to stand upright and to lie down and stretch out comfortably on their bunks.

5.11.3

Compartments or chambers that serve as transfer locks are to have internal dimensions sufficient to allow the simultaneous transfer of at least two divers. The floodable volume is not to be less than 105 ft^3 ($3.0m^3$).

5.11.4

The viewports/windows for the compartments or chambers that serve as living facilities are to allow the bunks to be seen as much as possible over their entire lengths from the outside.

5.11.5 *(2012)*

Toilet, hand washing, and shower arrangements are to be provided and are to be installed outside the living facilities in separate compartments.

5.11.5(a) Flush-type toilets, when installed, are to be provided with the following:

i) An interlock to prevent flushing of the toilet while the user is seated.

ii) Stand-offs on the toilet seat to prevent the formation of a complete seal between the toilet bowl and the user.

iii) Water for flushing at a pressure not less than the maximum operating pressure of the chamber.

iv) Flushing systems are to require two positive manual actions for operation.

v) Flushing systems are to have means to prevent the system from going open circuit upon operation.

vi) Effluent drain from the toilets is to be routed to an external holding tank.

Means for communicating with the dive control station are to be provided in the vicinity of flush type toilets.

5.11.5(b) Hand washing and shower systems are to be provided with the following:

i) A sink for hand washing and a shower head for showering.

ii) Water at a pressure not less than the maximum operating pressure of the chamber.

iii) Effluent drain from the hand washing and shower systems is to be routed to an external holding tank.

iv) Drainage systems may be manual or automatic. Means are to be provided to prevent the drainage systems from going open circuit upon operation.

5.11.5(c) *(2014)* Holding tanks are to be provided with the following:

i) Means (such as pilot and vent valves) to ensure that the tank pressure does not exceed the chamber pressure during operation of the flushing/drainage systems or during chamber decompression.

ii) Pressure gauge for indicating the tank pressure.

iii) Means to determine the tank level.

iv) Means to drain the tank. The means may be manual or automatic. Automatic means are to be of the fail-to-close type. Manual means are to require two positive manual actions for operation.

5.11.6

All compartments are to be provided with suitable heating, cooling and humidity control systems with controls and capacity sufficient to maintain a comfortable temperature and humidity level for the occupants. Heating, cooling and humidity control systems are to have full redundancy.

5.11.7

All compartments are to be provided with a gas circulation system. The circulation system is to have sufficient capacity to maintain homogenous gas mixtures and to avoid stratification of gas layers within the compartments.

5.13 Tests

Fully outfitted surface compression chambers are to be subjected to the following tests in the presence of the Surveyor:

5.13.1

Life support system tests as per the applicable requirements of Section 8.

5.13.2

Surface compression chambers are to undergo functional tests. Satisfactory operation at the maximum allowable working pressure using the normal breathing gas is to be demonstrated for the life support systems, piping systems, electrical systems, communication systems, locks, etc.

7 Diving Bells

7.1

Diving systems used for operations exceeding 300 FSW (91.46 MSW) in depth are to be provided with diving bells.

7.3

Diving bells are to be designed for the carriage of at least two divers. They are to be provided with adequate internal space for the number of occupants envisaged, together with their equipment. Floodable volumes of diving bells are not to be less than those specified below:

i) Two occupants: 105 ft^3 (3.0 m^3)

ii) Three occupants: 160 ft^3 (4.5 m^3)

iii) More than three occupants: 53 ft^3 (1.5 m^3) per occupant in excess of that specified in 13/7.3

7.4 *(2012)*

Diving bells are to be provided with means to prevent internal flooding of the bell in the event of uncontrolled descent from the surface or an intermediate depth to the design depth.

7.5

Diving bells are to be provided with adequate mechanical protection to prevent damage to the pressure boundaries and other critical components during handling operations and other normal or emergency operations. See 13/3.3.1.

7.7 *(2011)*

Diving bells are to be provided with one extra lifting point designed to take the entire dry (in-air) weight of the bell including the equipment as well as the weight of the divers within the bell. The extra lifting point is to be in-line with the center of gravity of the diving bell. Calculated stresses are not to exceed those specified in 13/3.3.1.

7.9

Diving bells are to be provided with permanent features for the attachment of recovery equipment. It is to be demonstrated by appropriate analysis that the recovery feature attachments on the diving bell are adequate for raising the bell to the surface. Calculated stresses are not to exceed those specified in 13/3.3.1.

7.11

Diving bells are to be provided with suitable means that permit the divers to exit and re-enter the bell safely when the bell is resting on the seabed. The means may include stand-off frames or two-stage emergency jettisoning mechanisms.

7.13

Medical/Equipment locks, when provided, are to meet the requirements of 13/3.7.

7.15

Diving bells are to be provided with suitable means that permit safe access to/from the surface compression chambers of the diving system. Access trunking, when provided, are to meet the applicable requirements of 13/3.5. Suitable means are to be provided to prevent the inadvertent release of diving bells from the surface compression chambers while the means of access is pressurized. Clamping arrangements, when provided, are to meet the applicable requirements of 13/3.9.

7.17

Suitable means are to be provided for taking unconscious divers into diving bells.

7.19

Seating is to be provided for each diver being transported by diving bells.

7.21

Diving bells are to be provided with sufficient number and size of viewports that as far as practicable allow the divers working outside the bell to be observed by divers within the bell.

7.23

Diving bells are to be provided with a main supply umbilical for supplying breathing gases, hot water, electrical power, communication, etc., to the bell. Umbilicals are to be securely attached to the bell by means of a strength member or strain relief fitting so that the individual connections are not subjected to tensile loads.

7.25 Communication and Emergency Location Equipment

7.25.1

Diving bells are to be provided with through-water communication equipment rated for the maximum operational distance from the dive control station. The through-water communication equipment is to be provided with a self-contained power source suitable for not less than 24 hours operation. Alternatively, the communication equipment is to be arranged to be powered by the onboard power supply of the diving bell.

7.25.2

A copy of the standard diving bell emergency communication tapping code is to be permanently displayed inside and outside the bell and the dive control station. The tapping code is to be in accordance with the requirements of Section 2.12.6 of IMO Resolution A.831 (19) "Code of Safety for Diving Systems" (See Appendix 1).

7.25.3

Diving bells are to be provided with a strobe light that serves as a surface emergency locating device. The locating device is to be provided with a self-contained power source suitable for not less than 24 hours operation. Alternatively, the locating device is to be arranged to be powered by the onboard power supply of the diving bell.

7.25.4

Diving bells are to be provided with an acoustic transponder that serves as a subsurface emergency locating device. The locating device is to be suitable for operation with a diver-held interrogator-receiver which is to be retained on board the dive support vessel/offshore facility. The equipment is to be designed to operate in accordance with Section 2.12.5 of IMO Resolution A.831 (19) "Code of Safety for Diving Systems" (see Appendix 1). The locating device is to be provided with a self-contained power source suitable for operation for a duration not less than 24 hours. Alternatively, the locating device is to be arranged to be powered by the onboard power supply of the diving bell.

7.27 Life Support System

7.27.1

The bell umbilical is to be provided with two independent supplies of breathing gases from the surface.

7.27.2

Diving bells are to be provided with an onboard life support system that is independent of the surface supply from the diving system. The onboard life support system is to be capable of being switched on manually or automatically without gas flowing back through the bell umbilical. The onboard life support system is to be capable of supplying breathing gases at all depths up to the maximum operating depth for all the divers using the bell. The onboard life support system is to include:

7.27.2(a) Reserve Life Support System. The system is to have sufficient capacity to provide at least 24 hours of metabolic oxygen and carbon dioxide scrubbing capabilities for the bell internal atmosphere. The partial pressure of CO_2 is not to exceed 0.005 atmosphere absolute (ata).

7.27.2(b) Emergency Life Support System (2011). The system is to provide suitable breathing gas mixtures to the divers' helmets or breathing masks. The system is to be designed such that the partial pressure of CO_2 in the gas being breathed does not to exceed 0.015 atmosphere absolute (ata). The emergency life support system is to be independent of the reserve life support system. The capacity of the emergency life support system is to be the greater of the following three items:

i) Capacity that is sufficient to supply each of the bell divers with breathing gas for at least 15 minutes when they are outside the bell. A respiratory minute volume of not less than 45 liters/minute or 1.5 actual cubic feet/minute (acfm) per diver for the lock-out divers under heavy work conditions and 62.5 liters/minute or 2.2 acfm per diver for the stand-by diver under severe work conditions at ambient pressure is to be used for determining the capacity.

ii) Capacity that is sufficient to supply all divers on BIBS supply during a contaminated atmosphere event while the bell is being recovered. A respiratory minute volume of not less than 12 liters/minute or 0.42 actual cubic feet/minute (acfm) per diver for average rest conditions and 22.5 liters/minute or 0.8 acfm per diver for light work conditions at ambient pressure is to be used for determining the capacity.

iii) Capacity that is sufficient to de-water a bell filled with 40% water while at the maximum operating depth.

7.27.3

The onboard reserve life support system is to consist of two separate distribution systems for supplying oxygen to the bell. Oxygen is to be stored in at least two banks with separate penetrations entering into the bell. These penetrations are to be positioned so as to minimize the possibility that a single incident would cause failure of both penetrators.

7.27.4

The oxygen supply for the onboard reserve life support system is to be provided with a dosage system to enable the oxygen within the bell to be maintained at the proper partial pressure.

7.27.5

Suitable self-contained life support instrumentation is to be provided onboard the bell to enable the occupants to monitor the partial pressures of oxygen and carbon dioxide. The life support instrumentation is to be capable of at least 24 hours of operation.

7.27.6 *(2012)*

For diving systems intended for operation in the vicinity of hydrocarbon production, exploration or storage facilities, means are to be provided for monitoring the bell atmosphere for hydrocarbons and for flushing the bell atmosphere of hydrocarbons.

7.27.7 Built-in Breathing System (BIBS)

7.27.7(a) Diving bells are to be provided with emergency breathing gas using a Built-in Breathing System (BIBS). The BIBS is to be independent of the normal surface supply.

7.27.7(b) The BIBS masks are to be capable of supplying breathing gases from both the emergency surface supply as well as the onboard emergency life support system. (Diver's masks and helmets with a gas supply are also considered acceptable for use as breathing masks).

7.27.7(c) The diving bell is to be provided with BIBS masks for the maximum number of divers within the bell plus one.

7.27.8

The divers' umbilicals are to be provided with breathing gases from both the surface supply as well as the onboard emergency life support system. Each diver's gas supply is to be arranged so that failure of one line does not interfere with another diver's breathing gas supply.

7.27.9

The primary breathing gas supply to the stand-by diver's umbilical is to be independent of the primary breathing gas supply to the lock-out divers' umbilicals. The primary breathing gas to the stand-by diver may be supplied from the surface or the bell onboard emergency life support system and is to be sufficient to allow the stand-by diver to exit the bell and recover an injured diver. The secondary breathing gas supply to the stand-by diver may be common with the lock-out divers' primary breathing gas supply, provided it has the capability to continue supplying breathing gas to the stand-by diver if the working diver's line fails.

7.27.10

Breathing gas supplies are to be arranged so that blowing-down or flushing the bell does not interfere with the breathing gas supply to any diver outside the bell.

7.27.11 *(2012)*

Diving bells are to be provided with two independent exhaust systems. The exhaust systems are not to permit internal flooding of an upright bell to a level above the location of the electrical and life support equipment (such as CO_2 scrubbers) equipment within the bell. The flooded volume is not to exceed 40% of the internal volume of the bell. One exhaust system is to be arranged so that a diver who intends to aid his or her entry by a partial flooding of the bell can operate it from the lower section within the bell. This exhaust system is to be fitted with a spring loaded valve that closes when the valve handle is released. The stop valve for the exhaust system not intended for partial flooding of the bell is to be clearly labeled, installed in a readily accessible location and is to be of a type that can be closed rapidly under emergency conditions (such as a ruptured umbilical).

7.27.12

Diving bells are to be provided with a manifold for the connection of emergency hot water and breathing gases. The manifold is to be located external to the pressure boundary of the diving bell and in a readily accessible location that is close to the main lifting attachment. The dimensions of the connections provided are to be as follows:

$^3/_4$ inch NPT (female) – for hot water

$^1/_2$ inch NPT (female) – for breathing mixtures

The connections are to be clearly and permanently marked and suitably protected.

7.27.13

For diving operations exceeding 500 FSW (152 MSW), suitable means are to be provided for heating the inspired gases of divers in the water. Suitable safety features are to be provided for preventing overheating of the inspired gases. For diving operations exceeding 12 hours, full redundancy is to be provided for the means of heating.

7.27.14 *(2014)*

Diving bells are to be provided with a heating system for maintaining the temperature of the bell internal atmosphere and divers in the water at a comfortable level. Suitable safety features are to be provided for preventing overheating by the heating system. Suitable means are to be provided for isolating the heating arrangement of the bell from the heating arrangement for the divers in the water. For diving operations exceeding 12 hours, full redundancy is to be provided for the surface based heating equipment.

7.27.15

Diving bells are to be provided with emergency means for preventing excessive heat loss by the divers for a period of at least 24 hours. This means is to be independent of the main umbilical. (Passive thermal insulation, heating the divers' breathing gas by active or regenerative methods, heating the divers directly by heated suits, etc., are considered to be acceptable means).

7.29 Electrical Systems

7.29.1

Diving bells are to be provided with a suitable onboard source of power.

7.29.2

The onboard source of power is to have sufficient capacity to supply power for at least 24 hours.

7.29.3

The onboard source of power is to be capable of feeding the emergency equipment including the emergency life support equipment, communication equipment and internal lighting.

7.29.4

Diving bells are to be provided with external lights that illuminate the bell over 360 degrees under normal operating conditions. These lights are to be wired in such a way that failure of one light does not cause the other lights to stop functioning. The lights are to be positioned at suitable distances from the acrylic windows in order to prevent inadvertent heating of the windows.

7.31 Stability

7.31.1 Positively Buoyant Diving Bells

7.31.1(a) Positively buoyant diving bells include bells that are inherently positively buoyant or bells that are provided with emergency jettisoning systems.

7.31.1(b) Emergency jettisoning systems are to release sufficient mass so that the bell, including umbilicals which may not get released, becomes positively buoyant. The jettisoning systems are to be capable of preventing inadvertent release of the masses. The jettisoning systems are to require at least two positive manual actions to activate and are to be independent of electric power.

7.31.1(c) Positively buoyant bells are to be provided with suitable means to release the umbilicals and the guide wires. The means are to be capable of preventing inadvertent release of the umbilicals and the guide wires. These means are to require at least two positive manual actions to activate and are to be independent of electric power.

7.31.1(d) For positively buoyant bells, calculations are to be submitted to demonstrate the following:

i) The diving bell is positively buoyant and has sufficient stability to maintain a substantially upright position during the ascent through the water column.

ii) The time taken to ascend to the surface does not to exceed the time equivalent to the capacity of the diving bell's onboard emergency life support system.

7.31.2 Negatively Buoyant Diving Bells

7.31.2(a) Negatively buoyant diving bells include bells that remain negatively buoyant under normal or emergency conditions.

7.31.2(b) Negatively buoyant bells are to be provided with two independent means of recovery, each capable of raising the diving bell to the surface. Each of these means is to meet the applicable requirements of this Section and Section 17.

7.31.2(c) (2011) In addition to 13/7.31.2(b) above, alternate means are to be available for emergency retrieval of the bell or the divers to the surface, should the two independent means of recovery fail.

The alternative means may utilize other assets operating in the area to provide alternative lift or personnel recovery assistance. (These means may include but are not limited to other underwater vehicles or systems, lifting appliances based on other vessels, transfer of the divers to another diving bell, etc.). The alternative means are to be suitably rated for the deepest anticipated sea-bed depth for diving operations. When part of a classed diving system, the alternative means are to meet the applicable requirements of these Rules.

7.31.2(d) For negatively buoyant bells, it is to be demonstrated by appropriate analysis that the time taken to recover the bell does not to exceed the time equivalent to the capacity of the diving bell's onboard emergency life support system.

7.31.2(e) (2011) Suitable equipment is to be provided for preventing negatively buoyant diving bells from descending below the design depth. Alternatively, negatively buoyant diving bells are to be designed for external pressure corresponding to the deepest anticipated sea-bed depth for diving operations.

7.33 Tests

Fully outfitted diving bells are to be subjected to the following tests in the presence of the Surveyor:

7.33.1

Life support system tests as per the applicable requirements of Section 8.

7.33.2

Diving bells are to undergo functional tests. Satisfactory operation at the maximum allowable working pressure using the normal breathing gas is to be demonstrated for the life support systems, piping systems, electrical systems, communication systems, etc.

7.33.3

Positively buoyant bells are to undergo stability tests on the surface and submerged in shallow waters in order to verify that the diving bell is positively buoyant and has sufficient stability to maintain a substantially upright position.

7.33.4

Diving bells are to undergo a test dive as per the applicable requirements of Subsection 3/5.

7.35 Diving Bell Handling Systems

7.35.1 *(2011)*

Each diving bell is to be provided with a handling system to ensure safe transportation of the diving bell between the subsea work location and the surface compression chambers. Handling systems for diving bells are to meet the applicable requirements of Section 17.

7.35.2

Handling systems for diving bells are to be designed to permit safe operation in the design sea state when the dive support vessel/offshore facility is rolling, pitching or heaving. The most probable extreme values of amplitude due to predetermined motions of the dive support vessel/offshore facility is to be used in the design.

9 Open/Wet Bells

9.1

Diving systems used for operations exceeding 220 FSW (67.07 MSW) in depth or two hours in-water decompression time are to be provided with open bells. For operations exceeding 300 FSW (91.46 MSW), see 13/7.1.

9.3

Open bells are to be designed for the carriage of at least two divers, including their equipment. The bells are to have suitable dimensions to carry the divers in an uncramped position.

9.5

Open bells are to be provided with adequate mechanical protection to protect the divers and to prevent damage to the critical components of the bell during handling operations and other normal or emergency operations. Frames and primary lifting lugs of open bells are to meet the requirements of 13/3.3.1 and 13/3.3.3(a). The lower section of the bell is to be provided with a platform enabling the divers to stand safely. Open bells are to be provided with internal handholds to support the divers.

9.7 *(2011)*

Open bells are to be provided with one extra lifting point designed to take the entire dry (in-air) weight of the bell including the equipment as well as the weight of the divers within the bell. The extra lifting point is to be in-line with the center of gravity of the open bell. Calculated stresses are not to exceed those specified in 13/3.3.1.

9.9

Open bells are to be provided with an enclosed upper section at head and shoulder level that provides an envelope capable of maintaining a bubble of breathing gases for the divers.

9.11

Suitable means are to be provided for taking an unconscious diver into an open bell and for securing the unconscious diver in the bell with his/her head in the enclosed upper section.

9.13

Open bells are to be provided with sufficient normal and emergency internal lighting to permit the occupants of the bell to operate the controls and read the gauges.

9.15

Open bells that are used for in-water decompression are to be provided with a suitable depth gauge.

9.17

Open bells are to be provided with a main supply umbilical for supplying breathing gases, hot water, electrical power, communication, etc., to the bell. Umbilicals are to be securely attached to the bell by means of a strength member or strain relief fitting so that the individual connections are not subjected to tensile loads.

9.19 Life Support System

9.19.1

The bell umbilical is to be provided with two independent supplies of breathing gases from the surface.

9.19.2 *(2011)*

Open bells are to be provided with an onboard emergency life support system that is independent of the surface supply from the diving system. The onboard emergency life support system is to be capable of supplying breathing gases to the divers at all depths up to the maximum operating depth. Breathing gases from the onboard emergency life support system is to be available to the divers' umbilicals and the enclosed upper section of the bell. The capacity of the emergency life support system is to be the greater of the following two items:

i) Capacity that is sufficient to supply each of the bell divers with breathing gas for at least 15 minutes when they are outside the bell. A respiratory minute volume of not less than 45 liters/minute or 1.5 actual cubic feet/minute (acfm) per diver for the working divers under heavy work conditions and 62.5 liters/minute or 2.2 acfm per diver for the stand-by diver under severe work conditions at ambient pressure is to be used for determining the capacity.

ii) Capacity that is sufficient to supply the divers while the bell is being recovered. A respiratory minute volume of not less than 12 liters/minute or 0.42 actual cubic feet/minute (acfm) per diver for average rest conditions and 22.5 liters/minute or 0.8 acfm per diver for light work conditions at ambient pressure is to be used for determining the capacity.

9.19.3

The divers' umbilicals are to be provided with breathing gases from both the surface supply as well as the onboard emergency life support system. Each diver's gas supply is to be arranged so that failure of one line does not interfere with another diver's breathing gas supply.

9.19.4

The primary breathing gas supply to the in-water stand-by diver's umbilical is to be independent of the primary breathing gas supply to the working divers' umbilicals. The primary breathing gas to the stand-by diver may be supplied from the surface or the bell onboard emergency life support system and is to be sufficient to allow the stand-by diver to exit the bell and recover an injured diver. The secondary breathing gas supply to the stand-by diver may be common with the working divers' primary breathing gas supply, provided it has the capability to continue supplying breathing gas to the stand-by diver if the working diver's line fails.

9.19.5

Breathing gas supplies are to be arranged so that blowing-down or flushing of the enclosed upper section of the bell does not interfere with the breathing gas supply to any diver.

9.21 Tests

Fully outfitted open bells are to be subjected to the following tests in the presence of the Surveyor:

9.21.1

Life support system tests as per the applicable requirements of Section 8.

9.21.2

Open bells are to undergo functional tests. Satisfactory operation at the maximum allowable working pressure using the normal breathing gas is to be demonstrated for the life support systems, piping systems, electrical systems, communication systems, etc.

9.21.3

Open bells are to undergo a test dive as per the applicable requirements of Subsection 3/5.

9.23 Open/Wet Bell Handling Systems

9.23.1 *(2011)*

Each open bell is to be provided with a handling system to ensure safe transportation of the bell between the subsea work location and the surface. Handling systems for open bells are to meet the applicable requirements of Section 17.

9.23.2

Handling systems for open bells are to be designed to permit safe operation in the design sea state when the dive support vessel/offshore facility is rolling, pitching or heaving. The most probable extreme values of amplitude due to predetermined motions of the dive support vessel/offshore facility is to be used in the design.

9.23.3

The handling system is to be capable of facilitating decompression stops in the water column.

10 Diving Baskets/Stages *(2011)*

10.1

Diving baskets or wet bells are to be provided for diving operations where the freeboard exceeds two (2) meters or where in-water decompression is to be carried out. For operations exceeding 220 FSW (67.07 MSW) in depth or two hours in-water decompression time, see 13/9.1. For operations exceeding 300 FSW (91.46 MSW), see 13/7.1.

10.3

Diving baskets are to be designed for the carriage of at least two divers, including their equipment. The baskets are to have suitable dimensions to carry the divers in an uncramped position.

10.5

Diving baskets are to be provided with adequate mechanical protection to protect the divers and to prevent damage to the critical components of the basket during handling operations and other normal or emergency operations. The lower section of the basket is to be provided with a platform enabling the divers to stand safely. Baskets are to be provided with internal handholds to support the divers and gates or chains to prevent the divers from falling out. Frames and primary lifting lugs of diving baskets are to meet the requirements of 13/3.3.1 and 13/3.3.3(a).

10.7

Diving baskets are to be provided with one extra lifting point designed to take the entire dry (in-air) weight of the basket including the equipment as well as the weight of the divers within the basket. The extra lifting point is to be in-line with the center of gravity of the diving basket. Calculated stresses are not to exceed those specified in 13/3.3.1.

10.9

Suitable means are to be provided for taking an unconscious diver into a diving basket and for securing the unconscious diver.

10.11

Diving baskets are to be provided with an on-board emergency life support system that is independent of the diver's surface supply. The on-board emergency life support system is to be capable of supplying breathing gases to the divers at all depths up to the maximum operating depth. The capacity of the emergency life support system is to be sufficient to supply the divers while the basket is being recovered including decompression. A respiratory minute volume of not less than 12 liters/minute or 0.42 actual cubic feet/minute (acfm) per diver for average rest conditions and 22.5 liters/minute or 0.8 acfm per diver for light work conditions at ambient pressure is to be used for determining the capacity.

10.13 Diving Basket/Stage Handling Systems

10.13.1

Each diving basket is to be provided with a handling system to ensure safe transportation of the basket between the subsea work location and the surface. Handling systems for diving baskets are to meet the applicable requirements of Section 17.

10.13.2

Handling systems for diving baskets are to be designed to permit safe operation in the design sea state when the dive support vessel/offshore facility is rolling, pitching or heaving. The most probable extreme values of amplitude due to predetermined motions of the dive support vessel/offshore facility is to be used in the design.

10.13.3

The handling system is to be capable of facilitating decompression stops in the water column that takes into account dynamic motion of the vessel including rolling, pitching and heaving.

11 Hyperbaric Evacuation

11.1 Hyperbaric Evacuation Methods

11.1.1

Diving systems are to be provided with appropriate means for the hyperbaric evacuation of divers in an emergency.

11.1.2

It is recognized that there are various methods available for evacuating divers and the suitability of the various options depends on a number of factors including the type of diving system, geographical area of operation, environmental conditions, and available offshore or onshore medical and support facilities. Some of the options available to diving system operators include:

i) Self-Propelled Hyperbaric Lifeboats (SPHLs)

ii) Towable Hyperbaric Rescue Chambers (HRCs)

iii) Hyperbaric Rescue Chambers (HRCs) that are suitable for offloading to or recovery by an attendant vessel/offshore facility

iv) Transfer of the diving bell to another vessel/offshore facility

v) Transfer of the divers from one diving bell to another when in the water and under pressure

vi) Units designed for underwater operation and capable of returning to the surface to await independent recovery.

Diving system operators are to examine and identify the option best suited for the area and type of operation in which they are engaged.

11.1.3

Diving bells that are working at depth are not considered to be an available option for the evacuation of divers in the surface compression chambers onboard the support vessel/offshore facility. Under these circumstances, diving bells may be considered as an available option for the evacuation of divers in the bell should an emergency arise that prevents the return of these divers to the support vessel/offshore facility.

11.1.4

The means of hyperbaric evacuation are not to be located in zone 0 or zone 1 hazardous zones. See 13/17.1.

11.3 Hyperbaric Evacuation Units (HEUs) for Saturation Diving Systems

11.3.1

Saturation diving systems are to be provided with at least one hyperbaric evacuation unit (HEU). For divers in saturation at significantly different depths, the HEU is to be designed so that the pressure differential may be maintained. Alternatively, two or more HEUs may be provided to cover the various pressure levels.

11.3.2

HEUs are to be designed for the rescue of all the divers in the saturation diving system when at the maximum operating depth.

11.3.3

HEUs that are used as living facilities under normal operating conditions are to also meet the applicable surface compression chamber requirements of Subsection 13/5.

11.3.4

HEUs are to be provided with adequate internal space for the number of occupants envisaged plus one, together with their equipment.

11.3.5

HEUs are to be provided with adequate mechanical protection to prevent damage to the pressure boundaries and other critical components during handling operations and other normal or emergency operations. See 13/3.3.1.

11.3.6

HEUs are to be capable of being recovered by a single point lifting arrangement. The lifting lug/attachment is to meet the requirements of 13/3.3.3(a). Means are to be provided on the HEU to permit a swimmer to hook on or connect the lifting arrangement.

11.3.7

Towable HEUs are to be provided with an accessible towing attachment point, appropriately sized for the anticipated conditions. Towing attachment points are to be situated such that there is no likelihood of the HEUs capsizing as a result of the towing force. When towing equipment is carried onboard the HEUs, the size, strength and weight of the equipment is to be appropriate for the anticipated conditions. Towing harnesses, when provided, are to be lightly clipped or secured to the HEUs and as far as practicable are to be free from snagging when pulled free.

11.3.8

HEUs that are designed for offloading to or recovery by an attendant vessel/offshore facility are to be provided with suitable attachment points to enable the HEUs to be secured to the deck of the vessel/offshore facility.

11.3.9

HEUs are to be provided with suitable means that permit safe access to/from the surface compression chambers of the diving system. The means of access is to be capable of quick disconnection in order to enable the HEUs to be launched within a short duration during emergencies.

11.3.10

Suitable means are to be provided to prevent the inadvertent release of HEUs from surface compression chambers while the means of access is pressurized.

11.3.11

Access trunking/tunnels, when provided, are to meet the applicable requirements of 13/3.5.

11.3.12

Clamping arrangements, when provided, are to meet the applicable requirements of 13/3.9.

11.3.13

Suitable means are to be provided for protecting the HEU manway mating flanges from damage during the launch and recovery.

11.3.14

When it is intended to carry out decompression of the divers after hyperbaric evacuation to the surface compression chambers of other diving systems, consideration is to be given to the suitability of the mating arrangements. Where necessary, suitable adapters and clamping arrangements are to be provided.

11.3.15

Suitable means are to be provided for taking unconscious divers into HEUs.

11.3.16

Seating or other appropriate arrangements are to be provided to ensure an adequate degree of protection to the divers while the HEU is being launched/recovered and while floating at sea.

11.3.17

Suitable arrangements are to be provided to allow the occupants of HEUs to be visually observed. If viewports are provided, they are to be situated so that risk of damage is minimized.

11.3.18

HEUs are to be provided with a suitable medical lock. See 13/3.7.

11.3.19

If the diving system is installed on a drilling rig or production facility where hydrocarbons may be released, then the HEU is to be provided with a means of propulsion or other means to rapidly transport the HEU away from the site. Propulsion systems, steering equipment and their control systems are to meet the applicable requirements of Subsection 11/23.

11.3.20 Self-Propelled Hyperbaric Lifeboats (SPHLs)

The lifeboat hull, propulsion system and associated equipment and machinery are to meet the applicable lifeboat requirements of IMO Resolutions MSC.48(66) and MSC.81(70) "Life-Saving Appliances Code".

11.3.21 Communication and Emergency Location Equipment

11.3.21(a) HEUs designed for surface operation are to be provided with VHF communication equipment with at least two channels for surface communication. One of the channels is to be Safety Channel 16-VHF. The VHF communication equipment is to be provided with a self-contained power source suitable for not less than 72 hours operation. Alternatively, the communication equipment is to be arranged to be powered by the onboard power supply of the HEU.

11.3.21(b) HEUs designed for underwater operation are to be provided with a through-water communication equipment rated for the maximum operational distance from the dive control station. The through-water communication equipment is to be provided with a self-contained power source suitable for not less than 72 hours operation. Alternatively, the communication equipment is to be arranged to be powered by the onboard power supply of the HEU.

11.3.21(c) A copy of the standard diving bell emergency communication tapping code is to be permanently displayed inside and outside HEUs and at the dive control station. The tapping code is to be in accordance with the requirements of Section 2.12.6 of IMO Resolution A.831 (19) "Code of Safety for Diving Systems" (See Appendix 1).

11.3.21(d) HEUs designed for surface operation are to be provided with a radar reflector and a strobe light or Emergency Position Indicating Radio Beacon (EPIRB) that serves as the surface emergency locating device. The locating device is to be provided with a self-contained power source suitable for not less than 72 hours operation. Alternatively, the locating device is to be arranged to be powered by the onboard power supply of the HEU.

11.3.21(e) HEUs designed for underwater operation are to be provided with an emergency locating device (acoustic transponder). The locating device is to be suitable for operation with a diver-held interrogator-receiver which is to be retained on board the dive support vessel/offshore facility. The equipment is to be designed to operate in accordance with Section 2.12.5 of IMO Resolution A.831 (19) "Code of Safety for Diving Systems" (see Appendix 1). The locating device is to be provided with a self-contained power source suitable for operation for a duration not less than 72 hours. Alternatively, the locating device is to be arranged to be powered by the onboard power supply of the HEU.

11.3.22 Life Support System

11.3.22(a) HEUs are to be provided with an onboard life support system that is independent of the normal surface supply from the diving system. This life support system is to be capable of supplying breathing gases at all depths up to the maximum operating depth for all divers within the HEU. The onboard life support system is to include:

i) *Reserve Life Support System.* The system is to have sufficient capacity to provide at least 72 hours of metabolic oxygen and carbon dioxide scrubbing capabilities for the HEU chamber internal atmosphere. The partial pressure of CO_2 is not to exceed 0.005 atmosphere absolute (ata).

ii) *Emergency Life Support System.* The system is to provide suitable breathing gas mixtures to the BIBS masks. The capacity of the system is to be sufficient to supply all divers on BIBS during a contaminated atmosphere event after the HEU has been launched at sea. A respiratory minute volume of not less than 12 liters/minute or 0.42 actual cubic feet/minute (acfm) for average rest conditions and 22.5 liters/minute or 0.8 acfm for light work conditions at ambient pressure is to be used for determining the capacity. The system is to be designed such that the partial pressure of CO_2 in the gas being breathed does not to exceed 0.015 atmosphere absolute (ata). The emergency life support system is to be independent of the reserve life support system.

11.3.22(b) The BIBS masks are to be capable of supplying breathing gases from both the emergency surface supply as well as the onboard emergency life support system.

11.3.22(c) The HEU is to be provided with BIBS masks for the maximum number of occupants within the HEU chamber plus one.

11.3.22(d) The HEU onboard reserve life support system is to consist of two separate distribution systems for supplying oxygen to the HEU chambers. Oxygen is to be stored in at least two banks with separate penetrations entering into the chambers. These penetrations are to be positioned so as to minimize the possibility that a single incident would cause failure of both penetrators.

11.3.22(e) The oxygen supply for the onboard reserve life support system is to be provided with a dosage system to enable the oxygen within the HEU chamber to be maintained at the proper partial pressure.

11.3.22(f) When HEUs are used for decompression of the divers, the necessary equipment and quantity of gases (including treatment mixtures) are to be provided to enable the decompression process to be carried out safely.

11.3.22(g) In addition to any controls and equipment fitted externally, HEUs are to be provided with adequate controls within the chambers in order to permit personnel to control the supply and maintain the appropriate breathing mixtures to any depth down to the maximum operating depth. As far as practicable, these controls are to be capable of operation without the person who operates them having to remove his/her seat belt.

11.3.22(h) Suitable self-contained life support instrumentation is to be provided onboard the HEU to enable the occupants to monitor the partial pressures of oxygen and carbon dioxide. The life support instrumentation is to be capable of at least 72 hours of operation.

11.3.22(i) HEUs are to be provided with emergency means for preventing excessive heat loss by the divers for a period of at least 72 hours when the HEU is at its maximum operating depth. (Passive thermal insulation, heating the divers' breathing gas by active or regenerative methods, heating the divers directly by heated suits, etc., are considered to be acceptable means).

11.3.22(j) An adequate supply of food, water, first-aid equipment, sickness bags, paper towels and all necessary operational instructions are to be provided to HEUs before launching at sea. In determining the amount of water to be provided, consideration is to be given to the area of operation and the environmental conditions envisaged.

11.3.22(k) Suitable arrangements for the collection or discharge of human waste are to be provided. These arrangements are to be suitable for not less than 72 hours duration. Flush-type toilets capable of discharging their waste to the outside are to be provided with suitable interlocks to prevent flushing while occupied.

11.3.22(l) HEUs are to be provided with a manifold for the connection of emergency hot or cold water and breathing gases. The manifold is to be located external to the pressure boundary of the HEU and in a readily accessible location. The dimensions of the connections provided are to be as follows:

$^3/_4$ in. NPT (female) – hot or cold water

$^1/_2$ in. NPT (female) – breathing mixtures

The connections are to be clearly and permanently marked and suitably protected.

11.3.23 Fire Protection

11.3.23(a) HEUs installed on dive support vessels/offshore facilities that are required to be provided with fire-protected lifeboats are to be also provided with a similar degree of fire protection.

11.3.23(b) For HEUs designed to pass through fires, the breathing gas cylinders, piping systems and other essential equipment are to be adequately protected. Thermal insulation, when provided, is to be non-toxic and suitable for fire protection applications.

11.3.24 Fire Fighting

For HEUs that are designed to float and pass through fires, a fixed external water spray system is to be provided for external cooling purposes.

11.3.25 Electrical Systems

11.3.25(a) HEUs are to be provided with a suitable onboard source of power.

11.3.25(b) The onboard source of power is to be suitable for supplying power for not less than 72 hours.

11.3.25(c) The onboard source of power is to be capable of feeding the emergency equipment including the emergency life support equipment, communication equipment and internal lighting.

11.3.26 Stability

11.3.26(a) HEUs Designed for Surface Operations

i) HEUs designed to float on the surface of water are to be provided with adequate stability for all envisaged operating and environmental conditions and are to be self-righting. They are to have sufficient reserves of buoyancy in order to enable the necessary rescue crew and equipment to be carried onboard. In determining the degree of stability to be provided, consideration is to be given to the adverse effects of large righting moments on the occupants of the HEU. If rescue equipment and personnel are required to be placed on top of the HEU during rescue operations, their effect on the stability of the HEU is to be also considered.

ii) The following calculations are to be submitted to the Technical Office for review:

a) *Detailed Weight Calculations.* Calculations are to be provided and are to include calculated positions of center of buoyancy (*CB*), center of gravity (*CG*), total weight of the HEU (*W*) and displacement (Δ). This can be achieved by maintaining a detailed weight and balance spreadsheet during design and construction.

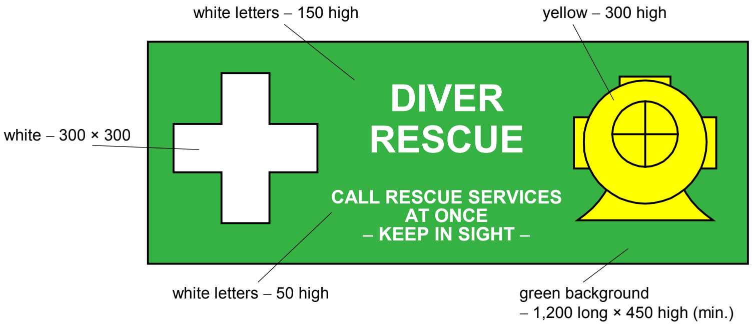
b) *Hydrostatic Model.* A mathematical model is to be used to calculate Δ, the positions of the center of buoyancy (*CB*) and the metacenter (*CM*), by computing the hydrostatic properties during design.

11.3.26(b) HEUs Designed for Underwater Operations. HEUs are to meet the applicable submersible stability requirements of Section 11.

11.3.27 Marking and Additional Information

11.3.27(a) HEUs are to be colored orange and are to be provided with retro-reflective material in order to assist in their location during hours of darkness.

11.3.27(b) HEUs are to be marked with at least three identical signs as shown below. One of these markings is to be located on top of the HEU and is to be clearly visible from the air while the HEU is afloat. The other two markings are to be mounted vertically on either side and are to be as high as possible in order to be visible while the HEU is afloat.



11.3.27(c) The following information and equipment are to be readily available in clearly visible locations on HEUs:

i) Towing arrangements (for towable HEUs)

ii) All external connections, particularly for the provision of emergency gases, hot/cold water and communication

iii) Maximum in-air weight of the fully loaded HEU

iv) Lifting points

v) Name of the parent dive support vessel/offshore facility and port of registration

vi) Emergency contact telephone, telex and facsimile numbers

vii) Instructions to enable the HEU to be recovered safely

11.3.27(d) Warning instructions. The following warning instructions are to be permanently displayed in two separate locations on HEUs. The instructions are to be clearly visible while HEUs are afloat:

"Unless specialized diving assistance is available:

1. Do not touch any valves or other controls;
2. Do not try to get occupants out;
3. Do not connect any gas, air, water or other supplies;
4. Do not attempt to give food, drinks or medical supplies to the occupants; and
5. Do not open any hatches."

11.3.28 Tests

Fully outfitted HEUs are to be subjected to the following tests in the presence of the Surveyor:

11.3.28(a) Life support system tests as per the applicable requirements of Section 8.

11.3.28(b) HEUs are to undergo functional tests. Satisfactory operation at the maximum allowable working pressure using the normal breathing gas is to be demonstrated for the life support systems, piping systems, electrical systems, communication systems, propulsion systems, etc.

11.3.28(c) Launch test of the fully loaded HEUs using the dedicated launch systems that are installed on the dive support vessel/offshore facility.

11.3.28(d) Additional Tests for HEUs designed for Surface/Underwater Operations:

i) *Deadweight Survey and Lightship Measurement.* The location, number and size of all items listed on the weight and balance spreadsheet are to be physically checked after construction and outfitting. Fully outfitted HEUs are to be weighed with a scale and the measured weights are to be compared to the total spreadsheet weights, compensating for any extraneous weights that may have been carried onboard the HEUs at the time of testing.

ii) *Inclining Experiments.* The completed HEUs are to be inclined on the surface and/or submerged (as applicable) in order to determine the *GM* (the distance between *CG* and the metacenter *CM*) and/or *GB* (the distance between *CG* and *CB*). Guidance for performing inclining experiments may be obtained from ASTM F 1321. Such testing is not required for HEUs that are duplicates (100% identical) of a previously tested HEU.

iii) Towable HEUs are to undergo a towing test at maximum speed in order to verify that there is no likelihood of the HEUs capsizing as a result of the towing force.

iv) HEUs designed for underwater operations are to undergo a test dive as per the applicable requirements of Subsection 3/5.

11.5 HEU Launch Systems

11.5.1 *(2011)*

Each HEU is to be provided with a dedicated launch system that serves as the primary means for the safe and timely evacuation of the divers. HEU launch systems are to comply with the applicable requirements of Section 17. Alternatively, launch systems for lifeboat type HEUs (such as SPHLs) are to comply with the applicable requirements of IMO Resolution A.692(17) “Guidelines and Specifications for Hyperbaric Evacuation Systems” and IMO Resolutions MSC.48(66) and MSC.81(70) “Life-Saving Appliances Code”.

11.5.2

Launch systems are to be designed for safely launching the HEUs when the ship/offshore facility is under unfavorable conditions of up to 20 degrees list and 10 degrees trim either way in the fully loaded or unloaded condition.

11.5.3

Each launch system is to be provided with a suitable means that depends on either stored mechanical power or gravity to safely launch the HEU and is independent of the power supply of the ship/offshore facility.

11.5.4 *(2011)*

For launch systems using falls for launching HEUs, the means provided for releasing the falls after the HEU is afloat is to permit easy disconnection. Falls are to be of rotation resistant and corrosion-resistant steel wire rope. The length of the falls is to be sufficient to allow the HEU to be launched in water when the ship/offshore facility is at its lightest draft and under unfavorable conditions of up to 20 degrees list and 10 degrees trim either way. (See 17/17.7 and 17/31.5.).

11.7 HEU Recovery and Life Support Equipment

11.7.1 Recovery Equipment

11.7.1(a) Diving system operators are to ensure that suitable recovery equipment is available for recovering HEUs after they have been launched at sea. Alternatively, suitable equipment is to be available for towing the HEU to a shore-based reception facility or another vessel or the HEU is to be self-propelled. The equipment is to be available at a suitable location from where it can reach the HEU within a reasonable amount of time. Diving system operators are to ensure that the recovery equipment is well maintained and ready for use at all times when diving operations are being carried out.

11.7.1(b) Recovery equipment, when part of a classed saturation diving system, is to meet the applicable requirements of these Rules.

11.7.1(c) Permanently marked clear instructions are to be provided adjacent to the recovery equipment. These instructions are to indicate the total in-air weight of the fully loaded HEU and the correct method for recovery.

11.7.2 Life Support Equipment

11.7.2(a) Diving system operators are to ensure that adequate life support equipment is available for maintaining appropriate life support conditions within HEUs after recovery or while it is being towed/self-propelled to a shore-based reception facility. This life support equipment may take the form of a portable life support package or fixed equipment onboard a vessel. The equipment is to be available at a suitable location from where it can reach the HEU within a reasonable amount of time. Diving system operators are to ensure that the life support equipment is well maintained and ready for use at all times when diving operations are being carried out.

11.7.2(b) Life support equipment, when part of a classed saturation diving system, is to meet the applicable requirements of these Rules.

11.7.2(c) The life support equipment is to be provided with an umbilical of suitable length to connect to the HEU. For HEUs that are being towed, the umbilical is to be longer than the towing line. The umbilical is to provide connections for breathing gases, hot/cold water, electrical power, communication, etc.

11.7.2(d) The life support equipment (including the breathing gases and connections) is to be compatible with the HEU.

11.7.2(e) The operational procedures for use of the life support equipment are to be available in the HEU and with the life support equipment.

13 Dive Control Stations

13.1

Diving systems are to be provided with a centralized dive control station for the safe operation of the systems.

13.3

Dive control stations are to meet the applicable requirements of Section 18.

13.5

Dive control stations are to be provided with suitable equipment for recording all audio communications with divers in bells and in the water.

13.7

Shipping containers used for housing portable dive control stations are to meet the applicable requirements of the ABS *Rules for Certification of Cargo Containers*. Special consideration will be given to containers that are designed and fabricated to other recognized industry standards that are not less effective than the Rules.

15 Utility Vans

15.1

Shipping containers used for housing diving system machinery, tools, spares, etc., that are part of a classed diving system are to meet the applicable requirements of the ABS *Rules for Certification of Cargo Containers*. Special consideration will be given to containers that are designed and fabricated to other recognized industry standards that are not less effective than the Rules.

17 Interface Between Diving Systems and Dive Support Vessels/Offshore Facilities

17.1 Installation of Diving Systems

17.1.1

Diving systems are to be installed in safe areas on a dive support vessel/offshore facility. Safe areas are those areas that are outside hazardous zones 0, 1 and 2 as defined by the International Electrotechnical Commission's Publication No.79-10 and Chapter 6 of the IMO MODU code:

- Zone 0: A zone in which an explosive gas-air mixture is continuously present or present for long periods.
- Zone 1: A zone in which an explosive gas-air mixture is likely to occur in normal operation.
- Zone 2: A zone in which an explosive gas-air mixture is not likely to occur, and if it occurs it will only exist for a short time.

Special consideration will be given on a case-by-case basis for diving systems that may be installed in Zone 2 hazardous zones.

17.1.2 Angles of Inclination *(2012)*

For diving systems installed on ships or ship-shaped offshore facilities, the PVHOs, machinery and systems essential for the safe operation of the diving system are to be designed for operation under the inclinations specified in Section 13, Table 2 below:

TABLE 2
Design Angles of Inclination *(2012)*

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

Notes

1 Athwartship and fore-and-aft inclinations occur simultaneously.

2 Up to an angle of inclination of 45 degrees, switches and controls are to remain in their last set position.

3 In vessels designed for carriage of liquefied gases and of chemicals, the emergency power installation is to remain operable with the vessel flooded to its permissible athwartship inclination up to a maximum of 30 degrees.

4 Where the length of the vessel exceeds 100 m (328 ft), the fore-and-aft static angle of inclination may be taken as 500/L degrees, where L is the length of the vessel in meters (1640/L degrees, where L is the length of the vessel in feet), as defined in 3-1-1/3.1 of the *Steel Vessel Rules*.

For diving systems installed on column-stabilized, self-elevating or surface offshore facilities, the PVHOs, machinery and systems essential for the safe operation of the diving system are to be designed for operation under the inclinations specified in Section 13, Table 3 below:

TABLE 3
Design Angles of Inclination *(2012)*

Offshore Facility	*Angle of Inclination (Degrees)*	
	Condition	
	Static	*Dynamic*
Column-Stabilized	15° in any direction	22.5° in any direction
Self-Elevating	10° in any direction	15° in any direction
Surface	15° list and 5° trim simultaneously	22.5° rolling and 7.5° pitching simultaneously

17.1.3 Temperature *(2012)*

For diving systems of unrestricted service that are installed on ships or offshore facilities, the ambient temperatures specified in Section 13, Table 4 below are to be considered for the selection and installation of PVHOs, handling systems, machinery and systems. For diving systems of restricted or special service, the ambient temperatures appropriate for the intended service are to be considered.

TABLE 4
Ambient Temperatures for Unrestricted Service *(2012)*

Position	*Location*	*Temperature Range (°C)*
In-Air	Enclosed Spaces (1), (2)	0 to +45
	Open Deck (1)	-25(3) to +45
In-Water		+32

Notes

1 Electronic equipment is to be suitable for operation up to 55°C.

2 Electrical equipment in machinery spaces is to be designed for 45°C, except that electric generators and motors are to be designed for 50°C. Electrical equipment outside machinery spaces may be designed for 40°C.

3 Acrylic windows are to be designed for a minimum temperature of -18°C.

4 For drilling units, refer to 4-1-1/Table 2 of the *MODU Rules*.

17.1.4

Diving systems and breathing gas storage facilities are not to be installed in machinery spaces that have machinery not associated with the diving system.

17.1.5

Diving systems are to be installed in spaces or locations that are adequately ventilated and provided with suitable lighting. Diving systems are not to be installed in the vicinity of exhausts/ventilation outlets from machinery spaces and galleys.

17.1.6

When any part of the diving system is located on open decks or similar structures, particular attention is to be given to providing reasonable protection from the sea, icing or any damage which may result from other activities onboard the dive support vessel/offshore facility.

17.1.7

In order to minimize deflections and to obtain satisfactory transfer of heavy loads through the deck foundations, it is recommended that diving systems be installed in such a way that the under-deck supporting structure of the dive support vessel/offshore facility is in-line with the deck foundations.

17.1.8

The diving system is to be located so that the diving operations are not affected by propellers, thrusters or anchors of the dive support vessel/offshore facility.

17.1.9 *(2013)*

Diving operations are to be conducted as far away as practicable from overboard discharge outlets/suction inlets of the vessel/offshore facility, in order to keep the diving site free of suction, turbulence and discharge products, which may obscure visibility in the water or might cause skin infections or expose divers to harmful chemicals.

17.1.10 *(2013)*

Impressed current system anodes, when installed in the vicinity of diving systems, are to be capable of being switched off during diving operations.

17.1.11 *(2013)*

It is recommended that pressure vessels for human occupancy (PVHOs) be are arranged along the longitudinal (fore and aft) direction of the vessel/offshore facility in order to minimize the rolling effect on divers within the PVHOs.

17.1.12

Approval of diving systems is based on the pressures, loads, environmental and operating conditions as specified by the diving system designers/operators. For diving systems, these factors may change after the diving system is demobilized from one dive support vessel/offshore facility, installed on another dive support vessel/offshore facility and mobilized for use. It is the responsibility of the diving system operator to advise ABS of changes to the pressures, loads, environmental and operating conditions due to the transfer of diving systems. The plans affected by the changes are to be updated and resubmitted to ABS for approval by the responsible party.

17.2 Breathing Gas Storage *(2013)*

Breathing gas cylinders for diving systems are to be stored on the open deck or in well ventilated enclosed spaces, and away from flammable substances and sources of ignition.

Where the breathing gas cylinders are stored on the open deck, they are to be provided with weather protection (particularly from heavy seas and heat) and are to be effectively protected from mechanical damage. Suitable drainage of the storage area is to be provided.

The boundaries between enclosed spaces housing the breathing gas cylinders and other enclosed spaces are to be gas tight. Access doors for these enclosed spaces are to open outwards. Suitable drainage of the enclosed spaces is to be provided.

The outlets of relief valves or bursting discs are to be piped-outside the enclosed spaces to the open deck and away from sources of ignition.

Each enclosed space is to be provided with a forced ventilation system capable of providing at least eight air changes per hour based on the gross volume of the space. The ventilation system is to be independent of ventilation systems of other spaces. The ventilation system air is to be drawn from a non-hazardous area. Ventilation system fans are to be of non-sparking construction.

Breathing gas mixtures containing more than 25% Oxygen by volume are to be treated and handled as pure Oxygen. Cylinders with these mixtures are to be stored on the open deck. They are not to be stored below the deck.

When breathing gas mixtures containing less than 18% Oxygen by volume is stored in enclosed spaces, at least two Oxygen analyzers with audio-visual alarms are to be provided. The Oxygen analyzers are to monitor low Oxygen levels. At least one analyzer is to monitor the upper areas of the enclosed space and at least one analyzer is to monitor the lower areas of the enclosed space. These enclosed spaces are to be thoroughly cleaned of hydrocarbons, fat, grease and other debris.

Where the diving support vessel/offshore facility is also used for fire fighting operations, means are to be provided to protect the Oxygen cylinders from heat that may radiate from the fire that is being extinguished.

17.3 Support Systems Provided by Dive Support Vessels/Offshore Facilities

17.3.1

Support systems are those systems that are provided by dive support vessels/offshore facilities and are not an integrated part of the diving system. These include among others:

- Electrical systems (Power supplies, etc.)
- Piping systems (Compressed air systems, hydraulic systems, sewage systems, etc.)
- Structural fire protection
- External fire extinguishing, fire detection and alarm systems
- Structural support (Means of fastening diving systems to the hull structure, deck foundations, under-deck supporting structure, etc.)
- Position keeping and stability of dive support vessels/offshore facilities

17.3.2

For diving systems installed on ABS classed vessels/offshore facilities, these support systems are to be in accordance with the *Steel Vessel Rules*. Drawings, specifications, data and calculations are to be submitted to ABS for review and approval.

17.3.3

When ABS-classed diving systems are installed on non-ABS-classed vessels/offshore facilities, documentation that these systems have been reviewed and approved by the Society classing the dive support vessel/offshore facility is to be provided. Alternatively, the details may be provided to ABS for review.

17.5 Position Keeping and Stability of Dive Support Vessels/Offshore Facilities

17.5.1

Dive support vessels/offshore facilities are to be capable of maintaining their positions safely during diving operations. The means to maintain position may be a mooring system with anchors or a dynamic positioning system.

17.5.2

Dynamic positioning systems used to maintain the position during diving operations are as a minimum to comply with the requirements for vessels with **DPS-2** notation (Equipment Class 2 as per IMO MSC/Circ.645) or equivalent.

17.5.3

The dive control station and the control station for the dynamic positioning system are to be linked by a communication system and a manually operated alarm system.

17.7 Deck Foundations, Fastening Arrangements, and Vessel/Offshore Facility Structures *(2013)*

17.7.1 General Requirements

Diving systems are to be securely attached to the hull structure of dive support vessels/offshore facilities using suitable permanent means of fastening such as welding or bolting. (Lashing is not considered to be a permanent means of fastening).

The design of deck foundations and fastening arrangements are to consider the relative movement between the components of the diving system. In addition, the deck foundations and fastening arrangements are to be designed to meet any required survival conditions of the dive support vessel/offshore facility as may be specified by the Flag State Administration.

In order to avoid exposing the diving system components to excessive deflections, the maximum deflections of the deck structure of dive support vessels/offshore facilities in-way of diving systems are to be evaluated. The evaluated deflections are not to exceed the defined acceptable level of deflections for the diving system.

17.7.2 Design Loads

Deck foundations, fastening arrangements and vessel/offshore facility structures in-way of diving systems are to be designed for the following loads:

17.7.2(a) Acceleration Loads. Accelerations due to dynamic motion of the vessel/offshore facility are to be derived from recognized national or international standards, seakeeping analysis using recognized engineering methodology or from actual or scaled-model tests, considering the most serve environmental conditions that the vessel/offshore facility is expected to encounter.

For offshore support vessels, the acceleration loads are to be derived in accordance with 5-5-3/5.3.1 of the ABS *Rules for Building and Classing Offshore Support Vessels (OSV Rules)*.

17.7.2(b) Static Inclination Loads. Deck foundations and fastening arrangements for diving system components are to be designed for a static inclination of 30°.

17.7.2(c) Hydrostatic Testing Loads. When it is intended to carry out hydrostatic testing of PVHOs and other pressure vessels while they are installed on the dive support vessel/offshore facility, the deck foundations and fastening arrangements are to be designed for supporting the maximum static load due to the hydrostatic testing, without unacceptable deflections.

17.7.2(d) Mating Loads. When mating operations are to be carried out on the dive support vessel/offshore facility, the deck foundations and fastening arrangements of pressure vessels for human occupancy (PVHO) are to be designed for mating loads. The mating loads are to consider a force of not less than twice the weight of the mating PVHO (diving bell, hyperbaric evacuation unit, etc.) and are to include other applicable loads such as the weight of entrapped mud and water.

17.7.2(e) Handling System Loads. The maximum expected operational loads are to be considered for the design of deck foundations, fastening arrangements and vessel structures in way of handling systems (LARS, davits, cranes, etc.) and handling system elements (winches, sheaves, dampers, etc.).

When handling systems are used for handling manned objects such as Diving Bells, Diving Baskets, etc., a dynamic factor of at least 2g vertical, 1g transverse and 1g longitudinal is to be applied. When handling systems are used for handing unmanned objects, a dynamic factor of at least 1.75g vertical, 0.75g transverse and 0.75g longitudinal is to be applied. For permanently installed systems, consideration may be given to lower dynamic factors, when it can be shown that the maximum expected loads are less than those specified above (See 17/7.3.4).

17.7.3 Allowable Stresses

The allowable stresses for the design are to be in accordance with the applicable requirements of the Rules/Guides used to Class the vessel/offshore structure.

For offshore support vessels, the allowable stresses are to be in accordance with 5-5-3/5.3.6 of the *OSV Rules*.

17.9 Moon Pools *(2013)*

Moon pools, where provided for diving operations are to meet the following requirements:

Openings are to be a suitable distance from the deck edge, from cargo hatch covers, from superstructure breaks and from other area of structural discontinuity.

The side structure of moon pools are to be designed for impact loads from diving equipment that may be guided through the moon pools. The moon pool side structure is to comply with requirements for side shell plating given in the Rules/Guides used to Class the vessel/offshore structure. For offshore support vessels, the moon pool side structure is to comply with requirements for side shell plating given in Section 3-2-2 of the *OSV Rules*.

The corner radius of the moon pool opening is not be less than 0.125 times the width of the moon-pool opening but it need not exceed 600 mm (24 in.). Free edges of the moon pool opening are to be suitably rounded in order to protect diving system umbilicals from sharp edges.

Means are to be provided to prevent personnel from falling into the moon pool.

17.11 Piping Systems *(2013)*

Piping systems carrying breathing gases under high pressure are not to be arranged inside accommodation spaces, engine rooms or similar compartments.

Piping systems carrying breathing gases are to run as far as practicable apart from electrical cable conduits.

Piping systems containing flammable fluids are not to run through enclosed spaces or open deck areas housing breathing gases.

17.13 Fire Protection

17.13.1 Diving Systems Installed in Enclosed Spaces

17.13.1(a) Enclosed spaces on dive support vessels/offshore facilities housing diving systems are to be separated from adjacent spaces by means of A-60 class bulkheads or decks. Piping and cables essential for the operation of the diving system are to be laid in separate structural ducts insulated to the A-60 class standard.

17.13.1(b) Enclosed spaces are to be provided with a separate forced ventilation system capable of providing at least eight air changes per hour. The air is to be drawn from a non-hazardous area.

17.13.2 Diving Systems Installed on Open Decks

When diving systems are installed on open decks or similar structures that are directly adjacent to Category A machinery spaces, the systems are to be separated from the machinery spaces by A-60 class bulkheads or decks.

17.15 Fire Fighting

17.15.1 External Fire Extinguishing Systems

17.15.1(a) Diving Systems Installed in Enclosed Spaces (2013)

i) Enclosed spaces on dive support vessels/offshore facilities are to be provided with manually actuated fixed fire extinguishing systems with a layout that covers the complete diving system. The fixed extinguishing system is to be either a water spray system or gas system approved for use in machinery spaces of Category A and complying with IMO MSC.1/1267 and the IMO Fire Safety Systems (FSS) Code. If a fixed gas extinguishing system is selected, the complete discharge of the extinguishing system in the enclosed space is not to result in a toxic concentration. Extinguishing agents/propellants that are carcinogenic, mutagenic, or teratogenic at the expected concentrations during use are not permitted. Agents/propellants are not to be used in concentrations greater than the cardiac sensitization NOAEL (No Observed Adverse Effect Level) and the ALC (Approximate Lethal Concentration) per IMO MSC/Circ.776.

ii) Means are to be provided for cooling the windows of PVHOs installed in enclosed spaces.

iii) Portable fire extinguishers of approved types are to be distributed throughout the enclosed space containing the diving system. One of the portable fire-extinguishers is to be stowed near the entrance to the enclosed space. Spare charges are to be provided on board for 100% of the first ten extinguishers and 50% of the remaining extinguishers installed within the enclosed space.

iv) Enclosed spaces intended for storage of breathing gas cylinders/pressure vessels are to be fitted with a manually actuated fixed water spray system with an application rate of at least 10 liters/m^2 per minute of the horizontal projected area, in order to cool and protect such cylinders/pressure vessels during fires. Alternatively, the enclosed spaces may be fitted with a water-mist system with an application rate of not less than 5 liters/m^2 per minute.

17.15.1(b) Diving Systems Installed on Open Decks

i) The areas where diving systems are situated on decks or similar structures of dive support vessels/offshore facilities, are to be equipped with fire extinguishing systems suitable for the locations and areas concerned. Fire hoses connected to the fire main of the dive support vessels/offshore facilities may be considered as providing the necessary protection.

ii) Means are to be provided for cooling the windows of PVHOs installed on open decks or similar structures.

17.15.2 External Fire Detection and Alarm Systems

17.15.2(a) Diving Systems Installed in Enclosed Spaces (2013). Enclosed spaces on dive support vessels/offshore facilities are to be provided with automatic fire detection and alarm systems suitable for the location and area concerned. For offshore support vessels, the fire detection and alarm systems are to comply with the applicable requirements of 4-7-3/11 of the *OSV Rules*.

The loop or group of detectors covering these enclosed spaces is to be independent of those for other spaces.

The fire detection panel is to be located in the vessel's position control station and is to be provided with repeaters at the dive control station and the engine control room.

17.15.2(b) Diving Systems Installed on Open Decks. The open decks or similar structures of dive support vessels/offshore facilities are to be provided with automatic fire detection and alarm systems suitable for the location and area concerned. Consideration will be given to continuous direct visual/video camera monitoring of the diving system by the dive control station personnel in lieu of fire detection and alarm systems.

SECTION 14 Atmospheric Diving Suits (ADS) and Systems *(2014)*

1 Scope

This Section, along with Sections 1 through 10, as applicable, provide the requirements for the design, fabrication and testing of tethered Atmospheric Diving Suits (ADS) and systems.

3 Definitions

3.1 Atmospheric Diving Suit (ADS)

An *ADS* is an anthropomorphic, single person suit with muscle powered articulated arms that is capable of withstanding external pressure and is designed for functions such as underwater observation, intervention, survey, inspection or other tasks. Pressure within the suit is normally maintained at or near one atmosphere.

3.3 Atmospheric Diving Suit System (ADS System)

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

5 Class Notation

New construction ADS and ADS Systems built under ABS survey are to be assigned the Class notations **✠ A1 ADS** and **✠ A1 ADS System** respectively, subject to the conditions of classification referenced in Section 1 of these Rules.

New and existing ADS and ADS Systems not built under ABS survey are to be assigned the class notation **A1 ADS** and **A1 ADS System** subject to the conditions of classification referenced in Section 1 of these Rules. (*Note:* The Maltese cross notation (✠) signifying survey under construction is to be omitted).

7 Human Occupancy Pressure Boundary Components

7.1 General

Human occupancy pressure boundary components are to meet the applicable requirements of this Section and Sections 3, 4, 5 and 6.

7.3 Personnel Access

The means of personnel ingress to or egress from the ADS are to be configured and sized appropriately to permit the pilot to enter or exit the suit with relative ease.

Safe access to the entry/exit opening is to be provided by appropriate accessory equipment or stands.

The entry/exit opening is to be fitted with a safety mechanism to prevent accidental closure during entry/exit.

The entry/exit opening is to be fitted with a locking device to secure the opening during diving operations. A safety mechanism is to be provided to prevent inadvertent opening of the locking device during diving operations.

7.5 Joints

Joints between moving pressure boundary components of the limbs are to meet the following requirements:

i) Joints are to maintain flexibility of the limb and are to permit the full range of motion at all depths up to the design depth.

ii) Moving joints are to provide a pressure tight seal under all normal operating conditions.

iii) Joints are to have a fail-safe design that, in the event of primary (moving) seal failure, will engage a secondary seal that will maintain the integrity of the pressure boundary and will prevent leakage.

iv) When in fail-safe mode, the joints may be immobilized.

9 Windows and Viewports

Windows and viewports are to meet the applicable requirements of this Section and Section 7.

Windows are to provide sufficient field of view to permit the pilot to see the arms and hands of the ADS throughout their full range of motion, as permitted by visibility.

Windows are to provide the pilot with a range of view to allow awareness of the ADS location and proximity to other objects as permitted by visibility.

11 Lifting Lugs/Attachments

11.1 Primary Lifting Lugs/Attachments

The ADS is to be provided with primary lifting lugs or attachments designed to support the entire weight of the ADS including the weight of the equipment, supplies and pilot within the ADS. They are to be designed for forces of at least 2g vertical (1g static plus 1g dynamic), 1g transverse and 1g longitudinal, unless otherwise determined by the designer, acting simultaneously under the most severe loading condition.

Where appropriate, the increased loading due to other applicable loads such as added mass and drag are to be also considered.

Calculated stresses are not to exceed those specified in 14/11.5 below.

11.3 Emergency Lifting Lugs/Attachments

Additional lifting lugs or attachments are to be provided for emergency recovery of the ADS.

The emergency lifting lugs or attachments are to be designed for lifting and raising the ADS to the surface under the heaviest emergency condition following a casualty.

Calculated stresses are not to exceed those specified in 14/11.5 below.

The design of the emergency lifting lugs or attachments is to permit secondary recovery lines to be self-attached or attached using a second ADS, an ROV or a diver.

11.5 Allowable Stresses

Calculated stresses are not to exceed the allowable stress f_a as obtained from the following equation:

$$f_a = f\eta_e$$

where

f = critical or shear stress for buckling considerations, or

= minimum specified material yield stress

η_e = usage factor as follows:

Type of Stress	η_e
Compressive or shear buckling	0.8
Axial and/or bending stresses	0.8
Shear stresses	0.53

13 Nameplates and Marking

The ADS main pressure hull component (such as the torso) is to be permanently marked to clearly indicate the design depth, maximum allowable working pressures/temperatures, hydrostatic test pressure, manufacturer's name, serial number, and year built. Markings may be on an inner or outer surface as permitted by the design of the ADS and available space.

In addition, each smaller and individual main pressure hull component (such as a body section, spacer and joint assembly) is to be permanently marked with a serial number uniquely identifying that part and clearly indicating design depth. Where practicable and space permitting, additional data such as hydrostatic test pressure, manufacturer's name, serial number, and year built may be incorporated into this marking.

All markings are to be permanently attached (name plates) or are to be engraved. They are to be of a type and configuration that will remain legible over the life of the ADS and its components.

15 Stability

Each ADS is to have adequate stability while operating underwater.

The ADS is to be configured such that it will automatically and naturally assume a normally upright or comfortable position with the pilot's head above the feet, when not influenced by the pilot's body motion or thrusters.

The ADS stability analysis, test procedures and test results are to be submitted to the Technical Office for review.

17 Position Control and Steering Systems

When thrusters are provided for position control and/or steering, the following documentation is to be submitted to the Technical Office for review:

i) Manufacturer's documentation indicating suitability of the thrusters for the design service conditions. The documentation is to include the thruster performance specification, depth rating, electrical rating, limit of temperature rise and class of insulation of the thruster motor.

ii) Evidence of satisfactory testing or service experience.

19 Navigational Equipment

ADS are to be provided with the following equipment:

i) Means to determine the depth from the surface, displayed in the ADS and at the surface

ii) External Lights

iii) Emergency locating devices (See 14/29.5 below)

21 Communication Systems

Tethered ADS are to be provided with a hard-wire communication system for two-way communication with the surface control box/station.

ADS are to be provided with an acoustic through-water communication system for two-way communication with the surface.

ADS hard-wire acoustic communication is to include means for switching at the surface by the supervisor to control communication to other systems, if applicable.

Appropriate means of electronic storage are to be provided at the surface for recording all communication with the ADS.

Communication systems are to be supplied by two independent sources of power, one of which is to be the emergency source of power.

23 Piping Systems

23.1 General

Piping systems are to meet the applicable requirements of this Section and Sections 8 and 9.

Piping/tubing are to be mechanically protected from damage.

23.3 Human Occupancy Pressure Boundary Valves

A manually operated stop valve that is accessible to the pilot is to be provided internally at all pressure boundary piping penetrations.

An additional stop valve or a check valve is to be provided for systems connected to sea suctions or discharges.

23.5 Oxygen Storage

Oxygen cylinders located on-board the ADS are to be stored outside the human occupancy pressure boundary of the ADS. There are to be at least two banks with separate penetrations entering the pressure boundary. These penetrations should be positioned so as to minimize the possibility that a single incident would cause failure of both penetrations.

Oxygen pressure is to be externally regulated, such that high pressure Oxygen does not enter the human occupancy pressure boundary of the ADS.

23.7 Pressure Relief Device

The human occupancy pressure boundary of the ADS is to be provided with a pressure relieving device to prevent the internal pressure from rising more than 10 percent above 1 ata.

25 Life Support Systems

25.1 General

Life support systems are to meet the applicable requirements of this Section and Section 8.

The ADS is to be provided with the appropriate equipment to generate, monitor and maintain suitable life support conditions inside the human occupancy pressure boundary.

The ADS is to be designed so that the concentration of O_2 (Oxygen) will be kept within the limits of 18.0 to 23.0 percent by volume.

The ADS is to be designed so that the concentration of CO_2 (Carbon Dioxide) will never exceed 0.5 percent by volume referenced to standard temperature and pressure.

As part of the analysis to demonstrate life support capacity, the ADS designer is to specify the normal ADS mission duration (including working and resting periods) as well as the reserve duration, along with the associated metabolic parameters that are applied to each of these durations.

As a minimum, the applicable metabolic parameters specified in the Table in 8/5.5 are to be used for the life support analysis.

25.3 Normal Life Support

The normal life support system is to have sufficient life support capacity for the anticipated maximum mission duration, including consideration of the metabolic workload(s). The anticipated maximum mission duration is to be defined by the ADS designer, but is not to be less than 6 hours.

The normal life support system is to include two independent Oxygen banks (supplies) and piping systems. One of the two independent Oxygen banks is to have sufficient Oxygen capacity to support the anticipated maximum mission duration. The remainder of the Oxygen capacity in the two independent banks (after considering the anticipated maximum mission duration) is to be sufficient to support the reserve mission duration as defined in 14/25.5 below.

The normal life support system is to include at least one Carbon Dioxide (CO_2) removal system. The scrubber of the CO_2 removal system is to have sufficient absorbent material capacity to support the anticipated maximum mission duration as well as the reserve duration defined in 14/25.5 below.

The CO_2 removal system may consist of a powered blower type circulation system or a lung powered arrangement using an oral nasal mask or a full-face mask.

25.5 Reserve Life Support

The ADS is to be provided with an on-board reserve of life support capacity.

The reserve life support capacity is to be sufficient for a duration that is consistent with the emergency rescue plan but is not less than 24 hours (over and above the anticipated maximum mission duration).

Under reserve conditions, the CO_2 removal system is to be capable of maintaining the concentration of CO_2 below 0.5 percent by volume.

25.7 Emergency Life Support System Operation

At least one of the ADS life support systems is to be provided with the capability to remain operational for at least 6 hours in emergency situations, where all surface connections and surface power are lost.

Actuation of internal controls intended for emergency operation are to be fully manual.

For emergency operation, the CO_2 removal system is to be capable of being used in a lung powered mode using an oral nasal mask or a full-face mask.

Under emergency conditions, the CO_2 removal system is to be capable of maintaining the concentration of CO_2 below 1.5 percent by volume.

25.9 Life Support Instrumentation

The ADS is to be provided with the following instrumentation for monitoring the life support conditions within the human occupancy pressure boundary of the ADS:

i) Oxygen analyzer

ii) Carbon Dioxide analyzer

iii) Temperature measurement device

iv) Suit internal pressure gauge

In addition to the above instrumentation, displays or gauges are to be provided to show the breathing gas cylinder supply side high pressure and regulated low pressure supply to the human occupancy pressure boundary of the ADS.

27 Electrical Systems

27.1 General

Electrical systems of the ADS are to meet the applicable requirements of this Section and Section 10.

Cables/wiring are to be mechanically protected from damage.

27.3 Normal Power

The ADS is to be provided with a normal source of power supply with sufficient capacity for the anticipated maximum mission duration.

27.5 Emergency Power

The ADS is to be provided with an on-board source of emergency power.

The emergency power supply is to be independent of the normal source of power supply and is to be capable of remaining operational in emergency situations, where all surface connections and surface power are lost.

The emergency power supply is to have sufficient capacity to provide electrical power to the emergency equipment, including as a minimum the life support instrumentation and communication systems, for the duration specified in 14/25.5 above.

Emergency power may be in the form of individual batteries for emergency devices, as opposed to a single source of supply.

29 Emergency Equipment and Systems

29.1 Emergency Surfacing System

The ADS is to be provided with an emergency surfacing system.

This system is to permit the ADS to ascend to the surface when disconnected from its tether/umbilical. The system is to provide positive buoyancy sufficient to ascend to the surface from any operational depth.

Emergency ascent calculations (addressing the net positive buoyancy provided and the resultant ascent rate) are to be submitted to the Technical Office for review.

Emergency surfacing system activation is to require at least two positive manual actions for operation and is to be independent of electrical power.

The emergency surfacing system is to operate properly under all anticipated conditions of heel and trim.

29.3 Entanglement

External attachments and equipment are to be configured to minimize the risk of entanglement.

Thrusters, when fitted, are to be provided with means of jettisoning them from the ADS by the pilot. The means of jettisoning is to require at least two positive manual actions for operation. As an alternative to jettisoning, consideration may be given to the availability of other ADS, underwater vehicles or assets having rescue capability to free the ADS from entanglement.

29.5 Emergency Locating Devices

The ADS is to be provided with a strobe light that serves as a surface emergency locating device.

The ADS is to be also provided with an acoustic transponder that serves as the subsurface emergency locating device. The locating device is to be suitable for operation with a diver-held interrogator-receiver which is to be retained on-board the support vessel. The equipment is to be designed to operate in accordance with Section 2.12.5 of IMO Resolution A.831 (19) "Code of Safety for Diving Systems" (see Appendix 1).

Electrically operated locating devices are to be powered by a self-contained power source suitable for not less than 24 hours of operation. Alternatively, the locating devices are to be powered by the emergency power supply of the ADS.

31 Umbilicals/Tethers

Umbilicals and/or tethers are to be securely attached to the ADS by means of strength members or strain relief fittings, so that individual electrical and/or optical connections are not subjected to tensile loads.

When the strength member of the umbilical/tether supports the weight of the ADS in air, the strength member and strain relief fitting is to meet the applicable requirements of Section 17, "Handling Systems".

When the strength member of the umbilical/tether does not support the weight of the ADS in air, the strength member and strain relief fitting are to be configured to support the anticipated design loading conditions.

Umbilicals/tethers are to be provided with means of disconnecting them from the ADS by the pilot. The means of disconnecting is to require at least two positive manual actions for operation. As an alternative to disconnection, consideration may be given to the availability of other ADS, underwater vehicles or assets having rescue capability.

The length of umbilicals/tethers are to be appropriate for the design depth of the ADS and are to include extra length for re-termination of the umbilicals/tethers.

33 ADS Control Boxes/Stations

33.1 Control Boxes

ADS control boxes, when provided, are to have sufficient controls and displays to monitor and control the ADS operations.

33.3 Control Stations

ADS control stations, when provided, are to meet the requirements of Section 18, "Dive Control Stations", as applicable to the ADS.

Sufficient controls and displays are to be provided in the ADS control stations to monitor and control the ADS operations.

ADS control stations are to be provided with two-way direct communication with the following positions, as applicable:

- Navigation bridge of the vessel/offshore facility
- ADS handling system
- Control station for the dynamic positioning system of the vessel/offshore facility
- Control stations for other underwater vehicles/systems (ROVs, Diving Systems, etc.) operated from the same support vessel/offshore facility
- Control stations for subsea equipment (such as well intervention equipment) operated from the same support vessel/offshore facility

Shipping containers used for housing ADS control stations are to meet the applicable requirements of the ABS *Rules for Certification of Cargo Containers*. Special consideration will be given to containers that are designed and fabricated to other recognized industry standards that are not less effective than the Rules.

35 Utility Vans

Shipping containers used for housing ADS machinery, tools, spares, etc., that are part of a classed ADS System are to meet the applicable requirements of the ABS *Rules for Certification of Cargo Containers*. Special consideration will be given to containers that are designed and fabricated to other recognized industry standards that are not less effective than the Rules.

37 Handling Systems

Handling systems for launch and recovery of the ADS, that are part of a classed ADS System, are to meet the applicable requirements of Section 17, "Handling Systems".

39 Tests

The test procedures for the testing are to be submitted to the Technical Office for review prior to the testing. Upon completion of the testing, the test results are to be submitted to the Technical Office for review.

39.1 Hydrostatic Proof Testing

The human occupancy pressure boundary of the ADS is to be hydrostatically proof tested in accordance with the applicable requirements of Subsection 3/3, "Proof Testing".

39.3 Life Support Testing

After the ADS is completely outfitted and before conducting the test dive, the life support system is to be tested in the presence of the Surveyor.

Such testing is not required for ADS that are duplicates (100% identical) of a previously tested ADS.

The life support testing is to include the following tests:

i) A manned test or simulated occupancy test is to be conducted to determine time to CO_2 scrubber breakthrough, where breakthrough is defined as a CO_2 concentration of 0.5 percent by volume referenced to standard temperature and pressure. The test may be continued beyond a CO_2 concentration of 0.5 percent (up to a maximum of 1 percent) to ensure that breakthrough is reached. The time required to achieve breakthrough is to be used in confirming the quantity of CO_2 absorbent required to be carried on-board the ADS. During testing, the Carbon Dioxide (CO_2) levels are to be monitored and recorded at intervals not exceeding 15 minutes.

ii) A manned test is to be conducted until equilibrium is achieved by the CO_2 scrubber, plus an additional one hour. This test is to be conducted for a minimum of three hours in all cases. The test is to demonstrate that O_2 and CO_2 levels, internal cabin pressure and temperature can be maintained within required parameters. During testing, the Oxygen (O_2) and Carbon Dioxide (CO_2) levels, the internal cabin pressure and temperature are to be monitored and recorded at intervals suitable to verify the life support system design but not exceeding 15 minutes. The monitored parameters are to be within acceptable ranges to the satisfaction of the Surveyor.

39.5 Functional Demonstration Dive

Each ADS is to be subjected to manned functional testing in the presence of the Surveyor.

The testing may be conducted at shallow depths (e.g., in a test tank).

The functional testing is to demonstrate satisfactory performance of life support systems, position control and steering systems, electrical systems, and other items required for safe operation of the ADS.

39.7 Test Dive

Each ADS is to be subjected to a test dive to the design depth in the presence of the Surveyor. The test dive is to be conducted with the ADS manned to verify proper operation of the joints and controls at depth.

During the test dive, the ADS is to be visually inspected at a depth of approximately 30.5 m (100 ft) before proceeding to greater depths. The submergence is then to be increased in increments of approximately 20 percent of the design depth until design depth is reached. At each 20 percent increment, constant depth is to be maintained while the ADS is visually inspected.

Where the depth of water available is less than the design depth, both the rated depth (depth reached during test dive) and the design depth will be indicated in the *Record*. The rated depth may subsequently be increased by performing a test dive to a greater depth, not exceeding the design depth, in the presence of the Surveyor. In-lieu of a separate dive solely for testing purposes, the test dive may be a working dive as part of a diving operation, provided it is witnessed by the attending Surveyor.

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SECTION 15 Remotely Operated Vehicles (ROVs) *(2014)*

1 Scope

This Section, along with Sections 1 through 10, as applicable, provides the requirements for the design, fabrication and testing of Remotely Operated Vehicles (ROVs).

3 Class Notation

New construction ROVs, hybrid ROVs and ROV Systems built under ABS survey are to be assigned the Class notations ✠ **A1 ROV, Class *X***, ✠ **A1 HROV, Class *X***, and ✠ **A1 ROV System, Class *X***, respectively, subject to the conditions of classification referenced in Section 1 of these Rules. (*Note:* "***X***" represents the Roman numerals "I, II, III, IV or V", depending on the category of the ROV (See Subsection 15/7 below). For example, a work class ROV would receive the Class notation ✠ **A1 ROV, Class III**.)

New and existing ROVs, hybrid ROVs and ROV Systems not built under ABS survey are to be assigned the class notation **A1 ROV, Class *X***, **A1 HROV, Class *X***, and **A1 ROV System, Class *X*** subject to the conditions of classification referenced in Section 1 of these Rules. (*Note:* The Maltese cross notation (✠) signifying survey under construction is to be omitted).

5 Definitions

5.1 Remotely Operated Vehicle (ROV)

An *ROV* is a tethered unmanned unit designed for functions such as underwater observation, survey, inspection, construction, intervention or other tasks.

5.3 Hybrid Remotely Operated Vehicle (HROV)

A hybrid unit that incorporates features of both ROVs and AUVs and can be operated in either ROV mode or AUV mode.

5.5 ROV System

An *ROV System* includes the ROV and associated support systems such as the handling system and ROV control station.

7 ROV Categorization

7.1 Class I (Pure Observation)

Pure observation ROVs are primarily employed for underwater video observation. In general, they are small vehicles fitted with video cameras, lights and thrusters.

In order to undertake tasks other than video monitoring, they would need considerable modification.

7.3 Class II (Observation with Payload Option)

Class II ROVs include ROVs capable of carrying additional sensors (over and above those carried by Class I ROVs) such as data measurement instrumentation, sonar systems, additional video cameras, still cameras, etc. In general, they are somewhat larger than Class I ROVs.

Class II ROVs are to be capable of carrying additional payload without loss of functional capabilities.

7.5 Class III (Work Class Vehicles)

Work class ROVs are primarily employed for conducting work while submerged in the water column. In general, these ROVs are larger and more powerful than Class I and II ROVs. These vehicles are large enough to carry additional sensors and/or manipulators.

Class III vehicles commonly have multiplexing capability that allows additional sensors and tools to be added to the ROV and operated, without the need for being separately hardwired through the umbilical.

7.7 Class IV (Seabed-working Vehicles)

Seabed-working vehicles generally operate on the seafloor. These vehicles travel/maneuver using wheels, belt traction systems, thrusters, water jets or by combinations of these methods.

In general, Class IV ROVs are larger and heavier than Class III ROVs. These vehicles are configured for special purpose tasks. Such tasks typically include cable and pipeline trenching, excavation, dredging or other seafloor construction work.

7.9 Class V (Prototype or Development Vehicles)

Vehicles in this category include those that are being developed for special applications and those that are regarded as prototypes. Special-purpose vehicles that do not fit into one of the other categories specified above may also be designated as Class V ROVs.

9 Pressure Boundary Components

Pressure boundary components are to be certified by the manufacturer as being suitable for the intended service.

11 External Structures

11.1 General

External structures include all non-pressure retaining structural members located outside metallic pressure boundary components (e.g., frames, hydrodynamic fairings, brackets, lugs, etc.).

In order to avoid the detrimental effects of buoyancy, all free flooding external structures are to be designed so that all their inner spaces are fully floodable and ventable. Suitable openings in the uppermost and lowermost parts of the structures are to be provided. Flood and vent openings are to be properly dimensioned to ensure free circulation of water.

11.3 Corrosion Protection

Metallic external structures are to be provided with appropriate means to manage/mitigate corrosion, marine growth and galvanic action.

11.5 Mechanical Protection

ROVs are to be provided with adequate mechanical protection to protect the critical components during handling operations and other normal or emergency operations.

11.7 Frames

Frames, when provided, are to be of adequate construction, consideration being given to their size and the loads which may be imposed upon them.

Loads to be considered include those which result from bottoming, striking objects, wave slap, bumping alongside the tender, and other loads resulting from being launched and recovered in sea state 6 (see Section 17, Table 1). A lesser sea state may be considered when it is intended that the ROV be operated with a launch and recovery system whose design parameters are less than sea state 6.

When it is intended to carry out hydrostatic testing of pressure boundary components when they are installed on the support frames, the maximum static load due to the hydrostatic testing is to also be considered in the design.

The calculated stresses are not to exceed the allowable stress f_a as obtained from the following equation:

$$f_a = f\eta_e$$

where

f = critical or shear stress for buckling considerations, or

= minimum specified material yield stress

η_e = usage factor as follows:

Type of Stress	η_e
Compressive or shear buckling	0.8
Axial and/or bending stresses	0.8
Shear stresses	0.53

11.9 Lifting Lugs/Attachments

The lifting lugs/attachments used for launch and recovery of ROVs are to be designed for forces of at least 1.75g vertical (1g static plus 0.75g dynamic), 0.75g transverse and 0.75g longitudinal, unless otherwise determined, acting simultaneously under the most severe loading condition. Where appropriate, the increased loading due to other applicable loads such as entrained water and mud, added mass and drag are to be also considered. Calculated stresses are not to exceed those specified in 15/11.7 above.

Removable equipment on ROVs are to be provided with lifting lugs/attachments to facilitate their easy retrieval.

11.11 Towing Attachments

For towed ROVs, an accessible towing point, appropriately sized for the anticipated conditions is to be provided.

13 Nameplates

ROVs are to be fitted with permanent nameplates indicating their design depth, maximum allowable working pressures/temperatures, hydrostatic test pressure, manufacturer's name, serial number, and year built. The nameplates are to be stainless steel or other suitable material and are to be permanently attached to the ROV.

15 Emergency Recovery Features

ROVs are to be provided with permanent features for the attachment of recovery equipment. It is to be demonstrated by appropriate analysis that recovery feature attachments are adequate for lifting and raising the ROV to the surface, under the heaviest emergency condition following a casualty. The analysis is to include consideration of entrained water, mud and sand.

17 Variable Ballast Systems

Variable ballast systems, when provided, are to have ballasting/deballasting capabilities and the capability to compensate for all loading conditions.

Hard ballast tanks subject to internal and/or external pressure, when provided, are to meet the requirements of Subsection 15/9 above.

19 Stability

ROVs are to have adequate stability while operating underwater or on the surface.

21 Propulsion and Steering Systems

21.1 General

ROVs are to be provided with appropriate means of propulsion and steering.

21.3 Thrusters

Thrusters are to be certified by the manufacturer as being suitable for the intended service.

23 Navigational Equipment/Systems

As a minimum, ROVs are to be provided with the following navigational equipment / systems:

i) Cameras for navigation

ii) External lights

iii) Means to determine the depth from the surface

iv) Emergency locating devices (See Subsection 15/25 below)

25 Emergency Locating Devices

ROVs are to be provided with a surface locating device (such as a strobe light) and a subsurface locating device (such as an acoustic pinger, sonar reflector or buoy).

Acoustic subsurface locating devices are to be compatible with the navigational/positing keeping systems onboard the support vessel/offshore platform.

27 Communication Systems

ROVs are to be provided with appropriate means of communication to enable the transmittal of data from the onboard sensors/equipment to and/or from the Control Box/Dive Control Station.

29 Piping Systems

Piping systems, when provided, are to meet the applicable requirements of this Section and Section 9.

Piping systems are to be mechanically protected from damage.

31 Umbilicals/Tethers

31.1 General

Umbilicals are to be securely attached to ROVs by means of strength members or strain relief fittings so that individual electrical connections are not subjected to tensile loads.

The length of umbilicals is to be appropriate for the design depth of the ROV and is to include extra length for re-termination of the umbilicals.

When the strength member of the umbilical supports the weight of the ROV, the strength member is to meet the applicable requirements of Section 17, "Handling Systems".

31.3 Tether Management System (TMS)

Tether management systems, when provided, are to meet the following requirements:

i) The TMS is to be provided with an appropriate means to house and secure the ROV during launch and recovery operations and travel through the water column.

ii) Where applicable, the TMS frame is to be capable of accommodating additional packages or equipment (such as tool packages).

iii) The TMS frame is to meet the applicable requirements of Subsection 15/11. Lifting lugs, when installed, are to meet the requirements of 15/11.9. The TMS frame and lifting lugs are to be designed for lifting the fully outfitted ROV and additional packages when subjected to a dynamic factor of at least 1.75g vertical, 0.75g transverse and 0.75g longitudinal, unless otherwise determined, acting simultaneously under the most severe loading condition.

iv) The TMS is to be provided with a tether spooling mechanism to store and deploy the ROV excursion tether. The spooling mechanism may be fitted on the TMS frame. Means are to be provided for monitoring the length of the excursion tether spooled out by the spooling mechanism.

v) The spooling mechanism is to be designed for the applicable design loads.

33 Electrical Systems

Electrical systems are to meet the applicable requirements of this Section and Section 10.

Electrical systems are to be mechanically protected from damage.

When electrical systems use voltages above 1000V AC or DC, additional precautions are to be taken to protect personnel (see 10/7.3).

When ROVs are intended for operating in hazardous areas, the electrical equipment on the ROV is to meet the requirements of 10/3.5.

35 Access to Equipment

Adequate access space for maintenance and handling is to be provided around the equipment and tools of ROVs.

37 ROV Control Boxes or Stations

Each ROV/ROV System is to be provided with a control box or control station for monitoring and controlling ROV operations, as applicable.

37.1 ROV Control Boxes

ROV control boxes are to be provided with sufficient controls and displays to efficiently and reliably control the operations and functioning of ROVs.

37.3 ROV Control Stations

i) ROV control stations, when provided, are to meet the applicable requirements of Section 18, "Dive Control Stations".

ii) Sufficient controls and displays are to be provided in ROV control stations to efficiently and reliably control the operations and functioning of ROVs.

iii) Shipping containers used for housing portable ROV control stations are to meet the applicable requirements of the ABS *Rules for Certification of Cargo Containers*. Special consideration will be given to containers that are designed and fabricated to other recognized industry standards that are not less effective than the Rules

39 Handling Systems

Each ROV System is to be provided with a handling system to ensure safe transportation of the ROV to and from the subsea work location.

Handling systems for ROV Systems are to meet the applicable requirements of Section 17, "Handling Systems".

Handling systems for ROV Systems are to be designed to permit safe operation in the design sea state when the support vessel/offshore facility is rolling, pitching or heaving. The most probable extreme values of amplitude due to predetermined motions of the dive support vessel/offshore facility is to be used in the design.

41 Hybrid Remotely Operated Vehicles (HROVs)

HROVs are to also meet the appropriate requirements for AUVs (see Section 16), as applicable to the specific design.

43 Tests

ROVs and ROV Systems are to be subjected to the following tests in the presence of the Surveyor:

i) Hydrostatic testing of piping systems (see Subsection 9/7) and umbilicals (see Subsection 8/13)

ii) Insulation resistance testing of electrical equipment rated at or above 440V AC or DC

iii Functional testing of all instrumentation, equipment and systems

iv) Load testing of handling systems

v) Sea trials

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SECTION 16 Autonomous Underwater Vehicles (AUV) *(2014)*

1 Scope

This Section, along with Sections 1 through 10, as applicable, provides the requirements for the design, fabrication and testing of Autonomous Underwater Vehicles (AUVs).

3 Class Notation

New construction AUVs and hybrid AUVs built under ABS survey are to be assigned the Class notation ✠ **A1 AUV** and ✠ **A1 HAUV** respectively, subject to the conditions of classification referenced in Section 1 of these Rules.

New and existing AUVs and hybrid AUVs not built under ABS survey are to be assigned the class notation **A1 AUV** and **A1 HAUV** respectively, subject to the conditions of classification referenced in Section 1 of these Rules. (*Note:* The Maltese cross notation (✠) signifying survey under construction is to be omitted).

5 Definitions

5.1 Autonomous Underwater Vehicle (AUV)

An *AUV* is an unmanned untethered unit, designed to operate autonomously and carry out functions such as underwater observation, survey, inspection, intervention or other tasks.

5.3 Hybrid Autonomous Underwater Vehicle (HAUV)

A hybrid unit that incorporates features of both AUVs and ROVs and can be operated in either AUV mode or ROV mode.

7 Pressure Boundary Components

Pressure boundary components are to be certified by the manufacturer as being suitable for the intended service.

9 External Structures

9.1 General

External structures include all non-pressure retaining structural members located outside metallic pressure boundary components (e.g., frames, hydrodynamic fairings, brackets, lugs, etc.).

In order to avoid the detrimental effects of buoyancy, all free flooding external structures are to be designed so that all their inner spaces are fully floodable and ventable. Suitable openings in the uppermost and lowermost parts of the structures are to be provided. Flood and vent openings are to be properly dimensioned to ensure free circulation of water.

9.3 Corrosion Protection

Metallic external structures are to be provided with appropriate means to manage/mitigate corrosion, marine growth and galvanic action.

9.5 Mechanical Protection

AUVs are to be provided with adequate mechanical protection to protect the critical components during handling operations and other normal or emergency operations.

9.7 Frames

Frames, when provided, are to be of adequate construction, consideration being given to their size and the loads which may be imposed upon them.

Loads to be considered include those which result from bottoming, striking objects, wave slap, bumping alongside the tender, and other loads resulting from being launched and recovered in sea state 6 (see Section 17, Table 1). A lesser sea state may be considered when it is intended that the AUV be operated with a launch and recovery system whose design parameters are less than sea state 6.

When it is intended to carry out hydrostatic testing of pressure boundary components when they are installed on the support frames, the maximum static load due to the hydrostatic testing is to also be considered in the design.

The calculated stresses are not to exceed the allowable stress f_a as obtained from the following equation:

$$f_a = f\eta_e$$

where

f = critical or shear stress for buckling considerations, or

= minimum specified material yield stress

η_e = usage factor as follows:

Type of Stress	η_e
Compressive or shear buckling	0.8
Axial and/or bending stresses	0.8
Shear stresses	0.53

9.9 Lifting Lugs/Attachments

The lifting lugs/attachments used for launch and recovery of AUVs, when provided, are to be designed for forces of at least 1.75g vertical (1g static plus 0.75g dynamic), 0.75g transverse and 0.75g longitudinal, unless otherwise determined, acting simultaneously under the most severe loading condition. Where appropriate, the increased loading due to other applicable loads such as entrained water and mud, added mass and drag are to be also considered. Calculated stresses are not to exceed those specified in 16/9.7 above.

11 Nameplates

AUVs are to be fitted with permanent nameplates indicating their design depth, maximum allowable working pressures/temperatures, hydrostatic test pressure, manufacturer's name, serial number, and year built. The nameplates are to be stainless steel or other suitable material and are to be permanently attached to the AUV.

13 Variable Ballast Systems

Variable ballast systems, when provided, are to have ballasting/deballasting capabilities and the capability to compensate for all loading conditions.

Hard ballast tanks subject to internal and/or external pressure, when provided, are to meet the requirements of Subsection 16/7 above.

15 Stability

AUVs are to have adequate stability while operating underwater or on the surface.

The stability analysis for AUVs is to take into consideration the maximum payload that the vehicle is capable of carrying.

17 Emergency Surfacing System

AUVs are to be provided with an emergency surfacing system or are to be inherently positively buoyant.

The emergency surfacing system, when provided, is to be independent of the normal means of surfacing and is to be capable of operating in the event of failure of the main source of power.

19 Propulsion and Steering Systems

19.1 General

AUVs are to be provided with appropriate means of propulsion and steering.

19.3 Thrusters

Thrusters are to be certified by the manufacturer as being suitable for the intended service.

21 Control Systems

21.1 General

AUVs are to be provided with the appropriate equipment to facilitate autonomous operation of the vehicle under the design conditions.

21.3 Emergency Operations

AUV control systems are to have the capability to abort the mission and return to the surface/ pre-determined location based on specific commands from the operator or resume the mission when the failure/malfunction has been resolved.

23 Navigational Equipment/Systems

AUVs are to be provided with the appropriate equipment/systems that enable the vehicle to determine its three dimensional position in hydrospace while on the surface or underwater.

As a minimum, the following navigational equipment/systems are to be provided:

i) Means to determine heading and position

ii) Means to determine roll and pitch

iii) Emergency locating devices (See Subsection 16/25 below)

25 Emergency Locating Devices

AUVs are to be provided with a surface locating device (such as a strobe light) and a subsurface locating device (such as an acoustic pinger, sonar reflector or buoy).

27 Piping Systems

Piping systems, when provided, are to meet the applicable requirements of this Section and Section 9.

Piping systems are to be mechanically protected from damage.

29 Electrical Systems

29.1 General

Electrical systems are to meet the applicable requirements of this Section and Section 10.

Electrical systems are to be mechanically protected from damage.

When AUVs are intended for operating in hazardous areas, the electrical equipment on the AUV is to meet the requirements of 10/3.5.

29.3 Power Supply

The on-board source of power is to have adequate capacity for the mission duration.

31 Hybrid Autonomous Underwater Vehicles (HAUVs)

HAUVs are to also meet the appropriate requirements for ROVs (see Section 15), as applicable to the specific design.

33 Tests

AUVs are to be subjected to the following tests in the presence of the Surveyor:

i) Hydrostatic testing of piping systems (see Subsection 9/7)

ii) Insulation resistance testing of electrical equipment rated at or above 440 V AC or DC

iii) Functional testing of all instrumentation, equipment and systems

iv) Sea trials

SECTION 17 Handling Systems

1 Definitions *(2009)*

1.1 Handling System (Launch and Recovery System) *(2002)*

A system supporting launch, recovery and other handling operations of underwater units, hyperbaric facilities and their ancillary equipment and may include cranes, booms, masts, frames, davits, foundations, winches and associated hydraulic and electrical systems as necessary for the intended operations.

1.3 Rated Load or Safe Working Load *(2009)*

The rated load or safe working load is the maximum load that the assembled handling system is certified to lift at its rated speed when the outermost layer of rope or umbilical is being wound on the winch drum, under the parameters specified in the equipment specifications (e.g., hydraulic pressures, electrical current, electrical voltages, etc.).

1.5 Design Load *(2009)*

The design load is the maximum expected load on the handling system which consists of an appropriate combination of the rated load (see 17/1.3), dynamic effects associated with the rated load, weight of the rigging (hooks, blocks, deployed rope, etc.) and other applicable loads such as, wind load, drag, added mass effect and weight of entrained mud and water. See also Subsection 17/7.

1.7 Rigging *(2009)*

Rigging is a general term for all ropes and other gear (hooks, blocks, etc.) used in handling systems.

1.7.1 Running Rope

Running rope consists of moving or movable rope (wire rope, fiber or synthetic line) that passes over sheaves or through rollers and is used for hoisting, lowering or moving equipment.

1.7.2 Standing Rope

Standing rope consists of non-moving or non-movable rope that provides support to the structures of the handling system such as the A-frame, masts, etc.

1.7.3 Rotation-Resistant Rope

A rope designed to resist spin or rotation under load.

3 Submissions of Plans, Calculations and Data

(2011) Before commencement of fabrication, plans and other documents indicating the required particulars are to be submitted. Plans should generally be submitted electronically to ABS. However, hard copies will also be accepted.

3.1 Plans *(2009)*

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

- General arrangements showing the equipment locations and indicating the safe working load of the assembled handling system
- Details indicating sizes, sections, and locations of all structural members

- Winch drum and flange details
- Material specifications
- Dimensioned weld joint details
- Welding procedures and NDT methods
- Type and size of rivets, bolts, and foundations
- Foundation and support arrangements
- Hydraulic piping systems, materials, sizes, details of fittings, and valves and overpressure protective devices
- Electrical systems, cable, and wiring types and sizes, nominal characteristics and overcurrent protection settings of all electrical protections
- Rope sizes and data indicating material, construction, quality, and breaking strength
- Manufacturer's ratings, braking capabilities, and power drive requirements for electrical, hydraulic, and mechanical equipment
- Details of emergency source of power

3.3 Documentation

The following documentation is to be submitted for review, as applicable to the particular design features:

- A schematic or logic diagram giving the sequence of handling operations
- Operating procedures
- Procedures for operating normal and emergency electric, pneumatic and hydraulic power supplies
- List of degrees of enclosure of all electrical components
- List of materials, fittings, contacts and support for all components
- Electric feeder list
- Motors and battery characteristics

3.5 Design Analyses and Data

Design stress analysis, based on recognized engineering analytical methods and including environmental conditions, load plans indicating loads, shears, moments and forces for all rope members, strength welds, and connections including interaction forces with the supporting deck are to be submitted. (When the results of computer calculations are submitted, input data, summaries of input and program assumptions, output data, and summaries of conclusions drawn from the output data are to be included as part of the design analysis.) In addition, the following analyses are to be submitted as applicable to the particular design features.

- Foundation stress analysis
- Electric load and electric fault analysis including power source and power requirements
- Standard wiring practice and details, including such items as cables, wires, conduit sizes and their support, cable splicing, watertight and explosion proof connections
- Strain gage measurements may be required for novel designs or in association with acceptance of computer data

5 Manuals

5.1 Operating Manuals

An operating manual describing normal and emergency operational procedures is to be provided and is to be submitted for review. The manual is to include the following as applicable.

- Operation check-off list (to include list of equipment requiring maintenance or inspection prior to each operation and verification of the existence of appropriately updated maintenance schedule. (See 17/5.3.)
- System description
- Electrical system description
- Hydraulic system description
- Pneumatic system description
- Sea state capabilities
- Maximum dynamic loads
- Handling operating procedures
- Liaison with support vessel
- Emergency procedures developed from system analysis for situations such as power failure, break in lifting cable, break in umbilical cord, loss of communication, etc.
- Special restrictions based on uniqueness of design and operating conditions

5.3 Maintenance Manual

A maintenance manual containing procedures for periodic inspection and preventive maintenance techniques is to be submitted for review.

The manual is to include the expected service life of vital components/equipment along with particular instructions for the maintenance of items requiring special attention.

5.5 Availability *(2007)*

The operating and maintenance manuals together with operational and maintenance records are to be readily available at the operation site and copies are to be made available to the Surveyor upon request. Summarized procedures for normal and emergency operations and essential drawings are to be carried with the unit.

7 Design

Design calculations are to be based on recognized standards or recognized engineering methods, which are to be clearly referenced in the required calculations. Some recognized analytic methods are contained in "Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings Part I," published by the American Institute of Steel Construction and "Specifications for Aluminum Structures," published by the Aluminum Association.

7.1 Factors of Safety

7.1.1 Wire Rope *(2009)*

The factor of safety is to be not less than 5 for both conventional and rotation-resistant running rope. The factor of safety for standing rope is to be not less than 4.0. These factors of safety are to be based on the design load of the system as compared to the minimum breaking strength of the rope.

7.1.2 Fiber and Synthetic Rope *(2009)*

Safety factors for fiber and synthetic rope except nylon are to be not less than 7.0 for running rope and 5.0 for standing rope based on the design load of the system as compared to the minimum breaking strength of the rope. Safety factors for nylon rope are to be not less than 9.0 for running rope and 7.0 for standing rope.

7.1.3 Structural Members in Axial Tension or Compression

Individual stress components for members in tension or compression are not to exceed the allowable stress obtained from the following equations:

$$F_a = F_y/1.33 \qquad \text{if } F_y/F_u \le 0.7$$

$$F_a = (F_y + F_u)/3.25 \qquad \text{if } F_y/F_u > 0.7$$

where

F_y = minimum specified yield strength of the material

F_u = minimum specified tensile strength of the material

7.1.4 Structural Members in Bending

Individual bending stress for members in bending is not to exceed the allowable stress specified in 17/7.1.3.

7.1.5 Structural Members Subject to Shear

The shear stress for members subject to shear is not to exceed the allowable stress obtained from the following equation:

$$F_s = 0.577F_a$$

7.1.6 Structural Members Subject to Combined Axial Compression and Bending

When structural members are subjected to axial compression in combination with compression due to bending the computed stresses are to comply with the following requirement:

$$(f_a/F_a') + (f_b/F_b) \le 1.0$$

where

f_a = computed axial compressive stress

f_b = computed bending stress (compressive)

F_a' = allowable compressive stress, which is to be the least of the following:

i) F_a value as obtained from 17/7.1.3 for axial stress.

ii) F value as obtained from 17/7.1.11 for buckling.

F_b = allowable compressive stress due to bending as specified in 17/7.1.4.

Note: Above criterion for combined axial compression and compression due to bending is applicable when f_a/F_a' is less than or equal to 0.15. Otherwise, formulation in Section 1.6 of AISC "Specifications for the Design Fabrication and Erection of Structural Steel for Buildings Part 1" is to be followed.

7.1.7 Structural Members Subject to Axial Tension and Bending

When structural members are subjected to axial tension combined with tension due to bending, the computed stresses are to comply with the following requirement:

$$f_a + f_b \le F_a$$

where F_a is defined in 17/7.1.3.

7.1.8 Riveted Joints

Rivets are not to be subjected to tension. Riveted joints are to have at least two rivets aligned in the direction of the force. The computed shear stress is not to exceed the allowable stress, F_s, as obtained from the following equations:

$F_s = 0.6F_a$ (single shear)

$F_s = 0.8F_a$ (multiple shear)

The computed bearing pressure on walls of holes is not to exceed the allowable stress, F_N, as obtained from the following equations:

$F_N = 1.5F_a$ (single shear)

$F_N = 2.0F_a$ (multiple shear)

7.1.9 Bolted Joints

The computed stresses in bolts are not to exceed the following allowable values:

Tension:	$F_T = 0.65F_a$	
Shear:	$F_s = 0.6F_a$	(single shear)
	$F_s = 0.8F_a$	(multiple shear)
Combined:	$(F_T^2 + 3F_s^2)^{1/2} = F_a$	

The computed bearing pressure on walls of holes is not to exceed the allowable stress, F_N, as obtained from 17/7.1.8.

7.1.10 Structural Members Subject to Crippling

The computed crippling of the structural member is not to exceed 75% of the yield stress.

7.1.11 Structural Members Subject to Buckling

When buckling of a structural member due to compressive or shear stresses or both is a consideration, the compressive or shear stress is not to exceed the allowable stress, F, as obtained from the following equations:

$F = F_{cr}/1.25$ (for flat members)

$F = F_{cr}/1.55$ (for curved members)

where

F_{cr} = critical buckling stress in compression or shear of the structural member, appropriate to its dimensional configuration, boundary condition, loading pattern, material, etc.

7.1.12 Aluminum

Tensile and yield strengths for welded aluminum alloys are to be in accordance with 5/9.3.

7.1.13 Chains

Chains are to have a safety factor of 4.5 based on their minimum specified ultimate strength. Chains are not to be subjected to torsional loads.

7.3 Design Loads *(2008)*

The following loads and forces are to be taken into account when designing structural members and joints.

7.3.1 Dead Load

The minimum dead load assumed in design is to consist of the weight of structural parts of the launch and recovery system and materials permanently attached to the structure.

7.3.2 Live Load

The live load is to be based on the maximum weight in air of the underwater vessel or related systems together with all weights, including personnel, tools, consumables, and water in the vessel to be carried by the system.

7.3.3 Other Loads

Added mass, entrained water and mud, etc.

7.3.4 Dynamic Loads

These are loads produced by accelerations in the vertical, longitudinal and transverse directions. As a minimum, loads resulting from simultaneous accelerations of 1 g (in addition to static gravitational acceleration – a total of 2 g) vertical, 1 g transverse, and 1 g longitudinal are to be used for design except for handling systems intended solely for units not associated with manned operations (e.g., ROV launch and recovery systems) in which case the foregoing minimum dynamic loads may be reduced by 25 percent (to 1.5 g, 0.75 g and 0.75 g). For permanently installed systems, consideration may be given to lesser loads where it can be shown that the maximum expected loads are less than those given above.

7.3.5 Wind Forces

The wind load on the projected area of the structure is to be considered as a design assumption at a value appropriate to the design conditions.

7.3.6 Maximum Forces

Structural members are to be determined using the maximum appropriate combination of the loads and factors of safety above.

7.5 Structural Members

Structural members are not to be less than 6.4 mm ($^1/_4$ in.) thick and are to be suitably protected from corrosion.

7.7 Power Systems

Power systems and equipment are to be designed for 100% of the design load. Electric motors may have continuous ratings less than ratings corresponding to the design load and suitable short time ratings not less than the design load when such ratings are supported by the design analysis.

7.8 Power Sources *(2011)*

An independent emergency power source is to be available for supplying power in case of failure of the primary source of power. (See Subsection 10/5).

7.9 Sheave and Drum Sizes

The minimum ratio of pitch diameter to rope diameter for sheaves and drums is to be as listed below:

Wire rope	
Application	*Ratio, min.*
Load block sheaves	16:1
Load hoisting sheaves	18:1
Load hoisting drums	18:1
Boom hoisting sheaves	15:1
Boom hoisting drums	15:1
Fiber and synthetic rope	
All applications	8:1

9 Structural Materials

9.1 General

Structural materials are to be suitable for the intended service conditions. They are to be of good quality, free of injurious defects and are to exhibit satisfactory formability and weldability characteristics. Materials used in the construction of the handling systems are to be certified by the mill and verified by ABS Surveyors. Material is to be clearly identified by the steel manufacturer with the specification, grade and heat number.

9.3 Toughness

For handling systems with design service temperature of –10°C (14°F) and colder, primary structural members such as those listed in Subsection 17/11 are to be in conformity with the toughness criteria in Subsection 17/13. For systems with design service temperature warmer than –10°C (14°F), primary structural members are to have fracture toughness satisfactory for the intended application as evidenced by previous satisfactory service experience or appropriate toughness tests similar to those in Subsection 17/13.

9.5 Additional Requirements

In cases where principal loads from either service or weld residual stresses are imposed perpendicular to the material thickness, the use of special material with improved through thickness (Z direction) properties is required. Material complying with 2-1-1/17 of the ABS *Rules for Materials and Welding (Part 2)* is considered as meeting this requirement.

9.7 Steel

Materials, test specimens, and mechanical testing procedures having characteristics differing from those prescribed herein may be approved upon application, due regard being given to established practices in the country in which the material is produced and the purpose for which the material is intended. Wrought iron is not to be used.

9.9 Other Material

Materials other than steel will be specially considered.

9.11 Fasteners *(2013)*

Fasteners (including bolts, studs and nuts) subjected to tensile loading (other than pre-tensioning), employed in joining of components in the primary load path of handling systems are to be selected to meet strength and corrosion resistance requirements suitable for the intended service and are to be in accordance with a recognized national or international standard for fasteners. Round bottom or rolled thread profiles are to be used for fasteners in the primary load path of the handling system. Based on the design service temperature, the fracture toughness of these fasteners is to be as per 17/9.3 or Subsection 17/13, as applicable.

High-Strength Steel Fasteners: Zinc or Aluminum coated fasteners or Cadmium plated fasteners of tensile strength greater than 150 ksi are not be used in applications exposed to the weather, or where they may be subjected to periodic wetting or heavy condensation. (Under wet conditions, these coatings/platings increase the susceptibility of the fasteners to hydrogen embrittlement).

11 Primary Structural Members

The following load-carrying structural members are to meet the requirements of Subsection 17/13.

i) A-frame, mast or gantry chord members

ii) Boom or jib chord members

iii) Load carrying beams

iv) Winch and frame foundations

v) Luffing system mechanisms

vi) Pins and axles

vii) Eye plates and brackets attached to primary members

viii) Winches and structural components not covered in Section 17, Table 2

13 Material Toughness Requirements for Primary Structural Members of Handling Systems with Design Service Temperatures of –10°C (14°F) and Below

Appropriate supporting information or test data is to indicate that the toughness of the steels will be adequate for their intended application in the system at the minimum design service temperature. In the absence of supporting data, tests are required to demonstrate that steels would meet the following longitudinal Charpy V-notch (CVN) impact requirements.

13.1 Steels up to and Including 41 kg/mm^2 (58,000 psi) Yield Strength

Steels up to and including 41 kg/mm^2 (58,000 psi) yield strength are to meet the following longitudinal CVN requirements:

Yield Strength		*CVN (longitudinal)*		*Test Temperature*
kg/mm^2	*ksi*	*kg-m*	*ft-lb*	
24–31	34–44	2.8	20	10°C (18°F) below design service temperature
32–41	45.5–58	3.5	25	

13.3 Extra High Strength Steels above 41 kg/mm^2 (58,000 psi) Yield Strength

Steels in the 42–70 kg/mm^2 (60,000–100,000 psi) yield strength range are to meet the following longitudinal CVN impact requirements.

Design Service Temperature	*kg-m (ft-lb) at Test Temp*
–10°C (+14°F)	3.5 (25) at –40°C (–40°F)
–20°C (–4°F)	3.5 (25) at –40°C (–40°F)
–30°C (–22°F)	3.5 (25) at –50°C (–58°F)

13.5 Alternative Requirements

As an alternative to the requirements in 17/13.1 and 17/13.3, one of the following may be complied with:

i) For transverse specimens, $^2/_3$ of the energy shown for longitudinal specimens.

ii) For longitudinal specimens, lateral expansion is not to be less than 0.5 mm (0.02 in.). For transverse specimens, lateral expansion is not to be less than 0.38 mm (0.015 in.).

iii) Nil-ductility temperature (NDT) as determined by drop weight tests is to be 5°C (9°F) below the test temperature specified in 17/13.1 and 17/13.3.

iv) Other means of fracture toughness testing, such as Crack Opening Displacement (COD) testing, will be specially considered.

15 Rope

Rope is to be constructed in accordance with a recognized standard applicable to the intended service such as API Specification 9A and Federal Specification RR-W-410a.

17 Winches *(2011)*

17.1 Design

Winches are to meet the applicable design requirements of Subsection 17/7.

17.3 Operation

Winches are to satisfactorily operate when handling the rated load at the rated speed.

17.5 Power Drives

Lowering of loads is to be controlled by power drives independent of braking mechanisms.

17.7 Drum Capacity

Winch drums are to be capable of accepting the full length of rope being used. Not less than 5 full wraps of rope is to remain on the drum under any operating condition. The drum flange is to extend a minimum distance of 2.5 times the diameter of the rope over the outermost layer, unless additional means of keeping the rope on the drum are provided (keeper plates, rope guards, etc.).

17.9 Spooling

For recovery systems, appropriate means are to be provided to ensure that the rope being recovered is correctly spooled on the winch drum.

17.11 Emergency Lifting Devices *(2014)*

Recovery systems for subsurface recovery of tethered manned underwater units are to be provided with a secondary means (such as a guide wire winch and guide wire) for lifting the appropriate design load to the surface, except where alternative lifting equipment adequate for the design load is provided with the underwater system.

17.13 Braking Mechanisms *(2014)*

Winches for personnel lifting are to be provided with two independent braking mechanisms.

All braking mechanisms are to set automatically upon loss of power to the winch.

All braking mechanisms are to be designed to hold 100% of the design load with the outermost layer of rope on the drum.

Hydraulic counterbalance valves, when used as dynamic braking mechanisms, are to meet the following additional requirements:

i) The valves are to be designed and built to a recognized industry standard.

ii) The valves are to be integrally connected to the hydraulic motor (No hoses are permitted between the counterbalance valve and the motor).

iii) The valves are to require positive pressure to release and are to actuate automatically in the event of loss of power.

iv) The valves are to be effective throughout the operating temperature range of the hydraulic fluid.

17.15 Testing *(2014)*

Testing of the winches is to be conducted in the presence of the Surveyor and is to demonstrate that rated line pull can be achieved at rated speed with the outermost layer of rope on the drum.

All braking mechanisms are to be independently load tested.

Static braking mechanisms are to be statically load tested to 100% of the vertical design load.

The load testing of dynamic braking mechanisms is to include functional (dynamic) testing to 125% of the rated load as well as static load testing to 100% of the vertical design load.

19 Welding

Welding procedures and welder qualifications are to be submitted and approved in accordance with 2-4-3/5 of the ABS *Rules for Materials and Welding (Part 2)*.

21 Nondestructive Inspection (NDT) of Welds

Inspection is to be in accordance with the *NDI Guide* or other recognized cases. The areas to be nondestructively inspected and methods of inspection are to be submitted together with the design plans. The Surveyor is to be provided with records of NDT inspections. The Surveyor may require additional inspections, at his discretion.

23 Surveys and Tests During Construction

23.1 Surveyor Attendance

Certification of launch and recovery systems will require attendance of the Surveyor at the plants of the supplier of component parts of the system to ensure proper quality control procedures are in effect. The number and frequency of these visits is to be as the Surveyor may require.

23.3 Static Load Tests *(2010)*

A static test load of 100% of the vertical design load is to be applied to the structural components of the completed handling system in the presence of the Surveyor.

23.5 Original Tests on Handling Systems

23.5.1 Loose Gear

23.5.1(a) Tests. All chains, rings, hooks, links, shackles, swivels, and blocks of the handling system are to be tested in the presence of the Surveyor with a proof load at least equal to the values in Section 17, Table 2.

23.5.1(b) Examination. After tests, gear is to be examined with the sheaves and the pins removed for the purpose of determining whether vital parts have been permanently deformed by the test.

23.5.1(c) Certificates. Articles of loose gear are to have a certificate written by the Surveyor. The certificate is to contain the distinguishing number or mark applied to the article or gear, a description of the particular article or gear, the material specification, date of tests, proof load applied and safe working load. These data are to be attached to the Record of Certification.

23.5.2 Rope Test

Each rope is to have a certificate of test furnished by the manufacturer, supplier, or the Surveyor indicating the load at which a test sample broke. This certificate is to show size of rope in inches, number of strands, number of wires per strand, quality of wires, and date of test, and is to be attached to the Record of Certification.

25 Functional Test *(2008)*

Prior to the system being placed in service, the system is to be tested with a load equal to 125 percent of the rated load in the presence of the Surveyor. Satisfactory operation of power drives, emergency lifting devices, and brakes is to be demonstrated. After being tested, the system with all its components is to be examined visually for permanent deformation and failure. A copy of the certificate of tests witnessed and issued by the Surveyor is to be attached to the Record of Certification.

27 Operation *(2011)*

The complete handling system is to operate satisfactorily when handling the rated load at the rated speed.

29 Repairs and Alterations

Alterations, significant repairs and component renewals, are to be carried out under the supervision and to the satisfaction of the Surveyor. Tests and examinations are to be carried out as deemed necessary by the Surveyor. Reports of these tests and examinations are to be placed in the Record of Certification.

31 Running Rope Maintenance Program

31.1 Lubrication of Wire Rope

The entire rope is to be lubricated with a lubricant that will penetrate and adhere to the rope. Lubrication is to be applied whenever there is no apparent lubrication between wires. Records of lubrication applications are to be maintained as part of the Record of Certification.

31.3 Ends Exchange

The ends of rope are to be exchanged every twelve months. Records of such exchange are to be maintained as part of the Record of Certification.

31.5 Testing *(2009)*

Following each ends exchange, except the first exchange, a section is to be removed from the end of the rope. The length of the section is to be the running distance from the drum through the system and terminating with the end on the deck. A sample from the remaining rope is to be tested to determine its breaking strength. When the breaking strength is less than 5.0 times the design load of the system for wire rope, 7.0 times the design load for fiber or synthetic rope (except nylon), and 9.0 times the design load for nylon rope, the rope is to be renewed.

33 Record of Certification

A Record of Certification is to be maintained by the Owner and is to be made available to the Surveyor at the time of repairs and periodical surveys. The Record is to consist of the following:

- Manuals indicating the design criteria, a description of the operating cycle and a set of design plans indicating the materials used in construction. See Subsection 17/5.
- Certificate for Handling Systems (see Section 1).
- Certificates for items of loose gear (see 17/23.5.1).
- Certificates for rope components (see 17/23.5.2).
- Report of tests and surveys during construction (see 17/23.1 and 17/23.3).
- Report of initial tests and examinations to system as a unit (see Subsection 17/25).
- Report of tests and examinations following repairs or design modifications (see Subsection 17/29).
- Rope maintenance program (see Subsection 17/31).
- Report on surveys after construction (see Subsection 17/35).

35 Surveys After Construction

35.1 Surveys

The surveys after construction for handling systems are to be in accordance with the applicable requirements as contained in the ABS *Rules for Survey After Construction (Part 7)*.

TABLE 1
Wind and Sea Scale for Fully Arisen Sea

		Wind				*Sea*						
Sea State	*Description*	*Beaufort wind force*	*Description*	*Range, knots*	*Wind velocity, knots*	*Wave Height, ft* Average	*Wave Height, ft* Average 1/10 highest	*Significant range of periods, sec.*	*T average period*	*ℓ average wave length*	*Minimum fetch, nmi*	*Minimum duration, hr*
0	Sea like a mirror.	0	Calm	Less than 1	0	0	0					
0	Ripples with the appearance of scales are formed, but without foam crests.	1	Light airs	1–3	2	0.05	0.1	Up to 1.2 sec	0.5	10 in.	5	18 min
1	Small wavelets, still short, but more pronounced; crests have a glassy appearance, but do not break.	2	Light breeze	4–6	5	0.18	0.37	0.4–2.8	1.4	6.7 ft	8	39 min
1 2	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.	3	Gentle breeze	7–10	8.5 10	0.6 0.88	1.2 1.8	0.8–5.0 1.0–6.0	2.4 2.9	20 27	9.8 10	1.7 hr 2.4
2 3	Small waves, becoming larger; fairly frequent white horses.	4	Moderate breeze	11–16	12 13.5 14 16	1.4 1.8 2.0 2.9	2.8 3.7 4.2 5.8	1.0–7.0 1.4–7.6 1.5–7.8 2.0–8.8	3.4 3.9 4.0 4.6	40 52 59 71	18 24 28 40	3.8 4.8 5.2 6.6
4 5	Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray).	5	Fresh breeze	17–21	18 19 20	3.8 4.3 5.0	7.8 8.7 10	2.5–10.0 2.8–10.6 3.0–11.1	5.1 5.4 5.7	90 99 111	55 65 76	8.3 9.2 10
5 6	Large waves begin to form; the white foam crests are more extensive everywhere (probably some spray).	6	Strong breeze	22–27	22 24 24.5 26	6.4 7.9 8.2 9.6	13 16 17 20	3.4–12.2 3.7–13.5 3.8–13.6 4.0–14.5	6.3 6.8 7.0 7.4	134 160 164 188	100 130 140 180	12 14 15 17
6 7	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind (spindrift begins to be seen).	7	Moderate gale	28–33	28 30 30.5 32	11 14 14 16	23 28 29 33	4.5–15.5 4.7–16.7 4.8–17.0 5.0–17.5	7.9 8.6 8.7 9.1	212 250 258 285	230 280 290 340	20 23 24 27
7 8	Moderately high waves of greater length; edges of crests break into spindrift. The foam is blown in well-marked streaks along the direction of the wind. Spray affects visibility.	8	Fresh gale	34–40	34 36 37 38 40	19 21 23 25 28	38 44 46.7 50 58	5.5–18.5 5.8–19.7 6.0–20.5 6.2–20.8 6.5–21.7	9.7 10.3 10.5 10.7 11.4	322 363 376 392 444	420 500 530 600 710	30 34 37 38 42
8 9	High waves. Dense streaks of foam along the direction of the wind. Sea begins to roll. Visibility affected.	9	Strong gale	41–47	42 44 46	31 36 40	64 73 81	7.0–23.0 7.0–24.2 7.0–25.0	12.0 12.5 13.1	492 534 590	830 960 1110	47 52 57
9	Very high waves with long overhanging crests. The resulting foam is in great patches and is blown in dense white streaks along the direction of the wind. On the whole, the surface of the sea takes a white appearance. The rolling of the sea becomes heavy and shock-like. Visibility is affected	10	Whole gale	48–55	48 50 51.5 52 54	44 49 52 54 59	90 99 106 110 121	7.5–26.0 7.5–27.0 8.0–28.2 8.0–28.5 8.0–29.5	13.8 14.3 14.7 14.8 15.4	650 700 736 750 810	1250 1420 1560 1610 1800	63 69 73 75 81

TABLE 1 (continued) Wind and Sea Scale for Fully Arisen Sea

		Wind				Sea							
Sea State	*Description*	*Beaufort wind force*	*Description*	*Range, knots*	*Wind velocity, knots*	*Wave Height, ft*		*Significant range of periods, sec.*	*T average period*	*ℓ average wave length*	*Minimum fetch, nmi*	*Minimum duration, hr*
						Average	*Average $^{1}/_{10}$ highest*					
9	Exceptionally high waves (small and medium-sized ships might for a long time be lost to view behind the waves). The sea is completely covered with long patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.	11	Storm	56–63	56 59.5	64 73	130 148	8.5–31.0 10–32	16.3 17.0	910 985	2100 2500	88 101
	Air filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	12	Hurricane	64–71	>64	>80	>164	10–(35)	(18)	~	~	~

TABLE 2 Loose Gear Tests

Article of Gear	*Proof Load* (1)
Chain, ring, hook, link, shackle, or swivel	100% in excess of the safe working load
Pulley blocks, single sheave block	300% in excess of the safe working load (2)
Multiple sheave block with safe working load up to and including 20,320 kg (20 tons)	100% in excess of the safe working load
Multiple sheave block with safe working load over 20,320 kg (20 tons) up to and including 40,640 kg (40 tons)	20,320 kg (20 tons) in excess of the safe working load
Multiple sheave block with safe working load over 40,640 kg (40 tons)	50% in excess of the safe working load

Notes:

1 Alternatively, the proof tests as recommended in the I.L.O. publication "Safety and Health in Dock Work" may be accepted where the items of gear are manufactured or tested or both and intended for use on vessels under jurisdictions accepting these recommendations.

2 The safe working load to be marked on a single block is to be the maximum load which can safely be lifted by the block when the load is attached to a rope which passes around the sheave of the block. In the case of single-sheave block where the load is attached directly to the block instead of to a rope passing around the sheave, it is permissible to lift a load equal to twice the marked safe working load of the block as defined in this note.

SECTION 18 Dive Control Stations

1 Submissions of Plans, Calculations and Data

(2011) Before commencement of fabrication, plans and other documents indicating the required particulars are to be submitted. Plans should generally be submitted electronically to ABS. However, hard copies will also be accepted.

1.1 Plans

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

- General arrangement
- Cross-section assembly
- Outline of station
- Layout of control stands and consoles
- Front view of all consoles and stands together with installation arrangements
- Control wiring diagram, wiring type and cross sections and nominal parameters along with overcurrent settings of all circuit protections
- Control piping diagram, piping material and dimensions, valves and overpressure protective devices, pressure reducing valves for all control piping systems
- Communication system diagram, arrangements and details

1.3 Documentation

The following documentation is to be submitted for review:

- A schematic or logic diagram, with a written description, giving the sequence of events and systems operating procedures for control of all diving functions and related operations
- A list of materials, fittings, contacts, supports of all components
- A list of type and extent of enclosure for all components
- Electric feeder list
- Generators, motors, battery characteristics

1.5 Calculations and Data

The following calculations and data are to be submitted:

- Data in order to establish that the electrical protective devices on each control console have a sufficient short circuit interrupting capacity
- A booklet with standard wiring practices and details including such items as cables and pipe supports, bulkhead and deck penetrations and sealing, cable splicing, watertight and explosion proof connections to equipment as applicable.

1.7 Basis of Review

The basis of the review by ABS will be the Sections of these Rules and the *Steel Vessel Rules* as applicable (or other recognized standards provided they are not less effective) and the following requirements.

3 Location of Dive Control Station

A dive control station may be located on the shore or on an offshore platform close to and in sight of the diving location.

The position of the dive control station is to allow the operations control personnel an overview of all systems and activities associated with the operations of the underwater vehicle and the dive. It is not to be located in hazardous areas.

When selecting the location of the dive control station, ship's motion or support structure vibrations are to be considered.

The dive control station is to be provided with air conditioning for control consoles when required by the operational characteristics of electronic components within the consoles.

The leading of pipes in the vicinity of control consoles is to be avoided as far as possible.

When such leads are necessary, care is to be taken in order to fit no flange or joints over or near the consoles, or stands, unless provision is made to prevent any leakage from injuring equipment.

The dive control station is to be provided with effective fire protection on all delimiting walls, bulkheads and decks.

5 Construction and Mechanical Protection

All enclosures in the dive control station are to be drip-proof and corrosion resistant when completed and are to be made of one or a combination of the following materials:

- Cast metal, except die-cast metal, at least 3 mm ($^1/_8$ in.) thick at every location.
- Non-metallic materials that have acceptable strength, and are non-combustible and non-absorptive (e.g., laminated phenolic material).
- Sheet metal of adequate strength. The supporting framework for all panels is to be of rigid construction. No wood is to be used, except for hardwood for non-conducting handrails.

The dive control station is to be located in a dry place. Clear working space is to be provided around panels, consoles and stands to enable doors to be fully opened and equipment removed for maintenance and replacement. Consoles, panels and stands are to be firmly secured to a solid foundation, be self-supported or be braced to the bulkheads.

7 Enclosed Dive Control Stations

Enclosed dive control stations are to have two means of access located as remote from each other as practicable.

Glass windows in the control station are to be of shatter-resistant type.

Sufficient light fixtures are to be installed to provide 540 lumens/m^2 (50 foot-candles) over all control stands, consoles and panels.

9 Controls, Displays and Alarms

9.1 General

Controls, displays and alarms are to provide for safe and reliable performance of all the required functions carried out from the dive control station.

Fire detection and fire fighting systems are to be provided for the protection of the station and are to be operable from outside the protected spaces.

Controls for fire fighting systems intended for the protection of diving facilities (e.g., deck decompression chambers, handling systems) are to be located in or as close as possible to the control station.

9.3 Control Consoles

All controls, displays and alarms are to be located and arranged in centralized positions and constructed in accordance with practices suitable for the service.

A separate control console is to be provided for each independently operated deck decompression chamber and underwater unit, and its handling system.

9.5 Displays and Alarms

The following operating parameters are to be monitored at the dive control station for each manned chamber and underwater unit:

- Pressure or depth
- Temperature
- Humidity
- Partial oxygen pressure
- Partial CO_2 pressure
- Pressure of connected breathing gas bottles
- Pressure at pressure reducing outlets
- Oxygen content in supply lines to chamber and compartment and to breathing masks
- Battery charge and discharge, voltmeter, ammeter and a capacity indicator
- Power supply distributions, voltmeter, ammeter and frequency meter if alternating current is used
- Electric leakage indicator for all chambers and compartments
- Fire alarm display panels
- Safety and signaling system monitors
- Display and control for breathing mixtures
- Environmental systems controls including heating and cooling system controls

11 Communications

Direct communication is to be provided among the following positions:

- Dive control station
- Dive control console on the support vessel
- Winch and crane local operation stand
- All compartments associated with saturation diving
- Master of the diving support vessel
- Underwater vehicle
- Diver in the water

Automatic recording of communication between the submersible and the control station is to be possible.

13 Testing

Testing of all equipment, apparatus, wiring and piping is to be conducted in accordance with these Rules and the *Steel Vessel Rules* in the presence and to the satisfaction of the Surveyor.

15 Trials

Before certification, all control systems are to be tested for proper functions and operations.

17 Surveys After Construction

17.1 Surveys

The surveys after construction for dive control stations are to be in accordance with the applicable requirements as contained in the ABS *Rules for Survey After Construction (Part 7)*.

SECTION 19 Surveys After Construction *(2002)*

1 Surveys

The surveys after construction for Underwater Vehicles, Systems and Hyperbaric Facilities are to be in accordance with the applicable requirements as contained in the ABS *Rules for Survey After Construction (Part 7)*.

APPENDIX 1 IMO – Diving Bell Emergency Locating Device

(2009) Code of Safety for Diving Systems, Para. 2.12.5 of IMO Res. A.831 (19).

A diving bell should have as emergency locating device with a frequency of 37.5 kHz designed to assist personnel on the surface in establishing and maintaining contact with the submerged diving bell if the umbilical to the surface is severed. The device should include the following components:

.1 Transponder

.1.1

The transponder should be provided with a pressure housing capable of operating to a depth of at least 200 m containing batteries and equipped with salt water activation contacts. The batteries should be of the readily available "alkaline" type and, if possible, be interchangeable with those of the diver and surface interrogator receiver.

.1.2

The transponder should be designed to operate with the following characteristics:

Common emergency reply frequency	37.5 kHz
Individual interrogation frequencies:	
Channel A	38.5 ± 0.05 kHz
channel B	39.5 ± 0.05 kHz
Receiver sensitivity	+15 db referred to 1 μbar
Minimum interrogation pulse width	4 ms
Turnaround delay	125.7 ± 0.2 ms
Reply frequency	37.5 ± 0.05 kHz
Maximum interrogation rates:	
more than 20 percent of battery life remaining	Once per second
less than 20 percent of battery life remaining	Once per 2 seconds
Minimum transponder output power	85 db referred to 1 μbar at 1 m
Minimum transducer polar diagram	–6 db at ±135° solid angle, centered on the transponder vertical axis and transmitting towards the surface
Minimum listening life in water	10 weeks
Minimum battery life replying at 85 db	5 days

.2 Diver-held Interrogator/Receiver

.2.1

The interrogator/receiver should be provided with a pressure housing capable of operating to a depth of at least 200 m with pistol grip and compass. The front end should contain the directional hydrophone array and the rear end the 3-digit LED display readout calibrated in meters. Controls should be provided for "on/off receiver gain" and "channel selection". The battery pack should be of the readily available "alkaline" type and, if possible, be interchangeable with that of the interrogator and transponder.

.2.2 *(2009)*

The interrogator/receiver should be designed to operate with the following characteristics:

Common emergency reply frequency	37.5 kHz
Individual interrogation frequencies:	
channel A	38.5 kHz
channel B	39.5 kHz
Minimum transmitter output power	85 db referred to 1 μbar at 1 m
Transmit pulse	4 ms
Directivity	±15°
Capability to zero range on transponder	
Maximum detectable range	more than 500 m

2.12.6

In addition to the communication systems referred to above, a standard bell emergency communication tapping code should be adopted as given below for use between persons in the bell and rescue divers. A copy of this code should be displayed inside and outside the bell and also in the dive control room.

Bell Emergency Communication Tapping Code

Tapping code	*Situation*
3.3.3	Communication opening procedure (inside and outside)
1	Yes or affirmative or agreed
3	No or negative or disagreed
2.2	Repeat please
2	Stop
5	Have you a got a seal?
6	Stand by to be pulled up
1.2.1.2	Get ready for through water transfer (open your hatch)
2.3.2.3	You will NOT release your ballasts
4.4	Do release your ballast in 30 minutes from now
1.2.3	Do increase your pressure
3.3.3	Communication closing procedure (inside and outside)